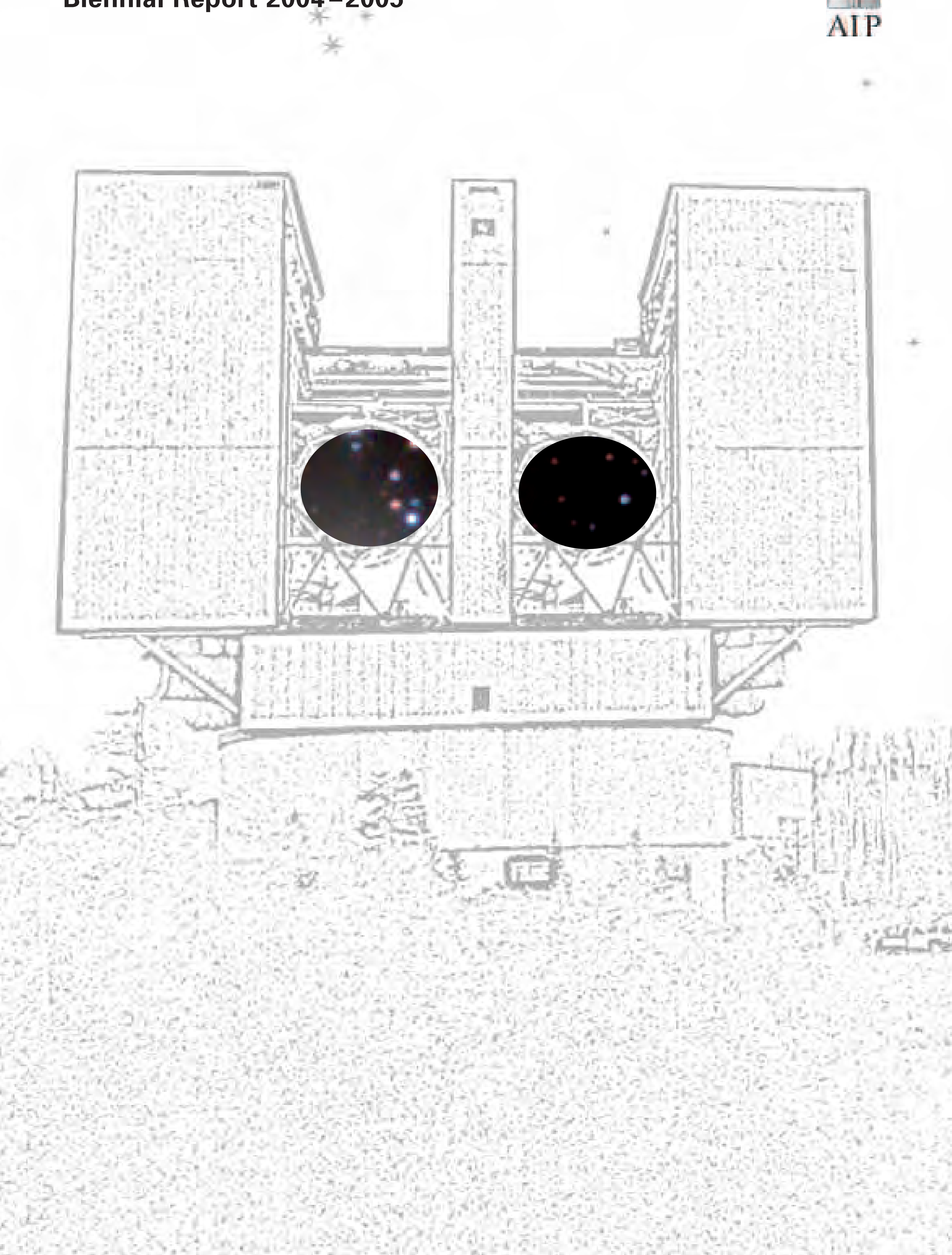
ASTROPHYSIKALISCHES INSTITUT POTSDAM

Biennial Report 2004 – 2005



Optische Aufnahme eines Himmelsauschnitts, in dem der Röntgensatellit XMM-Newton 90 neue Röntgenquellen entdeckt hat. Das optische Bild wurde mit dem "Wide Field Imager" des MPG/ESO 2,2m Teleskops aufgenommen und in mehreren Farbfiltern insgesamt über 7 Stunden belichtet.

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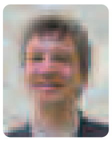
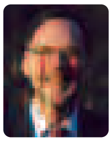
Vorwort
Preface

Astronomie gilt gemeinhin als die älteste Wissenschaft. Astrophysik ist modernste Grundlagenforschung und wesentlicher Treiber für die Entwicklung von Hochtechnologie im Bereich der Optik, der Sensorik und der Informationstechnologie. An wohl keinem Ort kommen diese beiden Aspekte der Himmelskunde so zusammen wie am Astrophysikalischen Institut Potsdam (AIP), wo die Bewahrung traditionsreicher Wissenschaftsgeschichte einhergeht mit der Teilhabe an internationalen technisch-wissenschaftlichen Großprojekten der Astrophysik. Gerade die beiden Jahre, die dieser Zweijahresbericht abdeckt, das Jahr 2004 und Einsteinjahr 2005, zeugen davon. Astrophysikalische Höhepunkte wie insbesondere das „First Light" mit dem Large Binocular Telescope stehen kulturellen Höhepunkten, wie der Rückführung des Großen Refraktors auf den Telegrafenberg gegenüber. Mit 63 wissenschaftlichen Kurzbeiträgen, mit 18 Projektberichten und mehreren Berichten und Darstellungen zur Situation des AIP in den Jahren 2004 und 2005 werden in dem vorliegenden Zweijahresbericht aktuelle Fragen und Antworten aus der modernen Astrophysik und dem Alltagsleben am AIP präsentiert und die Pflege des wissenschaftshistorischen Erbes dokumentiert.

An dieser Stelle bedanken wir uns bei den Zuwendungsgebern, Gremien und unseren wissenschaftlichen und administrativen Kooperationspartnern für die gute und erfolgreiche Zusammenarbeit im Berichtszeitraum.

Astronomy is usually considered to be the oldest of the sciences. Astrophysics, however, is modern fundamental research that drives many high-tech developments in the areas of optics as well as sensors and information technology. The Astrophysical Institute Potsdam (AIP) is uniquely positioned at this confluence of the history of science on the one hand side and large international projects on the other hand. In particular, the past two years, 2004 and 2005 (the world year of physics), covered by this biennial report prove the point. Highlights in astrophysical research, in particular the "First Light" at the Large Binocular Telescope, as well as cultural events like the return of the great refracting telescope to the Telegrafenberg deserve special mention. 63 scientific contributions, 18 project reports and several reports and presentations covering the situation of the AIP in the years 2004 and 2005 present current questions and answers of modern astrophysical research and everyday life at the AIP and document the fostering of its scientific and historical legacy.

We would like to thank our funding agencies and supporters, board members and administrative partners for the good and successful collaboration over the period covered by this report.

Prof. Matthias Steinmetz
Wissenschaftlicher Vorstand

Peter A. Stolz
Administrativer Vorstand

Potsdam, Mai 2006

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INTRODUCTION

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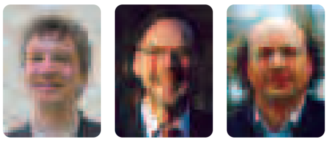


Matthias Steinmetz, Peter A. Stolz, Klaus G. Strassmeier

Das AIP betreibt Grundlagenforschung mit drei Forschungsschwerpunkten.

Forschungsschwerpunkt I: Kosmische Magnetfelder
Forschungsschwerpunkt II: Extragalaktische Astrophysik

Diese Forschungsschwerpunkte untergliedern sich thematisch in sechs Programmbereiche: "Magnetohydrodynamik und Turbulenz", "Physik der Sonne", "Sternphysik und Sternaktivität", "Sternentstehung und interstellares Medium", "Galaxien und Quasare" und "Kosmologie und großräumige Strukturen". Diese Forschungsgebiete sind durch die Anwendung verwandter mathematischer und physikalischer Methoden sowie gemeinsamen Projekten in der Entwicklung und dem Einsatz von neuen Technologien eng miteinander verbunden. Letztere bilden den

Forschungsschwerpunkt III: Entwicklung von Forschungsinfrastruktur und -technologie

mit den vier Programmbereichen „Teleskopsteuerung und Robotik", „Hochauflösende Spektroskopie und Polarimetrie", „3D-Spektroskopie" und „Supercomputing und E-Science".

The AIP conducts basic astrophysical research with experimental and theoretical techniques in three main directions:

Research Focus I: Cosmic magnetic fields
Research Focus II: Extragalactic Astrophysics

These research fields are thematically divided into six program areas: "Magnetohydrodynamics and turbulence", "Solar physics", "Stellar physics and stellar activity", "Star formation and the interstellar medium", "Galaxies and quasars" and "Cosmology and large-scale structure". These research fields are closely connected through the application of related mathematical and physical methods as well as common projects in the development and use of new technologies. The latter form

Research Focus III: Development of research infrastructure and technology

Covering the four program areas "Telescope control and robotics", "High-resolution spectroscopy and polarimetry", "3D-spectroscopy" and "Supercomputing and e-Science".

Das Large Binocular Telescope auf dem Mount Graham in Arizona

Der Forschungscampus am Babelsberg

Die Forschungsaktivitäten des AIP verteilen sich geografisch nach wie vor auf drei Standorte in und um Potsdam, wobei die Antennenanlage in Tremsdorf südlich von Potsdam ohne Personal betrieben wird. Sie wird in Zukunft als möglicher Standort für ein Antennenfeld des europäischen LOFAR-Projekt (Low Frequency Array) an Bedeutung gewinnen. Der Hauptstandort ist der Campus auf dem Babelsberg mit dem Hauptgebäude der ehemaligen Berliner Sternwarte, dem Technologiegebäude „Schwarzschildhaus", der "Villa Turbulenz", der neuen Bibliothek im ehemaligen Spiegelgebäude, dem Medien- und Kommunikationszentrum und einem mobilen Bürogebäude. Auf dem Telegrafenberg, eingebettet in den Wissenschaftspark Albert-Einstein, wird noch das 60cm Turmteleskop des Einsteinturms wissenschaftlich genutzt, momentan für die Tests des polarimetrischen Verzögerers von PEPSI für das LBT sowie für Kalibrationstests für das neue Sonnenteleskop GREGOR und für Simultanbeobachtungen mit dem Röntgensatelliten RHESSI. Die Kuppel des großen Refraktors sowie der darin beherbergte große Doppelrefraktor werden derzeit mit privaten Spenden renoviert und ab 2006 für die Öffentlichkeits-

Einweihung des LBT am 15. Oktober 2004:
V.r.n.l. Peter A. Stolz, Klaus G. Strassmeier, Konstanze Pistor, Matthias Steinmetz, Rainer Arlt

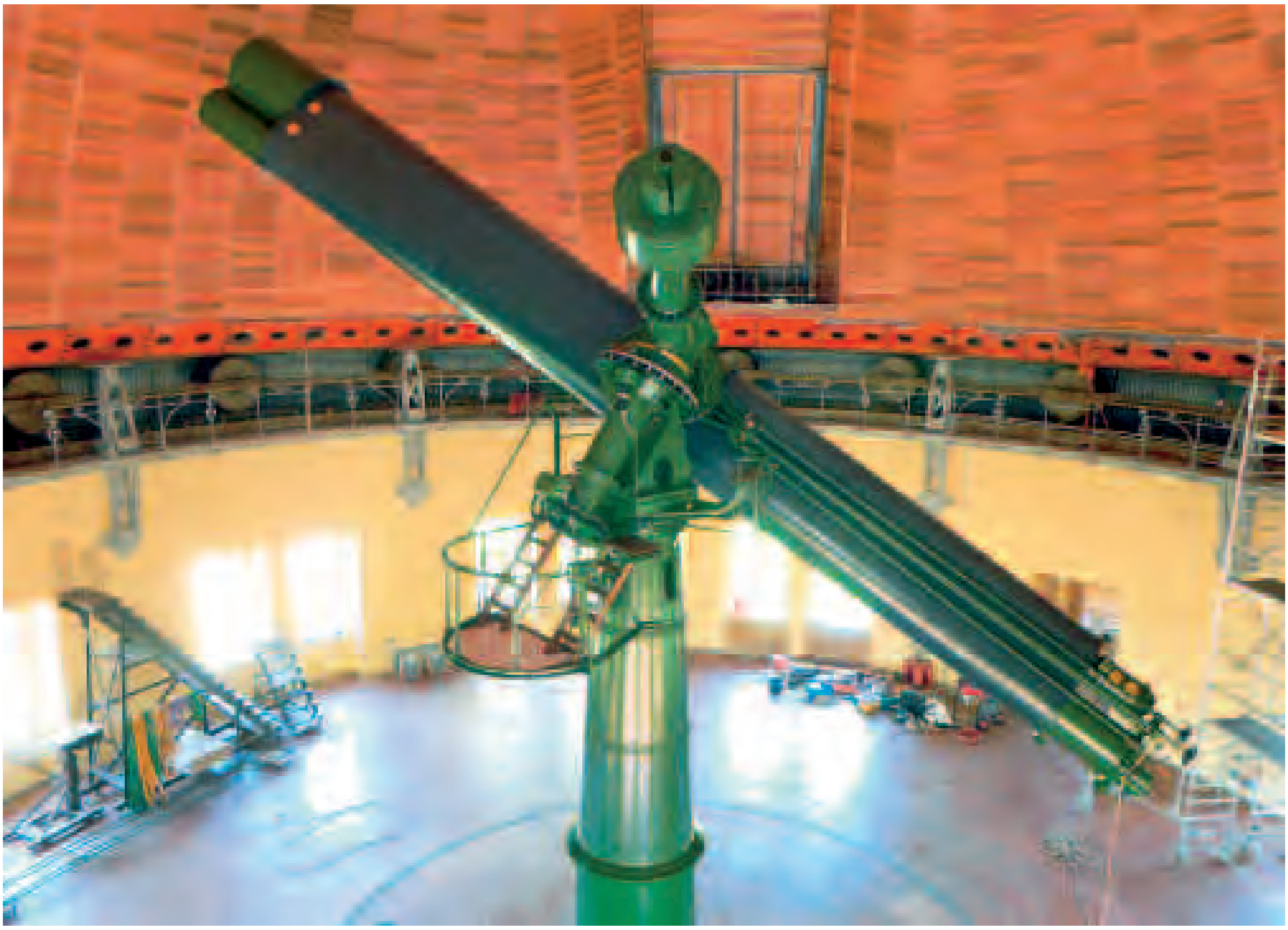
Dedication of the LBT on October 15, 2004:
from right to left, Peter A. Stolz, Klaus G. Strassmeier, Konstanze Pistor, Matthias Steinmetz, Rainer Arlt

The Babelsberg Research Campus

Research activities of the AIP are distributed over three locations in and around Potsdam. The solar radio observatory in Tremsdorf south of Potsdam is operated remotely from Babelsberg without personnel on site. It will gain importance in the future as a possible site for an antenna array of the European LOFAR project (Low Frequency Array). The main location of the AIP is the research campus in Babelsberg though with its main building from the former Berlin Observatory, the technology building "Schwarzschildhaus", the "Villa Turbulence", the new library in the former "reflector telescope building", the "Media and Communication center" (MCC) and a mobile office container. Located within the Albert-Einstein science campus the historic Einstein tower with its vector magnetograph is still used for science. Its 60cm tower telescope is still used for tests of the polarimetric retarders of PEPSI for the LBT, for calibration tests for the new solar telescope GREGOR, and for concerted observing campaigns with the solar X-ray satellite RHESSI. The astrodome of the „Great Refractor" and the large double refractor are currently being renovated by private donors and will be available for public relations purposes from 2006 on. On the ground floor student laboratories are being established together with the GeoForschungsZentrum Potsdam (GFZ).

Technology Development and Astrophysics

The formation and evolution of planets and stars, the galaxies, and the universe as a whole continue to set the framework in which astrophysical research is conducted. Many "Ansätze" for such research are possible, both experimental and theoretical, but both are usually technology driven. From the experimental side tremendous effort is currently undertaken to increase our "look-back" time - that is to observe the universe back to the times when it became transparent for electromagnetic radiation. NASA's "Origins" program and ESAs cornerstone missions, both culminating with the launch of the "James Webb Space Telescope" (JWST) in 2013, will aim to observe galaxies and the first stars back to redshifts of $z > 10$, i.e. an epoch where the universe was only 500 million years old. Around the same time the ESA cornerstone mission GAIA will make an extensive census of the stars in the Milky Way. The next step will be to take spectra of these objects, which requires the full light-gathering capability of the LBT and even the next generation of ground-based telescopes with apertures of 30-50m. The development of instrumentation for this class of telescopes is likely to occupy the AIP from 2015 on. Therefore, it is necessary to invest in the current technology infrastructure and the concepts of new technologies now, in order to be a key player in



Der Große Refraktor auf dem Telegrafenberg nach der Restaurierung, 23.6.2005

arbeitsarbeit zur Verfügung stehen. Im Erdgeschoß werden zusammen mit dem Geoforschungszentrum Potsdam Schülerlabors eingerichtet.

Technologieentwicklung und Astrophysik

Die Entstehung und Entwicklung der Planeten und Sterne, der Galaxien, und des Universums als Ganzes wird auf nicht absehbare Zeit weiterhin der Rahmen für jedwede astrophysikalische Forschung bleiben. Dazu gibt es viele unterschiedliche Ansätze, sowohl von experimenteller als auch von theoretischer Seite, jedoch sind beide meistens vom Stand der Technologie abhängig. Von experimenteller Seite her werden größte Anstrengungen unternommen, um die "look-back" Zeit zu vergrößern, also an die Grenzen des sichtbaren Universums vorzustoßen.

Das "Origins"-Programm der NASA bzw. auch der ESA, das mit dem Start des "James Webb Space Telescope" (JWST) seinen vorläufigen Höhepunkt etwa 2013 erreichen wird, wird

the decade to come. With its participation in different projects at current large telescopes the AIP is well positioned.

Scientific know-how in six departments: from the big bang to the Sun

Cosmology and Large-scale Structures

The formation of cosmic structures in the originally almost homogeneously expanding universe is investigated in this program area, how they evolve, how they influence their environment as well as what conclusions can be drawn regarding the cosmological model. Cosmic structures are dark matter halos and the directly observable objects contained therein, ranging from low luminosity dwarf galaxies to the most massive galaxy clusters. Furthermore, these structures are arranged in a network (the "cosmic web") of super clusters. This topic also includes the formation of the first stars, the evolution of the intergalactic medium and the

Galaxien und deren erste Sterne bei einer Rotverschiebung von z > 10 detektieren, d.h. zu einer Zeit, als das Universum erst 500 Millionen Jahre alt war. Etwa zur selben Zeit wird die Cornerstone-Mission der ESA, GAIA, eine umfassende Bestandaufnahme der Sterne in der Milchstraße machen. Der nächste Schritt wird dann sein, von diesen Objekten Spektren zu bekommen, was wiederum den Einsatz des "Large Binocular Telescope's" (LBT) und sogar eines der derzeit in Planung befindlichen erdgebundenen Teleskopen der 30-50m-Klasse erfordert. Die Entwicklung von Instrumenten für diese Teleskopgeneration wird die Instrumentenentwicklung des AIP ab etwa 2015 prägen. Es ist daher bereits heute wichtig, frühzeitig in die Entwicklung der Technologie dieser Teleskopgeneration zu investieren, um später ein Schlüsselspieler zu sein. Mit seiner Beteiligung an mehreren verschiedenen Projekten an gegenwärtigen Großteleskopen ist das AIP dazu hervorragend positioniert.

Wissenschaftliches Know-how in sechs Programmbereichen: vom Urknall zur Sonne

Kosmologie und großräumige Strukturen

Hier wird untersucht, wie in dem ursprünglich nahezu gleichförmig expandierenden Universum kosmische Strukturen entstehen, sich entwickeln, wie ihre Entwicklung von der Umgebung beeinflusst wird und welche Rückschlüsse sich daraus auf das kosmologische Modell ableiten lassen. Kosmische Strukturen sind einerseits die Halos aus dunkler Materie und die darin enthaltenen direkt beobachtbaren Objekte von lichtschwachen Zwerggalaxien bis zu den massereichsten Galaxienhaufen. Darüber hinaus ordnen sich diese Strukturen in einem das Universum überziehenden Netzwerk von Superhaufen an. Diese Thematik beinhaltet auch die Bildung der ersten Sterne und die Entwicklung des intergalaktischen Mediums sowie des von allen kosmischen Objekten erzeugten Hintergrundstrahlungsfeldes. Zur Erforschung dieser Phänomene dienen eigene Beobachtungsdaten, die Analyse von Archivdaten, analytische Rechnungen und numerische Simulationen.

Galaxien und Quasare

Dieser Programmbereich widmet sich der Struktur und dem Aufbau der größten eigenständigen Objekte im Universum: Galaxien, Quasare und Galaxienhaufen. Die Untersuchung ihrer Entstehung in der Frühphase des Kosmos und ihre nachfolgende Entwicklung bis hin zu der heute beobachteten Formen- und Farbenvielfalt stellen eines der zentralen Forschungsfelder der modernen Astrophysik dar. Viele der beobachteten Eigenschaften können als Folge vergangener Wech-

background ionization field produced by all cosmic objects. Research into these phenomena is conducted using observation data, the analysis of archive data, analytical calculations and numerical simulations.

Galaxies and Quasars

This program area is devoted to the structure and composition of the largest autonomous objects in the universe: galaxies, quasars and galaxy clusters. The study of their formation in the early phase of the cosmos and their subsequent evolution to the form and colour diversity observed today is one of the major research areas of modern astrophysics. Many of the observed properties can be understood as a consequence of past interaction processes between stars, gas and massive black holes in galaxies. Collisions of galaxies which form ever bigger units by merging also play an important role. The Milky Way is of particular importance as it can be interpreted as the prototype of a galaxy and it offers the opportunity to conduct a detailed analysis of its constituents.

Star Formation and the Interstellar Medium

With the question of star formation, research progresses to ever smaller scales. The long-term goal is to extend and deepen our understanding of the formation of stars and star clusters in our Universe. Stars form in interstellar clouds from molecular hydrogen gas by the complex interaction of gravity, turbulence and magnetic fields. The local process of star formation has to be embedded into the global, dynamic evolution of the parent galaxy. Altogether, the formation of stars has a dual meaning. On the one hand, it is the precondition for the formation and evolution of planets; on the other hand, it is an important motor for galactic evolution.

Stellar Physics and Stellar Activity

Stars are an important component of galaxies and are exclusively responsible for the production and distribution of heavy elements. Their existence ultimately allowed the formation of organic molecules and biological evolution. Thus it is critical to gain precise knowledge of the complex physical processes which proceed inside stars, at their surface and in the stellar wind. The experiments in this program area focus on high-precision, spatially resolved surveys of stellar magnetic and velocity fields. Our immediate goal is to understand dynamic phenomena in the plasmas of stars of different astrophysical parameters, e.g. what role does a planet system play in stellar evolution? The long-term goal is to integrate the mass loss, the stellar rotation and the magnetic flow ("Dynamo evolution") into models of stellar evolution.

Die Mitarbeiter und Mitarbeiterinnen des AIP bei der Verabschiedung von Ministerialdirigent Dr. H.-F. Wagner (mit gelber Krawatte) aus dem Kuratorium des AIP, 9.11.2004

Die CDU-Vorsitzende und heutige Bundeskanzlerin Angela Merkel besucht den Telegrafenberg für ein Fernsehinterview, 29.7.2005

selwirkungsprozesse zwischen Sternen, Gas und massereichen schwarzen Löchern in Galaxien verstanden werden. Eine bedeutende Rolle spielen auch Zusammenstöße zwischen Galaxien, die zur Verschmelzung zu immer größeren Einheiten führen. Eine besondere Rolle kommt der Milchstraße zu, die als Prototyp einer Galaxie interpretiert und für die eine detaillierte Untersuchung ihres Aufbaus durchgeführt werden kann.

Sternentstehung und interstellares Medium

Die Frage nach der Art und Weise wie Sterne entstehen setzt die Kette zu kleineren Skalen fort. Langfristige Zielstellung ist es, unser Verständnis für die Bildung von Sternen und Sternhaufen in unserem Universum zu erweitern und zu vertiefen. Sterne entstehen in interstellaren Wolken molekularen Wasserstoffgases über das komplexe Wechselspiel von Gravitation, Turbulenz und Magnetfeldern. Der lokale Prozess der Sternentstehung muss dabei eingebettet in die globale, dynamische Entwicklung der Muttergalaxie betrachtet werden. Insgesamt kommt der Bildung von Sternen eine zweifache Bedeutung zu. Zum einen ist sie die Voraussetzung für die Entstehung und Entwicklung von Planeten, und zum anderen ist sie eine wichtige Triebfeder der Galaxienentwicklung.

Sternphysik und Sternaktivität

Sterne sind ein wichtiger Bestandteil der Galaxien und ausschließlich für die Produktion und Verbreitung der schwereren Elemente verantwortlich. Deren Existenz hat letztendlich auch die Entstehung organischer Moleküle und die biologische Evo-

The three-dimensional description of the convective energy transport from the stellar interior to the stellar surface with attached radiation transport in presence of a magnetic field bears particular importance in this field.

Solar Physics

The focus is research into activity processes on the Sun caused by magnetic fields. The research activities concentrate on the key role of the solar magnetic field on different spatial and temporal scales, particularly to investigate the development of magnetic structures in the solar atmosphere, particle acceleration in the solar atmosphere and the analysis of effects of solar activities on Earth. The latter research field is of particular social interest since the sun affects our technical civilization directly.

Magnetohydrodynamics and Turbulence

Cosmic appearances are often magnetically conditioned. Complicated matter flows in stellar bodies can even amplify marginal magnetic seed fields. Thus, research in this program area mainly deals with dynamo theory in planets and stars as well as accretion discs and galaxies. The flows in stars and planets result from the convective instability, while interstellar turbulence is caused by supernova explosions. In accretion discs, the form of the flow depends heavily on the temperature: magnetic shear flow instability, barocline instability and hydrodynamic instability can all occur.

lution ermöglicht. Es ist daher von großer Bedeutung, präzise Kenntnisse der komplexen physikalischen Prozesse zu erlangen, die sowohl im Sterninneren, an der Sternoberfläche und im Sternwind ablaufen. Die Experimente in diesem Programmbereich fokussieren sich auf die hochpräzise, räumlich aufgelöste Erfassung von stellaren Magnet- und Geschwindigkeitsfeldern. Unmittelbares Ziel ist das Verständnis von dynamischen Phänomenen in den Plasmen von Sternen unterschiedlichster astrophysikalischer Parameter, z. B. welche Rolle Planetensysteme in der Sternentwicklung spielen. Langfristiges Ziel ist es, den Massenverlust, die stellare Rotation und den magnetischen Fluss („Dynamo-Evolution“) in Sternentwicklungsmodelle einzubauen. Der dreidimensionalen Beschreibung des konvektiven Energietransports vom Sterninneren bis zur Sternoberfläche, bei aufgesetztem Strahlungstransport in der Präsenz eines Magnetfeldes, kommt in diesem Rahmen eine besondere Bedeutung zu.

Konstanze Pistor (r.) verleiht den Wempe-Preis 2004 an Isabelle Baraffe (m.) und Gilles Chabrier (l.), 8.10.2004

Physik der Sonne

Im Fokus steht die Untersuchung magnetfeldbedingter Aktivitätsprozesse auf der Sonne. Die Forschungsaktivitäten konzentrieren sich auf die Schlüsselrolle des solaren Magnetfeldes auf unterschiedlichen räumlichen und zeitlichen Skalen, insbesondere die Untersuchung der Entwicklung von magnetischen Strukturen in der Sonnenatmosphäre, die Untersuchung der Energiefreisetzungsprozesse und der Teilchenbeschleunigung in der Sonnenatmosphäre und die Untersuchung der Auswirkungen der Sonnenaktivität auf unsere Erde. Die letztgenannte Forschungsrichtung ist von besonderem gesellschaftlichen Interesse, da die Sonne unsere technische Zivilisation unmittelbar beeinflusst.

Wempe-Preis 2005, v.l.n.r. Peter A. Stolz, Oskar von der Lühe, Klaus G. Strassmeier, Alexander G. Kosovichev, Rainer Koepke, Matthias Steinmetz, 4.11.2005

Magnetohydrodynamik und Turbulenz

Kosmische Erscheinungen sind oft magnetisch bedingt. Komplizierte Materieströmungen in den Himmelskörpern können selbst geringfügige magnetische Keimfelder verstärken. Die Forschung befasst sich daher hauptsächlich mit der Dynamotheorie der Planeten und Sterne wie auch der Akkretionsscheiben und der Galaxien. Die Strömungen in Sternen und Planeten resultieren aus der konvektiven Instabilität, während die interstellare Turbulenz von Supernova-Explosionen herrührt. In Akkretionsscheiben hängt die Strömungsform stark von der Temperatur ab: magnetische Scherströmungsinstabilität, barocline Instabilität und hydrodynamische Instabilitäten treten auf.

Technisches Know-how in vier Programmbereichen: von der e-Science zur Robotik

Teleskopsteuerung und Robotik

Das AIP entwickelt mehrere robotische Teleskope: die beiden STELLA-Teleskope auf Teneriffa, das Schulteleskop RoboTel auf dem Institutsgelände. Gemeinsam mit der Universität Wien betreibt das AIP die Zwillingsteleskope Wolfgang & Amadeus in Arizona. Auch das Sonnenteleskop Gregor auf Teneriffa soll mittelfristig für den Nachtbetrieb gemeinsam robotisiert werden. Noch im Anfang befindet sich ICE-T (International Concordia Explorer Teleskop), ein robotisches 60cm-Schmidt-Doppelteleskop am Dome C, in der Antarktis. Die Vielzahl verschiedener robotischer Teleskope legte die Entwicklung einer teleskopunabhängigen Steuerung nahe. Dementsprechend entwickelte das AIP eine auf XML basierende Metasprache, die an allen modernen robotischen Teleskopen verwendet werden kann. Neben den robotischen Projekten entwickelt und baut das AIP im Rahmen seiner LBT-Beteiligung die AGW-Einheiten (Aquisition, Guiding und Wavefrontsensing). Die erste der beiden Einheiten wurden 2005 erfolgreich im Labor geprüft und nach Florenz überstellt, um dort zusammen mit dem adaptiven Sekundärspiegel des LBT ausführlich getestet zu werden, bevor der endgültige Einbau im Frühjahr 2007 am LBT erfolgt.

Hochauflösende Spektroskopie und Polarimetrie

Der Bau von hoch- und höchstauflösenden Spektrografen und Spektropolarimetern ermöglicht eine Verknüpfung von Sonnenphysik und der Sternphysik, die historisch gesehen über gänzlich unterschiedliche Instrumentarien verfügt haben. Die moderne Generation von 8-10m-Großteleskopen erlaubt erstmals hohe spektrale Auflösung und sogar Polarimetrie für schwache extragalaktische Objekte, etwa so genannter aktiver Galaxienkerne oder die Untersuchung des interstellaren und intergalaktischen Mediums mittels Quasarabsorptionsliniensystemen. Die enormen technologischen Anforderungen bei der Entwicklung und dem Bau eines hochauflösenden Spektrografen bedingen konzertiertes Ingenieurwissen auf den verschiedensten Fachgebieten. Die Aktivitäten umfassen derzeit den Bau des Potsdam Echelle Polarimetric and Spectroscopic Instruments (PEPSI) für das 2x8,4m LBT sowie den STELLA Echelle Spektrograf (SES) für das erste der beiden robotischen 1,2m STELLA Teleskope auf Teneriffa.

Technical know-how in four departments: from e-Science to Robotics

Telescope Control and Robotics

The AIP is currently developing several robotic telescopes: the two STELLA telescopes on Tenerife and the school telescope RoboTel on the institute site. Together with the University of Vienna the AIP operates the twin telescopes Wolfgang & Amadeus in Arizona. Another common project is the medium-term automation of the solar telescope Gregor on Tenerife for night operation. ICE-T (International Concordia Explorer Telescope), a robotic 60cm Schmidt double telescope at Dome C, Antarctica, is still in its earliest stages. The number of different robotic telescopes suggested the development of a telescope independent control system. Thus the AIP has developed a meta language based on XML which can be used for all modern robotic telescopes. Apart from the robotic projects, the AIP builds the AGW units (aquisition, guiding and wavefront sensing) as part of its LBT participation. The first unit was successfully tested in the laboratory in 2005 and delivered to Florence. There it will be subjected to detailed testing with the adaptive secondary mirror of the LBT. The final installation is planned for spring 2007 at the LBT.

High-resolution Spectroscopy and Polarimetry

The construction of high-resolution spectrographs and spectropolarimeters allows one to combine solar physics and stellar physics, which historically used completely different instrumentation. The modern generation of 8-10m large-scale telescopes allows, for the first time, high spectral resolution and polarimetry even for weak extragalactic objects, like so-called active galactic nuclei or the investigation of the interstellar and intergalactic medium through the use of quasar absorption line systems. The enormous technological requirements for the development and construction of such a high-resolution spectrograph relies on concerted engineering expertise in different fields. At present, the activities comprise the construction of the Potsdam Echelle Polarimetric and Spectroscopic Instruments (PEPSI) for the 2x8.4m LBT, as well as the STELLA Echelle Spectrograph (SES) for the first of the two robotic 1.2m STELLA telescopes on Tenerife.

3D-Spektroskopie

Das AIP entwickelt seit 1997 Know-how im Bereich der 3D-Spektroskopie im optischen Wellenlängenbereich. Diese Aktivitäten umfassen sowohl die Instrumentenentwicklung mit einem Schwerpunkt bei Faseroptiken, als auch das Design von Reduktions- und Analyse-Software, z.B. im Rahmen des nationalen Kompetenznetzwerks D3Dnet, das vom AIP koordiniert wird. Das in Eigenregie am AIP entwickelte Potsdamer Multi-Apertur-Spektrophotometer (PMAS) ist seit 2001 am Calar Alto 3,5m Teleskop störungsfrei im Einsatz und gehört dort zu den am meisten nachgefragten Instrumenten. Im Rahmen des BMBF-Projekts zur „ultratiefen optischen 3D-Spektroskopie“ sind neue Methoden entwickelt worden, die als Wegbereiter für die AO-unterstützte 3D-Spektroskopie an 8m-Teleskopen gelten können. Durch die Integration des PPak-Faserbündels wurde PMAS zu einem 3D-Instrument mit herausragender Sensitivität für die Spektroskopie von Objekten mit extrem geringer Flächenhelligkeit und dem größten Gesichtsfeld weltweit. Ziel des Programmbereichs ist die Weiterentwicklung der 3D-Beobachtungstechnik und Datenanalyse durch die Mitwirkung an Neuentwicklungen für 8-10m-Teleskope, insbesondere dem Very-Large-Teleskop der europäischen Südsternwarte und dem Hobby-Eberly-Teleskop des McDonald-Observatory.

Supercomputing und E-Science

Supercomputing und E-Science (die enge internationale Vernetzung von Daten, Rechnern und wissenschaftlichen Geräten – das sogenannte Grid) bilden einen informationstechnologischen Arbeitsschwerpunkt des AIP. Das AIP entwickelt komplexe numerische Modelle auf den Gebieten Magnetohydrodynamik, Stern- und Sonnenphysik, Sternentstehung, Galaxienentwicklung und Kosmologie. Diese Modelle benötigen eine Rechen- und Datentransferleistung an der Grenze des technologisch Möglichen, die nur durch viele vernetzte Rechner bereitgestellt werden kann. Die Daten, die von Simulationen und Beobachtungen erzeugt werden, müssen in dynamisch wachsenden Speichersystemen mit hohem Datendurchsatz und schnellen Zugriffsmöglichkeiten gespeichert und kostenoptimal gesichert werden. Die wissenschaftliche Nutzung des Grid durch den Astrophysiker erfolgt über das International Virtual Observatory (VO), das entsprechende Nutzerschnittstellen und Anwendungsprogramme bereitstellt. Das AIP ist Konsortialführer beim Aufbau einer Grid-basierten Infrastruktur für die Astrophysik im Rahmen der deutschen E-Science-Initiative (AstroGrid-D) und Co-Initiator des German Astrophysical Virtual Observatory (GAVO).

3D-Spectroscopy

Since 1997, the AIP has been developing know-how in the area of 3D spectroscopy at optical wavelengths. These activities include instrument development with a focus on fiber optics as well as the design of reduction and analysis software, e.g. as part of the national competence network D3Dnet which is coordinated by the AIP. The Potsdam Multi-Aperture Spectrophotometer (PMAS), which was developed by the AIP, has operated failure-free on Calar Alto's 3.5m telescope since 2001 and is one of the most used instruments. In line with the BMBF project for "ultra-deep optical 3D spectroscopy", new methods were developed which may be considered as precursors for AO-supported 3D spectroscopy at 8m telescopes. By integrating the PPak fiber bundle PMAS became a 3D instrument with outstanding sensitivity for the spectroscopy of objects with extremely low surface brightness and the largest field of view worldwide. The goal of the program area is the improvement of 3D observational techniques and data analysis by participating in new developments for 8-10m telescopes, particularly the Very Large Telescope of the European Southern Observatory and the Hobby Eberly Telescope of the McDonald Observatory.

Supercomputing and e-Science

Supercomputing and e-Science (the close international networking of data, computers and scientific instruments – the so-called grid) form an information technological focus of the AIP. The AIP develops complex numerical models in the areas of magnetohydrodynamics, stellar and solar physics, star formation, galaxy evolution and cosmology. These models require computing power and data transfers that are at the limit of the technologically feasible and that can only be provided by networked computers. The data which are generated by simulations and observations must be stored and secured at optimal costs in dynamically growing storage systems with high data performance and quick access facilities. The scientific use of the Grid by astrophysics proceeds as part of the *International Virtual Observatory* (VO) which provides corresponding user interfaces and programs. The AIP is consortium manager in the architecture of a Grid-based infrastructure for astrophysics as part of the German eScience Initiative (AstroGrid-D) and co-initiator of the *German Astrophysical Virtual Observatory* (GAVO).

AN im Begriff zu wachsen

Das AIP gibt nach wie vor die Astronomischen Nachrichten/ Astronomical Notes (AN), die älteste astronomische Fachzeitschrift der Welt, heraus. Im Berichtszeitraum wurden 18 Bände mit 328 Originalartikeln und einer Gesamtseitenanzahl von 679 im Jahre 2004 und 1071 Seiten im Jahre 2005 editiert und bei Wiley-VCH in Berlin verlegt.

Der Große Refraktor ist zurück

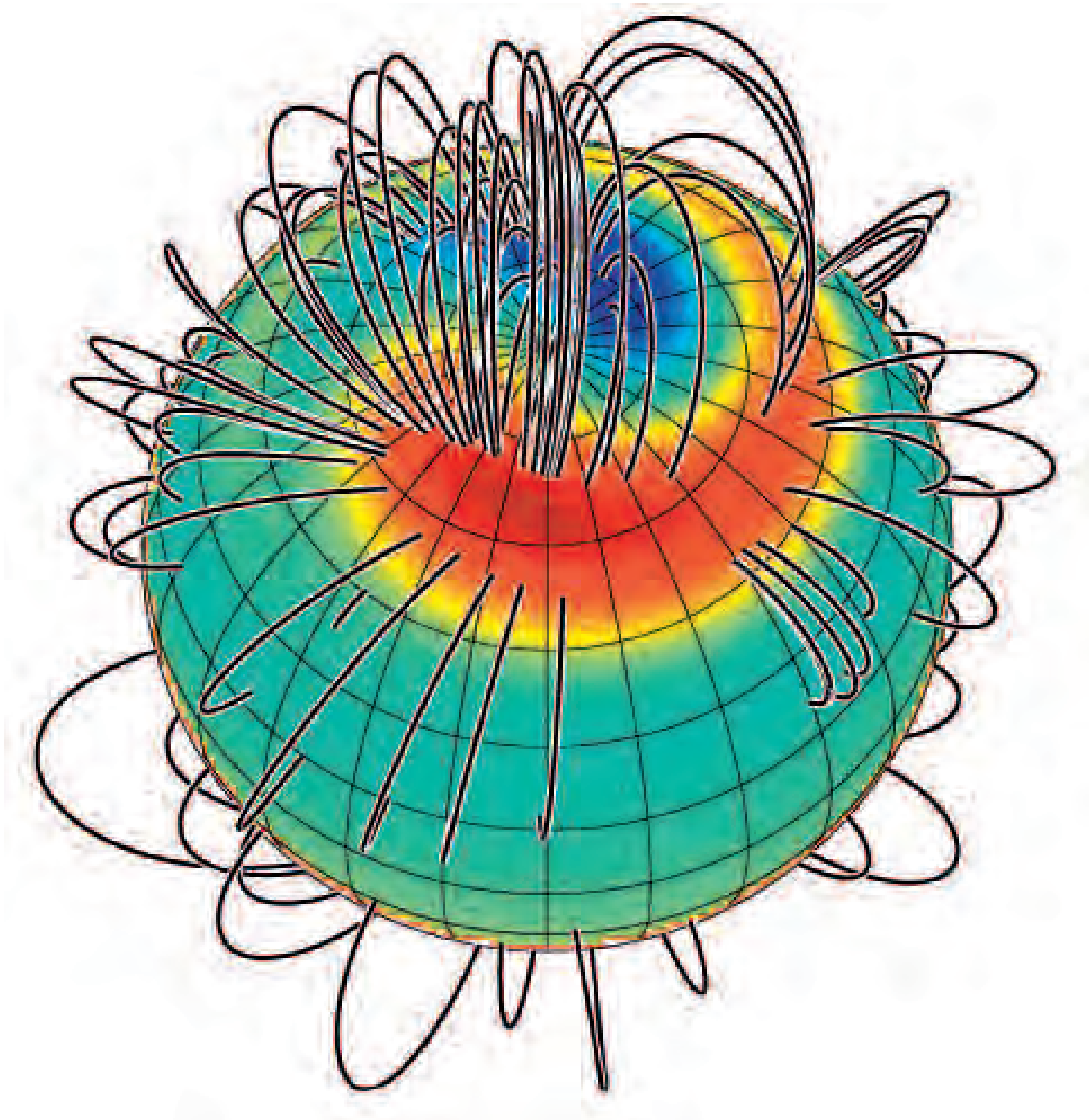
Das viertgrößte Linsenfernrohr der Welt wird saniert. Dank einer Privatspende und deren Aufstockung durch die Deutsche Stiftung Denkmalschutz ist es dem AIP gemeinsam mit dem Förderverein Großer Refraktor Potsdam e.V. gelungen, dem Fernrohr wieder eine Zukunft zu geben. Obwohl schon seit den sechziger Jahren wissenschaftlich außer Dienst gestellt, ist dem imposanten Gerät jetzt die Rolle der Volksbildung und der Öffentlichkeitsarbeit zugedacht. Das Gerät wurde 2005 als Höhepunkt des Wissenschaftssommers im Einsteinjahr aus den ehemaligen Zeissschen Werkhallen in Jena zurück nach Potsdam geliefert.

AN continues to grow

The AIP continues to edit Astronomische Nachrichten/Astronomical Notes (AN), the oldest astronomical periodical worldwide. In the reported period 18 volumes with 328 original articles and a total number of 679 pages in 2004 and 1071 pages in 2005 have been edited and have been published by Wiley-VCH in Berlin.

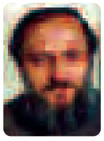
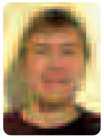
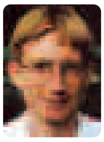
The Great Refractor is back

The fourth largest lens telescope worldwide is being renovated. Thanks to a private donation,watched by the Deutsche Stiftung Denkmalschutz, the AIP, in co-operation with the Förderverein Großer Refraktor Potsdam e.V. suceeded in providing the telescope with a future. Although the telescope has been decommissioned for scientific services since the Sixties, the impressive instrument is now forseen to serve for education and public relation purposes. The instrument was returned from the former Zeisssche Werkhallen in Jena to Potsdam as a highlight of the science summer of the World Year of Physics.



Field lines representing the hot corona

The MRI gallium experiment PROMISE

G. Rüdiger, M. Schultz, J. Szklarski, R. Arlt

Eine neue universelle und effiziente magnetohydrodynamische Instabilität (magnetorotational instability, MRI) kann sowohl das Drehimpulsproblem bei der Sternentstehung lösen, die enorme Helligkeit der Quasare erklären als auch auch die Turbulenz der interstellaren Materie und somit die riesigen galaktischen Magnetfelder erzeugen. Das weitgehend akzeptierte Phänomen, dass bei Anwesenheit selbst schwacher Magnetfelder alle astrophysikalisch relevanten Scherströmungen instabil und turbulent werden, ist in der Experimentalphysik bisher unbekannt geblieben. Die Verifikation im Laborexperiment PROMISE wird wesentlich zum Verständnis der Instabilität und des Überganges zur Turbulenz beitragen.

The magnetorotational instability has turned out to be a universal and efficient instability solving the angular-momentum problem in protostars and explaining the enormous energy output of quasars. It may also generate the turbulence of the interstellar medium, eventually leading to extended galactic magnetic fields. Today, it is a widely accepted phenomenon that the presence of weak poloidal magnetic fields (or the presence of strong toroidal fields) makes all astrophysically relevant shear flows unstable and turbulent. MRI is unknown in experimental physics though. The verification in the laboratory will be a major step in understanding the instability and the route to MHD turbulence in shear flows.

One challenge is the rather low electrical conductivity of liquid metals with magnetic Prandtl numbers smaller than 10^{-5}. This leads to vastly different scales for the flow and the magnetic field and leads to the conclusion that rotation of the cylinders must be extremely rapid. For high rotation rates, however, the flow is controlled almost entirely by the endplates present in any real experiment, which is a serious problem that cannot be overcome unless the cylinders are extremely long.

Investigations with high-performance computers delivered the parameters for the MHD Taylor-Couette experiment. The results also implied that the experiment design will not make use of liquid sodium and a purely vertical field, but employ liquid gallium and a magnetic field with a more complex geometry. Our most recent computations showed in particular that a successful experiment may use a spiral

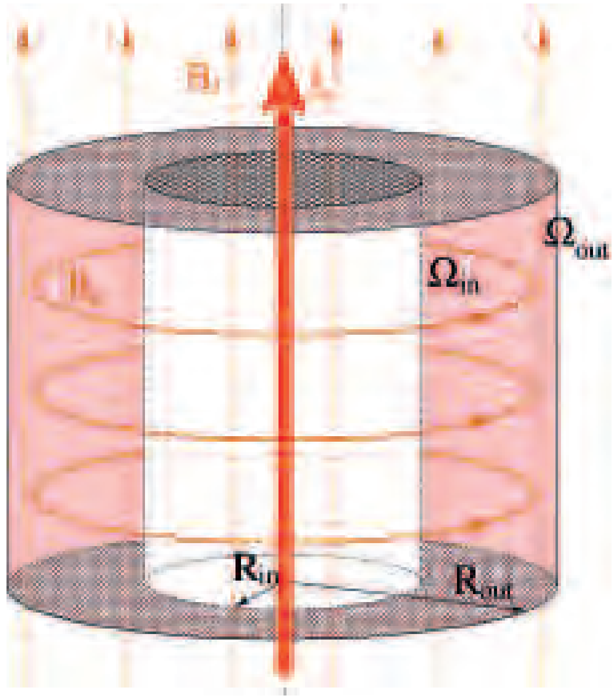


Fig. 1: Prototype of PROMISE with R_{in}=4 cm, R_{out}=8 cm, height = 40 cm. Cylinders are made from copper. Between the cylinders is liquid gallium. The insulating endplates rotate with the outer/inner cylinder.

geometry of the magnetic field. If the field lines have an angle of (say) 45° with the vertical, the critical Reynolds number for the onset of the MRI is reduced by several orders of magnitude compared with the vertical-field case. The Reynolds number becomes independent of the (small) magnetic Prandtl number of the liquid metal. We can thus use a gallium-indium-tin alloy which is much easier to handle at much reduced cost.

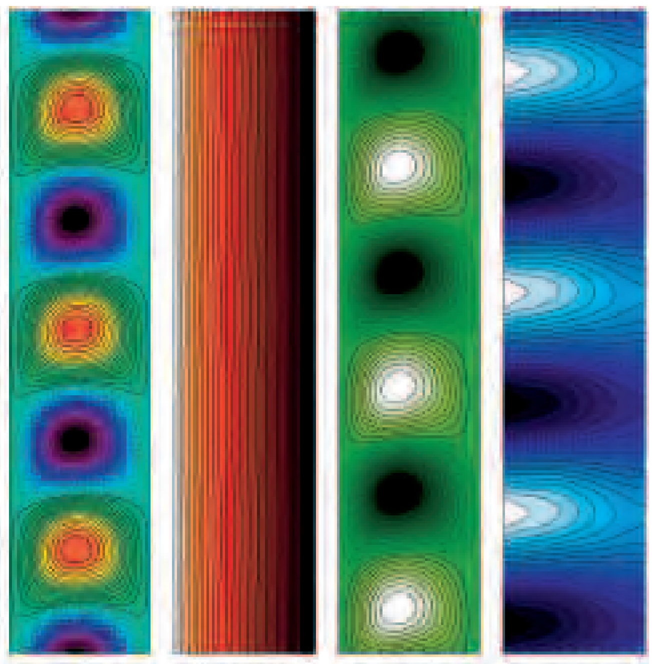


Fig. 2: An instability pattern for long cylinder and β=4 (strong toroidal field). Contour lines of (from the left): stream function, azimuthal velocity, current and magnetic field. We can see vortices which are travelling towards the top. The Reynolds number is only 880.

The investigation of such field geometries is also motivated by astrophysical problems in which poloidal magnetic fields always accompany toroidal fields. The results will have implications for the stability even for cold and weakly ionized star formation regions.

All of this leads to the idea of constructing an MRI experiment, being the world's first experiment especially devoted to this instability. It is a common project of two institutes of the Leibniz-Gemeinschaft. The collaboration of the MHD groups of the AIP and the Forschungszentrum Rossendorf has a long and fruitful history especially of designing an experiment capable of showing the MRI. We think that our numerical results will provide a good setup for the experiment PROMISE (Potsdam ROssendorf Magnetic InStability Experiment) and that we shall observe the MRI in laboratory for the first time.

The strength of the azimuthal magnetic field is described by parameter β which denotes the ratio of this field to the constant axial field B_z. We have also performed the first non-linear simulations of MHD Taylor-Couette flow with both axial and azimuthal external magnetic fields. According to the linear computations, it turns out that adding the azimuthal field indeed results in a dramatic change for the critical Reynolds number. The very important advantage is that one can avoid lots of technical problems when constructing a device which operates for slow rotation rates.

Geodynamo alpha effect and the reversal phenomenon


A. Giesecke, G. Rüdiger

Das Magnetfeld der Erde wird durch einen Dynamoprozess im flüssigen äusseren Bereich des Erdkerns erzeugt. Die konvektiv getriebene Strömung des flüssigen Eisens ist dabei in der Lage, unter dem Einfluss von Coriolis- und Lorentzkraft das Magnetfeld über lange Zeiträume aufrecht zu erhalten. Wesentliches Charakteristikum des Geodynamos sind unregelmässige Umpolvorgänge des Magnetfeldes, wobei der Zeitraum zwischen zwei solchen sogenannten *Reversals* im Mittel 500000 Jahre beträgt. Numerische Simulationen des kompletten Satzes an physikalischen Gleichungen zur Untersuchung des Erdmagnetfeldes sind sehr rechenintensiv, da innerhalb des flüssigen Erdkerns turbulente Prozesse auf sehr kleinen Skalen aufgelöst werden müssen. Es ist gegenwärtig nicht möglich, Langzeitsimulationen bei realistischen Parametern zur Untersuchung der Statistik des Reversalprozesses durchzuführen. Das entwickelte zweidimensionale Mean-Field-Modell beschränkt sich daher auf die deutlich einfachere numerische Lösung der Induktionsgleichung für das großskalige Dipolfeld und liefert so die Möglichkeit, lange Zeitreihen zu simulieren.

An axis-symmetric spherical mean field model of α^2 type is examined. The radial profile for the α-effect resembles the characteristics obtained from previously performed local box simulations of rotating magnetoconvection. The α effect vanishes at the boundaries and – on the northern hemisphere – α is positive (negative) in the upper (lower) half of the fluid outer core. Assuming antisymmetry with respect to the equator, the α effect is prescribed by a sine function as shown in Fig. 1.

This ideal sine function is slightly modified to vary the zero-crossing and the amplitude in the lower half of the sphere. A possible reversal of the geodynamo is interpreted as half of an oscillation and only occurs if the radial profile of the α effect lasts long enough ($\approx 0.3\tau_{diff}$) within the periodic solutions.

Due to strong fluctuations of the α-effect on the advective timescale (for the Earth: $\tau_{adv}=(R_{out} - R_{in})/u' \approx 0.01\ \tau_{diff}$) this is a rather rare event that occurs unpredictably. The typical timescale – the duration of a polarity transition from one sign to the other – is about one diffusion time $\tau_{diff}=R_{out}/\eta_T$ (Fig. 2).

A non-linear mean-field model which includes a local α-quenching as an equilibrium mechanism for the magnetic field demonstrates the plausibility of the presented theory with a long time-series of a geodynamo reversal sequence (Fig. 3).

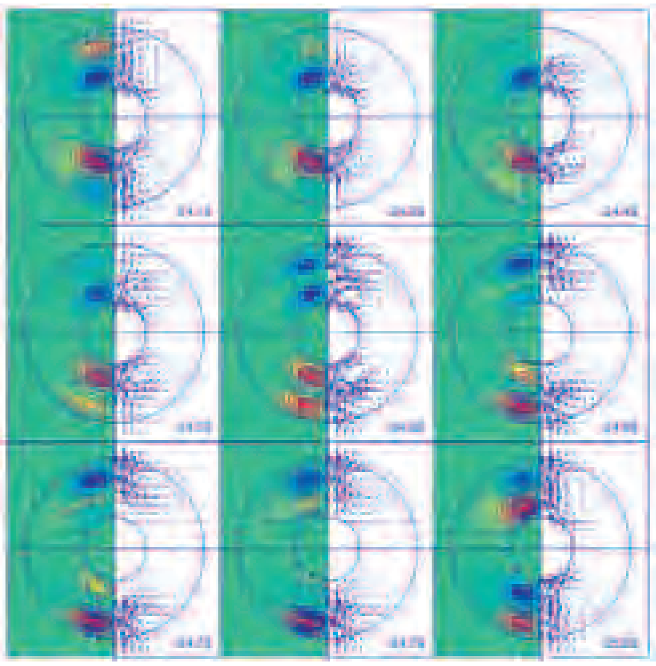


Fig. 2: Field pattern in a meridional plane during one polarity reversal. Left: toroidal field; right: poloidal field. Time is denoted in units of τ_{diff}

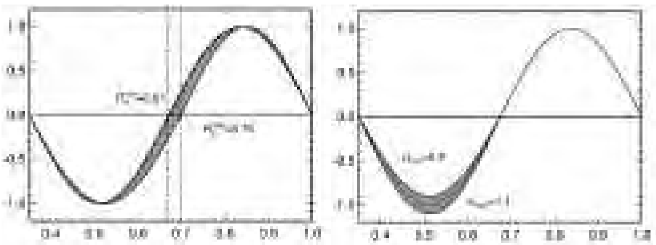
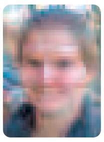
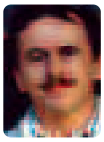


Fig. 1: Examples of α-profiles that result in oscillating solutions; critical interval for the location of the zero (left) and the lower amplitude (right).

Fig. 3: Reversals of the magnetic field. Long time run with 173 identified reversals, which leads to a mean polarity lifetime of approximately 11 τ_{diff}.

Stellar dynamos with flip-flop property

H. Korhonen, D. Elstner

Photometrische Langzeitbeobachtungen und Dopplertomografie zeigen für einige aktive Sterne einen periodischen Wechsel der Fleckenaktivität zwischen zwei gegenüberliegenden Längenbereichen. Wir untersuchten dieses sogenannte Flip-Flop-Phänomen mit synthetischen photometrischen Abbildungen, die aus numerischen Dynamo-Simulationen gewonnen wurden. Auch mögliche koronale Strukturen aktiver Sterne wurden mittels einer Potenzialfeld-Extrapolation aus dem Oberflächenfeld der Dynamomodelle hergeleitet.

We model the dynamo with a turbulent fluid in a spherical shell. A rotation law similar to the solar one is chosen, but with a smaller difference between core and surface rotation. This also leads to a reduced surface differential rotation. The mean electromotive force contains an anisotropic alpha-effect and a turbulent diffusivity. The nonlinear feedback of the magnetic field acts only on the turbulence. The boundary conditions describe a perfect conducting fluid at the bottom of the convection zone and at the stellar surface the magnetic field matches the vacuum field. For such models we find similar excitation conditions for oscillating axisymmetric and azimuthal migrating bisymmetric modes. The superposition of both modes shows a typical flip-flop phenomenon on the surface of the star. With our simulation we can follow this behaviour in the non-linear regime over thousands of cycles.

We have investigated in detail two flip-flop dynamo models, one with a thick convection zone and one with a thin one. The model calculations have been converted into temperature maps. This has been done by setting magnetic pressure values that are larger than 70% of the maximum value to 3500 K (umbra), values smaller than 70% and larger than 30% of the maximum to 4250 K (penumbra) and the rest to 5000 K (unspotted surface). Long time sequences of these maps with short time steps in between have been converted into long-term light-curves that span in real time approximately 30 years. Many active stars show similar long-term light-curve behaviour as we see in the models, i.e. behaviour where time periods with small and large amplitudes in the photometry alternate.

The types of possible coronal structure have also been investigated through potential field extrapolation of the model prediction of the surface magnetic field (Fig. 2). The model confirms that the high latitude spots, being of opposite polarity, will harbour connecting loops that would tend to give rise to pole-dominated emission. However, the model also shows the connection of these polarised high-latitude regions to lower latitudes whose polarity is opposite to that of the dominant spot. These lower latitude fields would give rise to significant rotational broadening, as appears to be seen in rapidly rotating active stars.

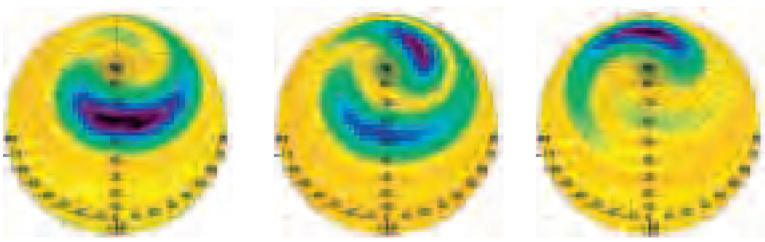


Fig. 1: Snapshots of the surface magnetic field strength for one flip-flop cycle.

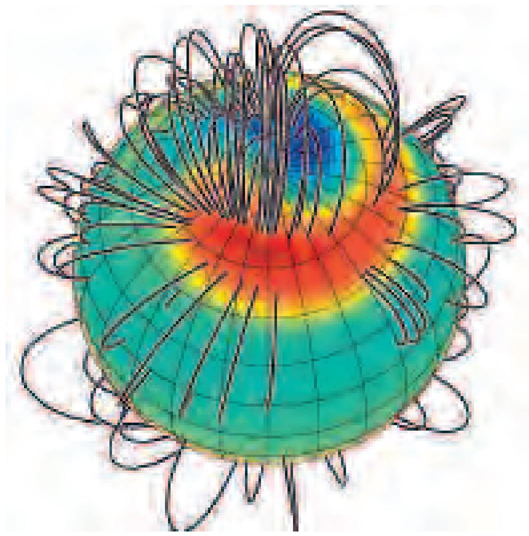


Fig. 2: A potential field extrapolation of the surface magnetic field predicted by the flip-flop models. Shown are the resulting surface flux distribution and 100 randomly selected closed field lines representing the hot corona (from Drake et al. 2006).

Numerical simulation of protostellar core collapse

U. Ziegler

Die Beobachtung liefert starke Hinweise dafür, dass Sterne häufig als Binär- oder Mehrfachsysteme entstehen. Die Theorie erklärt dies am plausibelsten anhand der Fragmentation eines gravitativ instabilen, kollabierenden Molekülwolkenkerns. Die Untersuchung des Fragmentationsprozesses erfordert die numerische Modellierung der zugrunde liegenden dynamischen Gleichungen (Hydrodynamik, Poissongleichung) auf adaptiven Gittern, um den auftretenden enormen Veränderungen in der Dichte und Veränderungen in den Längenskalen Rechnung zu tragen. Nahezu unverstanden ist der mögliche Einfluss interstellarer Magnetfelder während des Wolkenkollaps – ein numerisches Problem höchster Komplexität. Mit Hilfe des NIRVANA codes (http://nirvana-code.aip.de) wurden erste prototypische Simulationen in dieser Richtung durchgeführt.

Using the NIRVANA code -- a state-of-the-art Godunov-type central-upwind scheme with constrained transport for divergence-free magnetohydrodynamics, a multigrid-type Poisson solver for self-gravitating flows and adaptive mesh refinement -- the collapse of a bimodal perturbed solar-mass cloud has been investigated numerically under various assumptions, such as the type of equation of state of the gas, the amount of cloud rotation and the presence of a magnetic field. It has been shown that in the absence of ambipolar diffusion (which actually may be ignored only under special circumstances, but cannot be treated with the present version of the code), fragmentation is controlled by the strength and orientation of the applied magnetic field. In the case of an isothermal equation of state runaway collapse occurs both with and without a magnetic field and thin (singular) filaments exist, as might be expected from theoretical considerations. In case of a barotropic equation of state, however, which mimics the transition from a low-density isothermal state to a high-density adiabatic state of the medium in a more realistic way, the dynamical collapse is halted and turns into an accretion phase accumulating matter onto the compact object(s) which develops. The presence of a vertical magnetic field with a mass-to-flux ratio of twice the critical value here clearly favors binary formation, whereas at the same time in a model without a magnetic field, a single core emerges which is embedded in a bar and which is surrounded by a ring-like structure (see Fig 1). Future work aims to include the effect of ambipolar diffusion in order to further improve our understanding of cloud core fragmentation.

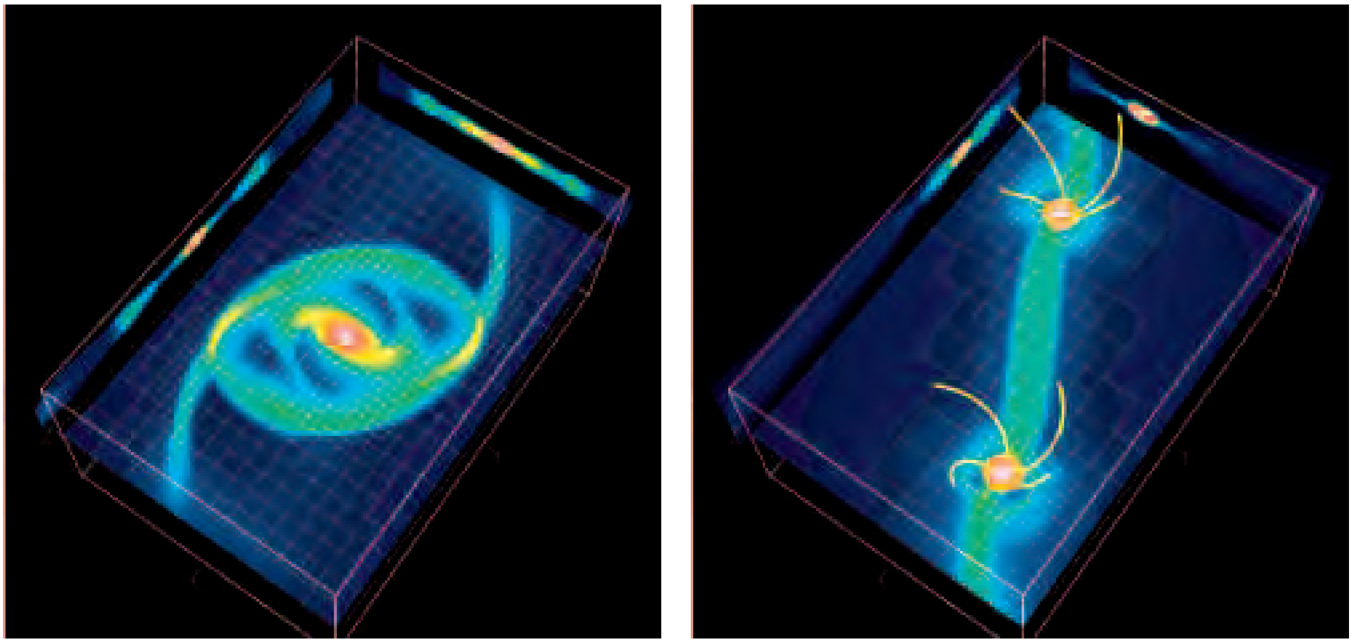
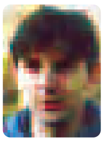


Fig 1: Density structure with overlaid block distribution for the barotropic collapse model, both with and without a magnetic field.

Numerical simulations of supernova-driven turbulence with NIRVANA3

O. Gressel, U. Ziegler

Großskalige Magnetfelder, wie sie in zahlreichen Galaxien beobachtet werden, sind das Resultat eines turbulenten, dynamischen Prozesses – eines sogenannten Dynamos. Im Rahmen der klassischen Dynamotheorie werden die Auswirkungen turbulenter Fluktuationen auf gemittelte Felder analytisch beschrieben. Für das interstellare Medium können solche Modelle jedoch nicht die hohen Wachstumsraten erklären, weswegen man nach einem schnellen Dynamoprozess forscht. Als wahrscheinlichste Antriebsquelle gelten Supernovaexplosionen; sie können immense Energien freisetzen. Hier soll durch direkte numerische Simulation supernovagetriebener Turbulenz untersucht werden, ob unter den gegebenen Annahmen ausreichend Helizität erzeugt werden kann, um einen schnellen Dynamo zu schüren.

The dynamic evolution of the turbulent interstellar medium (ISM) is simulated utilizing a three-dimensional ideal-MHD model. The domain covers a box of 500pc length at a resolution of currently 64x64x64 grid cells. Density and pressure are initially set to constant values roughly suited to the conditions within the ISM. A weak azimuthal seed-field of a few micro-Gauss is applied initially. The adiabatic equation of state is supplemented by a parameterized heating and cooling function allowing for thermal instability (TI). The source update due to heating and cooling is implemented implicitly using a Patankar-type discretization. The dual-energy feature of NIRVANA (version 3.2) is used to tackle the extreme ratio of kinetic and internal energy that arises from the violent energy input.

Turbulence is driven by supernova explosions which are modelled as local injections of thermal energy of approximately 10^{51} erg. The energy input is smeared over three standard-deviations of a Gaussian profile with FWHM of 20 pc (i.e. 7 grid cells in each direction for the current resolution). The initial SN state corresponds to the beginning of the adiabatic stage of the expansion and prevents further decrease of the hydrodynamic timestep without significantly altering the large scale dynamics. The supernova rates which are adopted are typical cited values. Within our model we make a distinction between Type Ia and Type II SNe. The latter are statistically clustered by the (artificial) constraint that the density at the explosion site be above average (with respect to a horizontal slab) – the former are spatially uncorrelated.

Further improvements of the model include a differentially rotating background (with shearing boundary conditions in the radial direction) as well as vertical stratification covering two pressure scale-heights. The model also runs on distributed memory parallel environments employing the message passing interface (MPI). This will allow for a "standard-run" of 500pc x 500pc x 2kpc at a resolution of 128x128x512, hopefully covering several Myr with an acceptable effort in computing time.

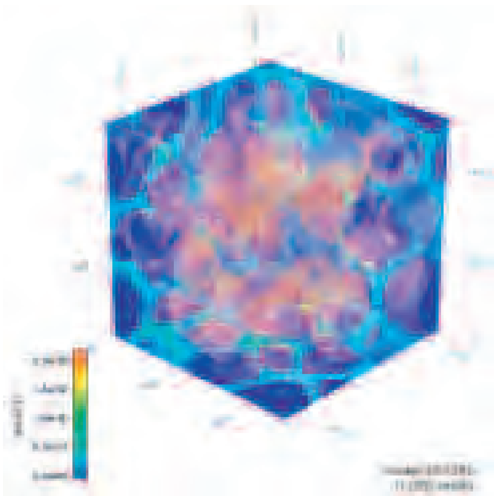


Fig. 1: slices of linear gas-density [kg/m^3] overlaid with iso-surfaces illustrating the cavities being formed by the supernova explosions

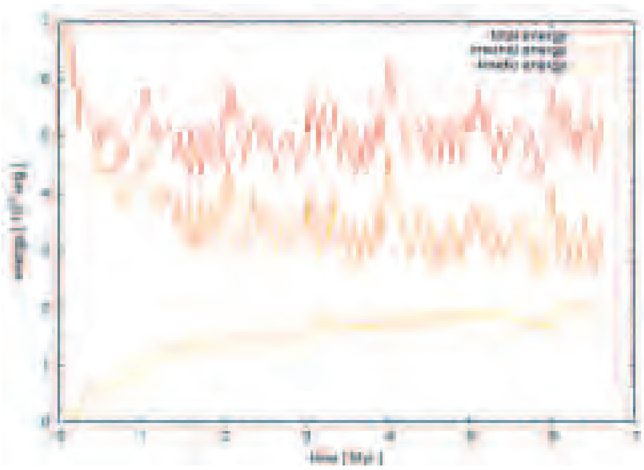
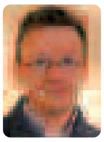


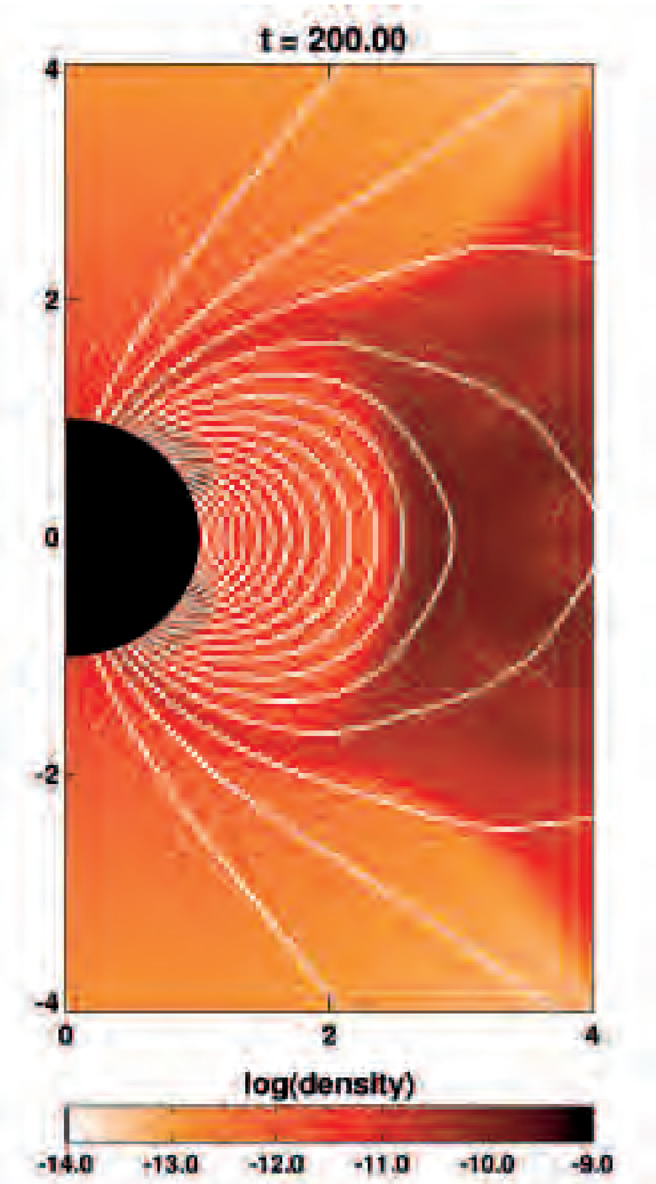
Fig. 2: temporal evolution of total, thermal and kinetic energy

Funnel flows from protoplanetary disks



M. Küker

Klassische T Tauri-Sterne sind junge Sterne, die von Akkretionsscheiben umgeben sind. Besitzt ein solcher Stern ein hinreichend starkes Magnetfeld, so bestimmt dieses die Gasbewegung in der unmittelbaren Nachbarschaft des Sterns. Es kann dann zur Ausbildung sogenannter Funnel Flows kommen, in denen das Gas die Scheibenebene verlässt und entlang den Magnetfeldlinien auf die Polkappen des Sterns fließt. Anhand von Simulationsrechnungen werden die Bedingungen für die Ausbildung der Funnel Flows sowie ihr Einfluss auf die zeitliche Entwicklung der Sternrotation untersucht.



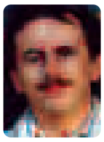
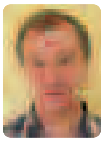
Classical T Tauri Stars are young stellar objects surrounded by accretion discs. Some of these stars have been observed to be magnetically active. A large-scale stellar magnetic field can cause the disruption of the disc close to the star and the launching of outflows from the system. In the case of a disrupted disc, the accretion flow is lifted out of the disc plane and directed towards the polar caps of the star. It then hits the stellar surface at high latitudes, causing a bright ring.

To study the interaction between the disc and the star, we have carried out numerical simulations. The setup is axisymmetric and contains the star, the disc, the halo above the disc where the density is low but finite, and the stellar magnetic field. Initially, the stellar magnetic field is a pure dipole that threads the disc, which is truncated at the corotation radius. As the system evolves, the magnetic field is wound up by the rotational shear between the star and the disc. The inner edge of the disc moves inwards, while farther away from the star gas is driven away from the star and the field lines break up, leaving the outer parts of the disc disconnected from the star.

After the initial phase a state is reached where the system switches between two configurations. In one state, the disc extends down to the stellar equator. The torque on the star is dominated by the accretion torque and the star is spun up. In the other state, the accretion flow is lifted out of the disc plane and forms a funnel flow towards the polar caps of the star. The poloidal field is compressed and forms a magnetosphere of closed loops that are not loaded with gas from the disc. The funnel flow is essentially torqueless, with both the magnetic and the accretion torques much smaller than in the disc accretion state. In the funnel flow state, the location of the inner edge of the disc is determined by the equilibrium between the magnetic pressure of the poloidal field and the gas pressure in the disc. As the funnel flow is an intermittent state and the star is spun up in the phases of (undisrupted) disc accretion, the net effect on the stellar rotation is an acceleration of the latter.

Density distribution and the poloidal magnetic field in the immediate vicinity of the star in the funnel flow state. The colour contour plots show the density distribution, the white lines the poloidal magnetic field.

Interstellar turbulence generated by the magnetorotational instablity

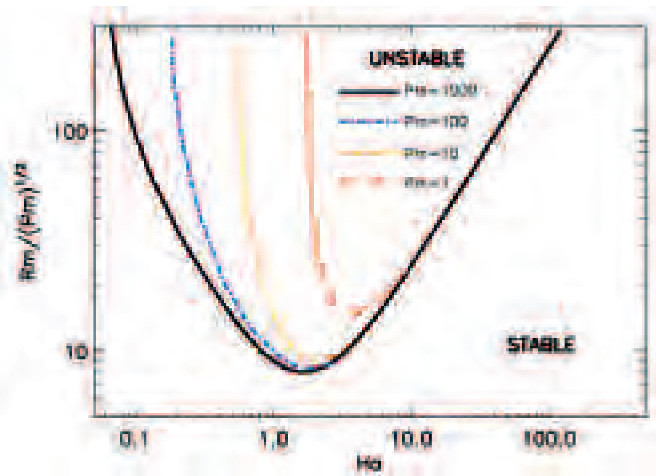
G. Rüdiger, D. Elstner, L. L. Kitchatinov

Bei Anwesenheit nicht zu starker magnetischer Felder führt jedes Rotationsgestz mit nach aussen abnehmender Winkelgeschwindigkeit zur Entstehung von Turbulenz durch die sogenannte Magnetorotationsinstabilität (MRI). Wir haben in diesem Sinne die Instabilität der galaktischen Rotation in zwei Richtungen untersucht. Einmal wurden mit einer linearen Instabiltätsanalyse die Extremwerte des Magnetfeldes bestimmt, innerhalb derer die Instabilität existiert. Die minimale Magnetfeldstärke für Galaxien ergibt sich zu nur 10^{-25} Gauss, ohne die es keine Turbulenzerzeugung gibt. Andererseits würden alle Felder stärker als 6 µGauss jede Instabilität unterdrücken. Eine voll nichtlineare Rechnung mit dem ZEUSMP Code bestätigt die genannte Obergrenze und fährt in Übereinstimmung mit den Beobachtungen auf Turbulenzintensitäten von etwa 5 km/s. Die Instabilität besitzt Wachstumszeiten von nur 100 Mio Jahren, so dass die MRI insbesondere die beobachtete Turbulenz in sehr jungen Galaxien erklären kann.

Magnetorotational instablity (MRI) leads to the formation of turbulence by the interaction of differential rotation and a weak axial magnetic field if the angular velocity decreases outwards. A linear model for the MRI is considered for galaxies with their extremely large magnetic Prandtl number. The resulting minimum field of about 10^{-25} Gauss is small, even compared to any seed fields currently discussed. We must therefore expect the generation of turbulence in all galaxies threaded by a large-scale intergalactic magnetic field. The growth times of the MRI are estimated as only about 100 Myr, which is short compared to the age of even the younger galaxies. MRI is thus a highly promising candidate as the driver of turbulence in very young galaxies where too few supernova explosions exist in order to maintain any turbulence.

The magnetic field modes with quadrupolar symmetry are more easily excited than the dipolar modes, so the basic parity selection problem of the galactic dynamo theory formulated by Krause & Beck (1998) seems to be solved. The maximum magnetic field which is still able to excite the MRI in galaxies is found from the perturbation theory to be about 6 µGauss – in excellent agreement with the amplitude of observed magnetic fields in galaxies.

Our global 3D nonlinear MHD simulations with the ZEUSMP code for vertically stratified galaxies confirm the basic findings of the linear theory. Due to MRI, toroidal and poloidal components of the magnetic fields are generated. The MRI-induced interstellar turbulence is minimal at the midplane and grows with the distance from the midplane. Such a behaviour of interstellar turbulence is known from observations and cannot be explained by other mechanisms. The simulated turbulent velocity of the interstellar gas reaches values of about 5 km/s, in perfect agreement with the measurements.



The stability diagram for axisymmetric quadrupolar magnetic modes. From these results the lower and upper limits for the magnetic field amplitude given in the text have been derived.

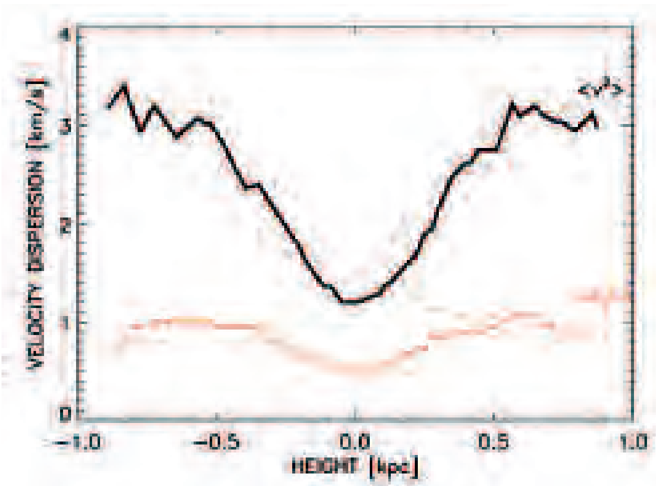
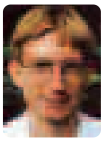
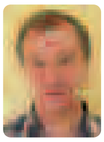


Fig.2: Vertical dependence of the velocity dispersion in MRI-driven turbulence of the interstellar matter.

The magnetic tachocline of the Sun
Die magnetische Tachocline der Sonne

R. Arlt, A. Sule, G. Rüdiger, L. Kitchatinov

Durch die Beobachtung der ununterbrochenen Sonnenbeben konnte die innere Rotation der Sonne ergründet werden. Die innersten 70% des Durchmessers rotieren fast wie ein starrer Körper, die äußere, sehr turbulente Schale rotiert am Äquator schneller als am Pol. Für den Ursprung der Magnetfelder der Sonne könnte die Übergangsregion zwischen beiden Schalen wichtig sein. Wie groß sind die Magnetfeldstärken, bevor sie instabil werden? Unsere Untersuchungen ergeben Felder bis 100 Gauß, werden aber mit schnelleren Computern bald präzisiert werden. Für den magnetfelderzeugenden Dynamoprozess ist es ebenso wichtig zu wissen, wie tief die Strömungen der Konvektionszone in den Kern eintauchen. Wir finden weniger als 1% des Sonnendurchmessers.

The origin of the magnetic field of the Sun is one of the key questions in solar astrophysics. It is very likely generated in a cyclic dynamo process based on the turbulence in the convection layer covering the upper 30% of the solar diameter. A large-scale circulation may transport magnetic fields below the convection zone and store them there. The tachocline is the thin transition between uniform rotation in the interior and the differential rotation in the upper convection zone.

If the magnetic fields are stored and amplified in the tachocline, they must be stable. If the tachocline becomes unstable for the strong fields which are necessary to produce sunspots, the dynamo must reside closer to the surface of the sun.

We investigated the stability of two belts of toroidal magnetic fields (red lines in Fig. 1). Numerical computations cannot directly reproduce solar conditions, but our present calculations lead to maximum magnetic fields of about 100 Gauss. Stronger fields cannot be stored below the convection zone. Faster computers will tell us the exact limit in future computations.

A related problem is the interaction between the convection zone and the solar core. The differential rotation in the convection zone continuously generates a large-scale circulation which is directed towards the pole at the solar surface, and towards the equator at the bottom of the convection zone. We show in a new model that the penetration of the circulation into the solar core is very small. The penetration depth depends on whether or not the tachocline is turbulent. However, even in the very unlikely case of a turbulent tachocline (left edge of Fig. 2), the penetration depth is only a few thousand kilometres, which is less than 1% of the solar radius. The transport of magnetic fields into the tachocline must be weak, too.

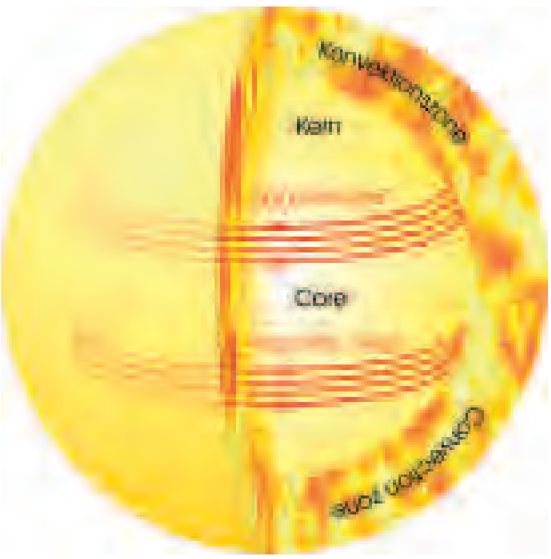


Fig. 1: Magnetic field belts are placed below the convection zone in order to study their stability. The belts are indicated by red field lines.

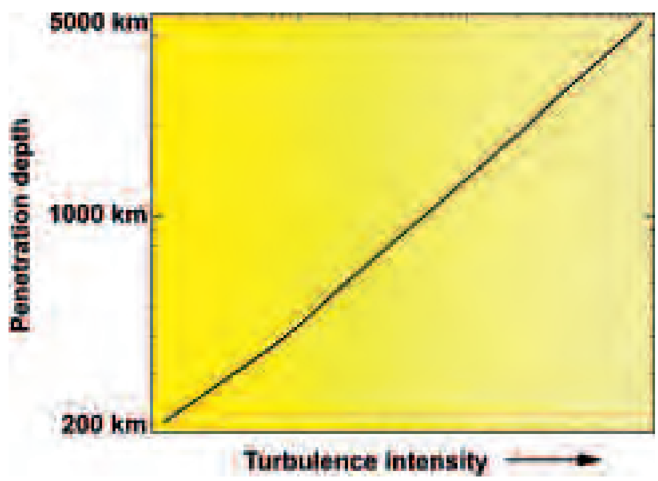
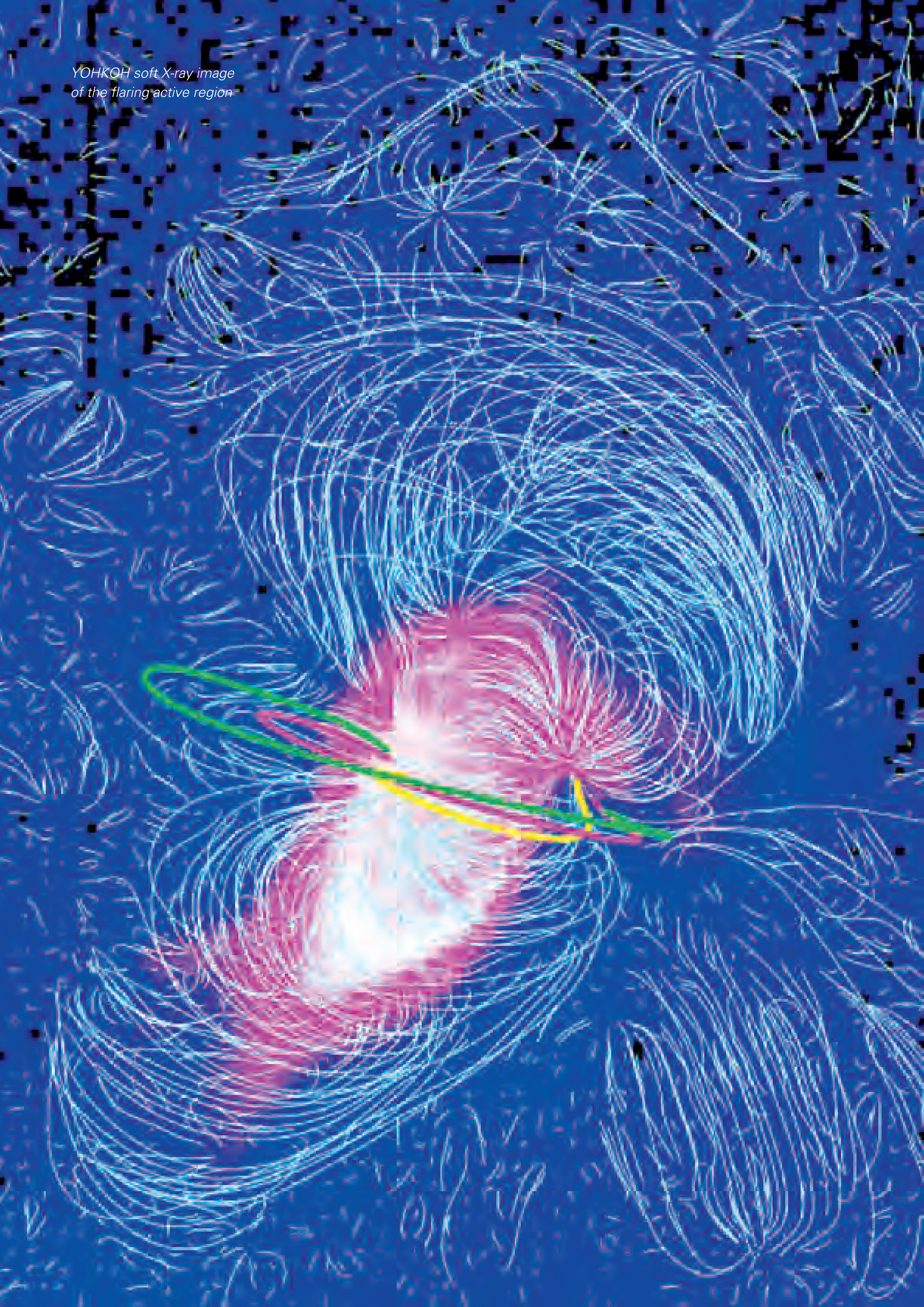
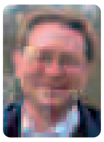
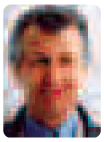
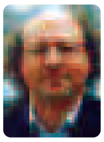


Fig. 2: Penetration depth of the meridional circulation at the transition between convection zone and core, as a function of the turbulence intensity.



YOHKOH soft X-ray image
of the flaring active region

GREGOR – ein neues 1,5-m-Teleskop auf Teneriffa
GREGOR – a New 1.5 m Telescope at Tenerife

J. Staude, A. Hofmann, K. G. Strassmeier

Wissenschaftliche Zielsetzung

Magnetfelder und deren Wechselwirkung mit dem turbulenten, elektrisch gut leitenden Gas sind für die meisten dynamischen Prozesse auf der Sonne und auf anderen Sternen von entscheidender Bedeutung. Solche fundamentalen Prozesse der Astrophysik sind häufig auf Längenskalen von weniger als 100 km sowie damit verknüpfte sehr kurze Zeitskalen konzentriert. Sie können nur auf der Sonne direkt beobachtet werden. Das Magnetfeld ist dabei der Schlüsselparameter, der alle Prozesse der Sonnenaktivität und deren Einwirkungen auf die Erde bestimmt. Das Magnetfeld ist auch das verbindende Gerüst der Strukturen von den tiefsten Schichten in der Sonne bis in die Korona. Die Beobachtung von Magnetfeld und Gasströmungen auf allen Skalen erfordert vor allem spektral-polarimetrische Messungen mit einer neuen Generation von Sonnenteleskopen.

Teleskop-Konzept

Im Herbst 2006 wird im Observatorio del Teide des IAC auf Teneriffa ''first light'' für GREGOR erwartet. Damit wird dann das leistungsfähigste Sonnenteleskop der Welt für die Sonnenforschung zur Verfügung stehen. Entwicklung und Bau von GREGOR sind ein gemeinsames Vorhaben der Institute KIS

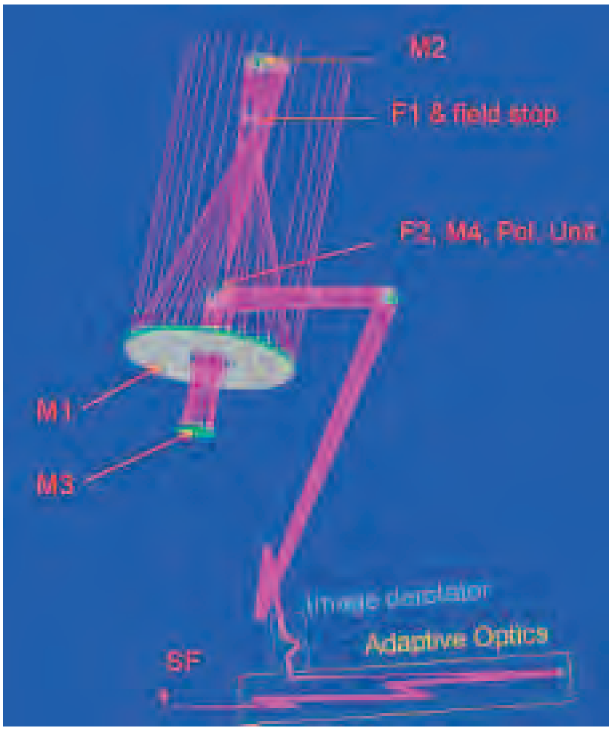


Abb.1: Strahlengang des GREGOR-Teleskops. Spiegel sind mit M bezeichnet worden, Brennpunkte mit F.

Scientific objectives

Magnetic fields and their interaction with turbulent, electrically highly conductive gas are responsible for most of the dynamic processes in the Sun and other stars. Such basic astrophysical processes are often concentrated on spatial scales of 100 km and less and involve very short time scales. In principle they can be observed only at the Sun. The magnetic field is the key parameter which controls all solar-activity processes and their influence on the Earth. Moreover, the magnetic field provides the interconnection of the structures between the different layers from the subphotosphere up to the corona. It is neccessary to study the magnetic field and gas motions on all scales using spectro-polarimetric measurements with a new generation of solar telescopes.

Telescope concept

In autumn of 2006 we expect "first light" for GREGOR at the Observatorio del Teide on Tenerife, and at that time the most effective solar telescope worldwide will be available for solar research. Development and construction of GREGOR are a common project of the institutes KIS (Freiburg), IAG (Göttingen), and AIP. GREGOR is an open telescope on an alt-azimuthal mount with an aperture of 1.5 m. It will be equipped with an adaptive optics system (AO) in order to compensate for the deformation of the wavefront of the incoming light caused by air turbulence. It is the only way to reconcile the conflicting requirements of high spatial, spectral, and temporal resolutions and of spectro-polarimetric precision. With its main mirror (M1) GREGOR will reach the

Abb.2: M3-Spiegeleinheit nach integration in die Teleskopstruktur.

(Freiburg), IAG (Göttingen) und AIP. GREGOR ist ein offenes Teleskop mit einer alt-azimutalen Montierung und einer Öffnung von 1,5 m. Es wird mit einem System adaptiver Optik (AO) ausgerüstet, um die durch Luftturbulenz verursachten Deformationen der Wellenfront des einfallenden Lichtes zu kompensieren. Nur auf diese Weise können die konkurrierenden Forderungen nach hoher Raum-, Spektral- und Zeitauflösung sowie spektralpolarimetrischer Präzision erfüllt werden. Der Hauptspiegel (M1) von GREGOR erreicht die Öffnung des größten Sonnenteleskops der Welt, des McMath-Pierce-Teleskops auf dem Kitt Peak, USA. Bei GREGOR werden modernste Teleskopbau-Prinzipien zum Einsatz kommen. GREGOR ist in erster Linie ein Sonnenteleskop, die große lichtsammelnde Fläche und die Ausrüstung bieten aber auch interessante Einsatzmöglichkeiten für die Nachtastronomie. Dies betrifft insbesondere spektroskopische Untersuchungen von Aktivitätsphänomenen auf anderen Sternen und damit einen anderen Forschungsschwerpunkt am AIP.

aperture of the greatest solar telescope worldwide, the McMath-Pierce Telescope at Kitt Peak, USA. GREGOR will make use of modern technology and telescope design principles. Conceived as a solar telescope, GREGOR offers a significant collecting area and operating modes which facilitate the observation of night-time sources as well. Thus, GREGOR may become an attractive facility for spectroscopically investigating activity on stars other than the Sun, another main research topic of the AIP.

Optical scheme

The optical design (see the optical scheme in Fig.1) includes at first an axial-symmetric 3-mirror configuration where the first two mirrors form a classical Gregory telescope. The first three mirrors (M1, M2 and M3, Fig. 2) are curved to provide imaging. The effective focal length is about 55 m, the entrance pupil diameter 150 cm, therefore the effective focal ratio is F/36.5 and the image scale becomes 3.75 arcsec/mm. M4 and several other flat mirrors reflect the light through the

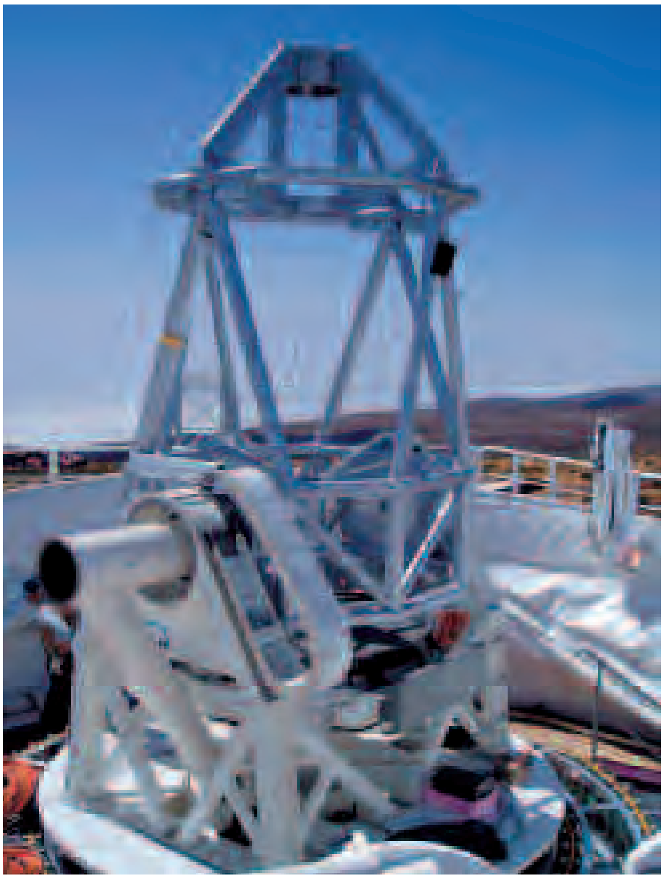


Abb.3: Teleskop-Struktur nach der Montage auf Teneriffa. Die Kuppel wurde hier heruntergeklappt.

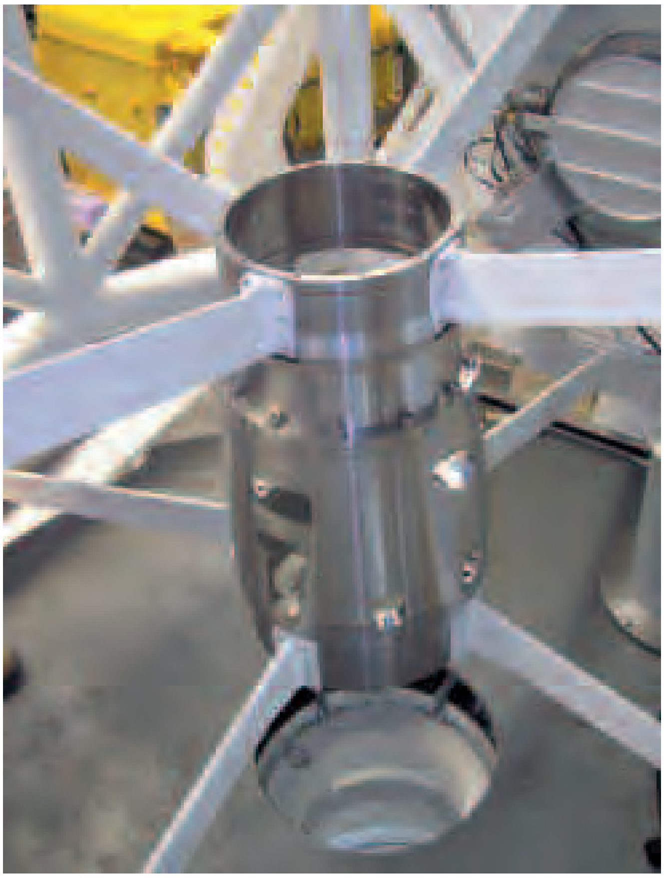


Abb.4: M4/F2-Einheit nach Einpassung in die Teleskopstruktur.

GREGOR – ein neues 1,5-m-Teleskop auf Teneriffa
GREGOR – a New 1.5 m Telescope at Tenerife

Optisches Schema
Der Lichtweg (siehe das optische Schema in Abb.1) geht zuerst über ein achsensymmetrisches 3-Spiegel-System, bei dem die ersten beiden Spiegel ein klassisches Gregory-Teleskop bilden. Die Abbildung erfolgt über die Krümmung dieser drei ersten Spiegel (M1, M2, M3, Abb. 2). Die effektive Brennweite beträgt etwa 55 m; bei einem Durchmesser der Eintrittspupille von 150 cm ergibt dies ein effektives Verhältnis von F/36,5 und eine Bildskala von 3,75''/mm. Über M4 und mehrere weitere ebene Spiegel wird der Strahl durch die Höhen- und Azimutachsen auf den Bild-Derotator und das AO-System reflektiert. Der Arbeitsfokus (SF) kann wahlweise in einer der beiden obersten Etagen des Gebäudes entstehen. Hier werden verschiedene hochleistungsfähige Fokalinstrumente das Teleskop ergänzen, u.a. ein hochauflösendes Fabry-Perot-Filterspektrometer, verschiedene Polarimeter, ein Czerny-Turner-Spektrograf und Instrumente für Infrarot-Spektroskopie und -Polarimetrie.

Zeitplan
Der Einsatz völlig neuer Technologien war natürlich mit kritischen Phasen bei der Fertigung verbunden. Um so erfreulicher war es, dass die ursprüngliche Planung mit relativ geringen Verzögerungen eingehalten werden konnte. Wichtige Etappen waren auf Teneriffa im Sommer 2004 die Fertigstellung der faltbaren Kuppel und im Herbst 2004 sowie im Sommer 2005 die Montage und Operationstests der Struktur (Abb. 3). Parallel dazu liefen die erforderlichen Umbauten des Gebäudes sowie die Fertigung und Tests der Spiegel und anderer Komponenten von GREGOR wie Steuerung, AO-System und Post-Fokus-Instrumente. Einige Beiträge des AIP werden im folgenden Abschnitt beschrieben. Die endgültige Integration aller Komponenten soll im Frühjahr 2006 erfolgen.

Beiträge des AIP
Wesentliche Beiträge des AIP zu GREGOR sind die Konstruktion und Fertigung der Einheiten für die Spiegel M3 sowie M4/F2 (Abb.4), die bereits abgeschlossen sind. Dazu kommt insbesondere das System zur Eichung der Polarisationsmessungen, das innerhalb des Teleskops im Schatten des Nasmyth-Spiegels M4, nahe dem Fokus F2, installiert wird. Allerdings stellen der große Öffnungswinkel des Lichtbündels und die Leistungsdichte in F2 extreme Anforderungen, die auch hier neue Wege bzgl. der eingesetzten Polarisationsoptik erfordern. Die Polarisationseinheit wird zurzeit noch im Labor des Einsteinturms getestet und soll im Mai 2006 in das Teleskop integriert werden.

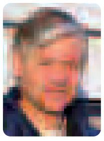
altitude and azimuth axes to the image derotator and the AO. The science focus (SF) can be fed into either of the two topmost floors of the building. Here different high performance focal instruments will be added. These are, e.g., a high-resolution Fabry-Perot filter spectrometer, different polarimeters, a Czerny-Turner spectrograph, and instrumentation for infra-red spectroscopy and polarimetry.

Schedule
Of course, the use of completely new technologies entailed critical phases during the completion. We were therefore pleased that there was only a minor delay with respect to the original schedule. Milestones reached in Tenerife were in spring 2004 the completion of the retractable dome and in autumn 2004 and summer 2005 the assembly and operational tests of the telescope structure (Fig. 3). Simultaneous efforts were focused on the reconstruction of the building, the construction and tests of the mirrors and other components of GREGOR such as the control and AO systems and the focal instruments. Some contributions of the AIP will be described in the subsequent section. The final assembly and test of all components are planned for spring 2006 in Tenerife.

Contributions of the AIP
Essential components contributed by the AIP to GREGOR are the units for the mirrors M3 as well as M4/F2 (Fig.4) which have already been designed and produced. These parts are complemented in particular by the package for the calibration and modulation of the polarization measurements, which will be placed inside the telescope, in the shadow behind the Nasmyth mirror M4, close to the focus F2. However the large aperture angle and the power density at F2 are extreme conditions which necessitate new ways for the polarisation optics. The polarimetric unit is currently tested in the laboratory of the Einstein Tower and will be integrated into the telescope in May 2006.

The GREGOR team at AIP
J. Staude (P.I.), A.Hofmann (project scientist),
K. G. Strassmeier (P. I. stellar spectrograph),
K. Arlt (software), H. Balthasar (secretary),
S.-M. Bauer (design), J. Paschke and
E. Popow (integration), J. Rendtel (assistant scientist)

Vertical electric current densities in sunspots



H. Balthasar

Elektrische Stromdichten können eine wichtige Rolle für das Verständnis der kleinräumigen Strukturen in Sonnenflecken spielen. Man kann sie allerdings nicht direkt messen, vielmehr muss man sie aus räumlichen Änderungen des Magnetfeldes ableiten. Es zeigt sich, dass auch die Stromdichten eine radiale Struktur in der Penumbra aufweisen, allerdings ergibt sich bei der zur Zeit möglichen Auflösung noch keine eindeutige Zuordnung zu den hellen und dunklen Filamenten. Darüber hinaus ist die Kenntnis der Stromdichten unverzichtbar, will man das Magnetfeld von der Photosphäre bis in die Korona extrapolieren.

The knowledge of electric current densities in photospheric layers is important for the extrapolation of the magnetic field up to the corona. It is also fairly probable that electric currents play a fundamental role in understanding the penumbral fine structures in sunspots. The Stokes vector field of a large sunspot was observed at the Vacuum Tower Telescope with the Tenerife Infrared Polarimeter. The magnetic vector was obtained with an inversion code based on response functions. From the horizontal components of the magnetic field, the vertical component of the electric current density is derived from Ampère's law. The required partial derivatives are approximated by the difference of the values of the two neighboring pixels. Fig. 2 shows the relation of the obtained current densities and the fine structure in the penumbra. A radial structure is clearly visible. However, one has to be very careful with the interpretation, because the true penumbral structures are smaller than the spatial resolution of the observations, and when obtaining the derivatives, one might mix data that do not belong together. Enhanced current densities up to 150 mA/m^2 are found in the range between the two umbrae.

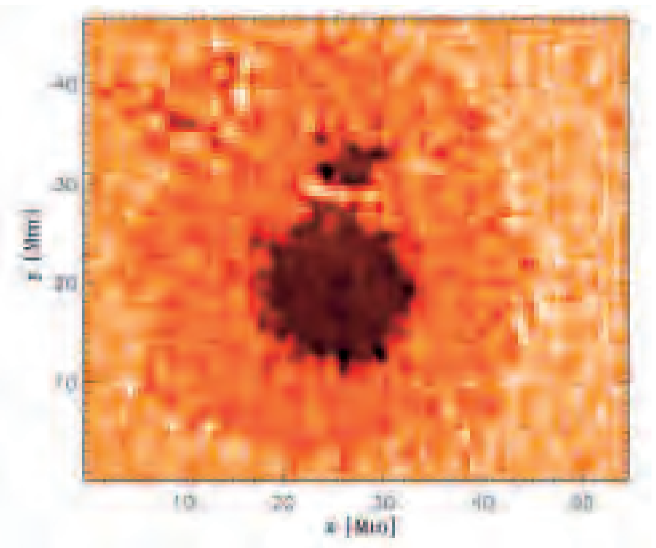


Fig. 1: Intensity map of a large sunspot observed on 19 June 2001 with the Tenerife Infrared Polarimeter at the German Vacuum Tower Telescope. This image is reconstructed from two spectral scans across the spot using the line Fe I 1089.6 nm. The spot was located at a distance of 8 degrees from disk center.

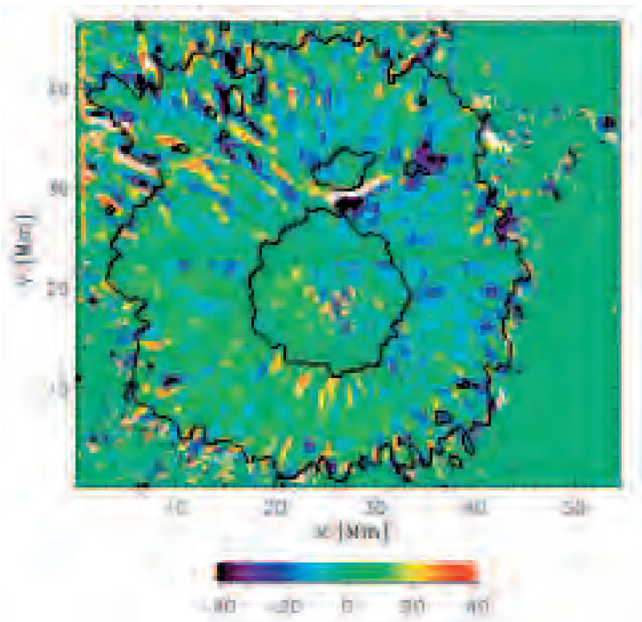
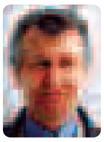


Fig. 2: Vertical component of the electric current density. Values are clipped at –40 mA/m^2 and 40 mA/m^2 to emphasize the penumbral structures. The contour lines indicate the inner and outer boundaries of the penumbra.

Type III radio burst prolific magnetic field configurations



A. Hofmann

Flares (solare Eruptionen) können zu Type III-Bursts (Strahlungsausbrüche im Radiobereich) führen. Diese werden durch schnelle Elektronen ausgelöst, die sich durch die Sonnenkorona bis in den interplanetaren Raum ausbreiten. Für das Zustandekommen solcher Type III-Bursts bedarf es einer speziellen Topologie des Magnetfeldes in der Sonnenatmosphäre. Statistische Methoden zeigten eine besondere Häufigkeit von Type III-Bursts bei Flares, die am Rande von aktiven Regionen und hier insbesondere an der führenden Kante, d.h. westlich der aktiven Region auftraten. Extrapolationen der gemessenen Magnetfelder zeigten, dass in diesen Lagen ein besonders guter Zugang der in niederen Höhen freigesetzten Elektronen zu offenen Feldlinien, die bis in die obere Korona bzw. den interplanetaren Raum hinausreichen, besteht.

Type III bursts are generated by beams of electrons accelerated up to 0.2-0.6 c, usually during the impulsive phases of flares, and can trace the path of the beam from the acceleration site through the corona and eventually into interplanetary space. The appearance of metric type III bursts shows that specific field line topologies must be present close to the energy release site, enabling the propagation of the fast electrons through the high corona. The primary result of our statistical analysis is that the probability for a flare to produce a type III burst is higher by about one order of magnitude if the flare occurs at the boundary compared to a position elsewhere inside the active region. Secondly we find a strong preference for the leading edge of the active region. For all examples we investigated by extrapolation, we find field lines open to coronal heights at the locations of associated flares. Always, it was close to the boundary of the active region. This indicates, in agreement with the statistical results, that the electrons can get access to open field lines much more easily at the periphery than within an active region. The inner part is mostly dominated by dense arcades between both polarities, shielding the field to coronal heights.

The studies of this project were done in close cooperation with V.Ruzdjak from the Hvar-Observatory (Croatia).

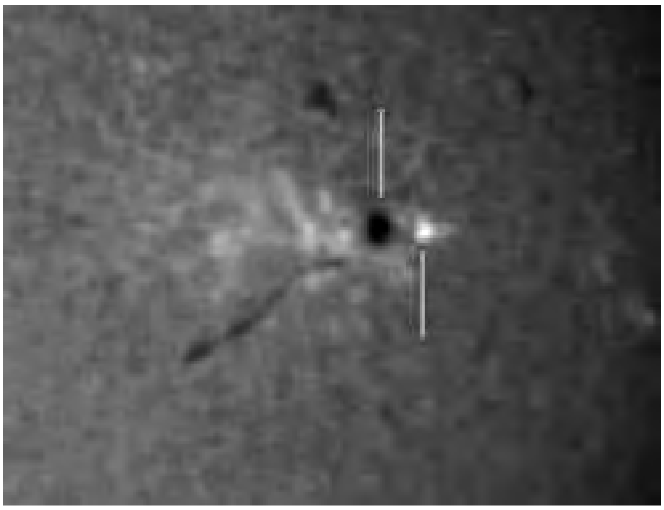


Fig. 1: Kanzelhöhe Hα filtergram of AR McMath 13738. The upper bar points to a sunspot of leading polarity. The lower bar points to a location of repeated flaring associated with type III bursts.

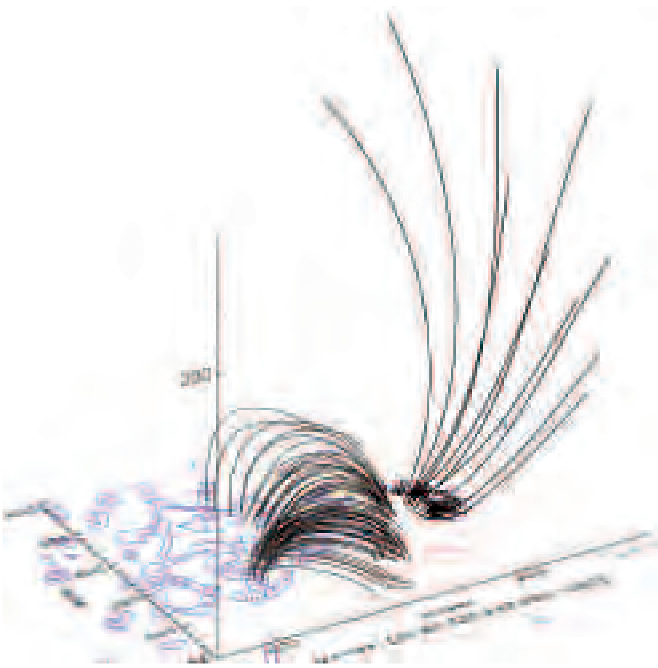
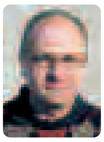
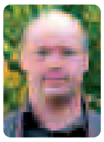


Fig. 2: Extrapolation of the photosperic longitudinal field magnetogram of AR McMath 13738. Selected field lines are drawn, representing some characteristics of the field configuration inside and at the leading edge of the active region.

On the structure and strength of coronal magnetic fields in postflare loops

H. Aurass, G. Rausche

Eine am AIP entwickelte neue Methode zur Bestimmung von Struktur und Stärke koronaler Magnetfelder wird benutzt, um die Entwicklung der Sonneneruption vom 7. April 1997 innerhalb einer Stunde nach Beginn des Ausbruchs zu verfolgen. Es zeigt sich, dass koronale Magnetfelder in diesem Zeitabschnitt der Eruption etwa 10mal schwächer sind als durch bisher akzeptierte Modelle vorhergesagt. Struktur und Stärke des koronalen Feldes lassen sich aus einer Potenzialfeldfortsetzung photosphärischer Messungen und Radiobeobachtungen in exzellente Übereinstimmung mit Ultraviolett- und Röntgenbildern der Sonnenkorona bringen.

We applied a method newly developed at the AIP (see the contribution of Rausche et al., this report) for determining the structure and the strength of coronal magnetic fields during the late phase of solar flares. As an example we studied the evolution of the 7 April 1997 14 UT event, Fig. 1.

In this case, the evolution of the postflare loop magnetic field can be observed within one hour after the onset of the impulsive flare phase. The colored magnetic field lines (yellow, magenta, green) are selected as characterizing the evolution of the eruption in the time intervals 10, 30, and 40 min after the onset of the impulsive flare energy release. In Fig. 2 the field strength, measured along the same field lines, is given as a function of height over the photosphere.

For comparison, we show the widely accepted model of the active region coronal magnetic field after Dulk and McLean (Solar Phys. 57, 1978, 279). For the analyzed event, the field strength in postflare loops is roughly one order of magnitude lower than the model field strength. As a confirmation of the results, we can reconstruct from the selected activated field regions the postflare loop footpoint spreading speed, in agreement with independent measurements in soft X-ray and ultraviolet coronal images from the YOHKOH and SOHO spacecraft. The result is the first direct measurement of coronal magnetic fields underneath an erupting flux rope and is relevant for flare models and for diagnostics of coronal loops by MHD waves.

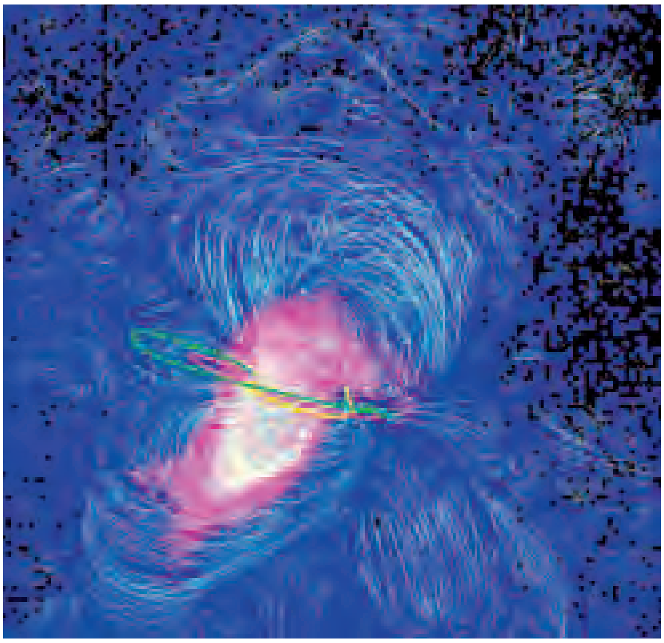


Fig. 1: April 7th, 1997: YOHKOH soft X-ray image of the flaring active region (N--upwards, W--to the right) with superposed potential field lines (grey) and overplotted flare-activated field lines. Yellow line - 10 min after flare start, magenta - 30 min, green - 40 min after onset.

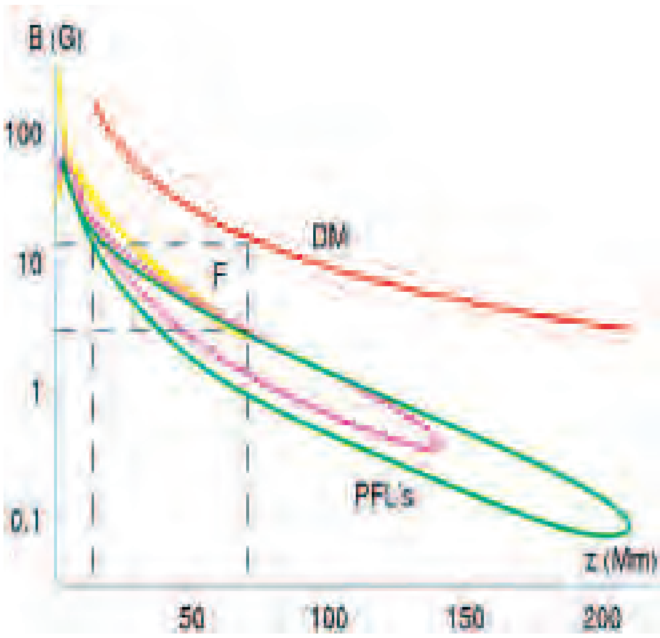
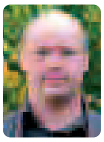
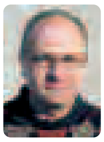
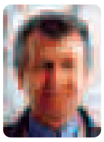


Fig. 2: Measured coronal magnetic field strength along the flare-activated field lines (PFL) versus height over the photosphere. Same color code as Fig. 1. The red curve (DM) is the mean active region magnetic field after Dulk and McLean's model. Dotted is the average field strength in the active region.

Using fiber bursts to measure the coronal magnetic field

G. Rausche, H. Aurass, G. Mann, A. Hofmann.

Fiberbursts sind eine Feinstruktur im Radiospektrum bestimmter Sonneneruptionen. Sie werden bei der feldparallelen Ausbreitung von Whistlerwellen in der Korona abgestrahlt. Aus ihrer Vermessung im Spektrum, aus Radiobilddaten und aus Magnetfeldmessungen in der Photosphäre gelingt die Bestimmung von Stärke und Struktur des koronalen Magnetfelds in verschiedenen Stadien eines Flares. Durch die Wahl des Dichtemodells der Korona und durch Zuordnung der Radiodaten zur 3D-Darstellung des in die Korona als kraftfreies Feld oder Potenzialfeld hochgerechneten photosphärischen Magnetfeldes findet man die aktivierten Feldgebiete und die darin herrschende Feldstärke. Am AIP wurde somit durch Verknüpfung von Radio- und optischen Beobachtungen eine neuartige Messmethode für veränderliche koronale Magnetfelder entwickelt.

Fiber bursts are a special kind of radio spectral fine structure occuring in complex solar eruptions. During solar flares, nonthermal energetic electrons are injected into coronal loops which act as magnetic traps. The particles oscillate between both magnetic mirror points near the loop foot points. Coulomb collisions due to the higher density there lead to an unstable distribution of the trapped electrons which causes whistler waves. Radio emission escapes and appears in the spectrum as patches of fiber bursts induced by the interaction of bunches of whistler waves ascending along the loop field lines with the nonthermal particles.

For the analysis we use dynamic radio spectra (regular AIP observations), Nançay Radio Heliograph data (courtesy: Observatory Paris-Meudon, France), and SOHO-MDI photospheric field data (Solar and Heliospheric Observatory, Michelson Doppler Imager, courtesy: NASA/ESA).

From the spectrum (Fig. 1, right panel), we derive the frequency drift rate and the instantaneous bandwidth of fiber bursts. Applying the whistler wave dispersion law we find from the spectral data an estimate of the magnetic field strength in the fiber burst source volume.

In the radio images we search for the fiber burst source sites at two or more observing frequencies, in projection on the solar disc. From the SOHO-MDI magnetogram we compute the (potential or force-free) extrapolation of these measurements into the corona. Comparing the 3D set of extrapolated field lines with the radio images of the fiber bursts a subset of field lines is selected, crossing the radio source at the imaging frequencies (Fig. 1, left panel). Next, we change the density model – and thus vary the height of a given observing frequency – until we obtain the best coincidence of the field strength derived from the "fiber burst source field lines" and (independently) from the spectral data. First tests of the method (see Aurass and Rausche, this report) are very promising.

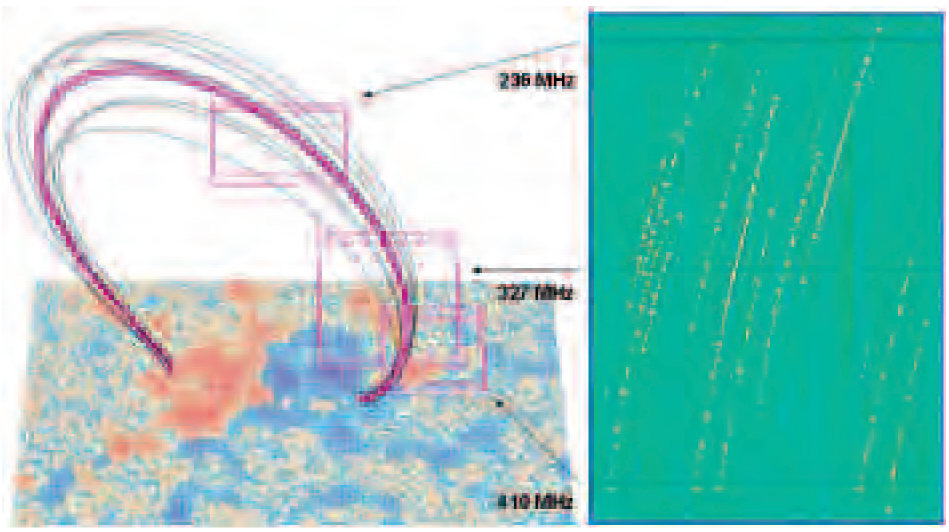
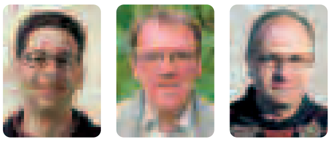


Fig. 1: Example demonstrating the combination of radio and optical observations for field determination. Right panel: AIP radio spectrum with fiber bursts. The abscissa is the time (60 s) and the ordinate is the observing frequency corresponding (via a coronal electron density model) with the height above the photosphere. Left panel: Part of a SOHO-MDI magnetogram, red and blue: magnetic north and south polarity. Thin arcs: magnetic field lines passing all fiber burst source sites (the boxes assigned by arrows with the observing frequency). We have plotted a perspective view using a 3.5 times Newkirk coronal density model. Thick line (magneta): the average fiber burst field line for a certain time interval during the flare.

First observations of coronal waves with the *GOES* Solar X-ray Imager



A. Warmuth, G. Mann, H. Aurass

Eruptive Prozesse in der Korona der Sonne sind oft mit sich global ausbreitenden Wellen assoziiert, welche wichtige Informationen über das koronale Medium und den Eruptionsprozess liefern können (*koronale Seismologie*). Allerdings besteht seit langem eine Kontroverse darüber, in welcher Beziehung die verschiedenen beobachteten Wellenphänomene miteinander stehen. Uns ist es nun gelungen, mit Hilfe neuartiger Röntgenbeobachtungen mit dem *GOES Solar X-ray Imager* erstmals zweifelsfrei nachzuweisen, dass die in verschiedenen Spektralbereichen beobachteten globalen Wellen tatsächlich Signaturen einer einzigen zugrunde liegenden koronalen Störung sind.

Eruptive processes in the solar corona - flares and coronal mass ejections - are often associated with globally propagating waves and shocks. These disturbances may provide important information on the ambient medium and the eruption process (*coronal seismology*). Historically, waves were first detected in Hα (Moreton waves). The observation of coronal waves in the extreme ultraviolet by the EIT instrument aboard *SOHO* has rekindled the interest in these phenomena during the last few years. However, there is a controversy on how the different observational signatures are related, since the low cadence of EIT does not allow a straightforward comparison.

Recently, high-cadence (2-4 min), full-disk coronal imaging data provided by the Solar X-ray Imager (SXI) aboard the *GOES-12* satellite have become available. We have since observed numerous coronal waves with SXI (see Fig. 1 for an example). They are morphologically similar to EIT waves, and we were able to show that the wavefronts seen with EIT, SXI, as well as in Hα, all follow the same kinematical curve (see Fig. 2).

The SXI observations confirm that all signatures of coronal waves are generated by a single, decelerating physical disturbance. The behavior of this perturbation is consistent with a shock formed from a large-amplitude simple wave, which subsequently decays to a linear fast-mode wave. SXI samples both phases -- the supermagnetosonic shock and the linear wave. The kinematics are thus resolved with a single instrument, and coupled with the continuous high-cadence coverage, this will result in a large event sample suitable for an in-depth analysis. For instance, the waves can be back-extrapolated to a starting time and location, which can then be compared with the evolution of any associated flares (see Fig. 2) and coronal mass ejections. Such a study will be crucial for addressing the long-standing question of how the waves are actually launched.

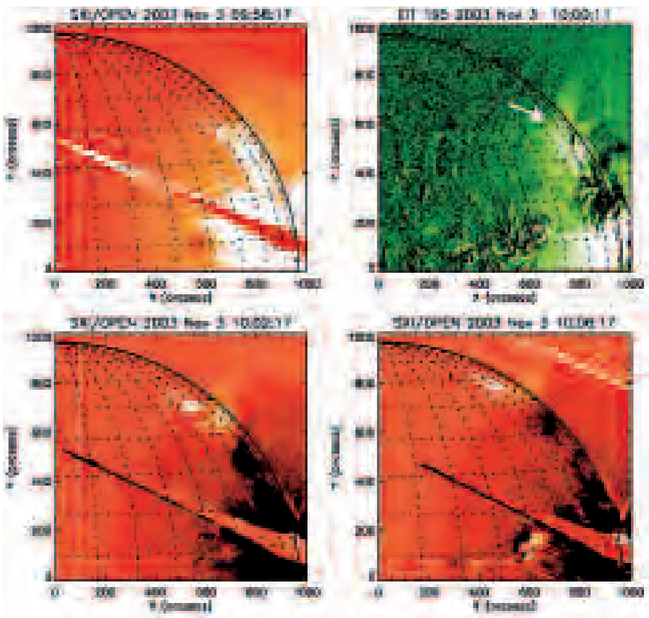


Fig. 1: Propagation of the coronal wave of Nov 3rd, 2003 as shown by SXI and EIT (upper right) running difference images. The wave is indicated by arrows. Note that the waves' signatures are very similar in soft X-rays and the extreme ultraviolet.

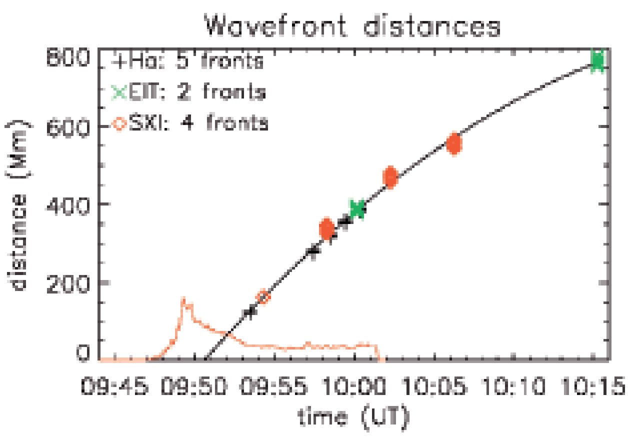
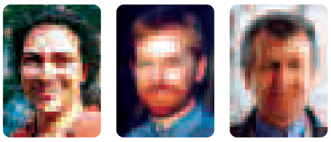


Fig. 2: Kinematics of the coronal wave of Nov 3rd, 2003. The distances d(t) of the wavefronts are plotted together with a polynomial fit. Distances are given in Mm (10^3 km). SXI, EIT, and Hα data are considered. Also included is the hard X-ray light curve (red) of the associated flare as measured by the RHESSI satellite.

Extrapolation of photospheric magnetic field measurements into the solar corona



G. Valori, B. Kliem, A. Hofmann

Solare Eruptionen (koronale Massenauswürfe und Flares) können Satelliten und Stromversorgungsanlagen auf der Erde Schaden zufügen. Für das Verständnis und die Vorhersage solarer Eruptionen ist die Kenntnis des koronalen Magnetfeldes unentbehrlich. Mit Hilfe von Extrapolationstechniken lässt sich das koronale Magnetfeld aus photosphärischen Magnetfeldmessungen bestimmen. Die Sonnenphysikgruppe des AIP hat in den letzten Jahren eines der zur Zeit weltweit führenden numerischen Verfahren zur Magnetfeldextrapolation entwickelt und ist damit in der Lage, einen entscheidenden Beitrag zur Erforschung solarer Eruptionen zu leisten.

Solar flares and coronal mass ejections are due to a sudden loss of stability or equilibrium of otherwise long-lived, slowly evolving, magnetically dominated structures, which are rooted in the photosphere and extend well up into the solar corona. Due to the extremely low density in the corona, measurements of the magnetic field are restricted to lower layers of the solar atmosphere. The extrapolation technique is then the prime tool for quantitative investigations of the coronal magnetic field.

The coronal plasma can be considered almost everywhere to be in a force-free state, i.e., the current is aligned with the magnetic field. In a force-free field the parameter α, equal to the ratio of the current density to the magnetic field, is constant along each individual magnetic field line, but it varies from field line to field line. Previously, a simplified extrapolation problem was solved, assuming α to be constant in the whole volume (linear approximation). Besides being physically inconsistent, such an approximation is unrealistic for many of the active regions observed so far, an example of which is given in Fig. 1.

We developed a numeric code for extrapolation which does not require α to be constant and which employs relaxation techniques to obtain nonlinear force-free magnetic equilibria. Our code was proven to be among the most accurate codes currently available.

As an example, in Fig. 2 the calculation of the coronal field from the measurements shown in Fig. 1 is presented. The Fig. shows a set of twisted field lines forming one of the coronal loops in the core region of the `Bastille event'. The extrapolation tool will be routinely employed in the analysis of measurements of solar magnetic fields performed both by groups at the AIP and by other international teams, including vector magnetograms from the forthcoming Solar-B satellite.

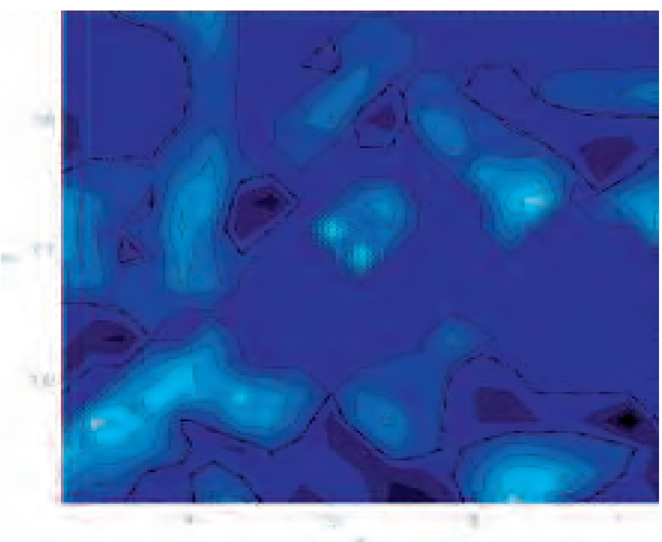


Fig. 1: $\alpha(x,y)$ in the photosphere during the so-called `Bastille event', a large coronal mass ejection event that took place on July 14, 2000.

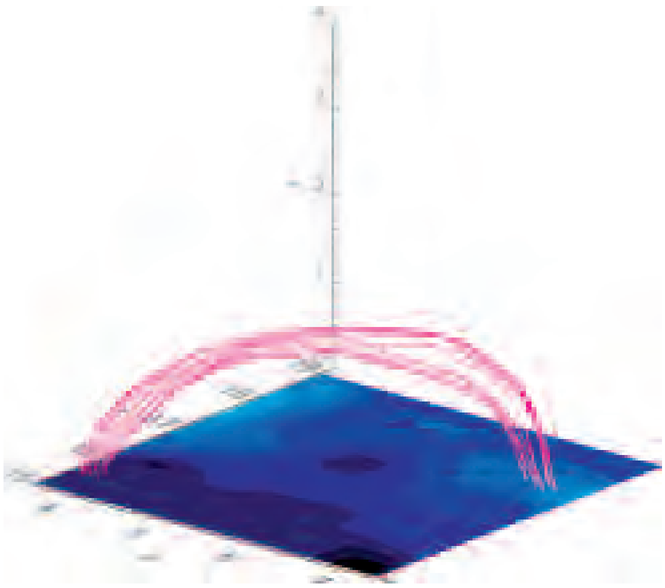
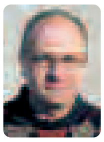
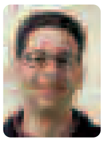


Fig. 2: Coronal loop in the extrapolated field from Fig. 1

Generation of energetic electrons in solar flares

G. Mann, H. Aurass, A. Warmuth

Die Sonne ist kein ruhiger Stern, sondern zeigt kurzzeitige Eruptionen, sogenannte Flares. Während solcher Flares werden enorme Energiemengen freigesetzt. Das zeigt sich u. a. in dem starken Anwachsen der Intensität elektromagnetischer Strahlung vom Radiobereich über das sichtbare Licht bis hin zur harten Röntgen- und Gammastrahlung. Gerade der starke Sonnen-Flare am 28. Oktober 2003 war mit einem extremen Anwachsen der Intensität der harten Röntgen- und Gammastrahlung verbunden. So maß der Satellit *INTEGRAL* eine starke Gamma-Emission bis zu 10 MeV für eine Minute während der Anfangsphase des Flares. Das zeigt, dass zu Beginn des Flares Elektronen mit Energien höher als 10 MeV erzeugt werden müssen.

During solar flares, a large amount of electromagnetic radiation from the radio up to the hard X-ray and γ-ray regime is emitted from the corona. For example, the huge solar event of October 28, 2003 (Fig. 1) was accompanied by a strongly enhanced emission of γ-ray radiation up to $\approx$ 10 MeV during the impulsive phase, as observed by the *INTEGRAL* spacecraft (Fig. 2). The radiation is generally regarded as bremsstrahlung generated by highly energetic electrons in the corona. Thus, an enhanced flux of γ-rays indicates the generation of electrons with energies > 10 MeV.

In the widely accepted magnetic reconnection model of solar flares, plasma shoots away from the reconnection region, leading to the establishment of a standing shock wave, i.e. the termination shock (TS). Solar radio data recorded by the radiospectralpolarimeter at the Tremsdorf Observatory (AIP) show signatures of such a shock (Fig. 2). The simultaneous appearance of the enhanced γ-ray fluxes and the radio signature of the TS implies that it is the source of the highly energetic electrons required for the generation of the γ-rays. Electrons can be accelerated up to high energies at the TS as demonstrated by a fully relativistic treatment of the *shock drift acceleration* mechanism. This model can reproduce the observations of the γ-ray fluxes during the solar event of October 28, 2003.

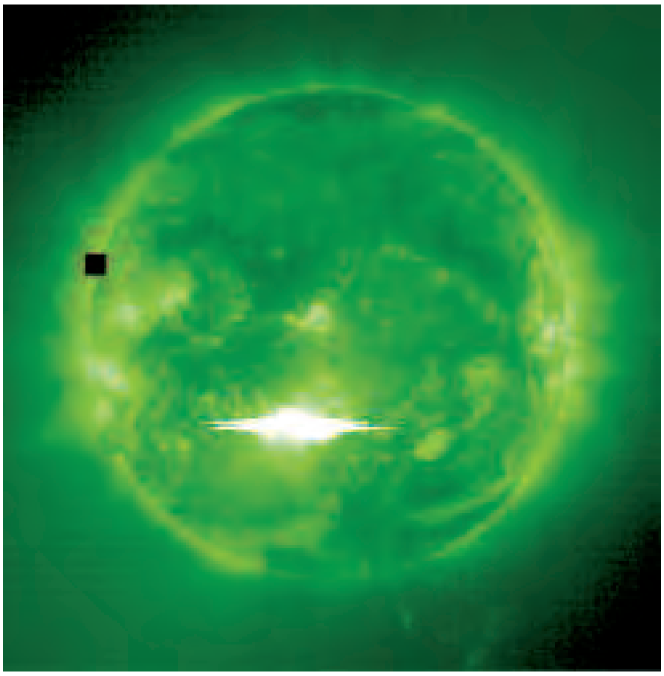


Fig.1: The solar flare of October 28, 2003 as observed in the extreme ultraviolet by the EIT instrument aboard the SOHO spacecraft.

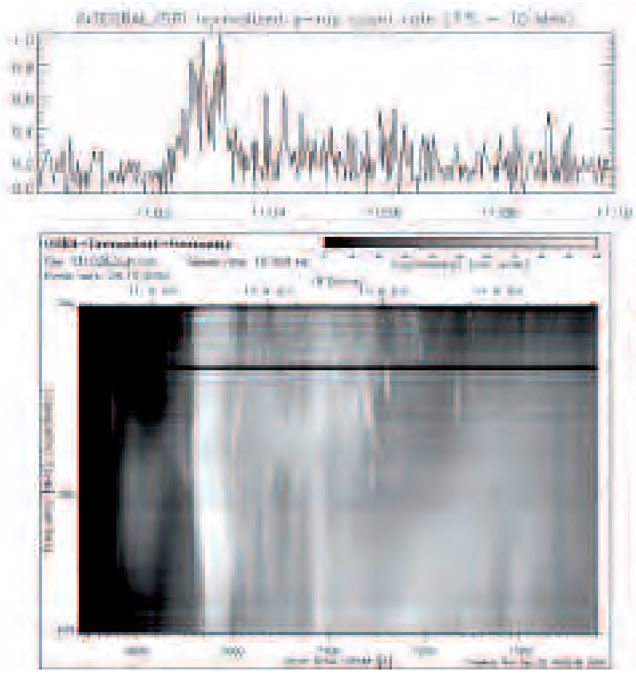
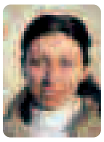


Fig.2: Temporal behavior of the γ-ray fluxes in the range of 7.5-10 MeV (top) during the initial phase of the event as measured by the INTEGRAL satellite. The corresponding dynamic radio spectrum (200-400 MHz) shows typical signatures of a standing shock wave (TS).

Collisionless heating and acceleration of electrons due to jet propagation in the solar corona




R. Miteva, G. Mann

Das Problem der Heizung und Beschleunigung von Teilchen in der Korona der Sonne ist eines der wichtigsten Probleme der Astrophysik. Die japanische Weltraum-Mission Yohkoh zeigte, dass die Wechselwirkung eines Plasmajets (Bild 1) mit dem ihn umgebenden Plasma einerseits zur stoßfreien Heizung der Elektronen und andererseits zur Beschleunigung der Elektronen führt, was durch Radiostrahlung (Typ III-U-Bursts) während solarer Flares beobachtet werden kann.

The heating and acceleration of particles in the corona of the Sun is one of the most important problems in astrophysics. During solar flares magnetic field energy is suddenly released by magnetic reconnection. If two magnetic field lines with opposite directions approach each other due to their photospheric footpoint motions, they can reconnect by the formation of a so-called diffusion region between them. Due to the strong curvature of the magnetic field lines after their reconnection, the plasma shoots away from this site leading to the establishment of jets of hot plasma (Fig. 1). Radio tracers of such jets are found in terms of so-called type III/U bursts in dynamic spectra of the solar radio radiation (Fig. 2). The interaction of such a jet with the surrounding plasma is studied by means of the multi-fluid equations. It gives rise to an instability exciting ion-acoustic waves. The instability appears only for a small range of jet speeds around 230 km/s (Fig. 3).

Any collisionless electron is affected by these waves in the following manner: the amplitude of the electrostatic field associated with the ion-acoustic wave is increased by the instability, leading to a trapping of the electron within the wave field. Thus, the electron recieves energy from the wave. This process represents a collisionless heating and acceleration of electrons. If these energized electrons leave the wave, they escape with high velocity along the magnetic field lines and propagate either along an open field line (away from the Sun), creating a type III burst in the metric radio spectrum, and/or propagate along a closed field line (magnetic loop), forming a type U burst as observed (Fig. 2).

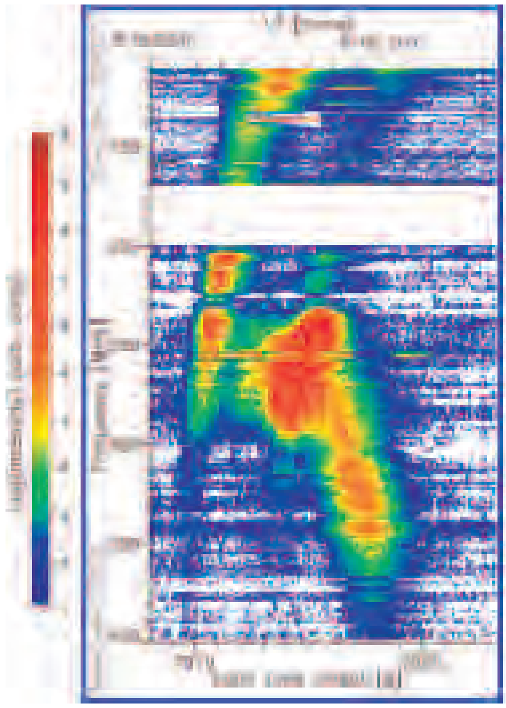


Fig. 2: Dynamic radio spectrum of type III and type U bursts from OSRA Tremsdorf.

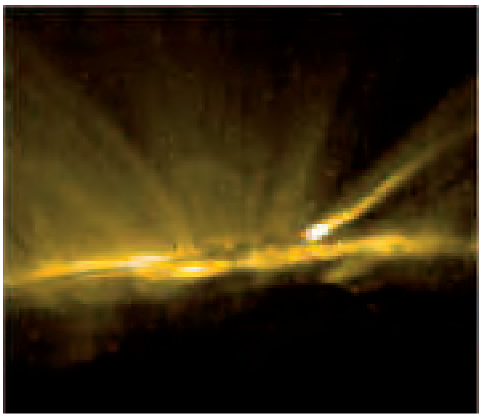


Fig. 1: Solar plasma jet at 195 Å as observed by the TRACE satellite (30.07. 2004).

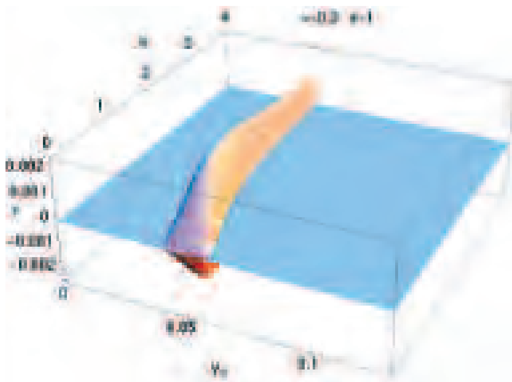
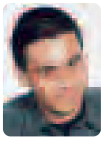


Fig. 3: Growth rate-initial flow-wave number diagram presenting the instability region for a jet under typical coronal circumstances.

Propagation of energetic electrons in the solar corona and the interplanetary medium




H. Önel, G. Mann

Während eines Flares steigt in der Korona der Sonne die Intensität der ausgesendeten Strahlung über das gesamte elektromagnetische Spektrum an. Zudem werden Elektronen und Ionen auf hohe Energien beschleunigt und breiten sich dann durch das Plasma der Korona hindurch aus. Dabei erfahren diese Teilchen Coulomb-Wechselwirkungen, während sie unter dem Einfluss von globalen elektrischen und magnetischen Feldern stehen. Der Transport solcher Elektronen wurde in Kooperation mit der Technischen Universität Berlin untersucht.

Electrons, which are accelerated up to high energies during solar flares, are of particular interest, since they are responsible for non-thermal radio and X-ray radiation (Fig. 1). These electrons are released during the process of magnetic reconnection taking place in the solar corona. From there, the generated electrons travel along magnetic field lines both toward the dense chromosphere, where they can emit X-ray radiation via bremsstrahlung, or into the interplanetary medium, where they can be observed by in-situ measurements, e.g. by the satellite WIND (Fig. 2).

On the other hand, high velocity electrons are sources for non-thermal radio emission, which also can be observed from space- and ground based observatories, e.g. AIP-Tremsdorf Observatory.

The electron's interaction with the coronal plasma has been studied in a diploma thesis with respect to local Coulomb collisions, while the electron propagates away under the influence of global electric and magnetic fields from the acceleration site to the place of hard X-ray emission (Fig. 1 and 2).

Our aim has been the development of a computer program, which could simulate the problem of electron propagation. Such a simulation is needed if one wants to find out more about the agents for the particle acceleration processes, which is supposed to be a main mission objective of NASA's RHESSI mission.

During the last decades our civilization has become very sensitive to space weather. Since our modern society continues to use satellite technology, global power and communication networks, accurate space weather forecasts will be essential. Regarded within that framework, our work delivers one more answer to the riddles about the Earth-Sun relation.

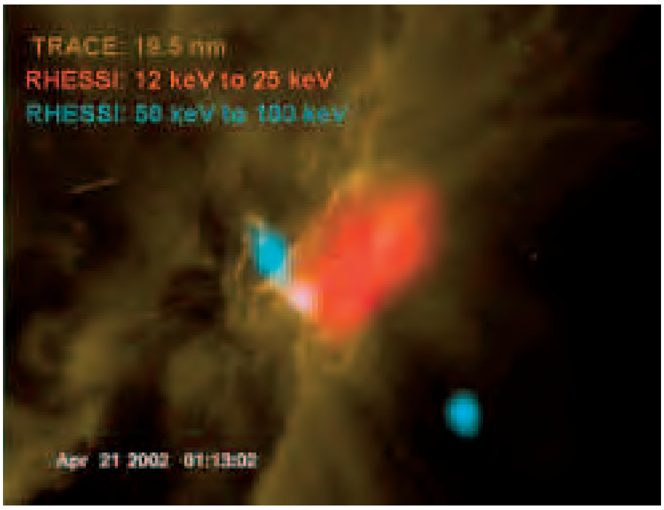


Fig.1: This image of the Sun from April 21, 2002 was obtained by the TRACE spacecraft. Superimposed on it are RHESSI measurements, which show the sources of X-ray radiation emittion during a flaring scenario.

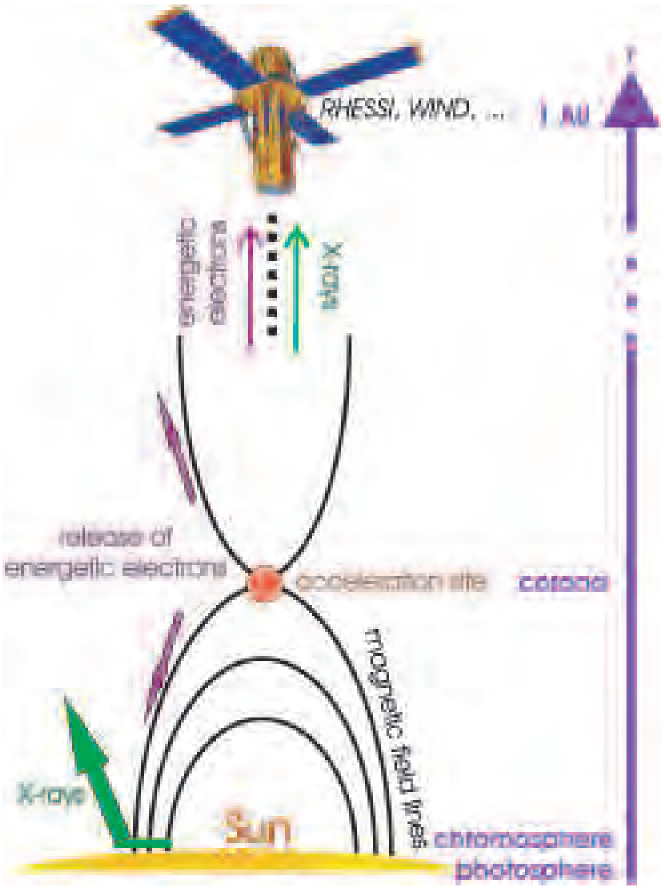
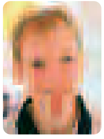


Fig.2: The propagation of electrons is illustrated schematically. Electrons with high energies are released at the acceleration site from where they travel along magnetic field lines, either toward or away from the Sun.

Whistler wave excitation by relativistic electrons during solar flares




C. Vocks, G. Mann

Während eines solaren Flares werden energetische Elektronen in koronale Loops injiziert. Durch Spiegelung an den Fußpunkten des Loops bilden diese Elektronen eine Verlustkegelverteilung. Diese ist instabil und kann zur Anregung von Whistlerwellen führen. Es wird ein relativistisches Verfahren zur Berechnung der Anwachsraten der Whistler verwendet und die Ergebnisse vorgestellt. Die gefundenen Anwachsraten sind hoch genug, um die beobachteten Eigenschaften von Fiber-Bursts in solaren Radiodaten zu erklären.

During a solar flare, energetic electrons are injected into magnetic loops. Due to mirroring at the loop footpoints, the electrons form a loss cone distribution within the loop. Such a distribution is unstable and gives rise to whistler wave excitation. If these whistler waves nonlinearly coalesce with high frequency plasma waves, e.g. Langmuir waves, they can be observed as fiber bursts in the solar radio radiation (see Fig. 1).

Fiber bursts appear as stripes of enhanced radio emission in the dm-range (≈ 400 - 800 MHz) in dynamical radio spectra. They are drifting from high to low frequencies with (intermediate) drift rates between those of type II and type III radio bursts.

The method for calculating whistler wave growth rates is based on finding a solution of the dispersion relation for a given wave frequency and propagation angle. The dielectric tensor is split into a `real' and `imaginary' part. While the `real' part is dominated by the thermal core of the electron distribution, the `imaginary' part is responsible for the wave growth. It follows from the resonance condition between electrons and waves that only a part of the electron distribution, e.g. the loss cone, contributes to the `imaginary' part. This method covers relativistic electrons that are produced in the solar flare.

Fig. 2 shows the whistler wave growth rates that have been calculated for a model electron distribution composed of a thermal component and a hot component with a loss cone. A region with wave growth in the frequency and wave propagation angle is clearly visible. The wave growth is strongest for waves propagating parallel to the background magnetic field. For nonzero propagation angles, the waves can interact with the thermal core and be absorbed due to higher-order resonances. Thus, the wave growth is limited to very small angles. An upper frequency limit can also be seen, since for higher frequencies the resonance moves into the thermal core of the electron distribution where the waves are strongly damped. The maximum wave growth rate that is found in the model plasma is fast enough to account for the observed time scales of fiber bursts.

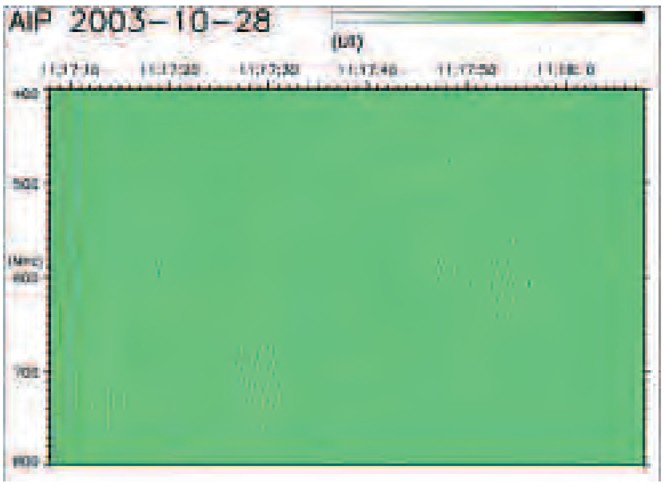


Fig. 1: A typical part of a patch of fiber bursts in the dynamical radio spectrum of October 28th, 2003. The image shows the spectrum's temporal derivative. The data were recorded by the Observatory of Solar Radioastronomy of the Astrophysical Institute Potsdam.

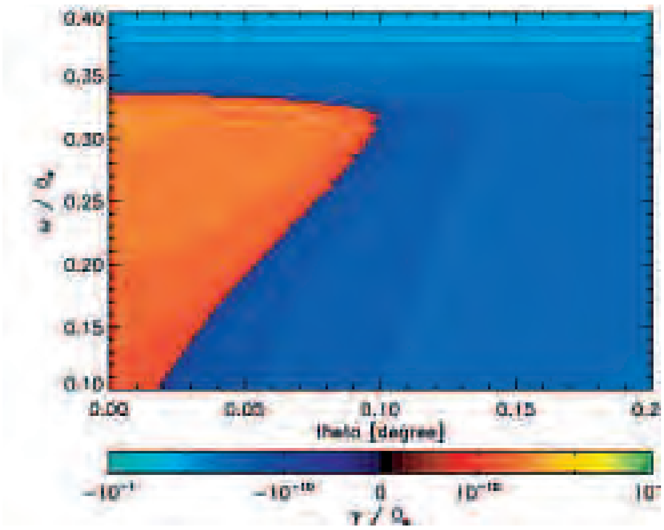
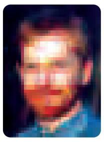


Fig. 2: Growth rates for whistler waves as a function of wave frequency, ω_r, and propagation angle, θ, normalized to the electron gyrofrequency, Ω.

Solar prominence eruptions



B. Kliem

Protuberanzen sind Kondensationen von Plasma, die in einem magnetisch dominierten Gleichgewicht, eingebettet in die heiße Korona, in geringem Abstand über dem Sonnenrand schweben. Das Gleichgewicht bleibt meist über längere Zeiträume von mehreren Tagen bis hin zu Monaten stabil, aber in vielen Fällen mündet es dennoch in eine Eruption, in der die Protuberanz innerhalb weniger Stunden stark nach außen expandiert. Häufig wird sie von der Sonne ausgeworfen und bildet eine riesige Plasmawolke im interplanetaren Raum, die das `Weltraumwetter' dominiert. Die Eruptionen können Satelliten beschädigen, Astronauten gefährden und erhöhte Strahlendosen auf Flügen in hohen Breiten verursachen; Nordlichter bilden wohl die einzige erwünschte Begleiterscheinung. Um das Weltraumwetter künftig vorhersagen zu können, untersuchen wir die physikalischen Mechanismen der Protuberanzeruptionen. In numerischen Simulationen auf Großrechnern können wir einzelne Eruptionen sehr gut nachbilden, was uns Aufschluß über die wirkenden Plasmaprozesse und damit die Auslösungskriterien gibt.

The triggering of solar prominence eruptions and subsequent coronal mass ejections (CMEs) remains enigmatic despite intense research in recent decades: no less than five models of the trigger process, differing in magnetic topology and in the role played by magnetic reconnection, are currently being discussed. We are pursuing a model that assumes energy storage in a coronal magnetic flux rope, searching for relevant ideal magnetohydrodynamic (MHD) instabilities while at the same time permitting magnetic reconnection to occur in the course of the eruption. Recent advances in computing power and performance of our numerical codes permit us to model prominence eruptions through increasingly realistic MHD simulations.

The helical kink instability can trigger the impulsive rise of the rope if the twist exceeds a threshold (the field lines must turn about the axis of the rope at least ≈ 1.5 times). This is a very plausible onset condition, since the energy storage requires the buildup of the current, which implies, in a flux rope topology, the buildup of twist. The comparison of the simulation with a prominence eruption in the Fig. reveals remarkable qualitative and quantitative agreement: both in observation and simulation the rising flux rope develops a strongly helical shape, the height-time profiles agree, and at the point where the rise comes to a stop, the top part of the rope spreads sideways and subsequently disintegrates. The disintegration results from magnetic reconnection, which also transforms magnetic energy originally stored in the flux rope current into heat and eventually into radiation.

Similar agreement is obtained for prominence eruptions that lead to CMEs. The simulations show that this most relevant case requires the magnetic field overlying the flux rope to decrease sufficiently rapidly with height. Then the temporal profile of the simulated rise matches the observations nearly perfectly, yielding the best agreement between an MHD simulation and an observed CME obtained so far. The conditions on the coronal magnetic field for the occurrence of CMEs obtained in the simulations (minimum flux rope twist and minimum steepness of field decrease above the rope) will contribute to improvements in forecasting space weather events.

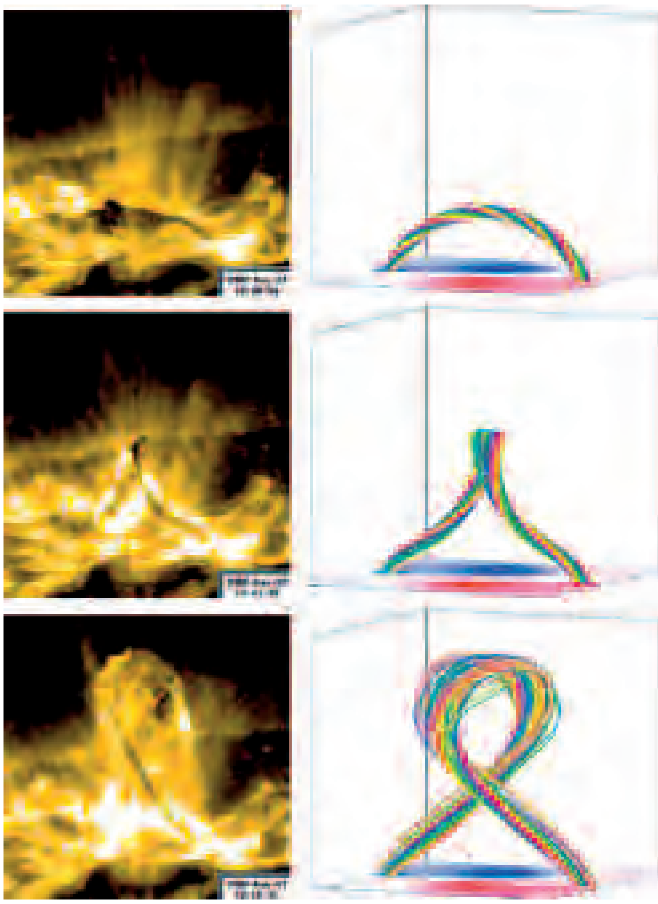
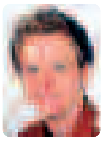


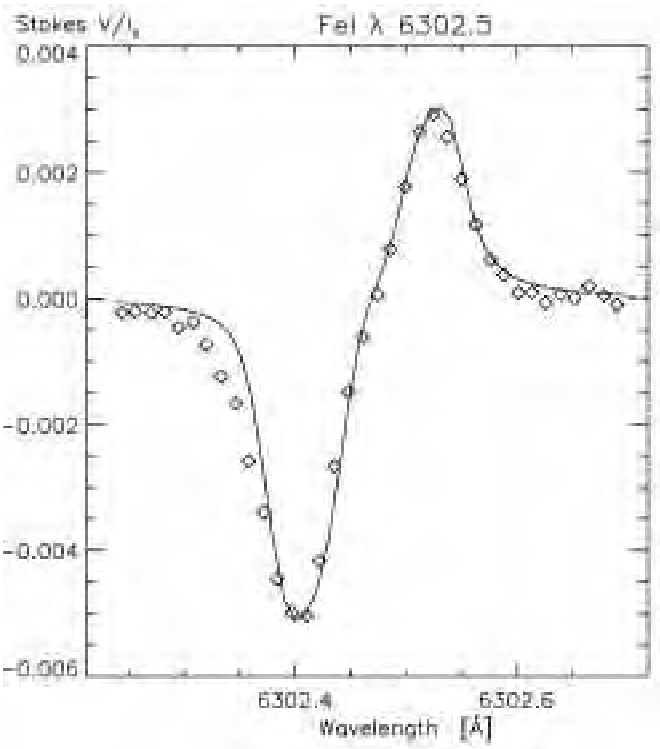
Fig. 1: Snapshots of a solar prominence eruption on May 27, 2002 observed in the EUV by the TRACE satellite (left panels). The simulation shows the rise of the twisted flux rope due to the kink instability (right panels). The core of the flux rope is represented by colored field lines. The distribution of magnetic field polarity and strength on the solar surface is color coded in red-blue, with the two field concentrations representing a sunspot pair.

The diagnostics of unresolved magnetic fields – a stochastic polarized radiative transfer approach

T. A. Carroll, M. Kopf

Die kleinskalige Natur der nichtaufgelösten magnetischen Strukturen innerhalb der solaren Photosphäre erfordern einen neuen Zugang der Modellierung und Interpretation von spektropolarimetrischen Messungen. Wir haben einen stochastischen Strahlungstransport für polarisiertes Licht formuliert, der die Linienentstehung in einer kleinskaligen sowie fluktuierenden Atmosphäre angemessen beschreibt. Dieser Ansatz, einer auf beliebigen, sogenannten mesoskal strukturierten Atmopshäre erlaubt es nicht nur weitgehend modellunabhängig, beobachtete spektropolarimetrische Profile (Stokes-Profile) zu untersuchen und zu interpretieren, auch erlaubt uns dieser Ansatz Rückschlüsse auf die den Strukturen zugrundeliegenden charakteristischen Größenordnungen zu ziehen. Wir haben diesen Ansatz auf verschiedene solare Gebiete angewandt, deren Eigenschaften wesentlich durch eine kleinskalige und nichtaufgelöste Magnetfeldstruktur bestimmt wird und konnten so deren zugrundeliegende charakteristische Längenskala bestimmen. Dadurch erhoffen wir uns ein wesentlich besseres Verständnis für das so wichtige und entscheidende Zusammenwirken von Magnetfeldern und solarem Plasma auf kleinsten Größenskalen zu erhalten.



An appropriate understanding of the process of line formation in unresolved and inhomogeneous atmospheres is one of the major obstacles towards a direct diagnostic and interpretation of spectropolarimetric observations from atmospheres which include a small-scale magnetic substructure. We have developed a stochastic (polarized) radiative transfer approach which accounts for an arbitrary horizontal and vertical structuring of unresolved magnetic components in solar and stellar atmospheres. This approach allows us to go beyond the restrictive and simplified assumptions of an atmosphere which is in a pure microstructured or macrostructured state.

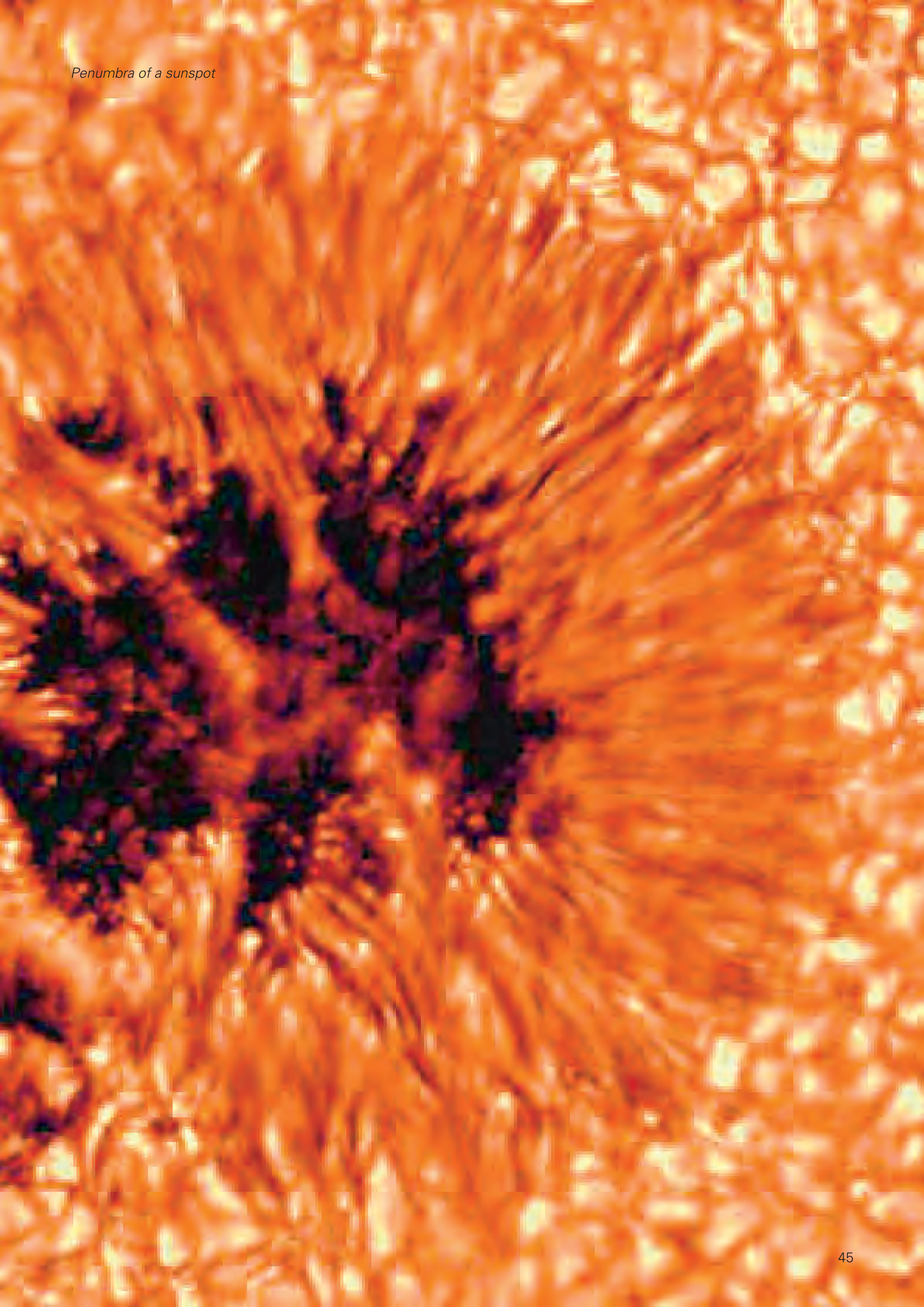
The Meso-Structured Magnetic Atmosphere (MESMA)

Since the inter-network regions cover a substantial fraction of the solar surface, they may account for most of the unsigned magnetic flux and energy existing on the solar surface at any given time. This fact may have important implications for the higher atmospheric layers of the Sun as well as for its global properties. The magnetic elements (the building blocks of solar magnetism) in the quiet solar atmosphere can still not be resolved, but spectropolarimetry enables us to detect their Zeeman-induced polarization – with their characteristic signatures.

The mesostructured magnetic atmosphere (MESMA) is an attempt to describe the atmosphere on a statistical basis. This approach goes beyond the limiting assumptions that the magnetic field is characterized by a static arrangement of monolithic magnetic flux tubes, or on the other extreme, that the field is in a purely microturbulent state. The MESMA approximation allows a more flexible and unbiased diagnostic of small-scale magnetic substructures in quiet and active regions of the solar atmosphere.

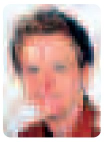
The MESMA-Approximation is not only a model to describe the polarized line formation in a fluctuating and maybe turbulent atmosphere it moreover allows to determine the characteristic length scale of the yet unresolved magnetic structures on the Sun and other Stars.

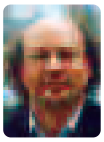
Fig. 1.: A fit – the result of an inverse calculation – between a theoretical and an observed Stokes profile, under the MESMA Approximation. A systematic investigation of so called inter-network revealed an underlying correlation length between 70 and 250 km. This demonstrates the highly dynamic state of the solar photosphere and seems to point to the existence of a local dynamo.



Penumbra of a sunspot

Stokes profile synthesis of solar-type stars





M. Kopf, T. A. Carroll, K. G. Strassmeier

Für das Verständnis der Entstehung und Entwicklung von Sternen, insbesondere unserer Sonne, spielen Magnetfelder eine bedeutende Rolle. Sie manifestieren sich bei der Sonne beispielsweise in den kühlen und dadurch dunklen Sonnenflecken. Während derartige Phänomene auf der Sonne räumlich aufgelöst beobachtbar sind, bedarf es bei allen übrigen Sternen, aufgrund ihrer großen Entfernung, einer indirekten Methode. Stellare Magnetfelder lassen sich mit Hilfe des Zeeman Doppler Imagings (ZDI) indirekt beobachten. Als einen ersten Schritt zu einem Zeeman-Doppler-Imaging-Code, haben wir einen Strahlungstransport-Code entwickelt, der es uns ermöglicht, Stokes-Spektren von Model-Sternen zu berechnen.

As a first step towards a fully applicable Zeeman-Doppler-Imaging (ZDI) code for the analysis of the magnetic field of solar-type stars we have developed a radiative transfer code to calculate local and disk-integrated Stokes spectra. The 'Stardust' code facilitates the modeling of artificial stars with an arbitrary and complex thermodynamic, chemical and magnetic field topology in all dimensions. It utilizes Kurucz model atmospheres and line data from the VALD database.

To assess the performance and the numerical accuracy of the new code we performed a large number of test calculation with an existing code for the solution of the polarized radiative transfer. The benchmark was performed with the COSSAM code. Disc-integrated line profiles as well as local line profiles show very good agreement with the COSSAM code.

We are focusing on solar-type stars. We extrapolate solar-type magnetic structures to rapidly rotating stars to analyze the characteristic features in their observable disk-integrated Stokes spectra. A simple configuration of a 'quasi-realistic' sunspot with its geometric, thermodynamic and magnetic field properties, retrieved from a Stokes profile inversion placed on a model star, is shown in Fig. 1 below, together with the corresponding Stokes line profiles, calculated for the Fe I 6173 A line (Fig. 2). The spectral signature of the sunspot already allows us to draw first conclusions about the underlying magnetic field.

Currently, we are implementing the inversion algorithm for the ZDI, which is based on a conjugated gradient method and makes use of maximum entropy or Thikonov regularization.

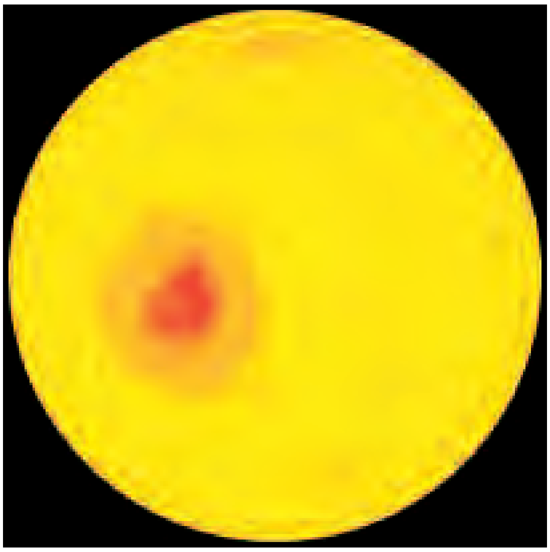


Fig. 1: A model star with a quasi-realistic sunspot retrieved from a Stokes profile inversion.

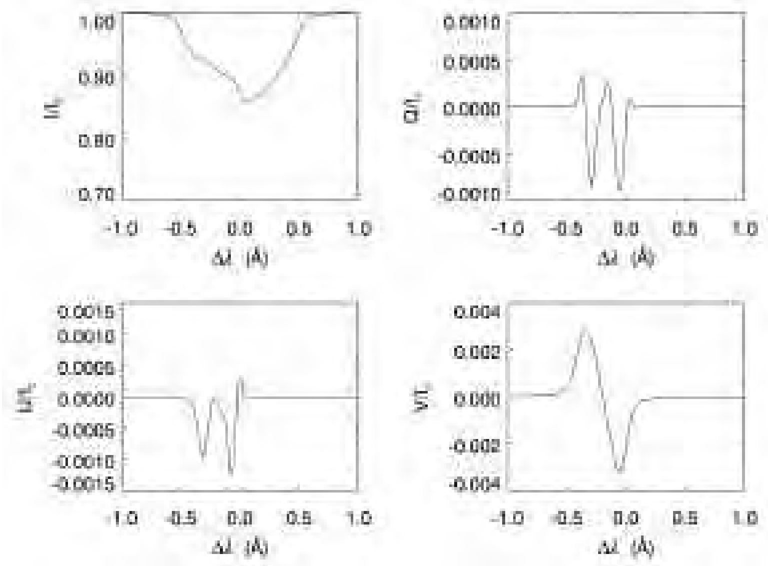
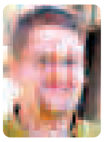


Fig. 2: Disc-integrated Stokes line profiles of an artificial star, which was modeled by placing a 'quasi-realistic' sunspot on its surface. A Kurucz atmosphere with solar parameters was used and the considered line was Fe I 6173.

Spotted stars that get bluer as they get fainter



V. Aarum-Ulvås

Einige sehr aktive Doppelsterne zeigen blauere photometrische Farbe mit schwächerer Helligkeit, im Gegensatz zu der erwarteten roteren Farbe. Einfaches Modellieren weist darauf hin, dass sogenannte Fackelgebiete, die die Sternflecken begleiten, die blauere Farbe verursachen, und nicht die heißeren, aber inaktiven Mitglieder der Doppelsternsysteme. Tests haben demonstriert, dass die Dopplerkartografie imstande ist, solche Oberflächencharakteristika unter sehr günstigen Bedingungen zu rekonstruieren.

The starspots of some active stars are large enough to affect wide-band photometric observations of the stars. Having a different temperature from the photosphere, the spots also affect the photometric colour. The intuitive change is towards a redder colour, since the spots are cooler than the photosphere; this is also observed for many stars. Some stars, however, change colour towards the blue, e.g. UX Ari. In the case of UX Ari, one possible explanation is its binary nature, in that the unspotted component is hotter than the spotted one. The bluer flux of the hotter component becomes more influential when the spots rotate into view and turn the colour of the system as a whole bluer. A simple model has been made to test this hypothesis.

The model calculates how the V-band magnitude and the B-V colour change when a spot rotates into view. The flux of each temperature component (stellar photospheres and spot) are calculated from the Planck functions corresponding to each temperature, and the fluxes are subsequently added and multiplied by the B- and V-band transmission curves. The resulting changes in V and B-V are compared to the observed ranges.

When the model was applied to UX Ari, it was found that spots alone cannot explain the observed behaviour. The unspotted component of the system is hotter, but it is too small to be able to modify the colour of the system as a whole. Introducing photospheric faculae with temperature 250 K above the photospheric temperature made the model results follow the observations nicely.

Following this result, a search was initiated for other stars showing the same 'bluer-when-fainter' behaviour. Thirteen additional stars have been found so far, and six of them have been modelled. All six require faculae to explain their observed colour-brightness relations. An example is shown in the Fig.: RS CVn, where the spotted component is smaller compared to UX Ari, and the unspotted is both hotter and larger. The best fit is obtained when faculae are included in the model, although all models get bluer for this star. The hotter and larger unspotted component is able to turn the colour of the system bluer, but not blue enough to fit the observations.

The photometric analysis has shown that there is reason to believe that dark spots and bright faculae can exist close to each other on surfaces of active stars. Would Doppler imaging be able to detect such surface features? A test was made to find out, in which synthetic spectral observations were generated from an artificial stellar surface with one active region consisting of a cool, dark spot surrounded by a hot, bright ring. It was found that Doppler imaging is able to reconstruct such an active region, but it requires very high signal-to-noise ratio (400), very high spectral resolution (80,000), very dense observations (0.025 apart in phase), and very rapid rotation (v sin(i) = 80 km/s). With more realistic values, the ring is not fully recovered, although facular regions surrounding the spot are still clearly present. The signal-to-noise ratio and rotational velocity were found to be the most crucial parameters for a satisfactory reconstruction.

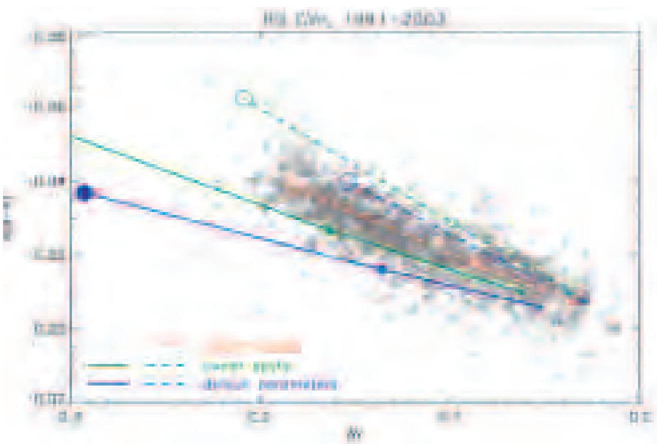
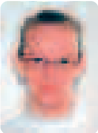


Fig.1: The observed photometric colour of RS CVn (grey crosses) as a function of its photometric magnitude. The coloured lines and circles represent different model calculations. Solid lines and filled circles represent models where only cool spots constitute the active regions, whereas dashed lines and open circles represent models where cool spots and hot faculae constitute the active regions.

Magnetic characteristics of sun-like stars



S. Järvinen

AB Dor und EK Dra gehören, wie auch ein weiterer Hauptreihenstern LQ Hya und die Sonne, zu einer Gruppe von sonnenähnlichen Sternen, die sich durch folgende Eigenschaften definiert: 1. zyklische Veränderung der mittleren Aktivität, 2. differentielle Rotation, 3. Migration aktiver, um 180 Grad versetzter Länge, 4. ein Flip-Flop Zyklus. Darüber hinaus zeigen fünf weitere Sterne die ersten beiden Eigenschaften, und drei von diesen außerdem zwei Minima in ihren Lichtkurven.
AB Dor and EK Dra, together with another Zero-Age Main Sequence star LQ Hya (Berdyugina et al. 2002, A&A, 394, 505) and the Sun (Berdyugina & Usoskin 2003, A&A, 405, 1121; Usoskin et al. 2005, A&A, 441, 347), belong to the group of Sun-like stars that are distinguished by the following specific activity patterns: 1. cyclic variations of the mean activity level, 2. differential rotation, 3. migrating active longitudes separated by 180 degrees, and 4. a flip-flop cycle. Also, five other young dwarfs studied by Messina & Guinan clearly show the first two patterns, and three of them have two minima in the light curves.

All four activity patterns can be detected using only photometric observations, although then it is not possible to say whether differential rotation is solar-like or not, i.e. whether the equator or the polar regions rotate faster. However, the advantage of using photometric observations instead of spectroscopic ones is long photometric records.

Figs. 1 and 2 show time evolution of spot phases for AB Dor and EK Dra. The locations of the spots on the stellar surface were determined from filling factor maps, which were produced using the Occamian inversion technique for the observed light curves. Although this technique is less informative than the Doppler imaging technique, the analysis of a long series of photometric observations allows us to recover longitudinal spot patterns and study their long-term evolution. The active longitudes migrate on the same timescale as the mean magnitudes of the stars vary. In most of the cases, two spot concentrations were detected. The spots prefer to stay about 180 degrees apart all the time, but the primary spot jumps regularly between active longitudes (the flip-flop phenomenon). If the solar-type differential rotation is present, then at the beginning of the cycle spots are on higher latitudes and move during the cycle towards lower latitudes, as in the solar butterfly diagram.

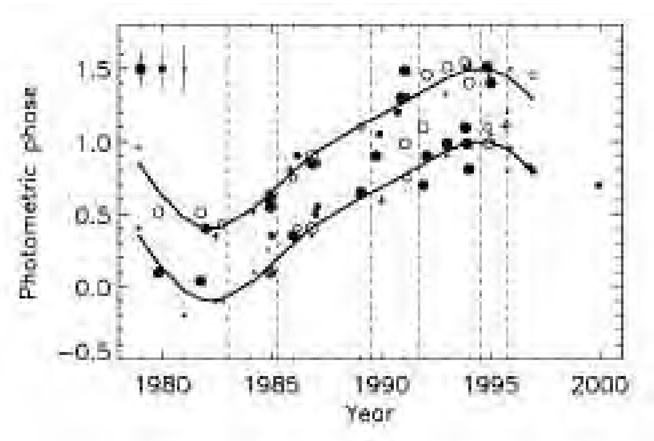


Fig. 1: Phases of the spots on AB Dor. Filled circles denote primary spots, open circles secondary spots and a + symbol is used when it is not possible to say which spot is the primary one. Two active longitudes are traced by solid lines and the vertical dashed lines show when flip-flops occur.

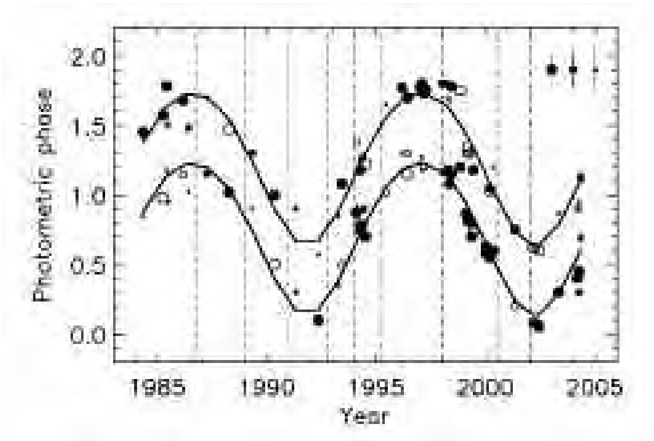
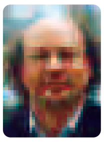


Fig. 2: Phases of the spots on EK Dra.

Binarity, activity and metallicity among late-type stars



K. G. Strassmeier

Die Rotation eines kühlen Sternes, wie z.B. unserer Sonne, ist der Schlüsselparameter für dessen magnetische Aktivität. Es ist bis heute aber noch nicht geklärt ob und wie sich diese Aktivität etwa mit der Anwesenheit in einem Doppelsternsystem ändert und, ob sich die chemische Häufigkeit durch unterschiedliche Diffusion dadurch ändert. Im vorliegenden Projekt untersuchen wir ausgesuchte Einzelsterne und vergleichen deren präzise astrophysikalische Parameter mit denen von analogen Doppelsternsystemen.

The magnetic activity level of a star, and hence the dynamo efficiency, is a function of the stellar rotation period. Although rotation is thought to be the necessary condition for magnetic activity, it is not clear to what extent binarity and metallicity influences the generation and morphology of magnetic fields and the corresponding chromospheric and coronal emission. The differential gravitational pull from a companion may cause a longitude- and latitude-dependent relationship between rotation rate and activity level. It may also contribute to an inhomogeneous chemical abundance by effectively lowering/enhancing the chemical stratification process, e.g. due to diffusion. If such relationships exist, the models of the evolution of close binaries would then need to be reconsidered.

The other burning question is the link between chemical surface abundances and binarity. The recent observation that (solar-like) stars with planets are on average more metal rich than similar stars without planets is at least suggestive that this maybe is also the case for binaries.

Together with collaborators from ESO and the Niels Bohr Institute in Copenhagen we attempted to investigate the relation between binarity, magnetic activity, and chemical surface abundances of cool stars (Dall, Bruntt & Strassmeier 2005, A&A 444, 573). We laid out and tested two abundance analysis methods and applied them to two well-known, active, single stars, HD 27536 (G8IV-III) and HD 216803 (K5V), presenting photospheric fundamental parameters and abundances of Fe, Al, Ca, Si, Sc, Ti, V, Cr, Co and Ni. The abundances from the two methods agree within the errors for all elements except calcium in HD 216803, which means that either method yields the same fundamental model parameters and the same abundances. Activity is described by the radiative loss in the CaII H&K lines with respect to the bolometric luminosity. Binarity is established by very precise radial velocity measurements using ESO/HARPS spectra. The spectral line bisectors are examined for correlations between RV and bisector shape to distinguish between the effects of stellar activity and unseen companions.

We found that HD27536 shows non-sinusoidal radial velocity variations of 100 m/s, which leads us to suggest either some non-linear surface activity or mimicking of the effect of a low-mass (4 Jupiter masses) companion in a relatively close (a 1AU) orbit. The variation is strongly correlated with the activity, and consistent with the known photometric period of 306 days, demonstrating a remarkable coherence between activity and the bisector shape, i.e. between the photosphere and the chromosphere.

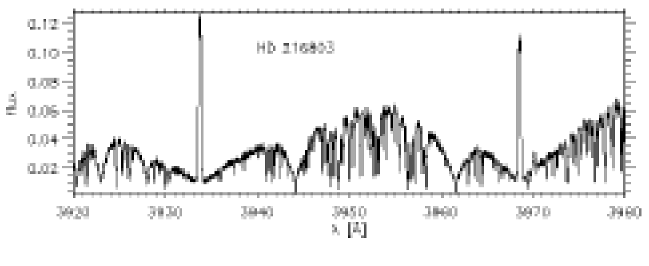


Fig. 1: HARPS spectrum of the CaII H&K region of the active, single K5 dwarf HD216803 (Gliese 879).

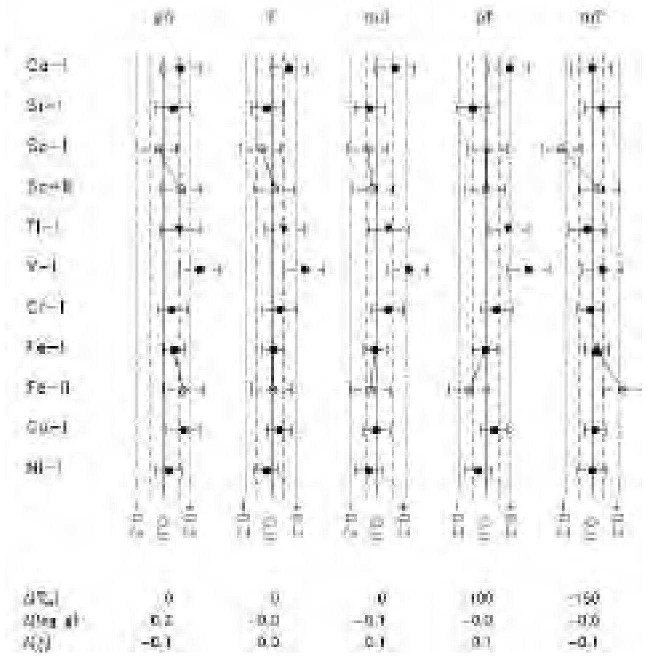
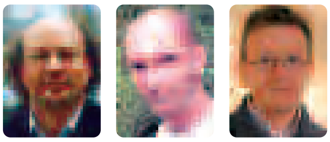


Fig. 2: Chemical abundance analysis for HD216803 relative to the Sun. The preferred model is labelled F while models with lower (higher) log g are labeled mG (pG) and models with lower (higher) T(eff) are labeled mT (pT). The differences with respect to model F are listed below each model. At the bottom are given the T(eff) and log g values relative to model F. Abundance values are always relative to the Sun.

First accretion-impact maps of a T Tauri star



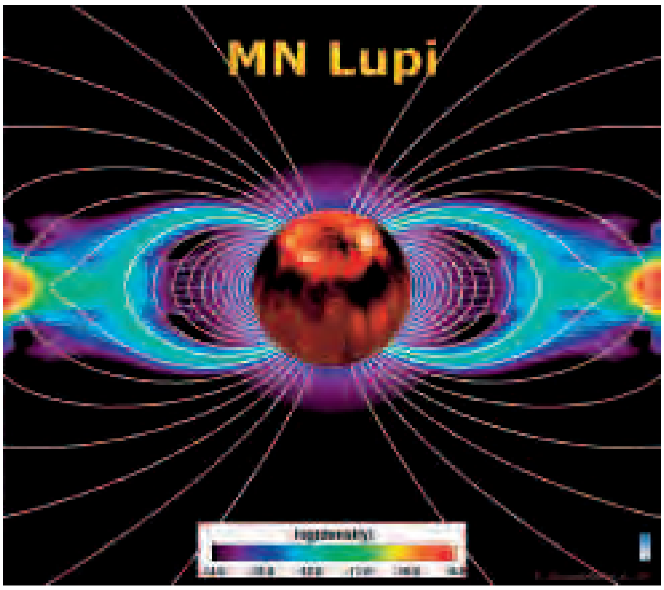
K. G. Strassmeier, A. Ritter, M. Küker

Zum ersten Mal wurden magnetosphärische Akkretionseinschläge auf der Oberfläche eines jungen Sterns nachgewiesen. Das Magnetfeld des T Tauri-Sterns lenkt die akkretierte Materie auf wohldefinierten Bahnen zum werdenden Stern, so dass zwei Einschlagregionen entstehen, die durch die Rotation des Objektes zu beobachtbaren Streifen verschmieren. Mit dem Very Large Telescope (VLT) der ESO auf dem Paranal in Chile wurden in zwei Nächten hochaufgelöste Spektren von MN Lupi gewonnen, um die zweidimensionale Oberflächenstruktur mit Hilfe des „Doppler Imaging"-Verfahrens zu rekonstruieren.

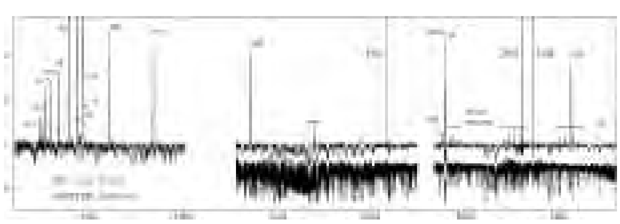
For the first time, we have spatially resolved and mapped accretion impact regions on the surface of a T Tauri star. Some of these stars are known to have accretion disks out to many stellar radii that are being continuously accreted onto the surface of the host star until nothing remains. Material is ripped off the disk far above the stellar surface if a magnetic field is present, and funnels its plasma along magnetic field lines onto the stellar surface. The impact happens predominantly near the polar regions, where the shock heats the atmosphere and produces a hot spot visible even in absorption spectral line profiles. Our observations show that accretion can occur even when no direct evidence for the presence of a disk is detected.

We used high-resolution, high-quality VLT/UVES spectra to reconstruct the two-dimensional surface structure of the rapidly rotating classical T-Tauri star MN Lupi on two separate nights. Both surface maps show a photospheric temperature of 3800 K with a structured warm (5000 K) band centered around the visible rotation pole at a latitude of 65°. Located within the band are two hot spots with temperatures of approximately or possibly even in excess of 5800 K, i.e. 2000 K above the effective photospheric temperature. Both maps appear with an adjacent equatorial band of temperature 3400 K, some 400-500 K below the effective photospheric temperature.

While we interpret the two hot spots and the warm high-latitude band to be the heating points from two accretion impacts at the time of our observations and their redistributed energy trailed due to the fast stellar rotation, respectively, the cool equatorial band may not be cool after all but due to obscuration of the stellar surface by the innermost region of the disk. The fact that the hot spots appear at high stellar latitude is in agreement with the magnetospheric accretion model that proposes material funnelling onto the star along a predominantly dipolar magnetic field at roughly 50° latitude. The evidence of ongoing disk accretion, together with the very fast rotation of MN Lupi of just 3-4 times below its break-up velocity, suggests that the accretion mechanism is the cause of its rapid surface rotation. We present a model of magnetic star-disk coupling for MN Lupi that predicts a polar surface magnetic field of 3 kGauss.

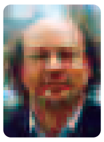


Doppler image of MN Lupi and a model of the magnetic disk-star connection. The Doppler image shows temperature as a color code, from 3370 K (black) to 5800 K (bright yellow). The star-disk model shows poloidal field lines and colour-coded density contours. The star has a rotation period in the region of 10.5 hours.



Optical and UV spectrum of MN Lupi (top spectrum) in comparison with the inactive M0 star HD 209290 (bottom spectrum). All hydrogen Balmer lines up to the Balmer jump appear in emission. Strong CaII H&K, Na D, and HeI emission are evident. The very strong forbidden oxygen OI lines are geocoronal in origin. Also notice the strong lithium absorption line at 670.8 nm.

Doppler imaging with molecular contribution

I. S. Savanov, K. G. Strassmeier

Aktive Regionen – sei es auf der Sonne oder auf anderen Sternen – beinhalten konzentrierte Magnetfelder, die den Energietransport aus dem Inneren des Sternes zum Teil unterbinden. Diese und andere Aktivitätsphänomene auf der Sternoberfläche können als ein Fingerabdruck des im Inneren des Sternes arbeitenden kosmischen Dynamos gesehen werden. Um sie zu beobachten und zu interpretieren, bedarf es einer räumlichen Auflösung der Sternoberfläche. Dies ist über den Umweg von rotationsverbreiterten atomaren Linien möglich. Um die Methode auch für sehr kühle Sterne und möglichweise sogar bei Braunen Zwergen anwenden zu können, haben wir eine Inversionsmethode entwickelt, die neben atomaren Spektrallinien erstmals auch molekulare Linien berücksichtigt.

We developed a new inversion code based on object principal components (OPC) of the inverse Doppler imaging problem. It allows the reconstruction of temperature maps from local line profiles with molecular features from TiO, CO, OH, CN etc., which are quite numerous in spectra of cool late-type stars. The astrophysical input includes a set of synthetic spectra at various aspect angles. The temperature range is usually 3500-6000 K and synthetic spectra are computed for nine angular points on the stellar disk. The radiative transfer equations are solved with atmospheric models from R. L. Kurucz. The input list of atomic parameters was obtained from the VALD database. We use different inputs for the molecular line list, including the SCAN data for the CH and CN red systems, Kurucz's CDs for the violet system CN and OH, NH, SiO, SiH, MgH, C2 and CO, and the data by Plez for TiO. Instead of only atomic lines, as in codes like TempMap and INVERS7, our input line list consists of thousands of molecular lines in addition to several hundreds of atomic lines. All of these lines are used in the inversion simultaneously. Note that the code can be expanded to an arbitrary number of wavelength regions and thereby combines, for example, particular infrared OH and CO bands and optical TiO bandheads with specific optical regions containing major atomic lines. Limits are solely set by the completeness (and reliability) of the line lists invoked and by the computational power available. We considered several hypothetical cool stars for the robustness tests of various line-profile reconstructions and were able to show the improvements made by including molecules.

The precalculated synthetic spectra revealed that most molecular contributions become dramatically different only for models cooler than 4250 K. At that temperature, the many molecular lines depress the continuum level of the forward spectra by 10%. A recovery without molecular contributions is impossible even with OPC and does not converge to a sensible solution. If molecules are included, OPC quickly converges and the surface map is well recovered, as shown in the Figure.

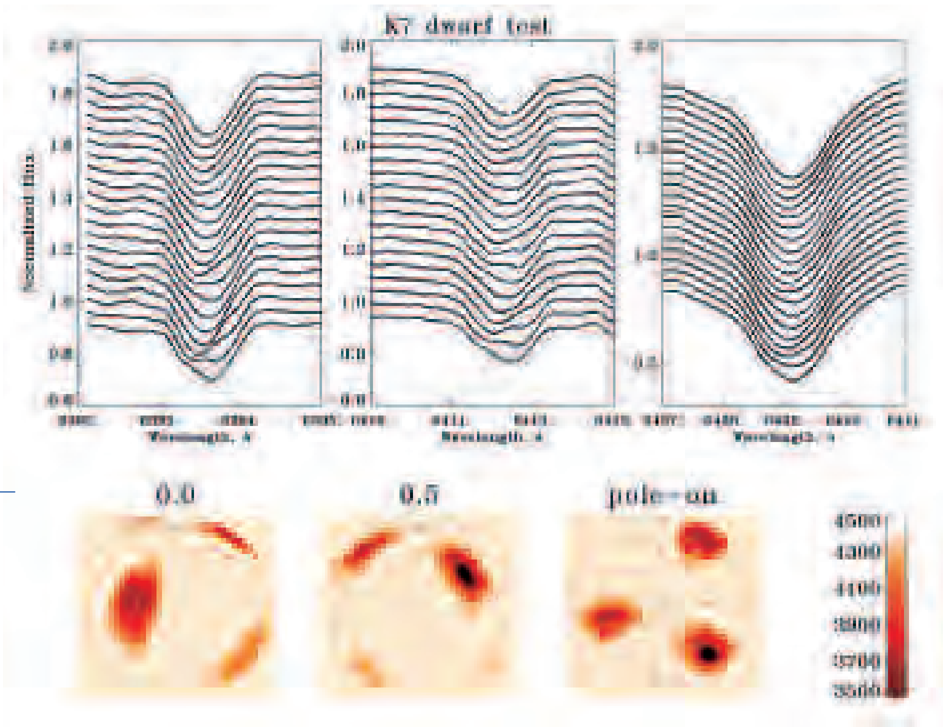
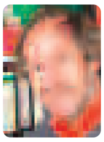
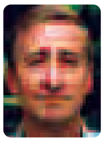
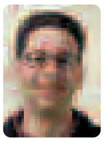


Fig. 1: A simulation of a K7 dwarf. The top row shows three wavelength regions with atomic and molecular features. The images in the bottom row show the inversion of the combined wavelength regions. Three spots are recovered.

The X-ray emission of planetary nebulae

M. Steffen, D. Schönberner, A.Warmuth

Planetarische Nebel sind ausgedehnte Gashüllen, die Sterne mittlerer Masse am Ende ihrer Entwicklung abstoßen und durch ihre ionisierende UV-Strahlung zum Leuchten anregen. Durch spektroskopische Untersuchungen ist seit langem bekannt, dass diese Nebel Temperaturen von typischerweise 10000 Kelvin und Dichten von einigen 1000 Teilchen pro Kubikzentimeter aufweisen. Mit Hilfe der Röntgensatelliten Chandra und XMM-Newton wurde nun entdeckt, dass viele Planetarische Nebel trotz ihrer relativ moderaten Temperaturen zweifelsfrei Quellen von Röntgenemission sind. Wie eine genauere Analyse der Beobachtungsdaten zeigt, stammt die Röntgenstrahlung aus dem zentralen Hohlraum des Planetarischen Nebels, wo Temperaturen von einigen Millionen Kelvin und Dichten von nur 10-100 Elektronen pro Kubikzentimeter vorherrschen müssen. Am AIP werden hydrodynamische Modellrechnungen durchgeführt, welche die auf den ersten Blick unerwarteten Röntgenbeobachtungen sogar quantitativ erklären können.

X-ray observations of Planetary Nebulae

Over the last few years, the two large X-ray space observatories XMM-Newton (ESA) and Chandra (NASA) have been used to map the X-ray emission of several Planetary Nebulae (PNe) with high spatial and spectral resolution. These observations have shown without doubt that the X-ray emission does not originate from the central star but from the central cavity of the nebulae. As is evident from the sample of composite images shown below, the extended diffuse X-ray emission (blue) is confined to the inner parts of the nebulae. Closer inspection indicates that the emission is somewhat brighter towards the limb. The observed spectra reveal that most of the X-ray luminosity is due to emission lines of highly ionized elements, mostly oxygen (OVII), nitrogen (NVI), carbon (CV), and neon (NeIX). From the strength of these emission lines and other spectral features, it is possible to determine the temperature and density of the emitting plasma quite accurately. For the shown sample of PNe, the resulting temperatures lie between 1.7 and 2.5 million K and the densities between 15 and 130 electrons per cm^3. These values

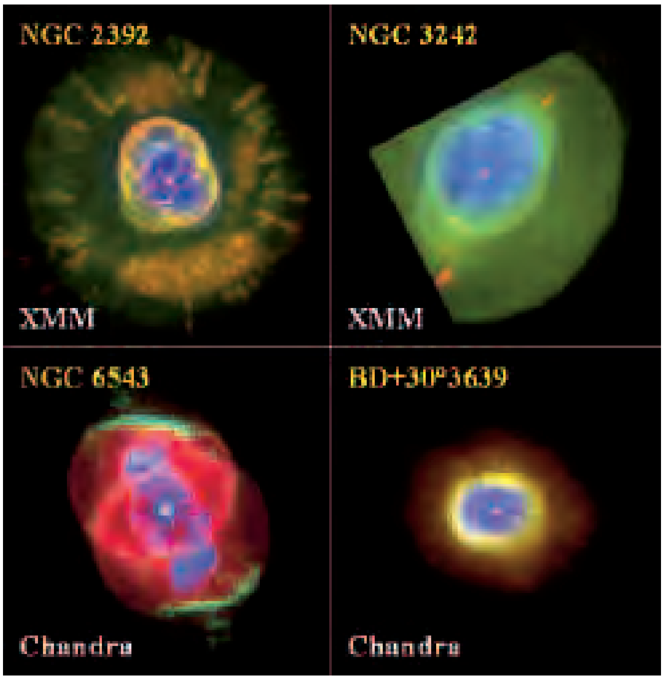


Fig.1: A sample of Planetary Nebulae observed with the X-ray space observatories XMM-Newton (ESA) and Chandra (NASA). The detected X-ray emission is shown in blue, superimposed on the optical Hubble Space Telescope images (red and green colors). Observations and image processing by M. Guerrero et al. 2005.

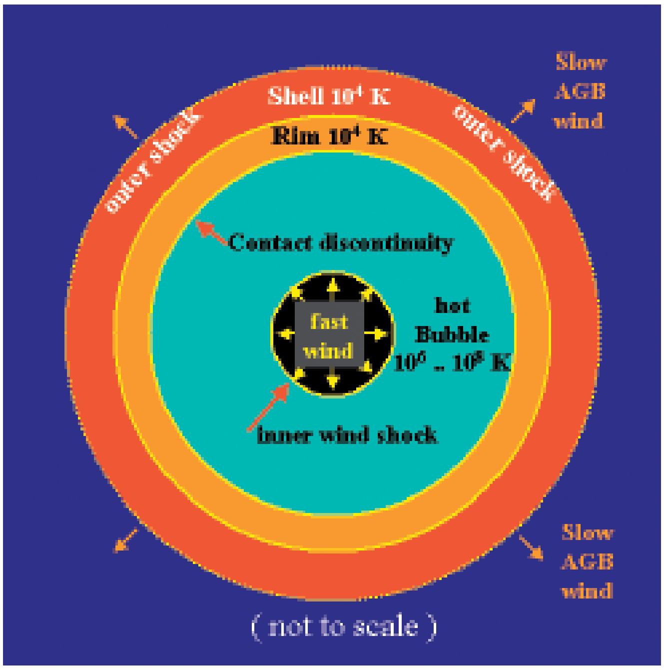


Fig. 2: Schematic physical structure of a Planetary Nebula. Only rim (orange) and shell (red) are visible in optical light.

are typical for all cases studied so far. As explained in the following section, standard hydrodynamic models describing the formation and evolution of Planetary Nebulae clearly fail to predict the observed X-ray emission. However, we demonstrate below that improved hydrodynamic models taking into account thermal electron heat conduction can reproduce the observed X-ray properties of PNe surprisingly well.

Hydrodynamical Modeling

According to the generally accepted scenario, the basic processes responsible for the formation of a Planetary Nebula are colliding winds and photo-ionization by the hot central star's UV radiation field. The related hydrodynamical processes lead to a complex structure of distinct radial shells (see sketch). The fast wind from the hot central star of several 1000 km/s is in free flow for only a short distance before being thermalized in the inner shock. At this point, roughly half of the wind's kinetic energy is converted into heat. The shocked gas constitutes the so called 'hot bubble'. Depending on the wind power, the standard models predict resulting temperatures of the order of 10^7 K to 10^8 K, and densities of about 1 electron per cm^3. Hence, the 'hot bubble' is found to be too hot and too tenuous to provide the observed X-ray emission. However, the hot gas is surrounded by much cooler (10^4 K) nebular gas, and electron heat conduction across the narrow interface between hot and cool gas (contact discontinuity) becomes an important energy transport mechanism. With this motivation, new hydrodynamic models including electron heat conduction have been computed at the AIP. It turned out that conductive heat losses efficiently reduce the temperature of the 'hot bubble', while at the same time evaporating the adjacent cool nebular gas. The physical conditions in the hot bubble are now very close to what has been inferred from the X-ray observations, as demonstrated in Fig. 3.

Observed and synthetic X-ray spectra

Based on the new PN models, we have computed detailed synthetic X-ray spectra using the software CHIANTI, a public IDL package developed for the solar physics community. The agreement between observed and synthetic X-ray spectra is encouraging. Adding up the total X-ray emission between 0.5 and 2.5 keV (5-28 Å) gives the X-ray luminosity L_X, which can be compared with the L_X values derived from observations. As seen in Fig. 4, the agreement between theory and observation is quite satisfactory, provided that the modeling includes heat conduction. Since magnetic fields efficiently suppress heat conduction, our results indicate that possible magnetic fields in the observed PNe must be very weak or have purely radial field lines.

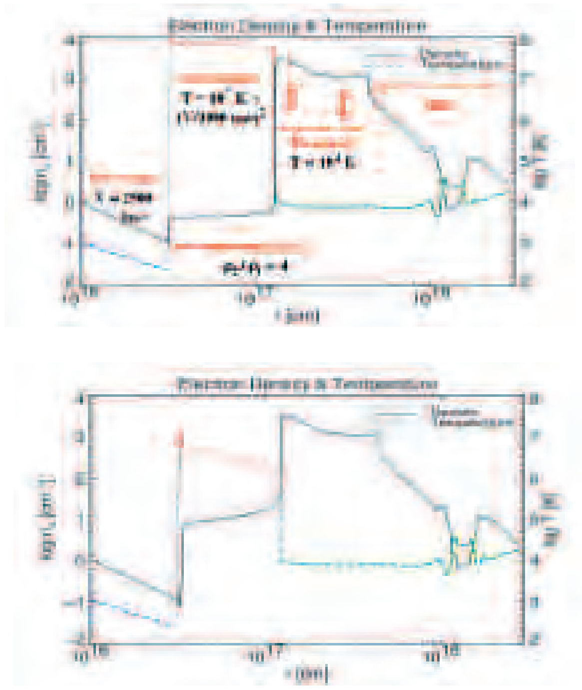


Fig. 3: Top: Radial dependence of temperature and electron density in the standard hydrodynamic PN model, with central star parameters $T_{eff} \approx 70000$ K, $L \approx 5000\ L_{sun}$. Bottom: Same plot for a corresponding model with electron heat conduction included. Note the much reduced temperature and increased electron density of the hot bubble.

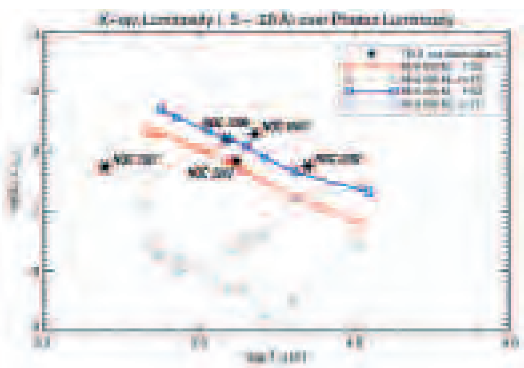
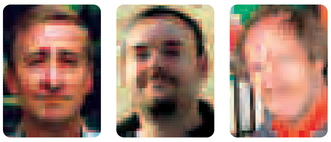


Fig. 4: Evolution of L_X/L^* as a function of Teff, where L_X , L^*, and Teff denote nebular X-ray luminosity (0.5-2.5 keV), stellar photon luminosity, and effective temperature respectively. Observed values are indicated as black stars, while blue ($M^*=0.7\ M_{sun}$) and red ($M^*=0.6\ M_{sun}$) lines refer to the calculations with heat conduction, and gray lines to the corresponding results without heat conduction. Note that L_X/L^* is unaffected by the poorly known PN distances. Plotting the quantity L_X/L_W shows that less than 1% of the wind power L_W is lost as X-ray radiation.

The internal kinematics of planetary nebulae and the problem of their distances



D. Schönberner, R. Jacob, M. Steffen

Die Endphase der Entwicklung aller Sterne mit weniger als ca. 6 Sonnenmassen ist charakterisiert durch sehr starke "Sternenwinde", die Masse und Impuls in das interstellare Medium eintragen und damit den kosmischen Kreislauf der Materie antreiben, die nukleare Entwicklung des Sterns aber vorzeitig beenden. In unmittelbarer Umgebung des heißen Reststerns ensteht für ca. 10000 Jahre ein sogenannter Planetarischer Nebel, geformt durch die Wechselwirkung des stellaren Strahlungsfeldes und des Sternwindes mit der bereits vorher ausgestoßenen Materie. Entfernungen sind aber nur sehr vage bekannt, so dass fundamentale Größen wie Nebelmasse und -leuchtkraft nicht mit der notwendigen Genauigkeit bestimmbar sind. Wir untersuchen eine neue Methode, die es im Prinzip erlaubt, die Entfernung zu einem Objekt aus seiner Winkelexpansion und der spektroskopisch gemessenen Expansion zu bestimmen.

Planetary Nebulae are a typical, short-lived phenomenon of stars below approximately 6 solar masses that occur when the evolution is truncated by mass loss and the stellar remnant (the central star) contracts to a very hot white dwarf. The fast stellar wind interacts with the wind matter ejected earlier and forms, together with the stellar radiation field, a so-called "Planetary Nebula" around the "dying" star: the ionisation by stellar photons generates a shock wave, called the `shell', which is rather extended and expands supersonically into the ambient matter, and the stellar wind compresses the inner parts of the shell into a much denser but relatively thin shell, called the `rim'. The result of this combined action of ionisation and wind power is a double shell structure typical for many objects. High-resolution spectroscopy reveals that both shells have distinct velocities: the rim is in general expanding more slowly than the (outer) shell (see Fig. 1).

Any detailed study of this important phase of stellar evolution is heavily corrupted by the fact that distances to individual objects cannot be determined directly and can at best only be estimated by statistical or indirect methods. Good distances are, however, necessary to derive luminosities and nebula masses which are important for the theory of late stellar evolution and for a quantitative description of the cosmic cycle of matter.

A very promising direct method to determine distances to individual objects is to measure the angular expansion of the bright rim and combine it with the spectroscopically derived Doppler expansion along the line-of-sight. The implicit assumption is that spectroscopy and imaging are sampling the same physical regime within the object, a fact that may not be correct: the Doppler-split line profiles depend on the object's density and ionisation structure, and, last but not least, on the internal velocity gradient.

This very tempting method has, however, another severe drawback not considered at all in previous applications: the outer edges of expanding nebulae are either ionisation or shock fronts whose propagation cannot be measured spectroscopically. For instance, the flow velocity of the gas behind a shock front is always lower than the propagation speed of the front itself. Ignoring the physical difference between these two types of velocities therefore leads to systematic underestimates of the distances by potentially large amounts.

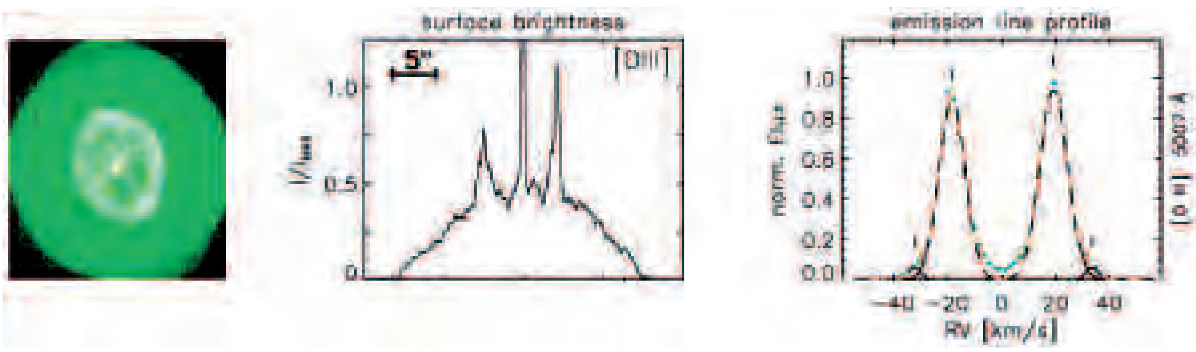


Fig. 1: (left): The Planetary Nebula IC 2448 observed in the strong emission line of [O III] 500.7 nm by the Hubble Space Telescope. One can clearly distinguish the bright inner rim and the fainter but more extended shell. (middle): Intensity cut along the semi-minor axis of IC 2448. This cut reflects the intensity distribution already evident from the image: a bright rim and a much fainter but more extended shell. (right): High-resolution line profile of [O III] 500.7 nm as observed through the center of the object. Since the whole nebula is optically thin, we see the Doppler-shifted signatures of the receding and approaching parts of the respective shells. The faster moving shell matter is only visible as faint outer extensions of the strong rim emissions. The whole profile (small circles) can be quite well fitted by 4 Gaussian components (continuous lines), and the fit reveals the following expansion pattern for IC 2448: 19 km/s for the rim and 33 km/s for the shell.

An estimate of this systematic error can be made by utilizing our existing (1D) hydrodynamic simulations of planetary nebula evolution. By means of these models we are able (i) to measure the advancement of shock fronts between successive models, and (ii) to determine typical flow velocities behind the fronts by decomposition of the model's emission-line profiles. These models give quite realistic descriptions of real objects in terms of morphology and expansion properties (see Fig. 2).

Our models show that indeed the spectroscopically measured expansion speed is always lower than the true expansion given by the shock propagation. This disparity can be quite large for the rim because the rim gas expands only slowly during the early part of the nebula's evolution (Fig. 3).

To date, the existing distance determinations using the expansion method are exclusively based on the angular expansion of the rim because this is the brightest structure of a planetary nebula. Thus, depending on the evolutionary stage of a particular object as indicated by the central star's effective temperature, the real distances will be larger by factors between 1.3 and about 3! (Fig. 4) A detailed discussion of existing distance determinations can be found in Schönberner, Jacob and Steffen (2005, A&A 441, 573).

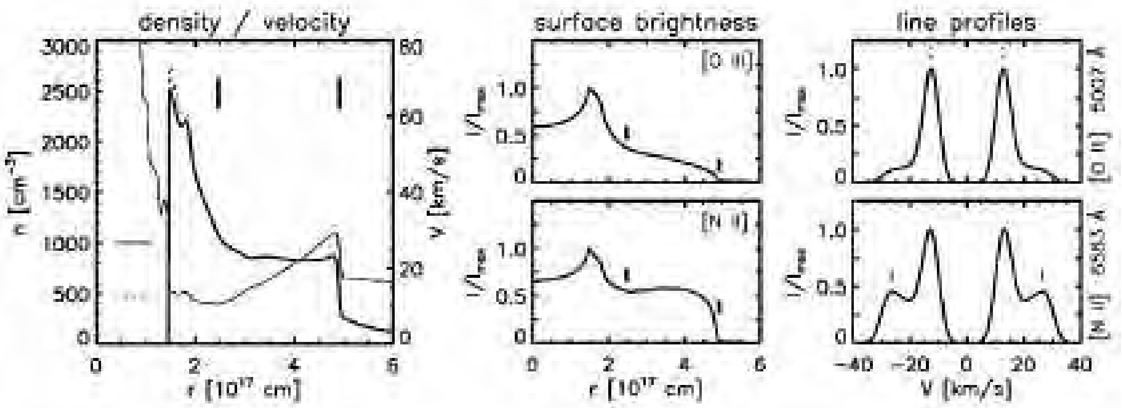


Fig. 2: Snapshot of the model structure with density (thick) and velocity (thin) as well as surface-brightness distributions and emission-line profiles at an age of 6000 years after the object has started to shrink. The stellar parameters are M=0.595 M_{sun}, L=5000 L_{sun}, and T_{eff} = 78000 K. The typical double-shell structure with a bright rim and a fainter shell is well developed. The positions of the leading shocks of the rim and the shell are indicated by thick vertical lines, while thin horizontal marks in the structure panel correspond to the profile panel and indicate the typical gas velocity as measured by the Doppler splitting of the emission lines.

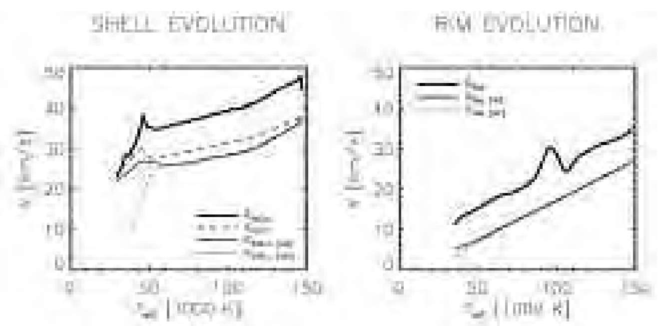


Fig. 3: Shock front propagation speed compared with the flow velocities as measured from the Doppler splittings of the strong N[II] and [O III] lines, for both the shell (left) and the rim (right). The effective temperature of the central star is used as a proxy of the evolutionary age, which increases from left to right and spans a range of about 10000 years.

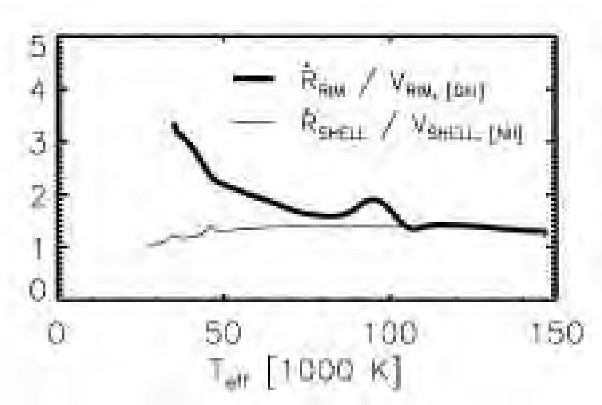
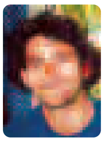


Fig. 4: Predicted ratio between shock propagation speed and corresponding flow speed measured from Doppler split emission lines as a function of the central star's effective temperature.

Differential rotation and the meridional flow on giant stars



M. Weber

Theoretische Überlegungen legen einen Zusammenhang zwischen differenzieller Rotation und meridionalen Strömungen nahe. An Hand einer kleinen Gruppe von Riesensternen soll dies demonstriert werden.

Using a small sample of giant stars which have a good set of Doppler imaging data available, we try to find a correlation between the relative differential rotation at the stellar surface and the surface meridional flow.

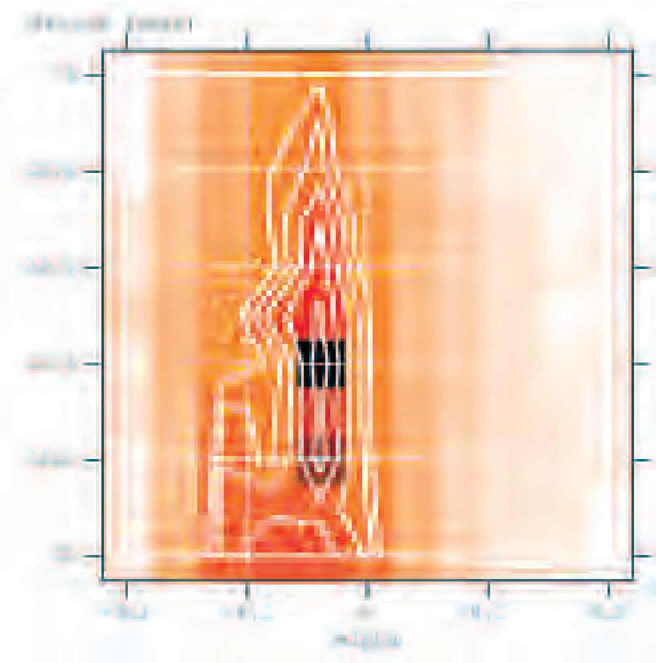


Fig. 1: Goodness of fit (the darker the better) for many pairs of rotation period and differential rotation of the giant binary star HD208472

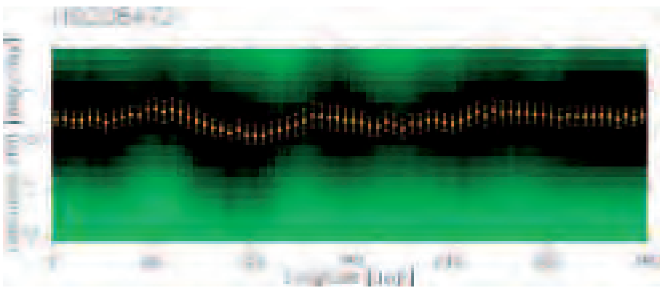


Fig. 2: Latitudinal cross correlation of HD208472. Superimposed is a line connecting the flow velocities of each longitude bin

Differential rotation

We imposed a differential rotation law like the one seen on the sun onto our stars. Starting from a satisfactory solution using rigid rotation and a rotation period derived from either photometry (single stars) or the orbital data (binaries), we varied both parameters in a physically meaningful range. The reconstruction with the least errors corresponds to the most probable parameter pair (see e.g. Fig.1).

Meridional flow

Comparing the reconstructed images of two consecutive stellar rotations can, apart from differential rotation as seen above, unveil surface flows in the latitudinal direction. In order to minimize the error, an average of all possible image pairs was derived from the available data set of HD208472. The result is one meridional velocity per longitude bin (Fig. 2).

Correlation

In order to find a correlation between differential rotation and meridional flow, the measured values for the seven available stars are plotted (Fig. 3). Even though the small number of measurements cannot yield a significant result, the two quantities seem to correlate with each other.

More observations of similar stars will be needed, which will be easier to achieve with new generation robotic instruments like STELLA, and more elaborate techniques for analysing the meridional flow must be developed.

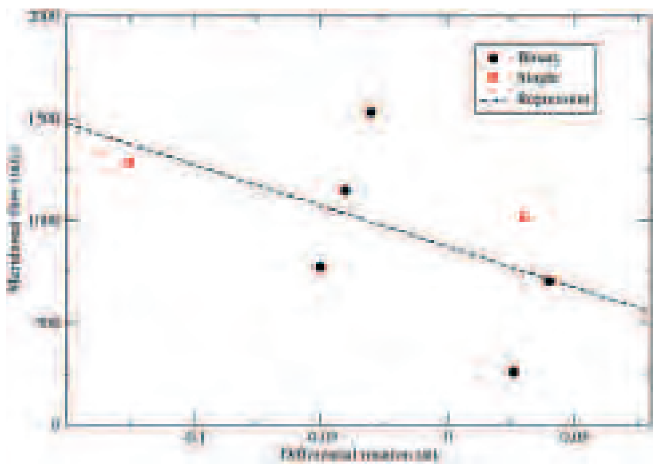


Fig. 3: Correlation of relative differential rotation of a meridional flow

A Bayesian search for stellar activity cycles


H.-E. Fröhlich, K. G. Strassmeier

Der RS CVn-Veränderliche HK Lac weist zwei Aktivitätszyklen auf. Ein bereits bekannter Zyklus kann jetzt auf 13,37±0,08 Jahre (90%-Intervall) eingeschränkt werden, ein weiterer auf 9,48±0,13 Jahre. Der 6,7-Jahre-Zyklus entpuppt sich als bloße Oberschwingung.

The RS CVn binary HK Lac exhibits two activity cycles, which establishes firmly the multi-periodicity of dynamo action in these overactive stars. We improve the previously published cycle period to 13.37±0.08 years and present strong evidence of an additional cycle with 9.48±0.13 years. The previously known 6.7 year cycle turns out to be a mere overtone of the dominating 13.4 year cycle.

Minor decadal brightness variations in very active stars may reveal cyclical behaviour.

If there is more than one fundamental mode indicated in the data, the question arises whether such a multi-periodicity, which would be of considerable interest, is – in view of the noise – really required by the data or not. A Bayesian time series analysis allows one to compare quantitatively a set of hypotheses: (1) no periodicity at all, (2) one fundamental mode with overtones, (3) two modes… Moreover, inspecting the marginal distribution of a period parameter, a mean as well as a confidence region can be assigned to it.

Starting with the simplest model, the zero hypothesis with only two free parameters – offset and linear trend – we have successively refined the analysis by introducing at first one and then two sinusoidal periodicities with unknown frequencies, amplitudes and phases. Overtones have been allowed too, in order to match any non-sinusoidality. The most ambitious model considered here is described by a total of twelve free parameters. When do we have to leave off this sequence of increasingly complex fitting functions?

In a Bayesian view, each model or hypothesis can be assigned a value, its strength, which measures its reliability. In mathematical terms, it is the likelihood integrated over parameter space, with the weight function being the prior density distribution of all proper parameters. Finding the average likelihood is computationally much more demanding than just searching for the most probable set of parameters, their modal values. Because the weight distribution is normalized, there is an inherent statistical penalty for inspecting too large a number of free parameters. In the case of an over-ambitious model the gain in goodness of fit is more than compensated for by an over-inflated parameter space! Of course, choices as to the dimension and the extent of the parameter space must be made beforehand.

The Bayesian approach has been applied to long-term photometry of the active RS CVn binary HK Lac. Over a time span of 48 years, 4766 brightness estimates have been collected, photographic (from Sonneberg Sky-patrol plates) as well as photoelectric ones (from Automatic Photoelectric Telescopes). The most ambitious model, that with two fundamental modes, the first one comprising two overtones, survived the evaluation!

Although the amplitudes are integrated away analytically, the numerical integration over the remaining six dimensions required the combined computing power of AIP's 128 node PC cluster "Sanssouci".

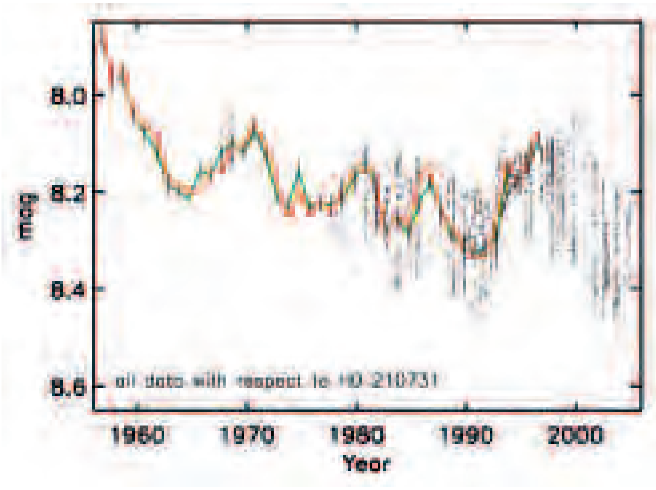
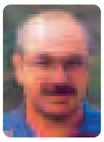


Fig. 1: B light curve of HK Lac. The green line connects photographic seasonal averages, the red one shows median values. Bars indicate the standard error of the mean. Overplotted are the photoelectric measurements.


Teil des Adler Nebels

The origin of the Orion Trapezium system



H. Zinnecker

Computer-Simulationen von turbulenten molekularen Gaswolken mit Eigengravitation zeigen, dass sich die Wolken beim Kollaps typisch in einige (ca. 4-5) dichte Unterwolken aufspalten (fragmentieren), und dass jede Unterwolke ihren eigenen kleinen Sternhaufen mit einem massereichen Stern bildet. Dieses Gas-Sterne-Gemisch verschmilzt schließlich zu einem großen Haufen, wobei sich die einzelnen massereichen Sterne der Unterwolken im Zentrum des Gesamtsystems wiederfinden und dort ein trapezartiges System bilden, ähnlich wie man es im Zentrum des Orion-Nebels beobachtet.

We are engaged in a project to understand the formation of a young star cluster, such as the Orion Nebula cluster. To this end, numerical simulations have been carried out with the smoothed particle hydrodynamics (SPH) approach to model the gravitational collapse of a 1000 solar mass, highly turbulent molecular cloud with a size of the order of 1 pc. The calculations displayed in the four panels of Fig. 1 show the successive steps of the evolution in the hierarchical fragmentation of the cloud towards a final stellar cluster. Each panel shows a region of 1 parsec on the side. The stars that are formed are indicated by the white dots. The four panels capture the evolution of the cloud at times of 1.0, 1.4, 1.8 and 2.4 initial free-fall times, where the free-fall time for the cloud is 2 x 10^5 years. The turbulence causes shocks to form in the molecular cloud, dissipating kinetic energy and producing filamentary structures which break up to form dense cores and individual stars (panel A). The stars fall towards local potential minima and hence form subclusters (panel B). These subclusters evolve by accreting more stars and gas, by ejecting stars, and by merging with other subclusters (panel C). There is one massive star per subcluster. The final state of the simulation is a single, centrally condensed cluster with little substructure but with 4 to 5 massive stars, one from each subcluster (Trapezium-system) (panel D). The cluster contains more than 400 stars and has a gas fraction of approximately 16%. The stellar initial mass function (IMF) of the new cluster can be determined and can be compared with observations of the Orion Nebula cluster (Fig. 2). We find good agreement between the simulated and observed IMFs.

In collaboration with I. A. Bonnell, University of St. Andrews and M. R. Bate, University of Exeter

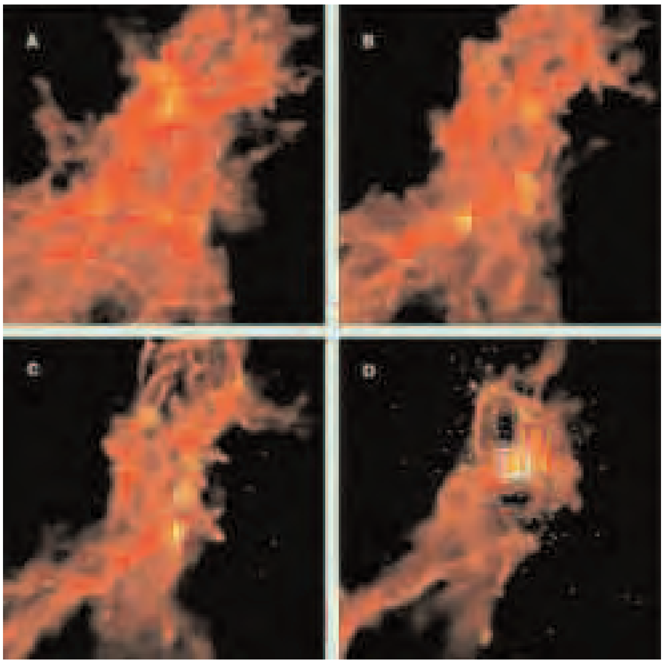
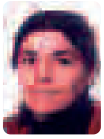
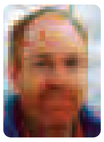


Fig. 1: Proto-cluster cloud collapse (see text)

Fig. 2: Infrared image of the Orion Nebula cluster (false color composite in the 1, 2, 3 micron filters) with the bright massive stars (Trapezium system) in the center (McCaughrean, Rayner & Zinnecker 1994, unpublished)

Near-IR spectroscopy in the Orion Nebula Cluster: Confirming Brown Dwarf Candidates

G. Meeus, M.J. McCaughrean

Wir diskutieren spektroskopische Untersuchungen im infraroten Wellenlängenbereich von 19 sub-stellaren Kandidaten im Trapez-Sternhaufen im Sternbild Orion. Zur Bestimmung der Oberflächentemperatur der Objekte vergleichen wir die beobachteten Spektren mit den Vorhersagen aus Sternatmosphärenrechnungen. Außerdem bestimmen wir die Helligkeit der Objekte und ihre Einordnung im Hertzsprung-Russell-Diagramm. Durch den Vergleich mit theoretischen Sternentwicklungsrechnungen können wir so Masse und Alter abschätzen. Wir finden, dass 15 Objekte eine Masse unterhalb von 75 Jupitermassen aufweisen. Diese sind damit eindeutig als Braune Zwerge klassifiziert. Bei einigen Objekten sagen allerdings die theoretischen Modellrechnungen ein für den Trapez-Haufen ungewöhnliches Alter vorher. Für diese Abweichung suchen wir noch nach einer Erklärung.

1. Observation and Target Selection

The ISAAC/VLT photometric data (Js, H and Ks bands) of the Trapezium Cluster (TC) are presented and described in McCaughrean & Meeus (2006, in preparation). For the purpose of target selection, we derived rudimentary photometric masses by dereddening the objects back towards the 1 Myr isochrone (DUSTY models; Chabrier et al. 2000, ApJ 542). The JHK-band spectra (resolution ≈ 500) of the candidate Brown Dwarfs were also obtained with ISAAC/VLT. The data were reduced with standard procedures in IRAF, using spectral standards observed at similar airmasses as our objects, to correct for telluric features.

2. Temperature derivation

We compared our spectra with a grid of reddened synthetic spectra with a temperature between 2000 and 4900 K, calculated by Allard et al. (2001, ApJ 556). In Fig. 1, we show the best fit for six of our objects. We used the Kolmogorov-Smirnov test to find the objectively best agreement between our data and the synthetic spectra.

3. Location in the H-R diagram: Age and Mass

Once both the temperatures and the luminosities of the objects are known, we can derive their ages and masses by comparison with theoretical isochrones. It is important to note that evolutionary tracks are critically dependent on the initial conditions, and only converge at the age of a few Myrs; it is only from this point that they should be considered valid (Baraffe et al. 2003, IAU211).

An important conclusion is that, regardless of which model we consider, several objects fall either below or above the isochrones. This means that the objects appear to be either older than 10 Myr or younger than 0.1-1 Myr. However, the assumed distance could be wrong, meaning that not all the objects would lie in the TC. More high-resolution spectra, together with dynamical masses of young, very low-mass objects are needed to clarify this issue.

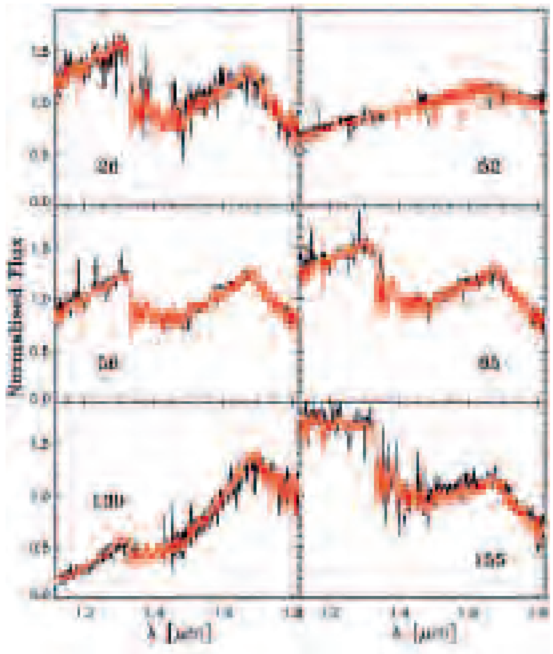


Fig. 1: Best fitting reddened synthetic spectra (red), overplotted on our spectra of 6 candidate Brown Dwarfs (black).

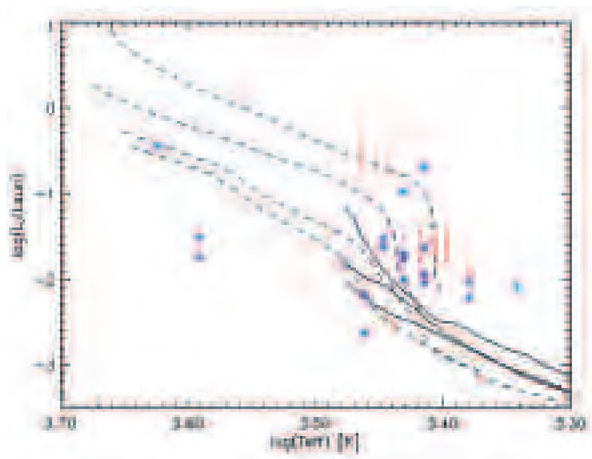
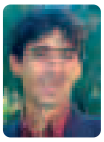
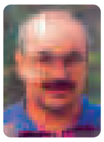


Fig. 2: HR Diagram for our sources (blue stars), overplot on isochrons for 0.5 to 10 Myr (top to bottom). The small red symbols are also ONC objects, from another study (Slesnick et al. 2004)

The disk around the Herbig Ae star R Corona Australis unveiled by VLTI/MIDI

S. Correia, H. Zinnecker

Es ist wohlbekannt, dass viele junge Sterne von zirkumstellaren Scheiben umgeben sind. Die Messung von Scheibenparametern ist ein Ziel von räumlich hochauflösenden Untersuchungen. Mit Hilfe von interferometrischen Beoachtungen im mittleren Infrarot (8-13 micron) mit MIDI am VLTI konnten wir zeigen, dass der junge A5e-Stern R CrA mit einer geschätzten Masse von 2-3 Sonnenmassen eine nicht-symmetrische Intensitätsverteilung auf einer Skala von 6-10 AE aufweist, was auf eine zur Sichtlinie geneigte Scheibe hindeutet. Erste Modelle legen ein radiales Temperaturprofil T(r) ~ $r^{-0.5}$ nahe, also eine passive Akkretionsscheibe.

The presence of circumstellar disks around intermediate mass (mass < 5 solar masses) Herbig Ae stars is supported by a large body of observational evidence. While the observed spectral energy distribution (SED) of such stars can be explained by both a disk-like distribution of material and other geometries like envelopes, clear evidence for circumstellar disks comes from resolved flattened structures observed by interferometry at millimeter, near-IR and recently also mid-IR wavelengths.

R CrA is a bright (100 solar luminosities) young Herbig A5e star, located at the center of a small cluster (the Coronet cluster) at 130 pc. Several characteristics indicate the presence of a circumstellar disk around R CrA: a flat mid-IR to far-IR/mm SED (although most of the mm excess is actually from the nearby embedded infrared source IRS7 and source confusion in the large IRAS beams might be an issue), a broad silicate emission feature, a UX Ori type, a high degree (8%) of optical linear polarisation, the possible association with an extended molecular outflow as well as with several Herbig-Haro systems, and a near-infrared reflection nebulosity whose resolved spatial polarization is consistent with a bipolar outflow being truncated by an evacuated spherical cavity.

MIDI visibilities at different projected baselines are best fitted using a uniform ring model with an outer radius increasing with wavelength from 6 to 10 AU, i.e. 45 to 75mas at 130pc (Fig.1). The inclination of the ring with respect to the plane of the sky is found to be ≈ 45 degrees, consistent with the 40 degrees suggested from near-infrared imaging polarimetry. A binary star model can be ruled out with a high degree of confidence.

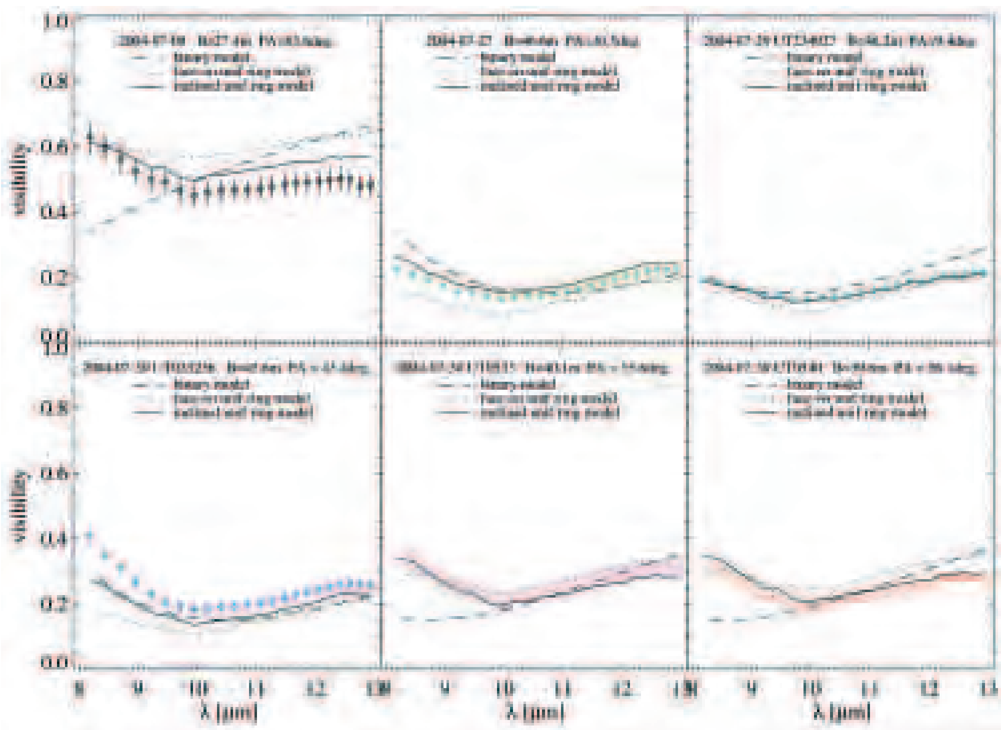
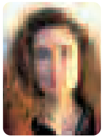


Fig.1: Set of observed spectrally-dispersed MIDI visibilities together with the best-fit geometrical models (face-on vs. inclined uniform ring vs. binary stellar system).

Discovery of a cool extrasolar planet of 5.5 earth masses through gravitational microlensing



D. Dominis

Der Mikrogravitationslinseneffekt wird hervorgerufen durch die Beugung des Lichtes im Schwerefeld eines Objektes in der Sichtline des Beobachters zur Lichtquelle. Die Relativbewegung zwischen Beobachter, Linse und Quelle führt zu einer Änderung der Linsengeometrie, die sich messbar in einer Veränderung der scheinbaren Helligkeit des Lichtquelle ausdrückt. Die Beobachtung solcher Lichtkurven ist eine neue vielversprechende Methode, um extrasolare Planeten zu suchen, die der Erde ähneln. Die Messdaten des Teleskopnetzwerkes der PLANET/RoboNet-Kollaboration vom Mikrolinsenereignis OGLE-2005-BLG-390 erhielten klare Hinweise darauf, dass es sich um mehr als ein gewöhnliches Ereignis eines einzelnen Linsensterns handelt. Eine genauere Analyse zeigte, dass die Daten nur erklärt werden können, wenn die Linse, ein roter Zwergstern mit 1/5 der Sonnenmasse, von einem Planeten mit 5.5 facher Erdmasse in einem 3 AE Orbit umgeben ist.

By measuring light curves (brightness magnitude changes) of Galactic stars caused by the bending of light due to the presence of the gravitational field of an object acting as a lens between the observer and the source star, gravitational microlensing turns out to be a unique method for detecting Earth mass extrasolar planets.

In the summer of 2005, the PLANET/RoboNet collaboration, alerted by the OGLE early-warning system, observed photometric light curves of the microlensing event OGLE-2005-BLG-390, which was modeled to correspond to a lens system of a 5.5 Earth mass planet (uncertain to within a factor of two) orbiting a red dwarf of 0.2 Solar masses close to the Galactic centre, at a semi-major axis of around 3 astronomical units and with a period of 11 years.

In order to be able to catch and characterize planetary deviations, nearly-continuous round-the-clock high-precision photometric monitoring of ongoing microlensing events towards the Galactic Bulge is required, which is achieved by the PLANET network of five 1m-class telescopes in Australia, Chile, and South Africa. Since 2005, PLANET has operated a common campaign with RoboNet, a UK operated network of 2m fully robotic telescopes.

The observed light curve of a microlensing event caused by a binary lens yields the event time-scale, the mass ratio of the binary components (the planet-to-star mass ratio in this case), the instantaneous angular planet-star separation and the time taken for the source to move relative to the lens by a distance equal to its own radius. However, there are some degeneracies in the possible solutions which can be derived from a single light curve. One important case is a degeneracy between a light curve produced by a binary source star with a single star acting as a lens, and a single source star passing behind a binary lens. The binary lens can consist of two stars, or a star with a planet. In our case this degeneracy was broken by very dense data sampling, which allowed us to confirm the planetary solution.

With a mass of only 5.5 M_{earth}, OGLE-2005-BLG-390Lb is probably the least massive exoplanet around an ordinary star detected so far, and with a surface temperature of around 50 K the coolest, so that it is undoubtedly of rocky/icy rather than gaseous nature. Its discovery marks a ground-breaking result in the search for planets that support life.

This work has been done as part of the PLANET/RoboNet, OGLE and MOA collaborations.

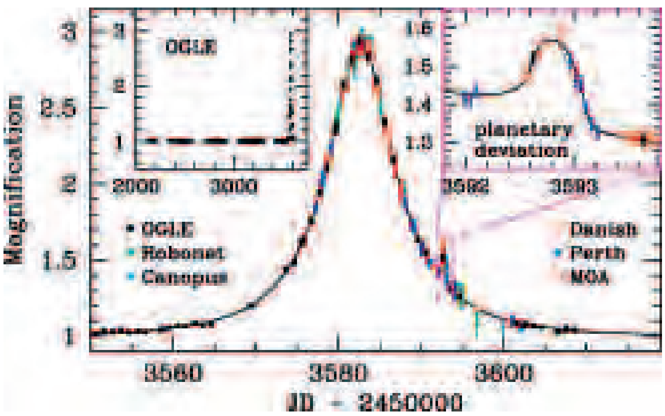
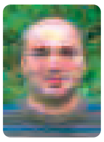
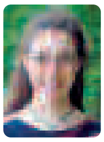
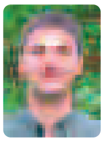


Fig. 1: Data obtained by PLANET/RoboNet, OGLE, and MOA on the microlensing event OGLE-2005-BLG-390 together with a model light curve, showing the planetary deviation on its falling part, lasting about a day. Also shown are best-fitting models with a single lens and a binary source (grey dashed line) and a single-source, single-lens light curve (orange dashed line). The data points are colour-coded in order to indicate the telescope used for the observations.

Numerical simulations of cloud-cloud collisions and gravoturbulent fragmentation using SPH with particle splitting

S. Kitsionas, A.-K. Jappsen, R. S. Klessen

Numerische Simulationen sind ein wichtiges Hilfsmittel, um die Entstehung von Sternen und Planeten zu untersuchen. Wir ermitteln die Effizienz der Sternentstehung in Wolkenkollisionen und verfolgen die Entwicklung von protostellaren Scheiben. Hierzu benutzen wir \`Smoothed Particle Hydrodynamics' in Kombination mit einer Methode, die es erlaubt, Teilchen aufzuteilen und somit die numerische Auflösung in beispielloser Art und Weise zu erhöhen.

Numerical simulations of cloud-cloud collisions using smoothed particle hydrodynamics (SPH) and particle splitting have been used to estimate the star formation efficiency (SFE = the fraction of gas mass that ends up in stars) of cloud-cloud collisions.

In particular, we have investigated the dependence of the SFE on the collision angle as well as on the cloud velocity and mass. Fig. 1 presents the result of such a collision: a network of filaments forms within the shocked layer that gets compressed at the collision interface, while resolved protostellar discs form along the filaments.

We have concluded that the SFE of cloud-cloud collisions ranges between 10% and 20%. We have reported that the SFE increases with increasing cloud velocity and mass. We have also concluded that the angular momentum of the protostellar discs increases with increasing collision angle and that although low angle collisions produce strong shocks, large angle collisions reduce the cloud interaction. The transition happens at an angle of ≈ 20 degrees. We have also shown that the angular momentum of the protostellar discs as well as the number and the density of the filaments increases with increasing cloud collision velocity.

The above mentioned SFEs were based on protostellar masses obtained by extrapolation, as the simulations could not be followed long enough due to numerical limitations. We have recently confirmed the above results by using, for the first time, star particles in SPH simulations with particle splitting. This has enabled us to overcome the numerical limitations and evolve the simulations for ≈ 0.5 Myr, and thereby to obtain direct estimates of the protostellar masses.

The SPH code combining particle splitting and star particles is very powerful, as it allows investigation of the evolution of protostellar disc clusters formed in simulations of turbulent self-gravitating media at unprecedented numerical resolution. (Particle splitting was developed to increase the numerical resolution locally only when this becomes necessary and it serves as the SPH analogue of Adaptive Mesh Refinement in grid codes.) Such high-resolution simulations are currently underway and each disc is being evolved at a resolution of a few hundred thousand SPH particles, allowing us to draw significant conclusions on the fragmentation of the disc in stellar and/or sub-stellar companions to the central protostar, as well as to constrain the validity of models for the formation of gaseous planets in such discs.

Collaborator: A. P. Whitworth (Cardiff University, UK).

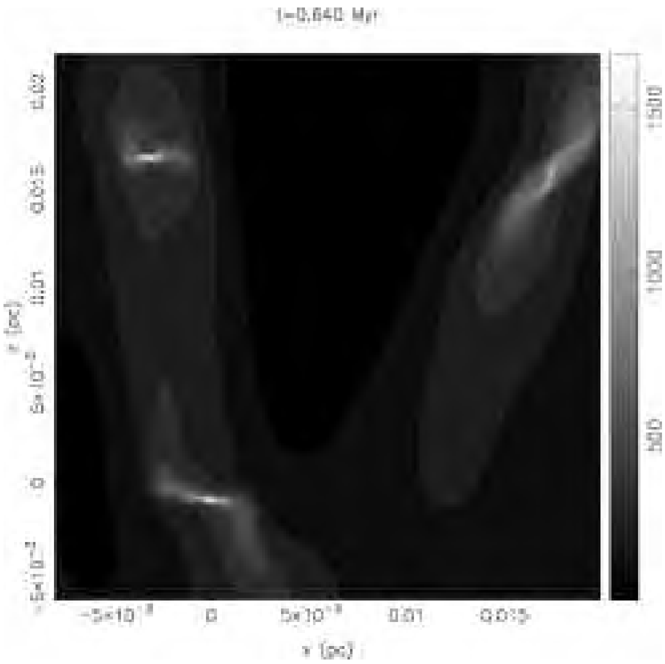
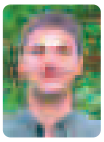


Fig.1: Column density plot for a collision of two 75 solar mass clumps, moving towards each other at 1 km/s and colliding at an angle of ≈ 10 degrees. The shocked layer is seen edge-on, at the end of the simulation at ≈ 0.64 Myr. The network of filaments forming within the shocked layer and three protostellar discs forming along the filaments are shown here. The size of the figure is 0.028 pc. The gray-scale (column density) table is in g cm^{-2} units.

Non-isothermal gravoturbulent fragmentation: Effects on the IMF

A.-K. Jappsen, R. S. Klessen

Sterne entstehen in turbulenten interstellaren Gaswolken aus molekularem Wasserstoff durch gravitativen Kollaps. Wir untersuchen den Einfluss des thermodynamischen Zustandes das Gases auf die anfängliche Massenverteilung der gebildeten Sterne. In unseren drei-dimensionalen hydrodynamischen Simulationen beschreiben wir das Wechselspiel von Heiz- und Kühlprozessen im Gas mit einer polytropen Zustandsgleichung. Unsere Resultate zeigen, dass diese Zustandsgleichung die charakteristische Masse der kollabierenden Fragmente der Gaswolke bestimmt.

The thermodynamic state of star-forming gas determines its fragmentation behavior and thus plays a crucial role in determining the stellar initial mass function (IMF). We address the issue by studying the effects of a piecewise polytropic equation of state (EOS) on the formation of stellar clusters in turbulent, self-gravitating molecular clouds using three-dimensional, smoothed particle hydrodynamics simulations. In these simulations, stars form via a process we call gravoturbulent fragmentation, i.e. gravitational fragmentation of turbulent gas. To approximate the results of published predictions of the thermal behavior of collapsing clouds, we increase the polytropic exponent γ from 0.7 to 1.1 at a certain critical density. The change of thermodynamic state at the critical density selects a characteristic mass scale for fragmentation, which we relate to the peak of the observed IMF.

Our investigation generally supports the idea that the distribution of stellar masses depends in part on the thermodynamic state of the star-forming gas. Supersonic turbulence in self-gravitating molecular gas generates a complex network of interacting filaments. Turbulent compression sweeps up gas in some parts of the cloud and collapse sets in. At densities where γ is below unity, fragmentation is very efficient. During the collapse, the gas density increases into regimes where γ is above unity, which results in less efficient fragmentation. Thus, we expect that most objects will form with masses above the Jeans mass at the density at which γ changes. The thermodynamic state of interstellar gas is a result of the balance between heating and cooling processes, which in turn are determined by fundamental atomic and molecular physics and by chemical abundances. Given the abundances, the derivation of a characteristic stellar mass can thus be based on universal quantities and constants. This work has been done in collaboration with R. B. Larson (Yale), Y. Li (Harvard) and M.-M. Mac Low (AMNH).

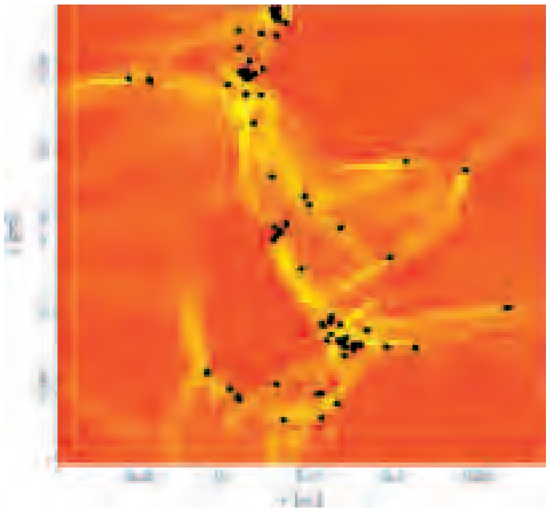


Fig 1: Column density map of the gravitational fragmentation of the simulated gas cloud. The black circles indicate the locations of identified protostellar objects.

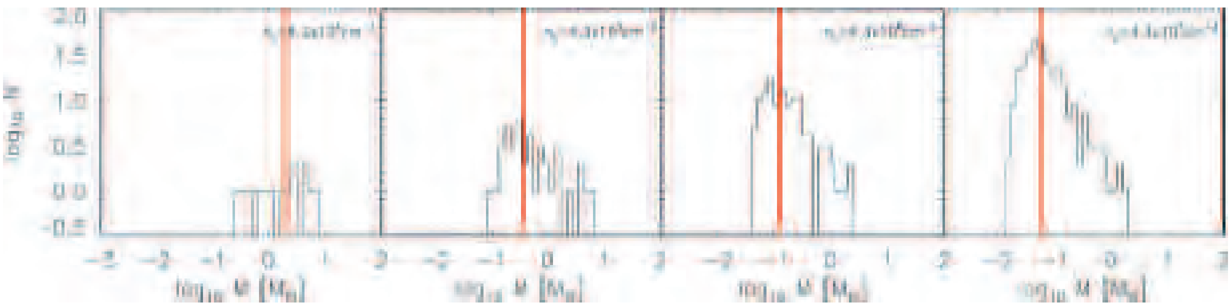
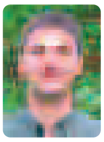


Fig 2: Mass spectra of protostellar objects for 4 models with different critical densities. A higher critical density results in a shift of the median mass (red line) towards lower values .

The structures of young star clusters

S. Schmeja, R. S. Klessen

Sterne entstehen nicht allein, sondern meistens in Gruppen von einigen hundert bis tausend Objekten. Die innere Struktur dieser Sternhaufen liefert uns wichtige Hinweise auf die physikalischen Prozesse, die die Entstehung der Sterne in unserer Milchstraße steuern. Zur Untersuchung der Haufen wurden in unserer Gruppe verschiedene statistische Verfahren entwickelt und getestet, und sowohl auf Beobachtungsdaten als auch auf Computersimulationen angewandt.

Understanding the formation and evolution of young stellar clusters requires quantitative statistical measures of their structure, which may give important clues to the formation process. While some clusters are centrally concentrated with a smooth radial density gradient, others show filaments and signs of fractal subclustering. Whether and how different structures are connected to the environmental conditions of the molecular clouds is not yet clear, nor is how they depend on the evolutionary state of the cluster.

To describe the clustering properties of star clusters, we use different statistical methods. In particular, we use the normalized correlation length and the mean edge length of the minimum spanning tree (MST) of the young stars, and a parameter combining the two. (The MST, a construct from graph theory, is the unique set of straight lines ("edges") connecting a given set of points without closed loops, such that the sum of the edge lengths is a minimum.) In addition, we introduce a new measure for the elongation of a cluster. It is defined as the ratio of the cluster radius determined by an enclosing circle to the cluster radius derived from the normalised convex hull. By considering the different evolutionary classes in the observations and the temporal evolution in models of gravoturbulent fragmentation, we can study the temporal evolution of the cluster structures.

The mean separation of young stars in observed clusters increases with the evolutionary class, reflecting the expansion of the cluster. The prestellar cores do not follow that sequence, leading to the speculation that not all objects classified as prestellar cores will eventually form stars. The clustering values of the models lie roughly in the same range as those from observed clusters. A particularly good agreement is reached when the clusters have similar elongation values. No correlation of the clustering parameters with the Mach number or the wavenumber of the underlying turbulent velocity field of the star-forming cloud is found. We conclude that possible influences of the turbulent environment on the clustering behaviour are quickly smoothed out by the velocity dispersion of the young stars. The temporal evolution of the clustering parameters shows that the cluster builds up from several subclusters and evolves to a more centrally concentrated cluster. New stars are formed faster than the cluster expands. Projecting the three-dimensional model clusters into a two-dimensional plane (as it is the case with the observed clusters) does not significantly change the picture. While the individual clustering measures can differ for the 2D case, the qualitative behaviour of the temporal evolution is more or less the same, independent of the projection.

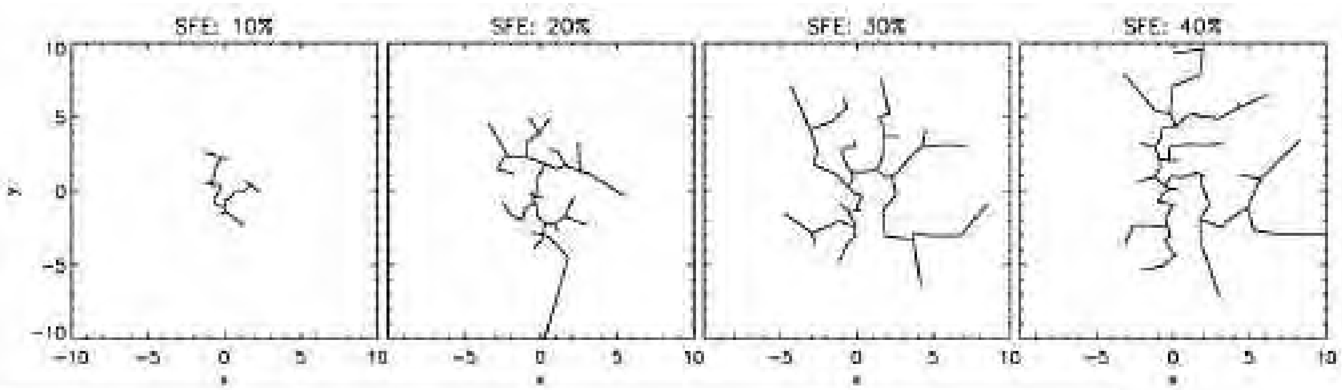
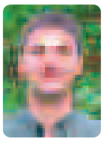


Fig. 1: The minimum spanning tree of a model star cluster seen in projection at different times, indicating the growth of the cluster.

Star Formation in Spiral Galaxies



Ralf S. Klessen

Unser gegenwärtiges Verständnis der physikalischen Prozesse, die die Bildung der Sterne steuern, stammt vor allem aus detaillierten Beobachtungen nahegelegener Sternentstehungsgebiete. Der lokale Prozess der Sternbildung ist allerdings eng mit der großskaligen dynamischen Entwicklung der Galaxie verknüpft. Diese Wechselbeziehung ist bislang nur sehr unzureichend untersucht. In Zusammenarbeit mit Dr. Yuexing Li und Prof. Mordecai-Mark Mac Low vom American Museum of Natural History in New York hat die Arbeitsgruppe Sternentstehung am AIP daher Modelle entwickelt, in denen die großräumige Stabilität von Scheibengalaxien (wie etwa unsere Milchstraße) mit deren Sternentstehungsrate in Verbindung gesetzt wird.

Our understanding of star formation is heavily influenced by the nearest star-forming regions, where protostars and their environments can be most readily observed. However, these nearby regions appear increasingly less likely to represent the dominant mode of star formation in galaxies. Observations of star formation integrated across galaxies reveal that the rate of star formation is proportional to a power of the total gas surface density. This is the so-called Schmidt law. We demonstrate that gravitational instability in galactic disks with an isothermal equation of state can quantitatively reproduce this law, thereby suggesting that the initial conditions for most star formation in galaxies is determined by large-scale gravitational collapse.

We simulate a large set of isolated galaxies using smoothed particle hydrodynamics (SPH), extended to include absorbing sink particles replacing gravitationally bound regions of convergent flows. Our model galaxies initially consist of a dark matter halo, and a disk of stars and isothermal gas. We use the sink particles as a numerical proxy for the formation of dense interstellar clouds which form further stars during the considered evolutionary time.

To quantify the instability of our model disks, we compute the gravitational instability parameter Q_{sg} for a combination of collisional gas and collisionless stars as a function of radius. We relate the minimum radial value $Q_{sg,min}$ with the observed star formation rate. For that, we assume that the gas entering sink particles forms stars with a constant local star formation efficiency (SFE) of 30% (the actual value is not central to our results), and that the rest of the collapsing gas becomes molecular, at least briefly.

Our isolated galaxies show star formation rates declining exponentially in time. The distribution of atomic gas, star formation, and dense, presumably molecular gas found in our models generally reproduces observed galaxies, as illustrated in Fig. 1. A good agreement is seen between the surface density of the star formation rate and of dense gas, as indicated by recent surveys of nearby star-forming spiral galaxies.

Altogether, the current models suggest that the bulk of star formation in galaxies occurs in regions collapsing gravitationally on large scales, forming molecules rapidly as they reach high densities. This naturally leads to both a Schmidt law and a star formation threshold.

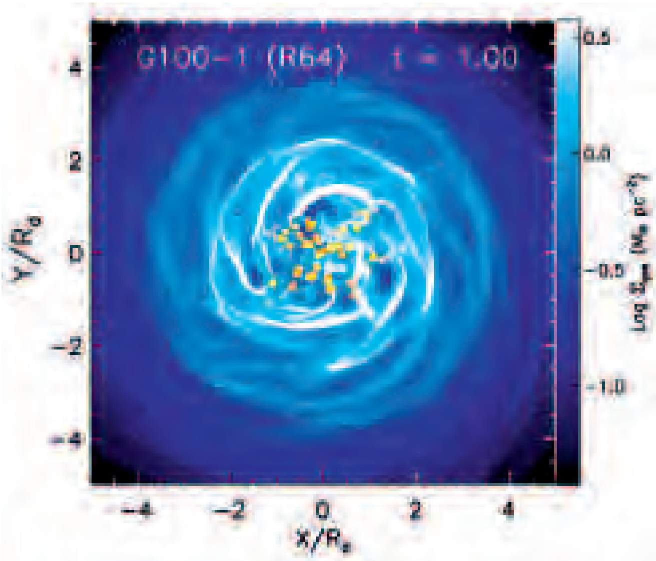
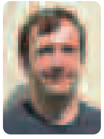
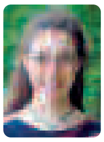
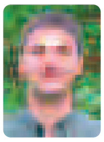


Fig. 1: Face-on view onto one of our model galaxies. Note the flocculent spiral pattern in the atomic gas (white-blue image), typical for isolated spiral galaxies. Yellow dots indicate regions of dense, molecular, star-forming gas.

Simulating molecular cooling in protogalaxies

S. Glover, A.-K. Jappsen, R. S. Klessen

Aktuelle kosmologische Modelle, die auf der Annahme kalter dunkler Materie basieren, besagen, dass die ersten Sterne im Universum in kleinen Protogalaxien entstehen. Im Unterschied zu lokalen Sternentstehungsgebieten besteht das Gas in diesen Protogalaxien vor allem aus atomarem Wasserstoff. Daher laufen Temperaturveränderungen aufgrund von dynamischen Prozessen nur langsam ab. In unseren numerischen Simulationen ist es deshalb von Bedeutung, sowohl die dynamische als auch die thermische Entwicklung des Gases zu verfolgen. Dies wiederum macht es notwendig, die Chemie des Gases adäquat zu beschreiben.

In cosmological models based on cold dark matter (CDM), the first stars to form are believed to do so within small protogalaxies, with masses comparable to those of present-day giant molecular clouds. However, unlike molecular clouds, these early protogalaxies are composed primarily of atomic hydrogen, with a molecular hydrogen fraction of at most a few parts in a thousand. This, together with the absence of metals and dust from the gas, means that the temperature of the gas cannot adjust itself quickly in response to dynamical changes. This means that an isothermal approximation of the kind that has been used with a great degree of success for modeling local star formation is not appropriate. To properly model the dynamical evolution of the gas, we must simultaneously model its thermal evolution, which in turn requires us to model its chemistry.

A number of different groups have studied this combined chemical, thermal and dynamical problem, using a variety of different computational models, and the basic sequence of events leading to the formation of the first stars now seems quite clear. However, there are many interesting questions that remain unanswered.

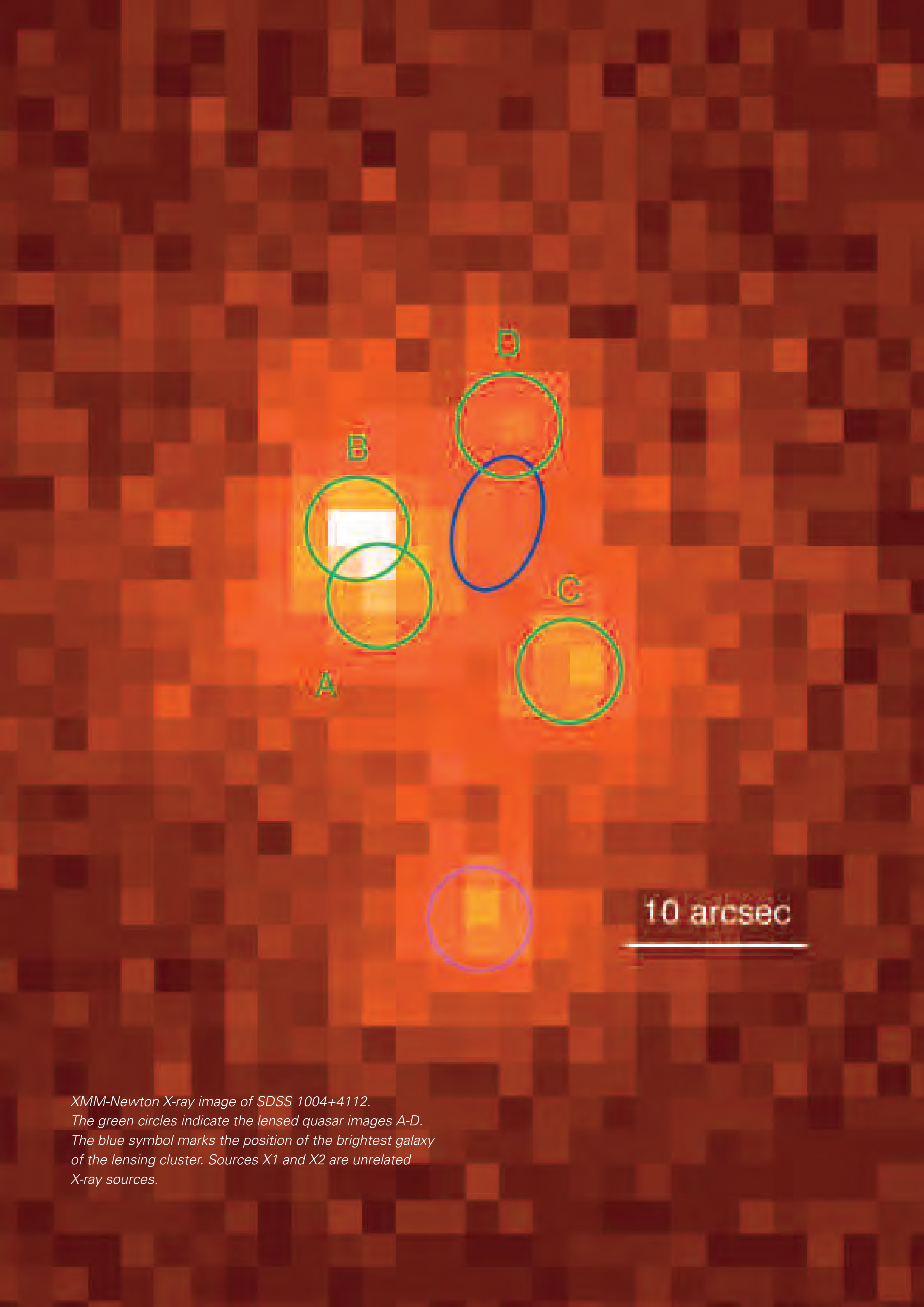
Our work in this area over the past two years has focused on two main issues. The first is an attempt, in collaboration with D. Savin (Columbia), to quantify the degree of uncertainty in model predictions that results purely from the uncertainties that exist in the chemical reaction rate coefficients used in the models. We have shown that uncertainties in the rates of two key reactions:

$$H^- + H \rightarrow H_2 + e^-$$

$$H^- + H^+ \rightarrow H + H$$

can in some circumstances lead to substantial and significant uncertainties in the outcome of the models, a situation which will only improve once better data on the chemical rates become available.

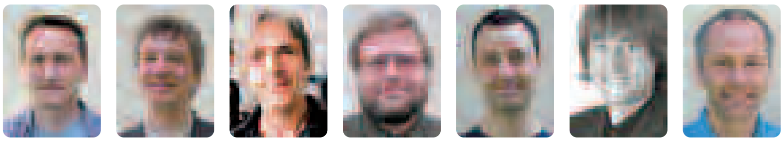
Our second major focus has been on developing an understanding of how the evolution of these early protogalaxies is altered once the gas forming them has been enriched with small quantities of heavy elements, which are produced and dispersed into the intergalactic medium by the first supernovae. Adding heavy elements to the gas, whether in the form of individual atoms or as microscopic dust grains, increases its ability to radiate away heat and to regulate its temperature, and it has been argued that it is enrichment beyond a certain `critical metallicity' that first allows solar-mass stars to form, with protogalaxies that have not been enriched to this level forming only massive stars, with masses greater than a hundred times solar. This idea has been accepted as a working hypothesis by many cosmologists, but it has yet to be rigorously tested. Although observational tests will likely have to wait until NASA's James Webb Space Telescope is launched, what we can do at the present time is to test this idea numerically, using high resolution hydrodynamical simulations that incorporate the effects of the appropriate chemical and thermal processes. Our work in this area is ongoing, but preliminary, low-resolution simulations have already produced some interesting results, such as the demonstration that at low densities, metal enrichment has little or no effect on the evolution of the gas.



XMM-Newton X-ray image of SDSS 1004+4112.
The green circles indicate the lensed quasar images A-D.
The blue symbol marks the position of the brightest galaxy of the lensing cluster. Sources X1 and X2 are unrelated X-ray sources.

Galactic archeology with RAVE and SEGUE

A. Siebert, M. Steinmetz, H. Enke, R.-D. Scholz, C. Boeche, M. Schreiber, A. Schwope



Eines der Schlüsselprobleme der Astrophysik ist die Entstehung der Galaxien. Unsere Milchstraße nimmt dabei eine Sonderstellung ein – sie ist die einzige Galaxie, für die wir die Eigenschaften einzelner Sterne im Detail studieren können. Leider erschwert die Nähe der Sterne aber auch die Arbeit, wir sitzen in der Milchstraße und ihre Sterne sind über den ganzen Himmel verteilt. Mit zwei internationalen Großprojekten beteiligt sich das AIP an Bestrebungen, die Entstehungsgeschichte unserer Milchstraße zu entschlüsseln.

Das vom AIP initiierte und koordiniterte internationale Großprojekt RAVE (Radial Velocity Experiment) führt seit 2002 eine spektroskopische Durchmusterung von etwa 1 Million Sternen unserer Milchstraße durch. Das Ziel besteht in der Bestimmung von Radialgeschwindigkeiten und Elementhäufigkeiten, um die Sterne in einzelne Populationen aufteilen zu können. Jede einzelne dieser Populationen kann dann statistisch untersucht und die Resultate mit den Ergebnissen theoretischer Simulationen verglichen werden. RAVE hat inzwischen (Ende 2005) bereits fast 100000 Spektren aufgenommen. Ein erster Katalog von 25000 Sternen wurde kürzlich veröffentlicht. Während RAVE versucht, den ganzen Südhimmel zu durchmustern, verfolgt ein zweites internationales Großprojekt unter AIP-Beteiligung eine andere Strategie. In SEGUE (Sloan Extension for Galaxtic Exploration and Extension) werden Spektren für einige wenige Sichtlinien der Nordhalbkugel genommen, diese reichen jedoch sehr viel tiefer in den galaktischen Haufen hinaus und erlauben es auch, die äußeren Bereiche unsere Milchstraße zu erkunden.

One of the key problems in modern astrophysics is to understand how galaxies formed. Confronting cosmological simulations of galaxy formation with observations is still a difficult task, both from the observational and the theoretical side. In this context, a key role is played by our very own Milky Way Galaxy. The Milky Way has the advantage that we have a detailed view of individual stars. On the other hand, owing to its proximity, the Milky Way is all around us, so extensive campaigns that cover substantial fractions of the sky have to be performed. The AIP is partner in two of those campaigns, RAVE (Radial Velocity Experiments) and SEGUE (Sloan Extension for Galactic Understanding and Exploration). Both projects are large international collaborations with the same goal, namely deciphering the mode of formation of our galaxy, but with quite different strategies.

RAVE is an international collaboration started in 2002 which aims to obtain spectra for about one million stars in the southern hemisphere of our Galaxy by 2010. These spectra provide us with radial velocities - the third component of the velocity vector (the two others being provided by astrometric surveys) - as well as chemical abundances. To reach this goal, we are using the 6dF multi-object spectrograph on the AAO Schmidt telescope in Siding Spring (Australia). This instrument allows us to obtain up to 150 spectra for our targets in one single pointing in a 6 degrees circular field at high resolution (R = 7500).

As of the end of 2005, RAVE has obtained close to 100000 spectra and has moved to its full operational mode using up to 25 nights per lunation. The first two years of observations, the so-called pilot survey, used only 7 nights per lunation. RAVE's first data release was made public in February 2006. This first catalog contains radial velocities for over 25000 stars in the southern hemisphere. Complemented by astrometric and photometric catalogs such as 2MASS, DENIS or USNO, the full 6 dimensional phase space (meaning position and velocities) is available, enabling us to study the various components of the Milky Way. As an example, we show the selection of the Arcturus group candidates using RAVE velocities. The Arcturus group was identified by Eggen in 1970 as a group of stars that is dispersed over the Milky Way but that joins similar orbits around the galactic center. Using a simulation of the Arcturus group, velocities were used to select a banana-shaped region where the membership probability is high. Then, using abundances, membership can be confirmed and the properties and history of this group can be reconstructed.

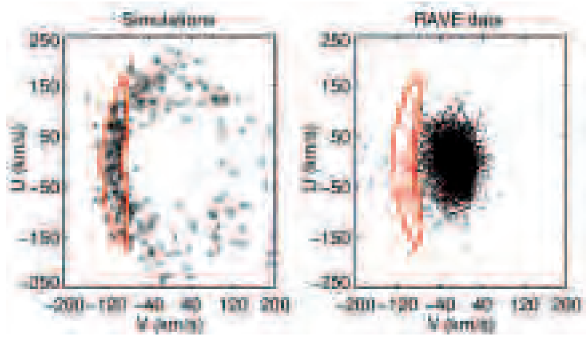


Fig. 1: Left: Simulation of the trace in the UV plane (velocities towards the Galactic center and in the direction of Galactic rotation) of an accreted satellite in the Galactic plane within 500 pc of the sun matching the Arcturus group. The red banana-shaped region shows the location where members are expected in the RAVE catalog. Right: RAVE targets UV plane distribution. The banana-shaped region is overplotted allowing the selection of a subset of the catalog where the probability of membership is high. This sub-sample is then used for further investigation (Williams et al. 2005).

A further example of the use of the RAVE survey is to decompose and study the gross properties of the Milky Way main stellar population. Fig. 2 (from Seabroke et al. 2005) shows how clearly the three main components (namely the thin disk, thick disk and halo) can be seen in a subset of only 2,000 of the RAVE stars using only the orbital velocities obtained from RAVE. Using these data, together with accurate photometry, allows us to measure with a very good accuracy the structural and kinematical properties of the main stellar components.

The structure and kinematics of the Milky Way disk is also useful for estimating the mass distribution in the solar neighborhood perpendicular to the plane of the disk. This gives useful information not only on the distribution of the dark matter and its contribution to local dynamics, but also on the surface density of the disk (mass enclosed in a cylinder at a given position in the disk) which provides strong constraints on chemical evolution models.

In the coming years, projects including the measurement of the escape velocity of the Galaxy (leading to an estimate of the total mass of the Milky Way), stellar cluster analysis, detailed structure of the thick disk and spectroscopic stellar classification will be completed. So far, RAVE is the largest radial velocity sample available and is growing larger. Metallicities for the brightest stars will also be computed allowing for combined (chemical + kinematical) studies of the Milky Way, leading to a new understanding of its formation.

A different strategy to that of RAVE is used in another Galactic Project, SEGUE. SEGUE is part of the Sloan Digital Sky Survey (SDSS), a extensive imaging and spectroscopic campaign of large parts of the sky accessible from the 2.5m Sloan Telescope at Apache Point, New Mexico. SDSS is scheduled to operate until the summer of 2008. Compared to RAVE, the SEGUE spectra are of lower resolution (R=1500), but cover a larger fraction of the optical bands (3800Å-9100Å). Unlike RAVE, the target list for spectroscopy does not homogeneously cover the sky. Instead, SEGUE attempts to take deep spectra for 1200 targets in 200 pencil beams. These pencil beams deeply probe the Galactic halo out to distances of 50 kpc from the Sun. In addition, SEGUE will provide detailed photometry for more than 3500 square degrees of the sky.

The usage of SEGUE is not limited to galactic dynamics, but has applications in other areas. With SEGUE photometry and spectroscopy (4 fibres per field granted to this program), researchers at AIP have designed a program to search for white dwarf/main sequence binaries with the ultimate goal of establishing a statistically meaningful sample of binary stars on their way from their common envelope to the CV stage. This program will uncover the still unknown space density of close interacting binaries and determine the relevance and strength of magnetic braking, widely regarded as the main angular momentum loss mechanism for the lower main sequence.

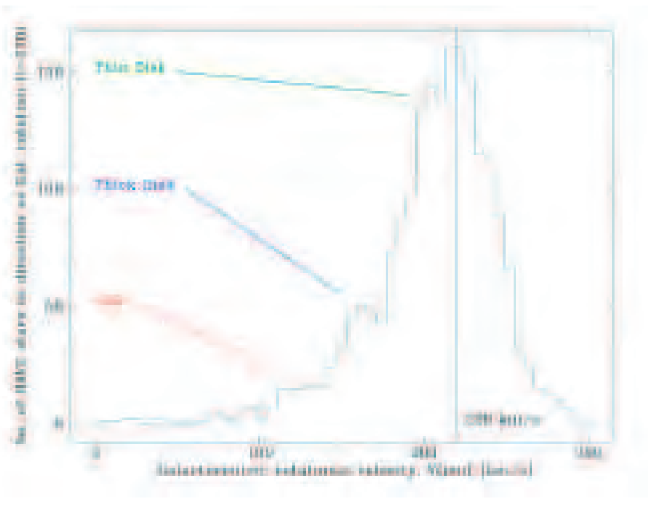


Fig. 2: Distribution of rotational velocity for a sub-sample of 2000 RAVE targets in the direction opposite to the Galactic rotation (Seabroke et al. 2005). This distribution clearly shows the presence and contribution of the three main Galactic components in the vicinity of the Sun: the thin disk, thick disk and stellar halo.

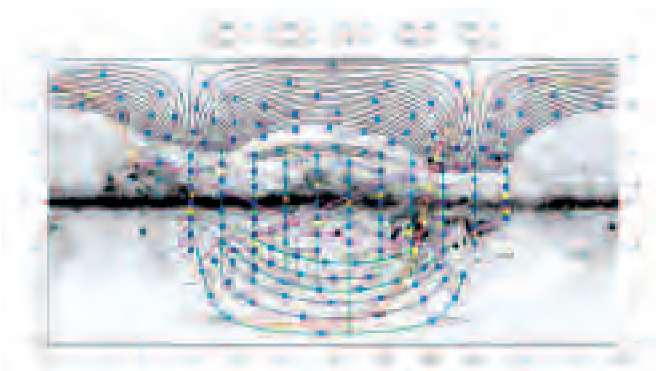


Fig. 3: Imaging and spectroscopic observing plane of the SDSS-SEGUE survey in Galactic Coordinates. The background is a dust emission/extinction map by Finkbeiner and Schlegel (1998). The solid black lines show the imaging scans of the Sloan Survey. The dotted black line corresponds to a declination of -20, the practical southern observing limit from Apache Point, NM. Blue and yellow circles denote the positions of the planned spectroscopic pencil beams.

Sub-stellar subdwarfs in the galactic halo

R.-D. Scholz, N. Lodieu, M.J. McCaughrean

Ein Stern mit extrem großer Eigenbewegung wurde bei der Durchmusterung von Archivdaten entdeckt und als sehr kühler Unterzwerg mit Merkmalen des Spektraltyps L klassifiziert. Es ist damit ein neuartiges Halo-Objekt, nah an der Grenzmasse von braunen Zwergen, das zur Zeit unsere direkte Nachbarschaft durchquert.

Sub-stellar objects (brown dwarfs) are failed stars which did not reach the critical mass of stars during their formation. With surface temperatures typically even lower than those of red dwarf stars, their colours are even redder. New spectral classes, L and T, describing these ultracool objects, were defined only recently. 50% of the L dwarfs and all T dwarfs in the Solar neigbourhood are brown dwarfs. Among late-M dwarfs only a few are sub-stellar objects.

For cool subdwarfs, having lower metallicity than Galactic disk dwarfs and showing large heliocentric space velocities typical of a membership in the Galactic halo, the classification scheme has still to be extended into the late-M, L, and T dwarf regimes. Only very few ultracool subdwarfs are known, compared to more than 450 L and T dwarfs.

As a result of a high proper motion survey we have detected possibly the nearest ultracool representative of the Galactic halo (Fig.1). With an extremely large proper motion of 3.5 arcsec/yr and radial velocity of -160 km/s, it crosses the Solar neigbourhood with the enormous speed of about 370 km/s. Its spectrum shows features of both late-M and L dwarfs (Fig.2). A comparison with models (Fig.3) reaches a moderately low metallicity as obtained for two other (suspected) L-type subdwarfs and a mass at the sub-stellar boundary (0.085 M_{sun}).

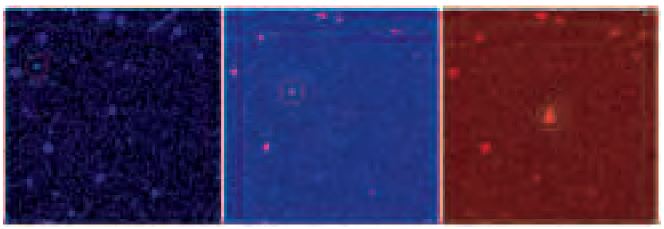


Fig.1: SSSPM 1444 (circled) observed at different epochs and in different passbands: 1976 B_J, 1985 R, 1994 I (from left to right). Each of the three SuperCOSMOS Sky Survey images is about 2 arcmin wide.

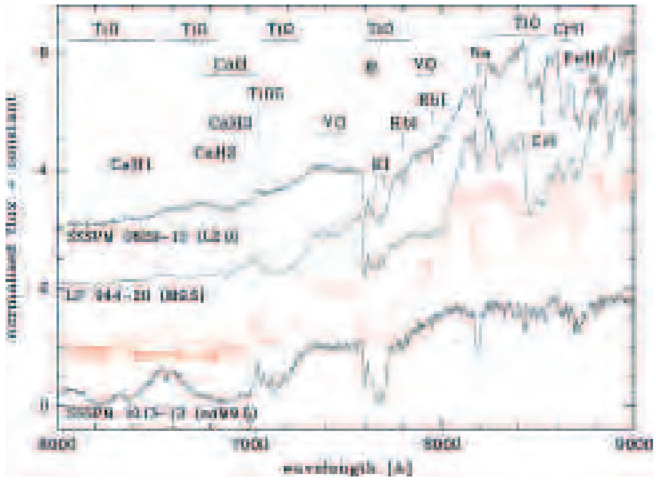


Fig.2: ESO 3.6m/EFOSC2 spectra for the newly discovered subdwarf SSSPM 1444, the L2 dwarf SSSPM 0829 (Scholz & Meusinger 2002), and the M9.5 brown dwarf LP 944-20, along with an NTT/EMMI spectrum of the latest known M-type subdwarf (sdM9.5) SSSPM 1013 (Scholz et al. 2004). Key spectral features of M and L (sub)dwarfs are labeled. According to the Gizis (1997) subdwarf classification scheme, valid only up to sdM7, SSSPM 1444 has a formal spectral type of sdM9. But it shows L-type features like the absence of VO bands and is as red as the brown dwarf and the L2 dwarf.

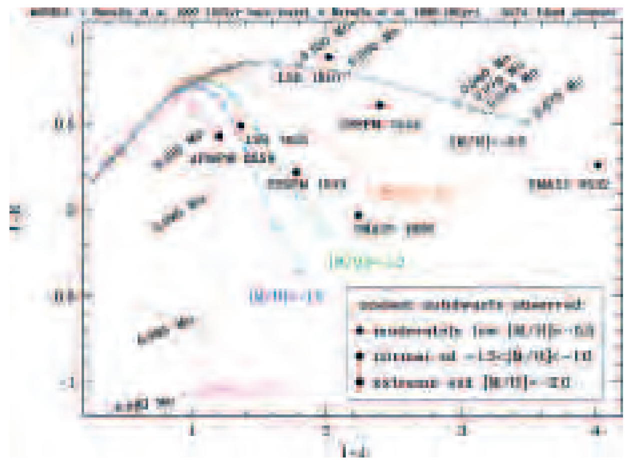
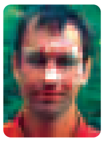
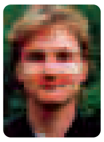
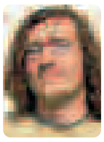


Fig.3: Colour-colour diagram for the coolest known subdwarfs compared with evolutionary models (Baraffe et al. 1997, 1998). The unique late-L subdwarf 2MASS 0532 (Burgasser et al. 2003) and the two subdwarfs with L-type features, LSR 1610 (Lepine et al. 2003), and SSSPM 1444, all appear more consistent with moderately low-metallicity models ([M/H]=-0.5) than with their normal or extreme subdwarf counterparts.

A new angular momentum loss mechanism in close interacting binaries?

A. Schwope, R. Schwarz, A. Staude, J. Vogel

Die Bewegung der Sterne in einem Doppelstern um das gemeinsame Massenzentrum ist vergleichbar mit dem Gang präziser Uhren, zumindest im Prinzip. Aus einer ermittelten Gangungenauigkeit lassen sich z.T. weitreichende Schlüsse ziehen. Das vielleicht prominenteste Beispiel ist die Periheldrehung des Planeten Merkur, die erst im Rahmen der Allgemeinen Relativitätstheorie befriedigend erklärt werden konnte. Die Physik der 'Uhren' in engen Doppelsternen (in kataklysmischen Veränderlichen) ist im Prinzip seit mehr als 20 Jahren bekannt und wurde seitdem nur in Nuancen verändert. Diese Systeme entwickeln sich unter dem Einfluss eines magnetisierten Sternwindes und unter der Abstrahlung von Gravitationsstrahlung von langen zu kurzen Umlaufszeiten. Die dabei wichtigen Zeitskalen sind jedoch so lang, dass man nicht erwartete, die entsprechenden Änderungen der Bahnumlaufszeit in einem Einzelobjekt sondern nur in einem statistischen Sinne nachweisen zu können. In mehr als 10jährigen hochpräzisen Messreihen haben wir jedoch diesen Effekt nachweisen können, der wesentlich stärker auftritt, als durch bisherige theoretische Modelle vorhergesagt.

The motion of stars around the center of mass in close binaries is like a clock, at least in principle. Deviations from the expected behaviour may have far-reaching implications. The perhaps most prominent example is the peculiar motion of Mercury's perihelion which was satisfactorily explained only in the framework of Einstein's general theory of relativity.

The physics of close binaries of cataclysmic variable type as 'clocks' is well established in the literature and essentially unchanged over the last 20 years or so. These systems develop by magnetic braking and emission of gravitational radiation from long to short orbital periods. The involved time-scales, however, are so long that direct observation of such an effect would not have been deemed possible. Common wisdom said that the imprints of the aforementioned effects could be made visible only in a statistical sense in the period distribution of all known systems. This quantity was intensively studied over the last few decades.

Meanwhile, by patient observations covering more than 50000, or in one case more than 120000 cycles of such binaries with highest possible precision, we have made the speeding-up of the binary directly visible in two cases. For our study, we are using eclipsing binaries, where the mass-accreting primary star, a white dwarf, is occulted by the mass-losing secondary star, a main sequence star, once per binary revolution. We were utilizing the Hubble Space Telescope, the X-ray observatories ROSAT and XMM-Newton, and high-speed cameras at ground-based telescopes like OPTIMA and ULTRACAM at the ESO-VLT. Fig. 1 shows an example of such an observation which allowed accurate timing of the white dwarf star with a precision of a few seconds.

Fig. 2 shows the measured time of the white dwarf's eclipse in HU Aqr compared to the expected time. The deviation is highly significant and the derived angular momentum loss rate about a factor of 100 higher than expected from current theory. In principle such deviations could be caused by the presence of a third body of low mass in the system and a corresponding light travel time effect. However, the observation of an effect of the same order of magnitude in three other objects makes this explanation highly unlikely. We suggest that a new angular momentum loss mechanism must be found, with yet to be formulated implications for the class as a whole.

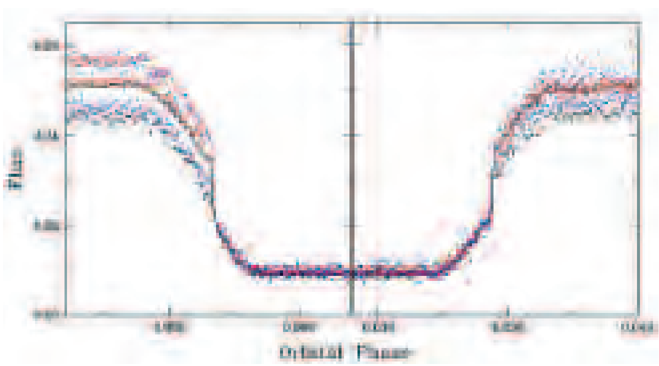


Fig. 1: Details of the eclipse light of HU Aqr, a 125 min binary observed with ULTRACAM at the VLT in May 2005. Ingress and egress of the white dwarf star lasts about 30 seconds. The eclipse light curve is highly structured due to the presence of the hot accretion spot on the white dwarf.

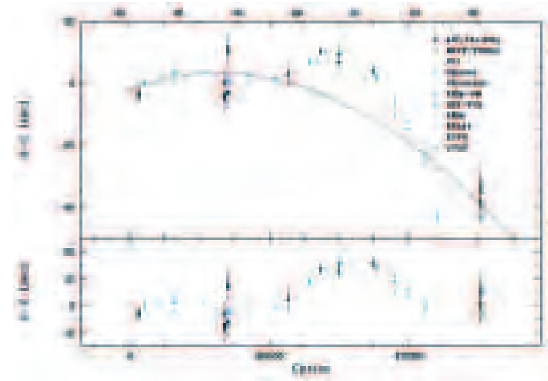
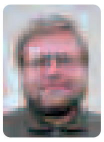
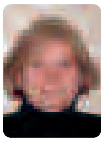
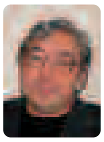


Fig. 2: Difference between observed and expected time of eclipse in HU Aqr observed with a large suite of ground- and space based observatories. While small differences (< 10 s) can be explained by variable spot positions on the white dwarf, large differences of the size of the white dwarf itself (30 s) require a new physical mechanism.

Revisiting the population of galactic open clusters

R.-D. Scholz, N.V. Kharchenko, A.E. Piskunov

Ein deutsch-russisches Gemeinschaftsprojekt lieferte grundlegende neue Erkenntnisse über die offenen Sternhaufen in der Galaxis. Die Daten für 520 Haufen wurden überarbeitet, 130 Haufen neu entdeckt. Mit der resultierenden bisher größten homogenen Stichprobe wurden Unterstrukturen in der räumlichen und Geschwindigkeits-Verteilung der Haufen entdeckt. Der jüngste identifizierte Haufenkomplex wird mit dem Gould-Gürtel in Verbindung gebracht, die älteste Gruppe von Haufen enthält die Hyaden und Praesepe und bewegt sich relativ schnell (40 km/s) in Richtung des Galaktischen Antizentrums.

A German-Russian collaboration on nearby open clusters and associations has been supported by the DFG grant 436 RUS 113/757/0-1 and the Russian RFBR grant 03-02-04028. The common work of Anatoly Piskunov (INASAN Moscow), Nina Kharchenko (INASAN Moscow/MAO Kiev), Elena Schilbach and Siegfried Röser (both from ARI, Heidelberg), and Ralf-Dieter Scholz (AIP), has led to a significant improvement in our knowledge of Galactic open clusters in general.

The basic tool used for this study was the All-Sky Compiled Catalogue of 2.5 million stars (ASCC-2.5; Kharchenko 2001) constructed from catalogues of the Hipparcos-Tycho family and ground based (PPM, CMC11) catalogues. The ASCC-2.5 is complete down to V=11.5 (V_{lim} =14), and contains proper motions in the Hipparcos system, B, V magnitudes in the Johnson photometric system and additional information like spectral types. The ASCC-2.5 was also supplemented with radial velocities. A combined kinematical-photometric cluster membership determination pipeline has been developed and applied to 520 known clusters identified in the ASCC-2.5. The same pipeline was applied in screening the whole sky for new clusters. This led to the discovery of 130 clusters.

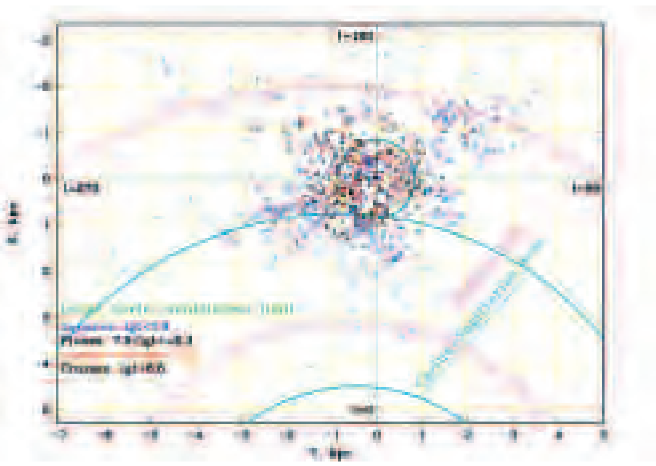


Fig. 1: Distribution of open clusters in the Galactic XY-plane centered at the location of the Sun.

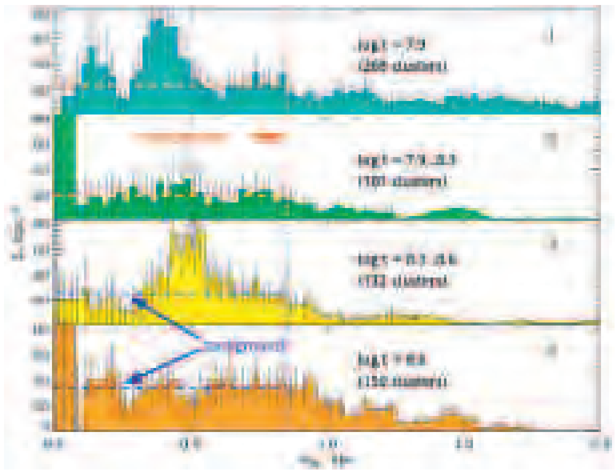


Fig. 2: Distribution of the surface density Σ of open clusters versus their distance d_{xy} from the Sun projected onto the Galactic plane for four subsamples of different ages.

With the combined kinematical-photometric cluster membership obtained in the same way for all 650 open clusters, new uniform scales of angular sizes, kinematics (average proper motions and radial velocities), distances, reddening and ages have been determined. The sample of 650 clusters was estimated to be complete within a distance limit of 0.85 kpc. About 260 clusters are located within that limit.

Fluctuations in the spatial and velocity distributions were attributed to the existence of open cluster complexes (OCCs) (Piskunov et al. 2006). Members in an OCC show the same kinematical behaviour, and a narrow age spread. The youngest complex, OCC 1 (log *t* < 7.9), is apparently a signature of Gould's Belt. The most abundant OCC 2 has moderate age (log *t* = 8.45). The clusters of the compact Perseus-Auriga group, having the same age as OCC 2, are seen in breaks between Perseus-Auriga clouds. The oldest (log *t* = 8.85) and sparsest group (including the Hyades and Praesepe) was identified due to a large motion in the Galactic anticentre direction (about 40 km/s).

The total surface density of clusters is $\Sigma = 114$ kpc^{-2}, which exceeds by a factor of 5 the value known from previous studies. The respective number of open clusters in the Galactic disk can be estimated as $\approx 10^5$ at present, and the formation rate and lifetime of open clusters are 0.23 ± 0.03 kpc^{-2} Myr^{-1} and 322 ± 31 Myr, respectively. The latter implies a total number of cluster generations in the history of the Galaxy of between 30 and 40, which allows only 10% of the total Galactic stellar disk population to have ever passed through an open cluster membership (Piskunov et al. 2006).

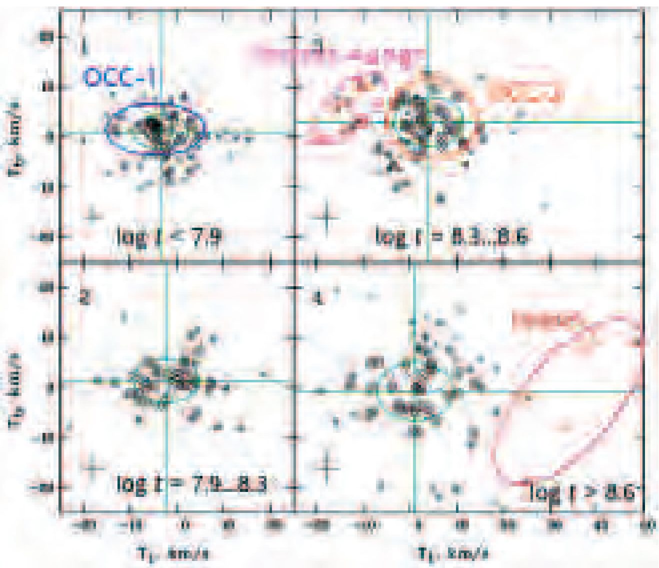


Fig.3: Vector point diagrams of tangential velocities of open clusters in four age samples. Open cluster complexes are marked.

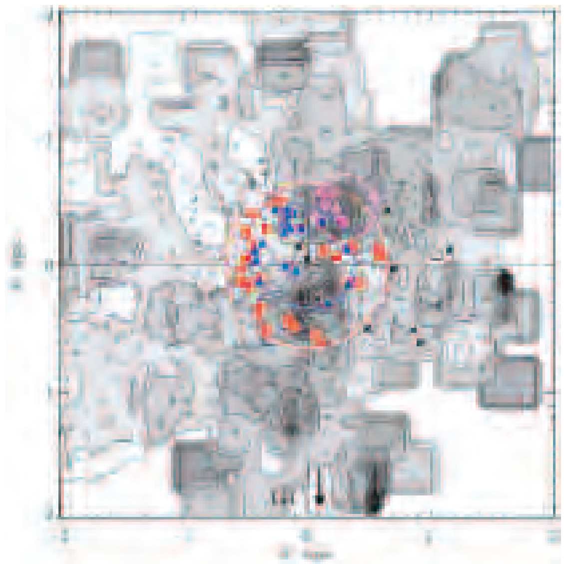
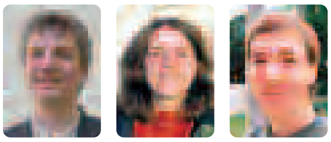


Fig.4: Relative position of the identified OCCs and groups in the XY plane on a background of interstellar clouds revealed from our data. Large symbols mark candidate members for the Gould's Belt complex (triangles), OCC 2 (circles), the Perseus-Auriga group (diamonds), and the Hyades group (crosses). Small open circles mark field clusters. Large circles and the ellipse are the apparent complex boundaries.

Probing structure formation theory with the properties of individual galaxies



M. Steinmetz, F. Köckert, I. Josopait

Galaxien sind keine Insel-Universen, vielmehr wechselwirken die verschiedenen Galaxien auf verschiedene Art und Weise miteinander. Dies kann auf die Ferne durch Gezeitenkräfte geschehen, ein Effekt der allgemein als ursächlich für die Rotation der Galaxien angesehen wird, im extremeren Fall bedeutet dies aber sogar das Verschlucken ganzer Galaxien durch galaktische Schwergewichte wie unsere Milchstraße. Mitarbeiter am AIP beschäftigen sich daher mit der detaillierten Simulation, wie Milchstraßensysteme entstehen und miteinander wechselwirken. Die Analyse dieser Simulationen helfen dann, beobachtete Daten, wie sie z.B. durch die Projekte RAVE und SEGUE geliefert werden, zu ordnen und zu interpretieren. Hier werden zwei Ergebnisse exemplarisch vorgestellt, zum einen eine Methode um zu beweisen, dass Gezeitenkräfte mit der umgebenden Massenverteilung in der Tat für die Rotation der Galaxien verantwortlich ist, zum anderen, welche Altersverteilung und welchen Ursprung die Sterne in dem Außenbereich simulierter Galaxien haben, mit entsprechenden Schlussfolgerungen für die Eigenschaften des stellaren Halos unserer Milchstraße.

Galaxies are no `Island Universes', galaxies interact owing to a variety of processes spanning the range from remote interactions by tidal torques, a process to which the origin of galactic rotation is usually ascribed, up to the swallowing of a whole galaxy by galactic heavyweights, like our Milky Way. A working group at the AIP deals with the detailed simulation of how galaxies form and how they interact. The analysis of these simulations enables us to better interpret observed data as delivered by surveys like RAVE and SEGUE. Here we present two example applications of this simulation work; one example is a method to prove that tidal torques exerted by the surrounding matter are indeed responsible for the rotation of galaxies, the other example is an analysis of the age distribution and of the origin of stars in the outskirts of simulated galaxies, with corresponding conclusions on the properties of the stellar halo of our Milky Way.

Tidal Torques and the Origin of Galactic Angular Momentum

The origin of galactic angular momentum (AM) is usually ascribed to tidal torques operating early on the material destined to form a galaxy. To leading order, galaxy spins result from the misalignment between the inertia momentum tensor I_{ij} of the material being torqued and of the `shear' tensor $T_{ij} = -\partial_i \partial_j \varphi$ generated by external material.

What is the alignment between spin and moment of inertia? Within linear theory, we found the angular momentum to be maximal along the *intermediate* axis of inertia. Angular momentum growth is typically linear with time at early times and effectively ends at turnaround. In general, then, the direction of the angular momentum will be determined by the *shape* of the protogalactic material at turnaround. A solid prediction of tidal torque theory (TTT) is, therefore, that galaxy spins should be nearly perpendicular to the minor axis of the collapsing material at late times.

However, the rather indirect mapping between the AM of dark halos and that of their baryonic components makes it difficult to assess the success of TTT in accounting for the spin of spiral galaxies. One may even say that the wide acceptance of TTT is mainly due to the lack of any viable alternative theories rather than to clear predictions firmly corroborated by observation.

We use high resolution gasdynamical simulations of the formation of galaxies in the concordance ΛCDM cosmology to investigate whether this alignment between the spin of galactic disks and the principal axis of the inertia momentum tensor persists for the baryons in the deeply non-linear

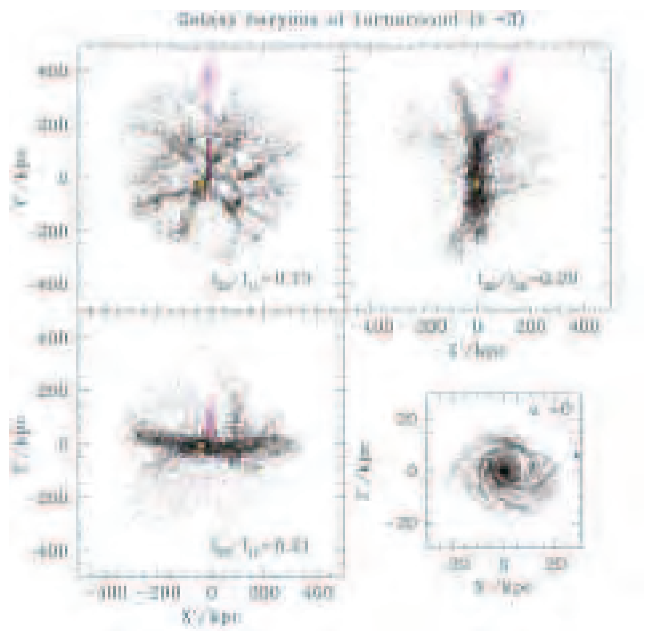


Fig. 1: Spatial distribution of all baryons that will collapse to form the galaxy at z=0, shown at turnaround (z~3). Arrows indicate the direction of the angular momentum. The bottom-right panel shows a zoomed-in projection of the same baryons at z~0.

regime. What started off as a roughly spherical region ~5 Mpc (comoving) across develops into a coherent sheet-like structure that surrounds the target galaxy (Fig. 1). The arrows in the panels of Fig. 1 indicate the direction of the angular momentum of the sheet, and confirm the TTT predicted trend for spins to be approximately perpendicular to the direction of maximum compression.

Can we test these ideas observationally? Galaxies in the vicinity of the Milky Way are arranged in a two-dimensional slab usually referred to as the *super galactic plane* (SGP). The plane of the Galaxy is approximately perpendicular to the SGP, as indicated by the low supergalactic latitude of the North Galactic Pole (~ 6°). This situation is similar to that of the simulated disk galaxy in relation to its surrounding structure shown in Fig. 1. It is therefore tempting to regard the rather peculiar orientation of the Galactic plane relative to the SGP as a result of early torques acting during the protogalactic stage. If this interpretation is correct, we would expect an excess of nearby galaxies whose rotation axes are approximately perpendicular to the normal to the SGP. As shown in Figs. 2 and 3, there is a clear excess of nearby edge-on galaxies highly inclined relative to the SGP. The significance of the excess decreases the larger the volume considered around the Milky Way. The TTT thus provides a natural explanation for the high inclination of the MW relative to the SGP, as well as for the excess of nearby edge-on spirals whose rotation axes lie approximately *on* the SGP.

The Origin of Extended Luminous Halos around Galaxies

Galaxies have no edge: with rare exceptions, the stellar spatial distribution in normal galaxies shows little sign of a sharp outer cutoff. Extrapolations of the inner luminosity profile, however, suggest that little light comes from regions of surface brightness much fainter than those traditionally used to define the luminous radii of galaxies. New datasets have started to unveil some unexpected properties of the stellar component that populates the outer confines of galaxies. These developments have been made possible by the development of panoramic digital cameras able to map the light distribution of external galaxies down to unprecedented surface brightness levels, complemented by efficient observational techniques designed to measure radial velocities of outer halo tracers in external galaxies, such as planetary nebulae. Furthermore, spectroscopic campaigns like RAVE and

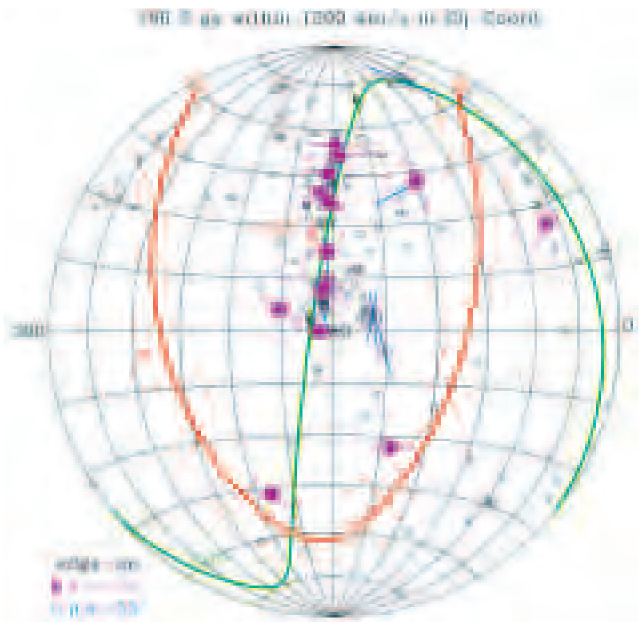


Fig. 2: Aitoff equatorial projection of all spirals with recession velocities less than 1200 km/s. The U-shaped thick curve is the Galactic plane (GP); the S-shaped curve is the SGP. The projected major axis of edge-on spirals is shown for galaxies with position angles of <35° (filled circles) and >55° (open circles).

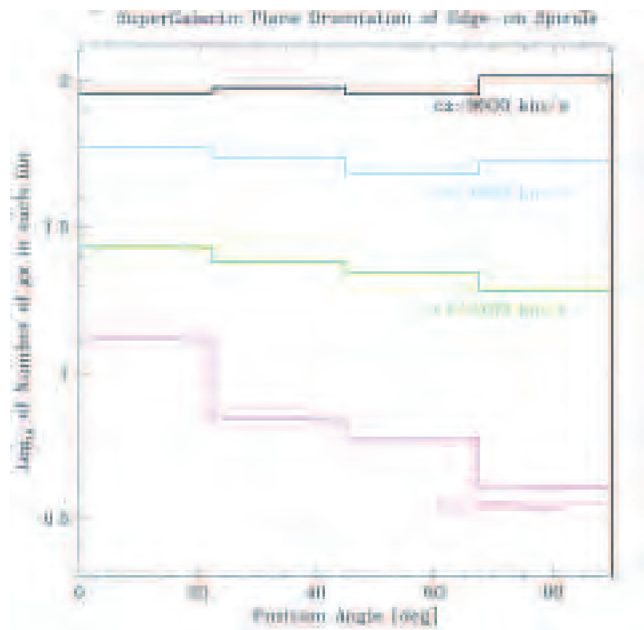


Fig. 3: Histogram of supergalactic position angles of edge-on spirals within various recession velocity limits, as labeled. A position angle of 0° means that the galaxy's plane is perpendicular to the SGP; 90° means that it is parallel to the SGP.

SEGUE have dramatically increased the sample of tracers in the halo of our own Milky Way. Here, we analyze the origin and structure of the luminous halos of galaxies simulated in the ΛCDM scenario.

Fig. 4 shows, at z=0, one of our simulated galaxies projected onto a box of 540 kpc on a side. The top panels show the dark matter particles (left) and stars (right) within the virial radius ($\approx$ 270 kpc), shown by the outer green circle. Dark matter particles are colored by their local density, while stars are colored by their age (from red=old to blue=young). The bottom panels separate the stars in two components: *in situ* stars that formed in the most massive progenitor (left) and *accreted stars* that formed in progenitors that merged with the main galaxy (right). Stars labeled as *accreted* exclude those associated with self-bound satellite systems that survive until the present. Roughly $\approx$48% of stars (by mass) formed *in situ* in this galaxy, compared with $\approx$44% which make up the accreted component. Satellites contribute a rather small fraction ($\approx$8%) of all stars within the virial radius.

Fig. 4 illustrates a number of properties of the stellar component common to all of our simulations. In particular, it is important to note that

- stars spread as far out as the virial radius of the system although they are more highly concentrated than the dark matter halo;
- *in situ* stars are responsible for most of the young stars in the main body of the galaxy and are practically absent from the outer halo;
- *accreted* stars make up preferentially the spheroidal component and dominate the stellar budget in the outer regions of the galaxy.

The age distribution of stars in the inner and outer galaxy, as well as that of satellites enclosed is shown in Fig. 5. The ages of stars in the outer galaxy differ significantly from those in higher density regions (like the inner galaxy or the surviving satellites), where star formation may proceed. The outer halo is populated mainly by older stars, reflecting the fact that the mergers responsible for its formation are more common at earlier times. Interestingly, the distribution of ages of stars in the outer halo is also fairly distinct from that of stars in satellites orbiting within the virial radius. This shows that relatively few stars in the outer halo originate in the ``harassment'' of satellites that have survived as self-bound entities until the present. Most stars in the outer halo come from merger events whose progenitors have long been fully disrupted, suggesting that the properties of the satellite population may be quite distinct from that of the smooth outer halo.

This work has been done in collaboration with Julio Navarro, Mario Abadi (both University of Victoria, Canada) and Andres Meza (Universidad de Chile, Santiago).

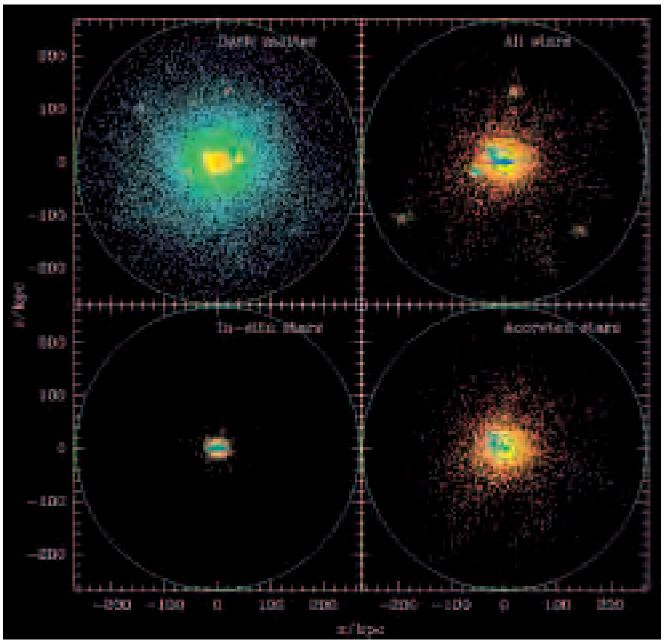


Fig. 4: Spatial distribution of the dark matter (upper left) and stars (upper right). Bottom panels split the stellar component into in situ stars and accreted stars

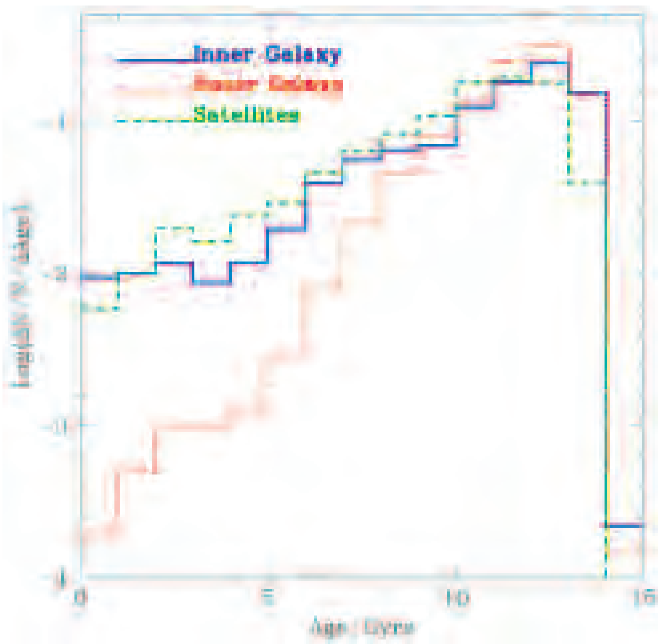
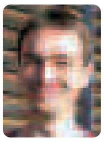


Fig. 5: Age distribution of stars in the inner galaxy (solid blue line), in the outer galaxy (dotted red line) and in satellites (dashed green line).

New observations of Tidal Dwarfs in the Dentist's Chair



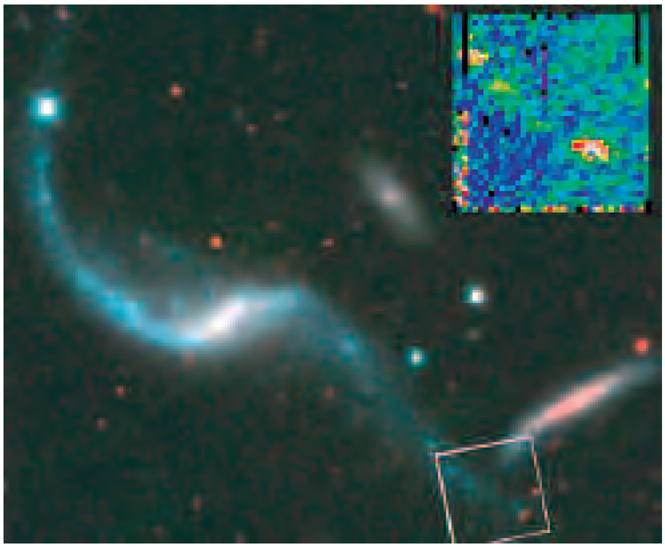
P. Weilbacher

Das Galaxiensystem AM 1353-272 mit Spitznamen „Zahnarztstuhl" zeigt zwei 30 kpc lange Gezeitenarme, als Folge der Wechelwirkung zweier Galaxien. Frühere Beobachtungen durch Multi-Objekt Spektroskopie haben gezeigt, dass diese Arme bis zu sieben Zwerggalaxien enthalten, die sich gerade in der Entstehung befinden und vom umgebenden Material entkoppeln. Neue Beobachtungen mit einem 3D Spektrografen bestätigen diese Beobachtungen für zwei dieser Zwerggalaxien, während sie die Existenz der kinematischen Signatur des Knotens, der bisher als massivste Zwerggalaxie betrachtet wurde, in Frage stellen.

The galaxy system AM 1353-272, nicknamed `The Dentist's Chair', contains two 30 kpc long tidal tails due to the interaction between the two main galaxies. Several clumps are visible in these long arms that have been interpreted to be so-called Tidal Dwarf Galaxies (TDGs), dwarf galaxies forming out of tidal debris of galaxy collisions. Previous spectroscopic observations using the FORS2 instrument at the VLT showed that seven of these TDGs seem to be real galaxies in formation, with kinematics that are decoupled from the surrounding tidal material, even showing signs of rotation. As these observations were difficult to prepare and analyze (using curved slits to target multiple clumps in one shot), the technique of integral field spectroscopy (IFS or 3D spectroscopy) seemed to be ideal to follow-up on these objects. This project is done in collaboration with P.-A. Duc, Saclay.

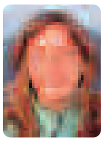
To carry out the observations, the VIMOS instrument at the ESO VLT was used, and the tip of the southern tidal tail was targeted with the higher resolution mode. Three TDGs and one fainter extra clump are encompassed in the small field of view and clearly visible in reconstructed narrow-band [OIII] images of the data-cube. The main purpose of the new observations was to try to confirm the observed velocity field with higher resolution and without slit constraints. To this end, a velocity profile was created using profile fits to the brightest emission line, [OIII]5007.

The result shows that for the two brighter clumps, kinematical signatures, with rotational axes approximately perpendicular to the ridge-line of the tail, were confirmed, with peak-to-peak velocity differences of 50 and 70 km/s. For the fainter knot, which was previously identified as a candidate TDG, the signal-to-noise ratio of the emission lines is not good enough to derive a velocity field. For the outermost clump, identified in previous observations as the TDG with the strongest velocity gradient (350 km/s peak-to-peak) and hence possibly the most massive dwarf galaxy in formation, the results from the VIMOS study are inconclusive: the strong velocity gradient could not be confirmed, but it is unknown if defects in the VIMOS observations (removal of sky lines, flexures in the instrument, etc.) or an unknown effect in the previous FORS2 observations are responsible for this discrepancy. Further observations are necessary to unambiguously determine the state of this TDG and the ones in the other tidal tail.



A colour image of the interacting system `The Dentist's Chair' (AM 1353-272). The interacting members are the galaxy with long arms (component 'A') and the disturbed disk galaxy (component 'B'). The tidal dwarf galaxies are visible as blue clumps in the tidal tails. The white square indicates the region targeted with VIMOS. A narrow-band image reconstructed from the VIMOS data is shown at the top right.

Integral field spectroscopy of low-z (ultra)luminous infrared galaxies



A. Monreal Ibero

Ultraleuchtkräftige Infrarot-Galaxien (kurz ULIRGs) wurden Ende der 1980er Jahre durch Beobachtungen mit dem Satelliten IRAS entdeckt. Sie definieren sich als Objekte mit (Infrarot)-Leuchtkräften in der Größenordnung von optisch selektierten Quasaren. Diese Leuchtkräfte können duch intensive Sternentstehung und/oder durch einen aktiven Galaxienkern erklärt werden, die jeweils den in der Galaxie vorhandenen Staub aufheizen.

Hier präsentiere ich den Beitrag, den ich im vergangenen Jahr zu einem Projekt geleistet habe, das sich mit der detaillierten Analyse eines repräsentativen Samples von ULIRGs durch 3D-Spektroskopie beschäftigt. Eine Korrelation zwischen dem Ionisationsstatus und der Geschwindigkeitsdispersion in nicht-zentralen Regionen dieser Systeme legt den Schluß nahe, dass die Ionisation durch Schocks zustande kommt, die im Laufe des Verschmelzens der Galaxien entstehen.

Fünf unserer sechs Systeme weisen diese Korrelation auf. Während in den Zentralregionen (r < 2 kpc) von ULIRGs Superwinde die Ionisationsstruktur erzeugen, ist es demnach in den äußeren Regionen der Verschmelzungsprozeß der Galaxien, der diese Struktur beeinflußt (r > 3 kpc).

Ultraluminous Infrared Galaxies (ULIRGs) were discovered by the IRAS satellite at the end of the 80's and they are defined as those objects with similar (infrared) luminosities to those of optically selected quasars ($L_{bol} \approx L_{IR} \gtrsim 10^{12}\ L_{sun}$), being locally twice as numerous as them. ULIRGs as a group share a series of properties. For instance, all of them show signs of mergers and interactions, have large quantities of gas and display emission lines in the optical.

The origin of the enormous infrared luminosity of these systems is due to the dust present in them that absorbs the energy of a certain source and re-emits it in the infrared. The nature of the emitting source is not still completely clear. On the one hand, it is known that ULIRGs are suffering an episode of extremely enhanced star formation (a starburst) that plays a key role as emitting source. On the other hand, evidence for an Active Galactic Nucleus (AGN) has been found in several cases, and an AGN is the dominant source in some systems.

In this context, ULIRGs have been proposed as the progenitors of optically selected quasars: ULIRGs would contain a dust-enshrouded AGN and as the system evolves, it gets rid of the dust envelope, leaving the AGN visible. However, this so-called evolutionary scenario does not seem to explain all the observed properties of every ULIRG and alternative scenarios had to be proposed.

The importance of ULIRGs in the evolution of galaxies doesn't end here. As merging systems, they are candidates to be the progenitors of some elliptical galaxies, in particular the intermediate-mass ones. Also, small galaxies made out of the debris of the interaction (the so-called Tidal Dwarf Galaxies) could be forming in the more external regions of these systems.

Fig. 1 shows a ULIRG as an illustrative example. Two nuclei, widespread star formation, and extended tidal tails are clearly seen, all of them indicative of a very complex structure. Because of that, Integral Field Spectroscopy (combined with high resolution imaging) is the ideal technique to tackle the study of these systems. I am collaborating with a group led by Dr. Luis Colina Robledo (IEM-CSIC) in Spain whose main aim is performing a very detailed study of a representative sample of ULIRGs using Integral Field Spectrographs. An example of the results obtained by this project is shown in Fig. 2, where I show maps of different observables obtained with the INTEGRAL unit at the WHT in La Palma for two galaxies.

Fig. 3 illustrates an important result obtained last year. When analyzing the ionization structure of the external regions, we have found a correlation between the ionization state and the velocity dispersion which indicates that ioniza-

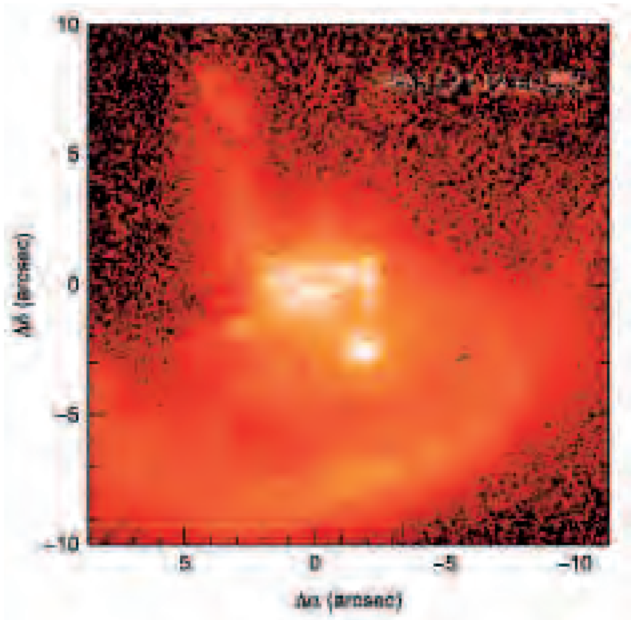


Fig. 1: Section of 20"x20" of the WFPC2/HST image with the F814W filter showing the central part of IRAS12112+0305.

tion is probably due to shocks induced by the merging process itself. Five of our six systems follow this correlation. While in the internal parts of the ULIRGs (r < 2 kpc) superwinds create the ionization structure, this result indicates that the merging process itself governs the structure in the external parts (r > 3 kpc).

During the next few years, we expect to increase our sample of ULIRGs using different Integral Field Spectroscopy facilities, such as PMAS, built at the AIP, or INTEGRAL and VIMOS. Also, we are starting to explore the luminosity range corresponding to the Very Luminous Infrared Galaxies (VLIRGs, 10^{11} L_{sun} < L_{IR} < 10^{12} L_{sun}). Less luminous than their big brothers, they are two orders of magnitude more numerous in the Local Universe.

VLIRGs and ULIRGs seem to be the local analogs of the galaxies responsible for the far-IR background: the submillimeter galaxies that make a significant contribution to the galaxy population at $z \approx 2$. We expect that the output of this project will be key references to understand the infrared-selected high-z galaxy population.

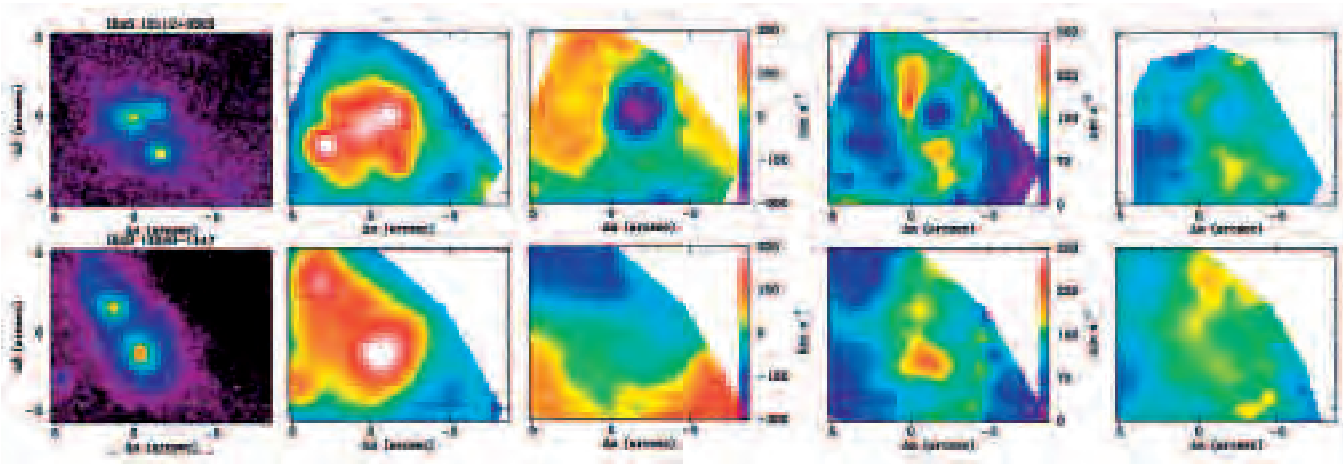


Fig. 2: INTEGRAL maps for several observables in IRAS 12112+0305 and IRAS 14348-1447. The distribution of the ionized gas is traced by the Hα emission line (second column), while the ionization state is traced by the [NII]λ6584/Hα ratio (fifth column). The colour table for this ratio has been chosen in such a way that for a typical [OIII]λ5007/Hβ ratio, the limit between a LINER-like and an HII ionization is indicated by the green colour (i.e. LINER-like excitation appears in red and yellow while HII-like appears in blue). Also, velocity field and velocity dispersion maps are shown (third and fourth columns).

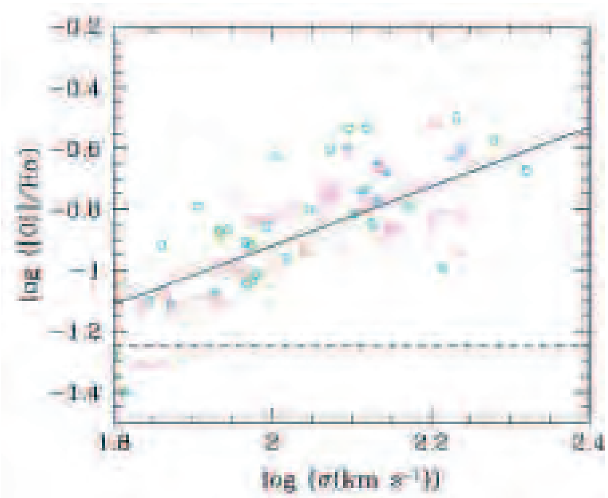
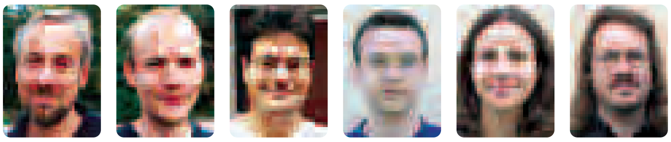


Fig. 3: Correlation between the ionization state, as indicated by the [OI]/Hα ratio, and the velocity dispersion in the external regions of a sample of ULIRGs. Each point represent an spatial element (i.e. a certain position within the system) and different galaxies have been plotted with different colours.

Quasar host galaxies at high redshifts

L. Wisotzki, K. Jahnke, S. F. Sanchez, M. Schramm, I. Gavignaud, A. Böhm

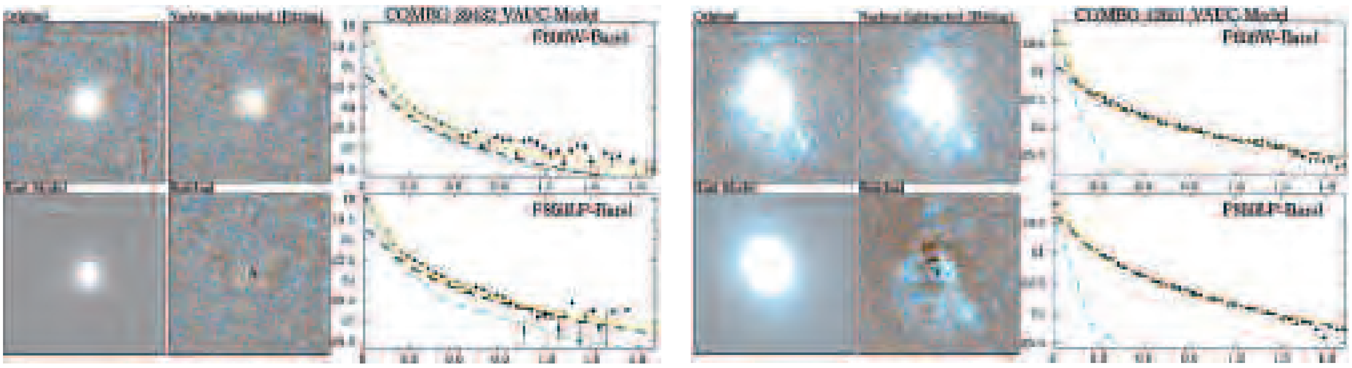


Quasare bei hohen Rotverschiebungen sind "kosmische Leuchttürme", mit denen sich der Entwicklungszustand von Galaxien im noch jungen Universum untersuchen lässt. In einer Reihe von Beobachtungsprojekten befasst sich unsere Arbeitsgruppe mit Quasar-Muttergalaxien bei z=0 bis z=3. Im Rahmen des GEMS-Projektes durchmusterten wir eine große Anzahl von Quasaren mit dem Hubble-Weltraumteleskop. Mit dem Very Large Telescope der Europäischen Südsternwarte haben wir einige extrem leuchtkräftige Quasare bei z=3 studiert. Unsere Untersuchungen zeigen durchweg, dass diese Galaxien erhebliche Mengen an jungen Sternen enthalten und offenbar mitten dabei sind, ihre stellare Komponente aus interstellarem Gas aufzubauen.

GEMS (Galaxy Evolution from Morphology and Spectra) is a large collaborative project to study morphological and colour transformations of normal and active galaxies over cosmological timescales. The data involve the hitherto largest colour mosaic using the Advanced Camera for Surveys aboard the Hubble Space Telescope (HST). Using this unique dataset we have investigated the host galaxy properties of a sample of some 60 QSOs between z=0.5 and z=3. As QSO host galaxies at these high redshifts are very dim, and the bright quasar nucleus in many cases outshines the host by a large factor, the high angular resolution of HST was a key to success. After carefully deblending the images into galaxy and nuclear components, we find that many of these galaxies show evidence for blue light due to young stars. On the other hand, this excess of blue light does not - contrary to popular expectations – go along with a strong excess of morphologically disturbed galaxies. While some QSO hosts are undoubtedly heavily disturbed, the majority are symmetric, isolated elliptical galaxies; yet they show blue colours.

Combining our results from GEMS with earlier data obtained at lower redshifts, we could for the first time place QSO host galaxies in an empirical context of increasing star formation towards higher redshifts, i.e. larger lookback times. As next steps we plan to perform more detailed morphological analyses, in particular comparing normal (inactive) galaxies with those that harbour a quasar nucleus. For a set of $z \approx 2$ QSOs we have also obtained additional deep near-infrared images with HST to study their rest frame UV-optical colours.

The hosts of high-luminosity high-redshift QSOs are particularly interesting, as these are expected to reside in the most massive galaxies at high redshifts. However, observations of such objects are extremely difficult and require lots



Analysis of HST host galaxy images in GEMS. The two sets of panels show two quasars at basically the same redshifts, ~ $z \approx 0.75$. In each set, the top-left panel is a two-band composite image of the object itself, and the best-fit host galaxy model is shown below; the next column shows the host galaxy as observed, after subtracting the nucleus, and the overall residual after subtracting both nucleus and galaxy model. The right-hand panels show radial profiles in the two observed bands. While the object in the left panel set has a huge and obviously highly irregular host galaxy, possibly from a recent merger, the QSO in the right-hand panel set is hosted by a modest, isolated and perfectly round elliptical galaxy.

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of telescope time under good conditions. We have succeeded in resolving two z=3 QSO hosts of extremely high nuclear luminosities with the ESO-VLT and its Near-Infrared camera ISAAC. Moreover, the hosts are detected in two bands (H and K, closely corresponding to rest-frame B and V), so that we could estimate a stellar mass-to-light ratio, and hence stellar mass. Comparing this with the black hole masses estimated from spectroscopy, we find that these two objects lie more than an order of magnitude below the present-day relation - the QSO hosts at z=3 are substantially undermassive in stars, given their black hole masses.

Another successful detection of galaxies hosting high-luminosity quasars was based on using the adaptive optics system ADONIS on the ESO 3.6 m telescope. With such an instrument one can partially remove the blurring of images due to the Earth's atmospheric turbulence, resulting in much sharper images. This is particularly useful for quasars, as the contributions of the bright central point source and the faint extended underlying host galaxy can be much better deblended. Beyond just detecting the galaxies, we could also measure their diameters, finding that these galaxies were unexpectedly compact given their high luminosities. This can be interpreted as another, although more indirect, indication that the host galaxies of high-redshift quasars are much less massive than expected from a simple extrapolation of the present-day relation.

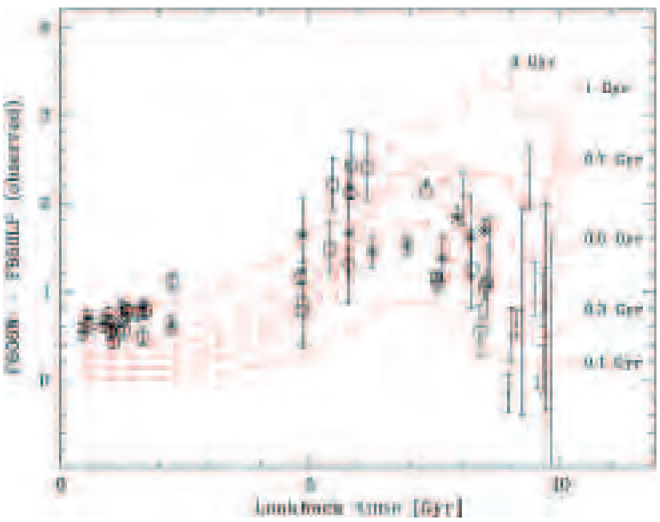
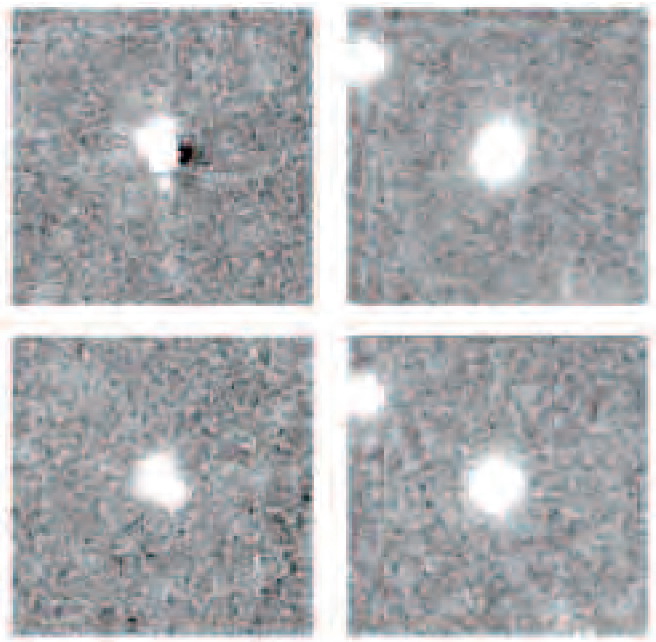
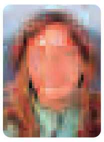
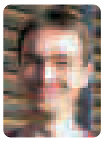
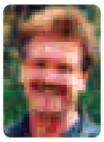


Diagram showing the distribution of observed-frame colours for our combined sample of QSO hosts using GEMS HST and ground-based data, as a function of lookback time. The overplotted curves represent the colours of single-age stellar populations at given age.



Images of the two z = 2.9 QSOs where we could resolve the host galaxies in two bands (H and K), taken with the ESO-VLT and its near-infrared camera ISAAC. Left is HE 2348-1444, right is HE 2355-5457; upper images are in the H band (1.65 micron), lower images are in K (2.2 micron). Notice that one of these objects is fairly smooth and round while the other appears to be highly asymmetric and probably disturbed. From a comparison between the two bands we infer that in both cases the host galaxy is rather blue, presumably due to large numbers of faint stars.

Super star clusters as drivers for the development of superwinds in starburst galaxies

A. Monreal Ibero, P. Weilbacher, M. M. Roth

Schon seit Jahrzehnten wird in nahen und fernen Galaxien beobachtet, dass Sternentstehungsausbrüche sogenannte „Supergalaktische Winde" (kurz SGWs) zur Folge haben, die Gas in das intergalaktische Medium transportieren. Obwohl dieses Phänomen schon so lange bekannt ist, sind noch viele grundlegende Fragen zu Superwinden offen und neue Beobachtungen sind notwendig, um detailliertere Modelle entwickeln zu können. Hier geben wir einen kurzen Überblick über ein Projekt, Superwinde mittels 3D Spektroskopie in nahen Galaxien zu beobachten. Erste Beobachtungen wurden für Februar 2006 genehmigt, so dass schon bald mit ersten Ergebnissen zu rechnen sein wird.

Bursts of star formation, or 'starbursts', are events where hundreds of solar masses of gas per year are transformed into stars. Often, these events happen in small regions near the nuclei of galaxies. Some of them end up expelling enriched material, processed during the outburst, to the intergalactic medium via the so-called Super Galactic Winds (SGWs).

Although the timescale for these events is indeed much smaller than the Hubble time, their impact on the host galaxies makes them essential phenomena to study to better understand galaxy evolution. SGWs are in fact considered to be the principal mechanism responsible for the presence of metals in the intergalactic medium.

In spite of observations of SGWs in many galaxies, our knowledge about them is still quite limited. Although it is more than 40 years ago that Lynds & Sandage announced the "evidence for an explosion in the center of the galaxy M82", the nature of SGWs is still unclear. Which conditions trigger them? How energetic are they? What mass, momentum, energy, and metals do they transport? From the theoretical point of view, models are still far from reproducing in detail the observed characteristics of SGWs while from the observational point of view, a multi-wavelength approach is necessary in order to probe all gas phases.

The Hubble Space Telescope (HST) has recently revealed that often the bursts of star formation responsible for the SGWs appear in the form of an assembly of very compact and luminous clusters: the so-called Super Star Clusters (SSC).

We recently started a project in collaboration with an international team led by Dr. Casiana Muñoz-Tuñón with the purpose of studying the regions where these SGWs are formed and determining the details of the physical link between the SSCs and the filamentary structure that emanates from the starbursts to compose a SGW.

Due to the irregular and clumpy nature of these targets, Integral Field Spectroscopy (IFS) is the ideal technique to perform this study. We intend to obtain two kinds of spectra. On the one hand, high spectral resolution data in the Hα + [NII]$\lambda\lambda$ 6548,6584 emission lines will be obtained to derive the kinematics of the ionized gas. On the other hand, lower resolution spectra covering most of the optical spectral range will be used to map the extinction and ionization structure of the gas. Also, these data will be used in combination with high resolution HST images to derive properties (ages, stellar masses, and metallicities) of the SSCs.

For this purpose, a selected sample of nearby starburst galaxies with high resolution images from the HST will be observed with different IFS instruments.

The first observing run took place in February 2006. With this data, we are looking forward to presenting the first observational results of this project in the next biennial report.

Fig. 1: M82, the most famous example of a galaxy producing a Supergalactic Wind. The image is a three-colors composition taken with FOCAS in the B, V, and Hα bands. Credits: Subaru Telescope, National Astronomical Observatory of Japan.

HE 0450-2958: An almost naked quasar?

K. Jahnke, L. Wisotzki

Bisher wurde zu jedem Quasar, der hinreichend genau untersucht wurde, eine zugehörige Muttergalaxie gefunden. Im Zuge von Beobachtungen des leuchtkräftigen Quasars HE 0450-2958 mit dem Hubble-Weltraumteleskop ist uns das überraschenderweise nicht gelungen. Die Qualität der Daten ist dabei so gut, dass selbst eine Galaxie mit nur einem Sechstel der erwarteten Leuchtkraft hätte nachgewiesen werden können. Möglicherweise ist der Quasar aus seiner Heimatgalaxie in einer Kollision herausgeschossen worden; aber möglicherweise ist die Galaxie auch nur durch große Mengen an Staub verdeckt. Welche von diesen oder weiteren Hypothesen zutrifft, das müssen zukünftige Beobachtungen erweisen.

In the course of a recently completed programme to study the host galaxies of low-redshift quasars in detail with the Hubble Space Telescope, we made a surprising discovery. The luminous quasar HE 0450-2958, at z=0.285, has revealed no detectable host galaxy down to very sensitive limits; if it exists at all, it must be weaker than expected by at least a factor of 6. This conclusion was reached after applying a thorough analysis using several state-of-the-art image decomposition methods. The quality of the HST data is high, and in our sample of 10 quasars, the hosts of the other nine objects are easily resolved into beautiful, large galaxies (see Fig. 1). HE 0450-2958 is the only object in our sample, and in fact the only such case known, without a detectable host galaxy. We can at present only speculate about the true nature of this object. It is possible that the quasar was ejected during the merger event which presumably shaped the heavily disturbed nearby galaxy. It is also possible that there is a host galaxy, but that it is obscured by large amounts of dust. And finally, the host could be substantially underluminous given its black hole mass. Only further observations of this very unusual object can clarify whether any of these hypotheses comes close to the truth.

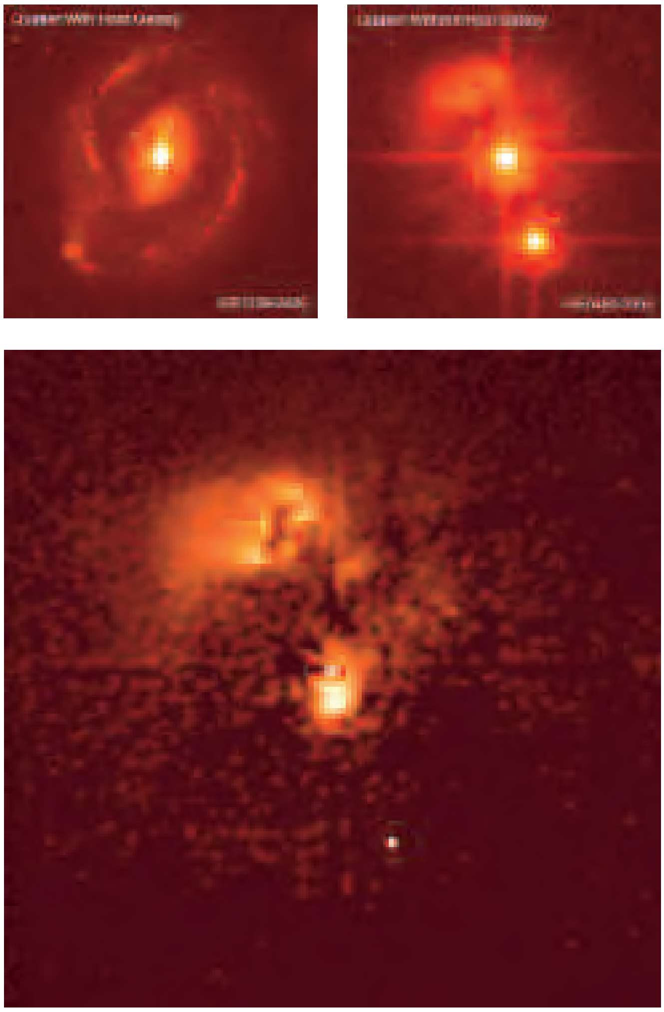
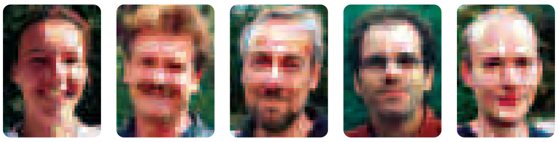


Fig.1: Upper left panel: Example from our HST survey of the relative ease with which we can usually detect the host galaxies of low-redshift quasars (this one is embedded in a grand-design spiral galaxy). Upper right: Although there is a close companion galaxy close to HE 0450-2958, no galaxy is readily visible underneath the bright QSO nucleus. Lower panel: Even extensive image processing and point source removal uncovers no clear trace of a proper host galaxy. The faint "blob" on one side of the quasar was shown spectroscopically to consist mainly of hot gas excited by the quasar.

On the connection between quasar absorption lines and galaxies

L. Christensen, M. M. Roth, L. Wisotzki, A. Kelz, K. Jahnke



Das Licht heller Quasare durchläuft das Universum zwischen ihnen und uns. Dabei trifft es immer wieder auf Klumpen intergalaktischer Materie, was zu charakteristischen Absorptionslinien in den Quasarspektren führt. Die stärksten dieser Absorptionslinien werden gedämpfte Lyman alpha-Absorber (engl. DLAs) genannt und entstehen vermutlich in gasreichen Galaxien. Bis heute ist kaum bekannt, was für Objekte diese DLAs eigentlich sind. Trotz der großen Zahl bekannter DLAs gibt es nur eine kleine Handvoll, für die optische Gegenstücke bekannt sind. Wir haben mit der neuen Beobachtungstechnik der Integralfeld-Spektroskopie eine systematische Suche nach Galaxien nahe von Quasaren mit DLAs in ihren Spektren durchgeführt. Die Erfolgsrate war hoch; bei großen Rotverschiebungen haben wir die Zahl der identifizierten Gegenstücke mehr als verdoppelt. Mit den gleichen Daten haben wir auch noch erfolgreich nach ausgedehnten Lyman alpha-Halos um die Quasare selbst gesucht.

Damped Lyman alpha absorbers (DLAs) are still enigmatic objects, although their important role in galaxy evolution has long been recognised. They contain a large fraction of neutral hydrogen at high redshift and are therefore prime reservoirs for star formation. Yet most DLAs are only known as absorption systems, and only for a handful have the counterparts so far been identified. Integral Field Spectroscopy is a powerful new observing technique well suited to search for faint galaxies near bright quasars. We mainly used the Potsdam Multi-Aperture Spectro-Photometer (PMAS), built at AIP and now mounted on the 3.5 m telescope on Calar Alto, to conduct a large survey of QSOs known to have a DLA in their spectrum. We observed 7 QSOs at $z<1$ and 9 QSOs at $z>2$ (most at $z>3$). In the low-redshift sample we could identify a likely counterpart in nearly all the cases. At high redshifts the yield was lower, unsurprisingly. Here we found 8 good candidate counterparts, out of 13 DLAs observed, with Lyman alpha emission centered on the DLA troughs (see Fig. 1). Observed impact parameters were 1-4 arcsec, the latter just within the field of view of PMAS. The measurement of impact parameters, which comes as a natural byproduct of integral field spectroscopy, allowed us to draw inferences about the spatial sizes of the galaxies responsible for the DLAs. The existence of an anti-correlation between the column density of neutral hydrogen in the DLA and the impact parameter (see Fig. 1) suggests that the lower columns occur in systems where the quasar line of sight pierces through the outer regions. The data are even consistent with a universal size of an exponential H I disk, although that would clearly be an unrealistic oversimplification. Converting the measured Lyman alpha luminosities into star formation rates, we found typical values of a few solar masses per year. Assuming typ-

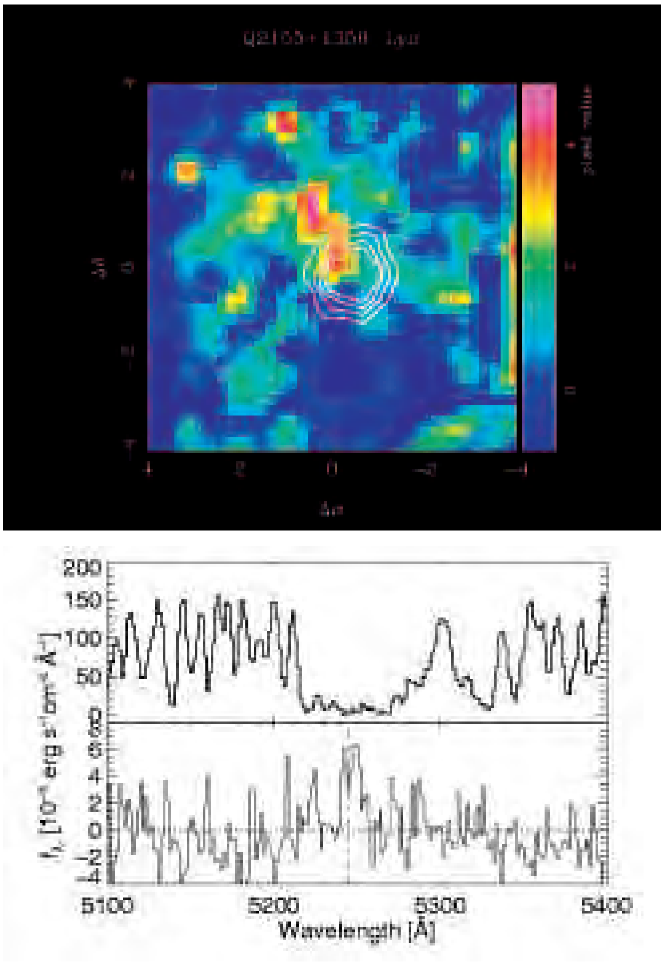


Fig.1: Detection of the galaxy that is probably responsible for the DLA at z=3.32 in Q 2155+1358. Upper panel: Narrow-band image centred on the DLA wavelength; the contours denote the position of the QSO. Lower panel: portions of the spectra of the QSO showing the damped absorption line, and of the object visible in the narrow-band image, showing an emission line precisely where it is expected.

ical sizes as stated above, the average star formation rate per surface area comes out to agree extremely well with the well-known Schmidt-Kennicutt law.

We have used the same data to study the extended Ly alpha emission line regions (EELRs) around the quasars themselves. This was possible for five QSOs at 2 < z < 4, out of which four are radio-quiet. From the IFS data cubes we could extract narrow band images at any chosen wavelength. We constructed images centred on the expected emission line wavelengths, and subtracted corresponding off-band images located nearby in wavelength from these. In all cases we find evidence for extended emission as shown in Fig. 2 and 3. Comparing our analysis with lobe-dominated radio-loud QSOs from literature, we find that the Ly alpha EELRs in our sample are considerably fainter, although the QSOs have comparable optical luminosities. The luminosities of the EELRs appear to be well correlated with the Ly alpha luminosities of the QSOs, but largely uncorrelated with the ionizing fluxes at shorter wavelengths.

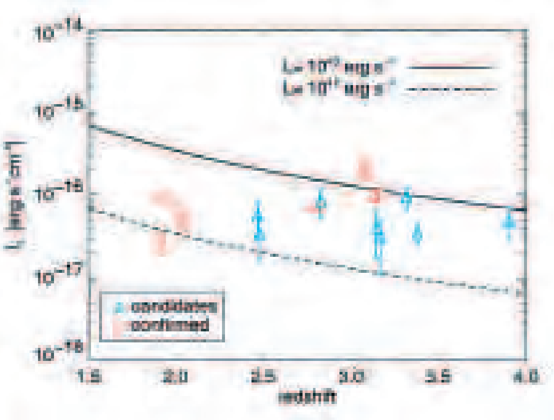


Fig. 2: Overview of detections in our survey (blue symbols) and comparison with the few detections in literature (red symbols). Plotted are the total line fluxes in the candidate optical counterpart for each absorber.

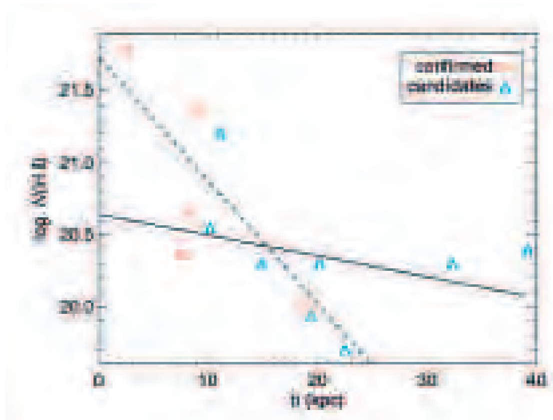


Fig. 3: Impact parameters for DLA counterparts, as a function of inferred hydrogen column density in the DLA. Except for two outliers, the data seem to lie closely to the relation expected for an H I disk with scale length 5 kpc (dashed line). If outliers are included, the scale length increases to 30 kpc, and the fit is much poorer.

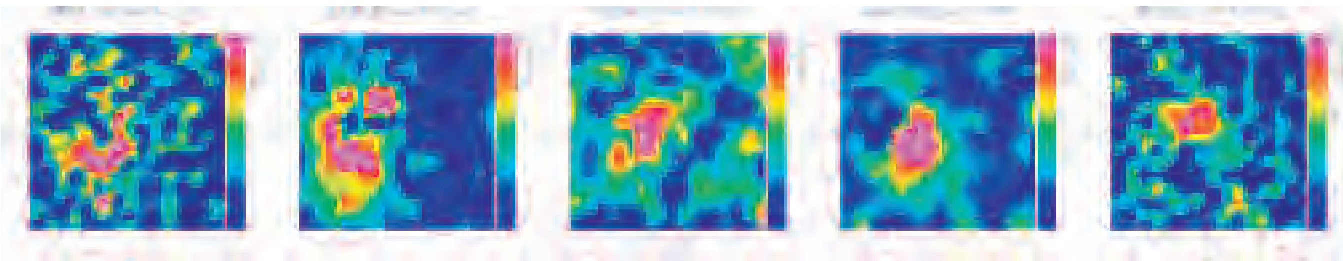


Fig. 4: Narrow-band images extracted at the Lyman alpha emission wavelengths of five high-redshift quasars, with the QSO continuum subtracted. In all cases shown there is significant extended residual emission. The centroids of the QSOs are always at the image centre (coordinates [0,0]).

Strange microlensing properties in the quasar SDSS 1004+4112

G. Lamer, A. Schwope, L. Wisotzki, L. Christensen

Die Gravitationslinse SDSS 1004+4112 wurde von uns simultan mit dem Röntgenobservatorium XMM-Newton und dem 3D-Spektrografen PMAS beobachtet. Dabei zeigte sich, dass das optisch hellste der 4 Quasar-Bilder im Röntgenbereich deutlich schwächer ist als erwartet und das UV- und Röntgenspektrum des Quasars über lange Zeiträume sehr variabel ist. Gleichzeitig wurde im optischen Spektrum dieses Quasar-Bildes ein erhöhter Fluss in den blauen Flügeln der Emissionslinien gemessen. Wir erklären das ungewöhnliche Erscheinungsbild dieser Gravitationslinse im optischen und Röntgenbereich mit dem Vorhandensein von intrinsischer Variabilität des Quasars und mit der Wirkung eines zusätzlichen Mikro-Gravitationslinseneffektes auf das hellste Quasarbild, der durch die Sterne einer Galaxie auf der Sichtline hervorgerufen wird.

The recently discovered quadruply lensed quasar SDSS 1004+4112 (= RBS 825) is the first quasar lensed by a cluster of galaxies. The maximum separation between the lensed images is 15 arcseconds. We observed the system with the X-ray observatory XMM-Newton in April 2004. On the same date, spectra of the 2 brightest images of SDSS 1004+4112 were taken with the integral field spectrograph PMAS at Calar Alto. The X-ray images of the XMM EPIC camera clearly resolve the distant components and marginally resolve the two closest quasar images A and B (title page of this section: The objects are indicated as in the optical image. Note the deficit of X-ray flux from the optically brightest image A.).

Deconvolution of the X-ray images shows that in X-rays the optically brightest component A is much fainter than expected from the simultaneous UV imaging with the XMM optical monitor. In the same component our optical spectroscopy shows the reappearance of a previously observed excess in the blue wing of the C IV emission line. The variable blue excess had been attributed to microlensing of component A by stars in an intervening galaxy. Our investigation of the spectral energy distribution shows that all lens components differ in their spectrum, indicating strong intrinsic variability of the lensed quasar. We conclude that the quasar continuum is intrinsically variable, which triggers also flux variability of the emission lines. In order to explain the selective variations of the blue line wings in lens image A only, microlensing of image A is needed. Most probably, microlensing magnifies a part of the quasar's broad line region and demagnifies the X-ray emitting core of the quasar.

The extended X-ray emission of the lensing cluster at z=0.68 is clearly detected in X-rays. From the X-ray flux of the cluster we can estimate its mass to be in the range 3-6 10^{14} solar masses.

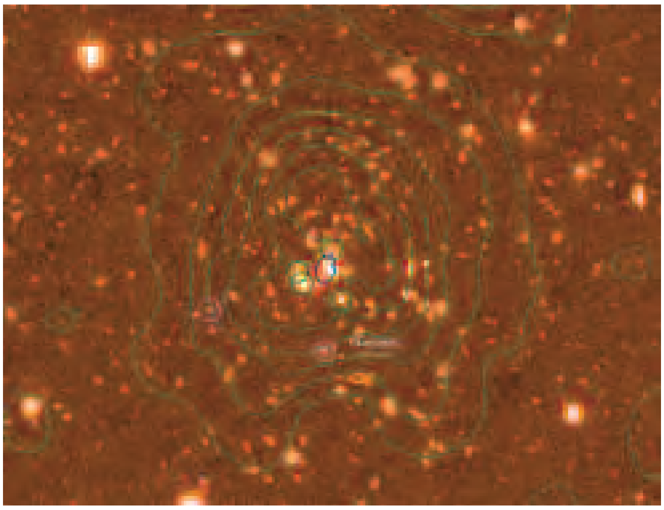


Fig. 1: Optical image of SDSS 1004+4112, taken with the Subaru telescope. The lensed images of the quasar are marked with green circles. The green contours show the extended X-ray emission of the lensing galaxy cluster after subtraction of the X-ray point sources.

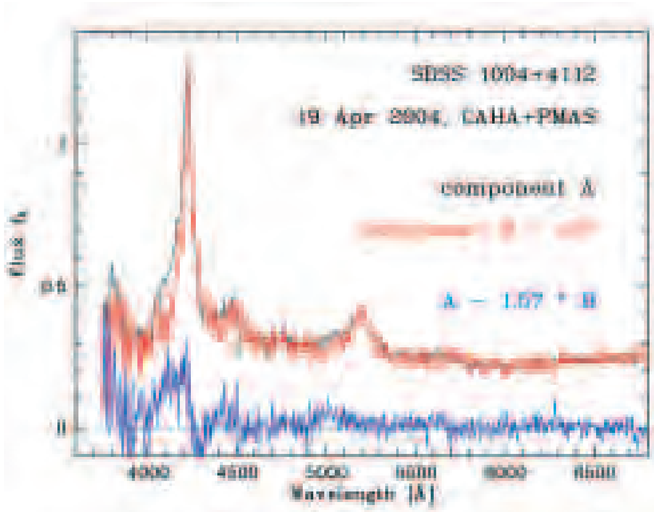
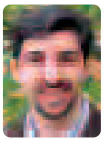


Fig. 2: Optical spectra of the quasar images A and B taken with PMAS almost simultaneously with the XMM-Newton observations. The comparison of the emission line profiles shows an excess of flux in the blue line wings of quasar image A. In May 2003, a similar excess was observed, which then disappeared.

Modelling the galaxy bimodality: Shutdown above a critical halo mass



Andrea Cattaneo

In den letzten Jahren wurde entdeckt, dass die meisten Galaxien in vielen Beobachtungsgrößen eine klar bimodale Verteilung zeigen. Massereiche Galaxien enthalten typischerweise hauptsächlich kühle, rote Sterne und haben eine elliptische Struktur, während massearme Galaxien jüngere Sterne enthalten und meist Scheibenform aufweisen. Ich stelle ein theoretisches Modell vor, dass die Entstehung dieser zwei Formen in einen Zusammenhang mit dem Einströmen von Gas in die Galaxien bringt. Kühles Gas bringt dabei Scheibengalaxien und starke Sternentstehung hervor, während heißes Gas die Sternentstehung abschaltet und die Bildung von elliptischen Systemen bevorzugt.

Hydro simulations show two galaxy growth modes. $M_{halo} > M_{crit} \approx 10^{12}\ M_{sun}$: gas at $T \approx T_{vir}$ cools in spherical inflows. $M_{halo} < M_{crit}$: gas streams to the centre in cold filaments. If the hot mode is inefficient in supplying galaxies with gas, then galaxies with $M_{halo} > M_{crit}$ run out of fuel and turn red and dead. I used a semi-analytic model of galaxy formation to test wether this hypothesis can reproduce the blue/red galaxy bimodality in the SDSS and found that preventing star formation when $M_{halo} > 2 \times 10^{12}\ M_{sun}$ greatly improves the fit with the observed colour-magnitude distribution (Fig. 1). This scenario, which relates the blue/red bimodality to the cold/hot flow transition, explain the observed colour-environment relation (Fig. 2). The justification for assuming that gas accretion in the hot mode is inefficient? I believe that it has to do with the different way a supermassive black hole interacts with a cold and a hot intergalactic medium. Recent observations suggest that all bulges contain a supermassive black hole. Black holes can accrete both cold gas and hot gas, but the continuity and dilution properties of the hot phase make it more vulnerable to feedback from black hole accretion. When the fuelling is with hot gas, the black hole accretion rate self-regulates to the value at which the black hole energy output compensates the hot gas X-ray luminosity, so no gas actually cools.

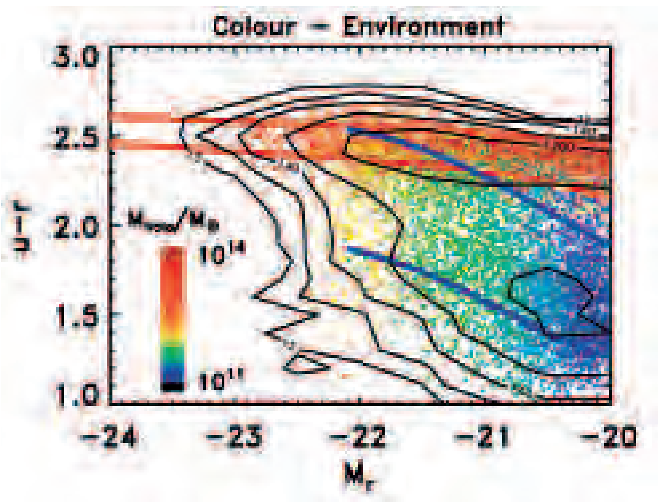


Fig. 1: The points show simulated galaxies, colour-coded according to environment (red points: dense environments; blue: sparse environments). The contours show the galaxy number density (mag^{-2} Mpc^{-3}) in both panels. The pair of blue and red lines show the position of the blue sequence and the red sequence in the SDSS.

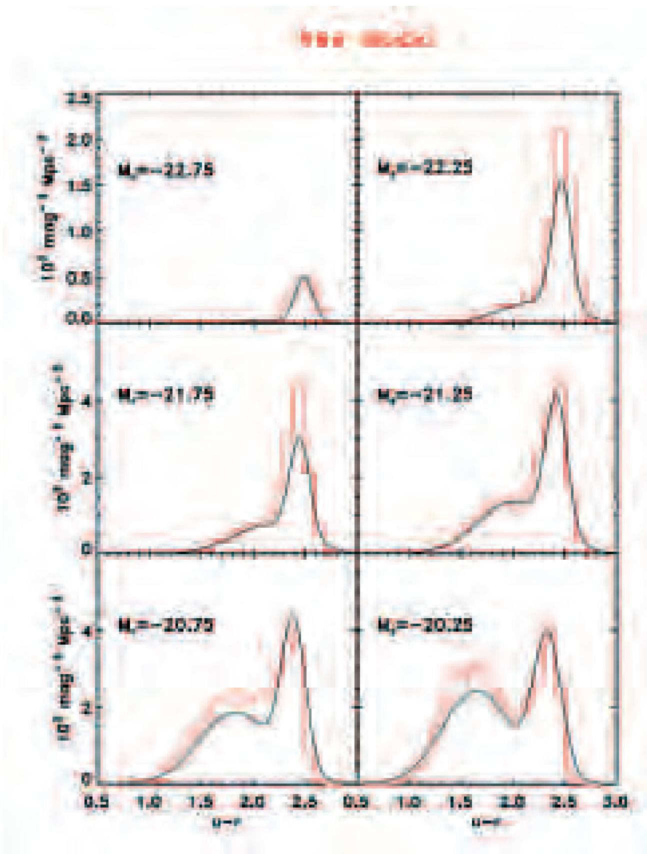
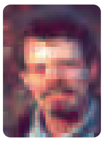


Fig. 2: Comparison of theoretically predicted (red) and observed (black) histograms of rest-frame galaxy colours, split by absolute magnitude. The theoretical model reproduces all essential features in the observed distributions.

The universality of the Cepheid period-luminosity relation



J. Storm

Cepheiden sind von fundamentaler Bedeutung für die Entfernungbestimmung zu fernen Galaxien und damit für die Messung der Expansionsrate des Universums. Wir entwickeln eine verbesserte Methode, um die Entfernung zu diesen Sternen zu bestimmen. Um diese Methode zu testen, haben wir das Interferometer des ESO "Very Large Telescope" und neue Beobachtungsdaten von Cepheiden in der Großen Magellanschen Wolke benutzt.

Cepheids are pulsating variable stars and statistically they follow a linear relation between the period of their pulsations and their brightness (luminosity). This relation makes them excellent standard candles, as we can easily measure their period and thus determine their intrinsic brightness from this relation. We can also measure how bright the Cepheid appears on the sky, and by comparing this to the brightness predicted for the star we can compute the distance to the star. In this way we can determine accurate distances to Cepheids in distant galaxies and thus measure the expansion of the Universe.

The accurate calibration of this relation is therefore of the utmost importance, but currently the universality of both the slope and the zero-point of the relation is being contested.

We are developing an improved version of the so-called Baade-Wesselink method to determine distances directly to individual Cepheid stars. The method combines observations of radial velocity and photometric brightness variations of the star to give the radius and distance.

Using observational data from the brand new ESO Very Large Telescope Interferometer (VLTI) for a particular galactic Cepheid (l Car) we have shown that the photometric part of the above scheme indeed gives the correct angular diameters and radii to this particular star (see Fig.1).

Using a sample of Cepheids which can all be assumed to be at roughly the same distance from us, as they are all located in one of our nearest neighbouring galaxies, the Large Magellanic Cloud, we found that the method had a systematic effect in the sense that the distances for short period stars were different from those found for long period stars (see Fig.2). This is clearly unphysical.

We can solve this problem by invoking a stronger effect of luminosity in the transformation of observed radial velocities into pulsation velocities. In this way we also reconcile the slope of the period-luminosity relation for Cepheids in the Large Magellanic Cloud and Cepheids in the Milky Way which suggests that the period-luminosity relation might after all be universally applicable.

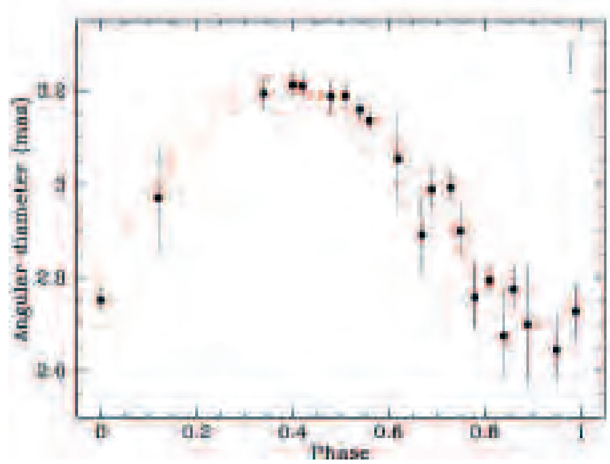


Fig.1: The angular diameter of the Cepheid l Car determined interferometrically using the VLTI (black circles) and from our Baade-Wesselink method (red crosses). (Kervella et al. 2004)

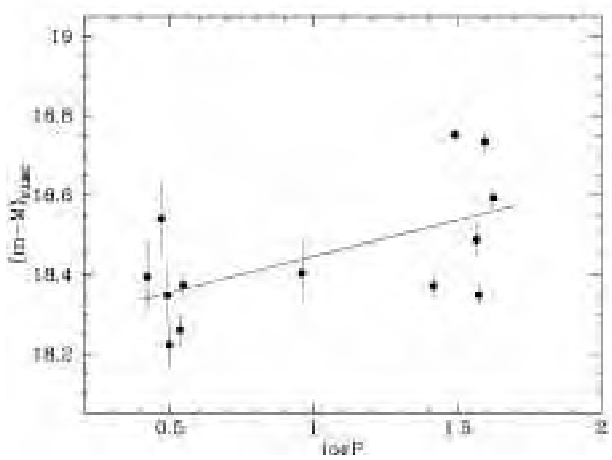
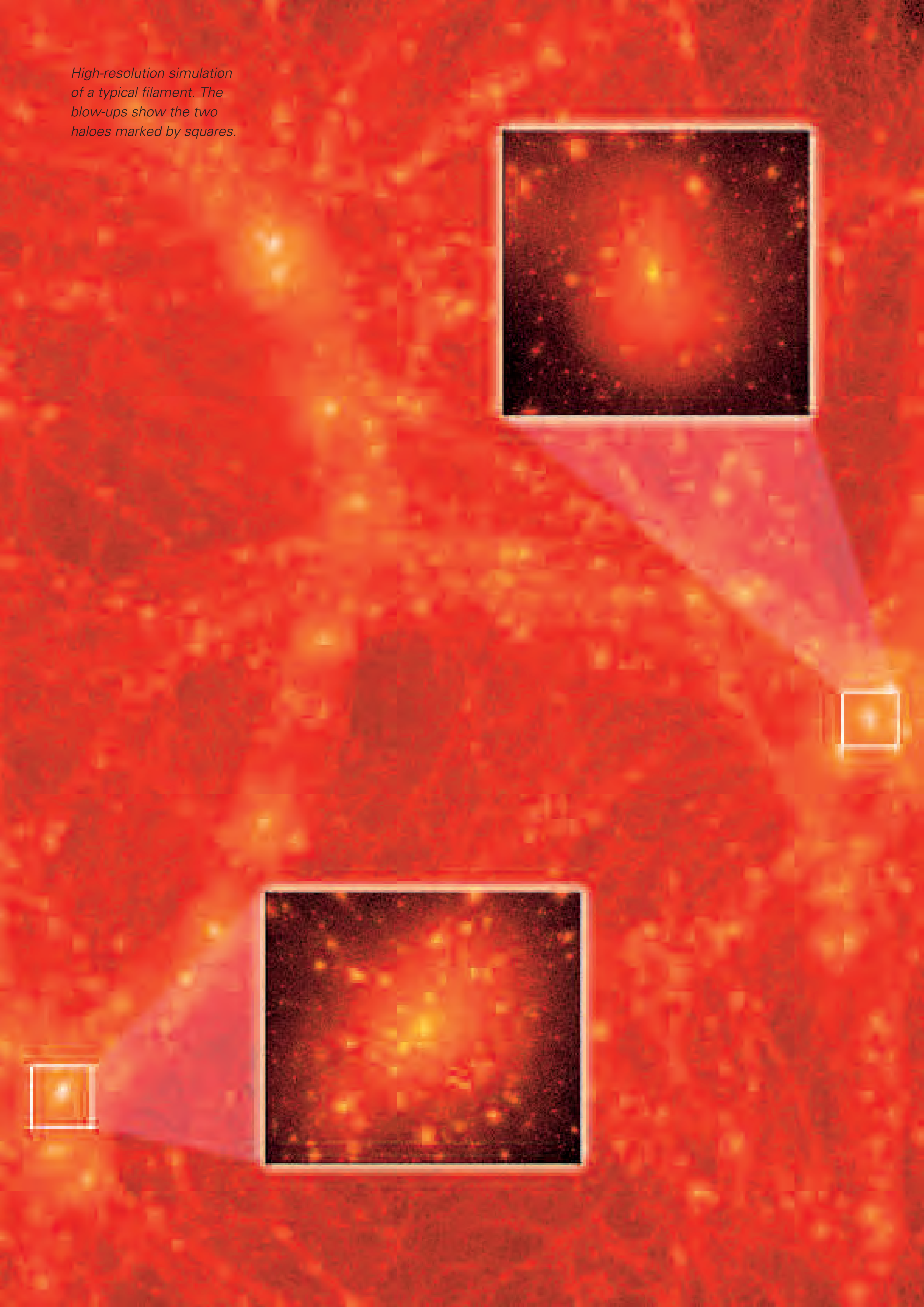
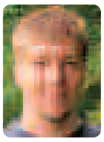
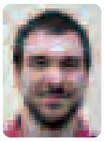
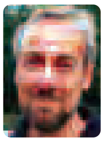


Fig.2: The distances to individual Cepheids in the Large Magellanic Cloud using the old correction to the conversion factor between radial velocity and pulsational velocity. The unphysical difference in distance to short and long period stars is evident. (Gieren et al. 2005)



High-resolution simulation of a typical filament. The blow-ups show the two haloes marked by squares.

The ‘Proximity Effect’ in quasar spectra

G. Worseck, A. Dall'Aglio, L. Wisotzki

Der im Universum verteilte Wasserstoff bewirkt Absorptionslinien in den Spektren entfernter Quasare. Durch die Einwirkung der ionisierenden UV-Strahlung der Quasare reduziert sich diese Absorption in der Nähe der Quasare; dies ist der sogenannte "Proximity-Effekt". Wir haben dieses Phänomen anhand von VLT-Spektren einer Stichprobe von 17 Quasaren eingehend untersucht. Aus unserer Analyse konnten wir die mittlere Intensität des metagalaktischen UV-Strahlungsfelds bestimmen. Beobachtet man zwei scheinbar nahe beieinander liegende Quasare, so sollte man unter gewissen Umständen auch einen "transversalen" Proximity-Effekt erwarten. Allerdings war es bisher kaum möglich, dieses Phänomen zu beobachten. Wir haben eine systematische Suche nach "Quasaren nahe bei Quasaren" durchgeführt, um hier Abhilfe zu schaffen. Als erstes kartierten wir die Umgebung eines bekannten Quasars mit vorhandenen spektroskopischen Messungen im optischen und im fernen ultravioletten Spektralbereich. Aus den Spektren ließ sich die spektrale Härte der jeweils für die Ionisation verantwortlichen UV-Strahlung abschätzen; es ergab sich, dass genau bei der Rotverschiebung eines jeden Vordergrundquasars die spektrale Härte besonders ausgeprägt ist. Somit zeigte unsere Analyse, dass die harte UV-Strahlung von Quasaren selbst über große kosmologische Distanzen reicht.

We have studied the interaction between intergalactic hydrogen and the UV radiation emitted by luminous quasars. The so-called proximity effect states that close to a quasar, the hydrogen is more highly ionized than far from it. This is observable as a reduction of absorption line density, and thus as a surplus of transmitted QSO flux, at wavelengths close to the Lyman-alpha emission line of the QSO. We have observed a sample of 17 luminous quasars with the ESO-VLT in order to study this effect. We used the flux transmission technique and a photoionisation model to estimate the metagalactic UV background from a combined analysis of the sample. Extensive Monte-Carlo simulations provided an estimate of the error budget. The result of this combined analysis is shown as a plot of the deviation of optical depths from the usual Lyman-alpha forest evolution against the quantity ω, which is the ratio of the quasar's own contribution to the ionizing continuum to that of the metagalactic UV background. The red line represents our best-fit model for a UV background of $(0.9 \pm 0.55) \times 10^{-21}$ erg cm^{-2} s^{-1} Hz^{-1} sterad^{-1}, in excellent agreement with previous measurements. We furthermore demonstrated that for most of our quasars, the proximity effect can also be clearly detected in individual spectra.

A much more elusive variant of the proximity effect is expected when a second quasar is located in the foreground, but close to the line-of-sight to the first (background) quasar. If the transverse distance is small enough and the foreground

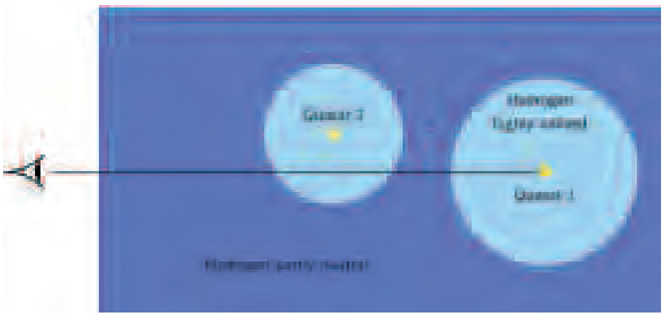


Fig. 1: Schematic view of the Proximity Effect. The observer records a spectrum of the line of sight towards Quasar 1. Neutral hydrogen in the intergalactic medium causes absorption; near Quasar 1, this absorption is suppressed because hydrogen is almost completely ionised. Near to the line of sight there is Quasar 2, around which there is also a region of overionisation. This is expected to show up as a transverse proximity effect.

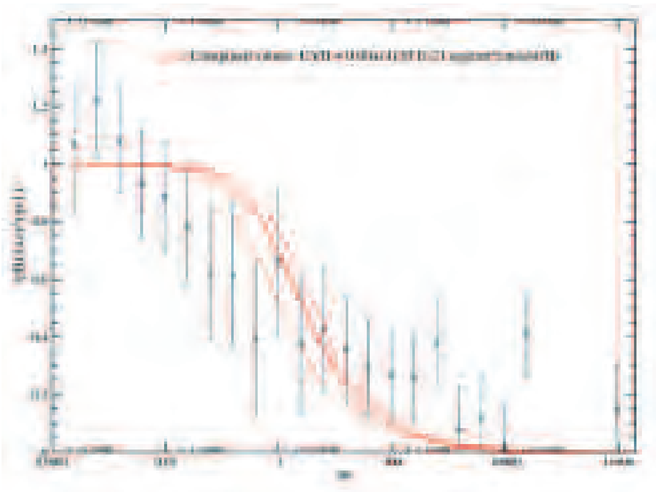


Fig. 2: Combined analysis of the line-of-sight proximity effect in our sample of 17 quasars. The red line shows the best-fit model.

quasar sufficiently luminous, then a region of enhanced Lyman-alpha forest transmission should be detectable at the redshift of the foreground QSO. So far, no clear case of a transverse proximity effect has been detected in the hydrogen Lyman-alpha forest, mostly just because very few suitable background/foreground QSO pairs exist. Some years ago we launched a project to map the vicinities of known bright QSOs in a search for foreground QSOs to study the transverse proximity effect. Using the Wide-Field Imager on the ESO-MPG 2.2m telescope with its grism mode we took slitless spectra of all objects within 24' x 30' fields around some 20 QSOs. With a fully automated pipeline we extracted the spectra and searched for emission-line objects. As a last step we obtained medium-resolution spectra with the ESO-VLT of each of our quasar candidates, yielding precise classifications and redshifts.

Altogether we found some 80 new quasars in these fields, many of which have interesting redshifts so that they can be used for the transverse effect. As a first application we investigated the field around QSO Q0302-003, which was one of the few quasars detected in the EUV wavelength range with the Hubble Space Telescope so that the He II Lyman forest could be studied. Combining the HST spectra with results from high-resolution optical spectroscopy we reconstructed the spectral hardness fluctuations of the UV radiation field along the line of sight and correlated this with the locations of the known foreground quasars. We found that at the redshift of each quasar the radiation field was considerably harder than on average; conversely, most of the local extrema in the spectral hardness corresponded to a known quasar. Although none of the quasars is luminous enough to cause a traditional transverse proximity effect in the hydrogen Lyman-alpha forest, we clearly detected, for the first time, a systematic transverse proximity effect in spectral hardness. We infer that the zone of radiative influence of individual quasars can reach out to several Mpc into the intergalactic medium. These observations also imply quasar lifetimes of the order of at least 10-30 million years.

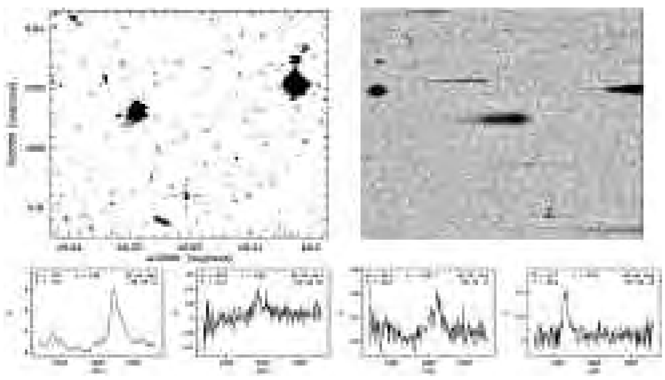


Fig. 3: Example illustrating our search technique for quasars near quasars. Top left: small section of a direct image around QSO Q0302-003. Top right: the same area as recorded with the Wide-Field Imager through a low-resolution grism. Bottom: sample slitless spectra of quasars extracted from the grism data; notice the prominent emission lines.

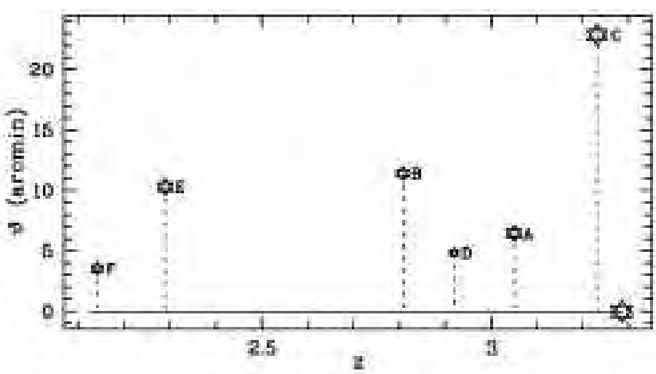


Fig. 4: Distribution of quasars towards Q0302-003, showing redshift versus the angular distance to the central line of sight.

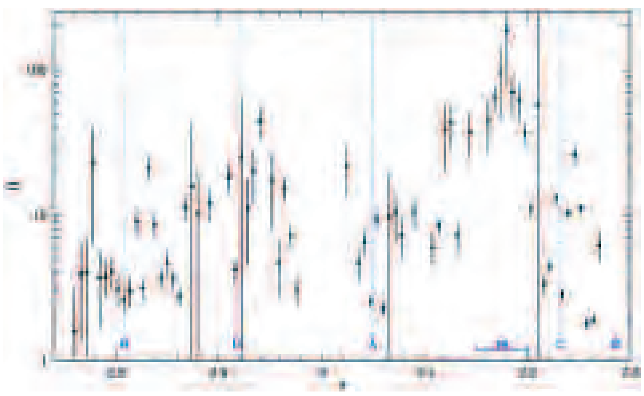
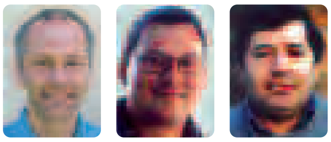


Fig. 5: Distribution of the optical depth ratio R, low values indicating a hard ionising spectrum, as a function of redshift in the line of sight towards Q0302-003. The letters A-D denote the redshifts of foreground QSOs, the asterisk stands for the central quasar itself. At each of these redshifts, the value R assumes a local minimum, presumably due to the hard radiation coming from that particular quasar.

Discovery of the most distant X-ray selected cluster of galaxies.



A. Schwope, G. Lamer, V. Hambaryan

Galaxienhaufen sind die größten durch Gravitation gebundenen Objekte im Universum. Da das zwischen den Haufengalaxien vorhandene Gas so heiß ist, dass es Röntgenstrahlung aussendet, können Galaxienhaufen besonders effektiv in Röntgendurchmusterungen des Himmels gefunden werden. In einer Suche nach fernen Galaxienhaufen wurde mit Hilfe des Röntgensatelliten XMM-Newton und des Very Large Telescope der bisher entfernteste röntgenselektierte Galaxienhaufen gefunden. Mit der Rotverschiebung von z=1.39 kann seine Entfernung mit 9 Milliarden Lichtjahren bestimmt werden.

In an ongoing survey for the most distant clusters of galaxies, we have searched 160 observations of the X-ray satellite XMM-Newton for extended X-ray sources. A total number of 155 extended sources were detected, most of them good candidates for galaxy clusters. The positions of the X-ray sources were inspected on digitized optical sky survey plates (Digitized Sky Survey, DSS). The extended X-ray sources with no visible counterparts on the optical plates are the best candidates for very distant clusters and were selected for further imaging observations with the ESO VLT. VLT snapshots in the R and z bands were taken at 47 positions.

Based on the magnitudes and R-z colours of the cluster galaxies detected in the VLT images, a first estimate of the cluster redshift can be made. This resulted in a sample of 10 good candidates for clusters with redshifts z > 1.

For the most promising candidate (XMMU J2235-2557), we took spectra of the cluster galaxies with the ESO VLT. The spectra of 12 member galaxies confirm that the redshift of this cluster is z=1.39. This makes XMMU J2235-2557 the most distant galaxy cluster which has yet been found in X-ray surveys. Its redshift means that we observe the cluster at a time 9 billion years ago, when the universe was only one third of its present age. Its X-ray luminosity and spectrum indicate a cluster of 1000 times the mass of our galaxy. It is remarkable to find an obviously fully evolved, very X-ray luminous and massive cluster at this early age of the universe.

In collaboration with: H. Boehringer, R. Fassbender, P. Schuecker (MPE), C. Mullis (University of Michigan), P. Rosati (ESO)

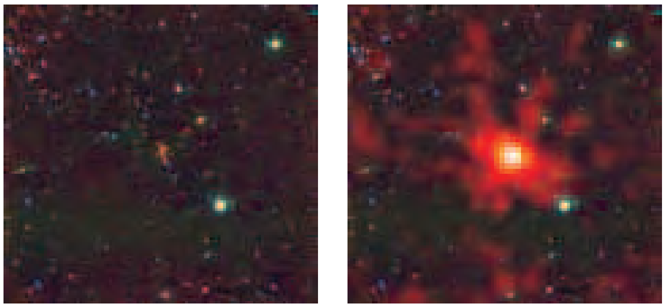


Fig. 1: left: Colour composite image of XMMU J2235-2557 from VLT R,z, and K-band images. Due to the high redshift, the distant cluster galaxies stand out as very red objects in this image. right: Diffuse X-ray emission measured with XMM-Newton overlaid in red onto the VLT image of XMMU J2235-2557.

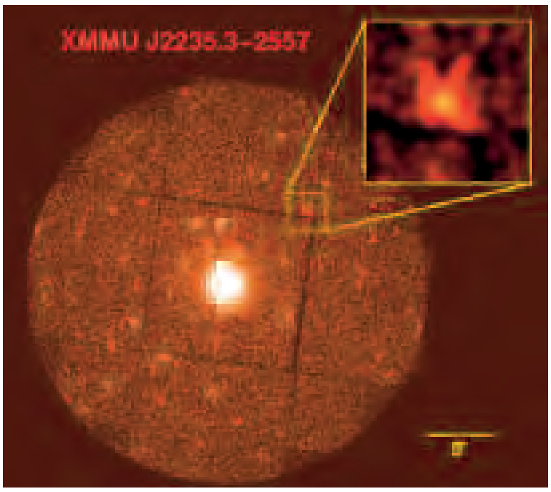
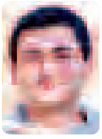
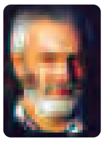
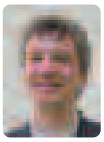


Fig. 2: XMM-Newton discovery image of XMMU J2235-2557. The target of the observation was a bright active galaxy. The cluster is visible as slightly extended X-ray source.

Fig. 3: Comparing the redshift and look-back time of XMMU J2235-2557 with other X-ray selected galaxy clusters. The new cluster exceeds the hitherto most distant cluster by 500 million years in look-back time.

The universe on small scales

A. Khalatyan, S. Gottlöber, M. Steinmetz

Während die großräumige Verteilung der Galaxien im Rahmen des kosmologischen Standardmodells ziemlich gut beschrieben wird, treten auf kleinen Skalen Diskrepanzen auf. In einer hochaufgelösten Simulation eines Filaments untersuchen wir die Eigenschaften von Halos und ihren Subhalos.

During the last 10 years, extensive new observations of the Universe were made using both ground-based telescopes and space-based instruments. These measurements have provided new insights into the structure of the Universe on various scales. This observational progress has been accompanied by considerable effort in developing our theoretical understanding of the formation of different components of the observed structure of the Universe: galaxies and their satellites, clusters of galaxies, and superclusters. A substantial part of this theoretical progress is due to the increasing possibilities of using ever-improving numerical models, which mimic the structure formation on different scales using the new generation of massively parallel supercomputers. Observations and numerical predictions agree well on large scales whereas several discrepancies have been identified on smaller scales. This concerns in particular the number and the properties of satellites of Milky Way type galaxies.

To study the evolution of small scale structures of the universe, we have performed, in cooperation with A. Klypin (NMSU), a simulation of a filamentary structure embedded into a cosmological volume. Using the mass refinement technique we have generated initial conditions which represent the region of the filament with 150 million particles within a larger simulation box of 120 Mpc size. For the simulation we have used the highly efficient parallel Adaptive Refinement Tree (ART) code in a hybrid MPI-OpenMP mode of parallelization. The initial conditions have been calculated on the SP4 at NIC Jülich. A substantial part of the simulation has been done using 512 CPUs of the Hitachi SR8000 at Leibniz Rechenzentrum Munich, the rest at NASA's SGI Altix 3000. The total CPU time used for this simulation was about 300000 CPU hours. Within the high resolution region the mass resolution is 5×10^6 M_{sun} and hence a Milky Way Galaxy is represented by 200000 particles. The force resolution reaches 300 pc.

Fig. 1 shows the refinement region of 36 Mpc size. This is only a small part (3%) of the total volume which is necessary to get the right cosmological environment. The right and the left blow-ups show halos with masses of about 10^{13} M_{sun} which are comparable to typical groups of galaxies. Almost 470 sub-halos have been identified in the right halo and 230 in the left one.

One of the puzzling questions in galaxy formation is the origin and the distribution of the angular momentum. In this dark matter simulation, we have studied the angular momentum of the dark matter halos which host the galaxies. The angular momentum is parameterized in terms of the dimensionless spin parameter λ. Fig. 2 shows the distribution of the spin parameter of the sub-halos of the two halos (black for the right halo, red for the left one). For comparison the histogram also shows the spin parameter distribution of halos identified in a simulation of 75 Mpc size. The blue curve is the log-normal distribution with parameters σ_0 =0.62 and λ_0 = 0.03 fitted to the histogram. One can clearly see that sub-halos tend to have lower spins than isolated halos. This can be explained by the tidal stripping of the high angular momentum particles, when the sub-halos are propagating through the host halo.

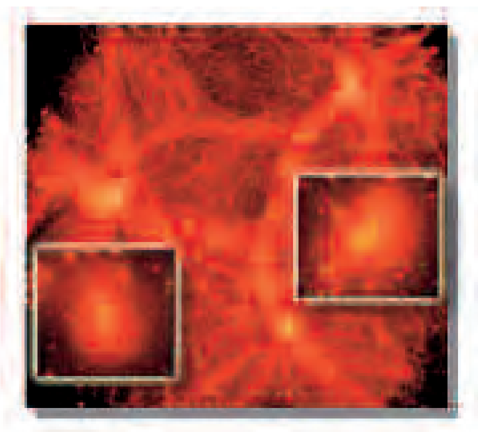


Fig. 1: High-resolution simulation of a typical filament. The blow-ups show the two halos marked by circles.

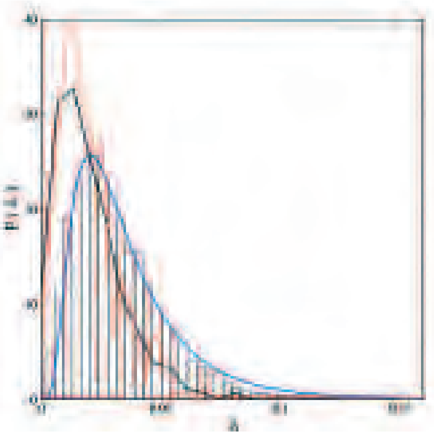
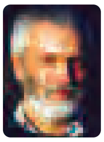
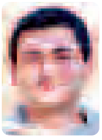
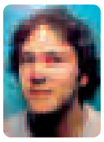


Fig. 2: Spin parameter distribution of sub-halos in comparison to isolated halos.

Cosmology with supercomputers

S. Gottlöber, A. Khalatyan, C. Wagner

Das frühe Universum war sehr homogen. Die Entwicklung der kosmischen Strukturen während der vergangenen 13 Milliarden Jahre ist ein nichtlinearer Prozess, der nur in Computersimulationen nachgebildet werden kann. Da im Universum sehr massereiche Objekte neben sehr kleinen Objekten existieren und alle Objekte Substrukturen besitzen, müssen kosmologische Simulationen eine sehr große Spanne an Massen und Entfernungen überdecken, wozu Supercomputer benötigt werden.

The exciting observational developments of the past couple of decades have been followed closely by comparable progress in our theoretical understanding of the main processes that govern the evolution of structure in the Universe. A substantial part of this progress is due to the increasing possibilities for simulating the formation and evolution of structure on different scales using the new generation of massive parallel supercomputers. Very large computers are necessary to cover the large dynamical and mass range in cosmological simulations. In fact, the most massive cosmological objects, superclusters, have diameters up to several megaparsecs and masses above 10^{16} solar masses. Dwarf galaxies have masses of less than 10^{10} solar masses and diameters of a few kiloparsecs.

The standard model of cosmological structure formation is based on surprisingly few parameters. Within the last decade, new satellite and earth based observations have been used to determine those cosmological parameters. According to the concordance cosmological model, at present the evolution of the Universe is dominated by some unknown dark energy. Most of the matter consists of dark matter particles the nature of which is also not yet known. Well-known baryons contribute less than 5% of the total energy density in the Universe. Based on the measured cosmological parameters, numerical simulations allow us to compute the abundance and distribution of galaxies and clusters of galaxies in the Universe. Recently, we have performed, in collaboration with G. Yepes, a simulation of the evolution of large scale structure within a volume of (750 Mpc)^3 using 1 billion Dark-Matter particles and 1 billion gas particles. This simulation took about 250,000 CPU hours on MareNostrum in Barcelona, which is with 4812 processors at present the fastest supercomputer in Europe.

In Fig. 1 we show a slice through the whole simulation centered on the most massive cluster of galaxies (M_{cl} = 3.5 x 10^{15} M_{sun}). The cluster is marked by a circle. The right panel shows a zoom on this cluster in which substructures can clearly be seen. In the left panel, the cosmic web can be

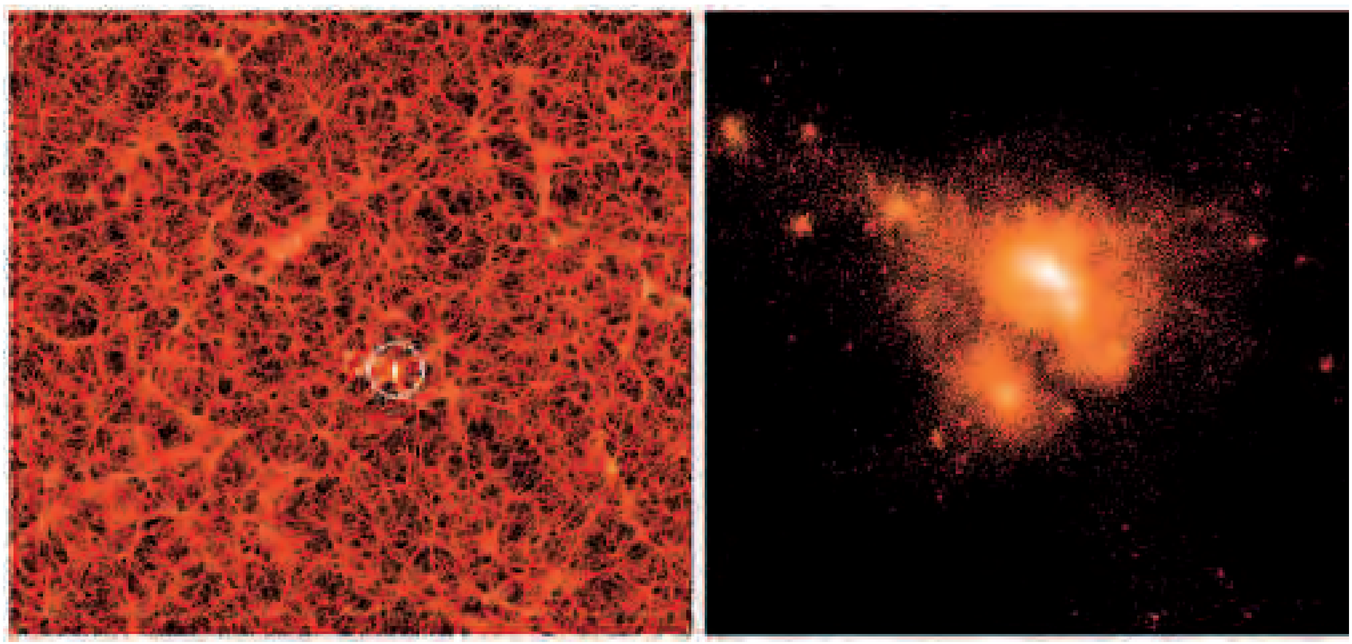


Fig. 1: Left: A slice of 18 Mpc thickness through the whole simulation is shown. Right: Zoom on the cluster marked in the left panel by a circle. A cube of (18 Mpc)^3 volume is shown.

seen, the large scale filamentary structure of the Universe which is formed by galaxies and clusters of galaxies in the knots of the web.

At redshift z=0 we have identified 4 741 935 halos with masses larger than 1.4 x 10^{11} M_{sun}. In Fig. 2 we show the total number of halos with masses larger than M found in the simulation box (thick blue line) in comparison to the prediction by Sheth and Tormen (thin red line). We found almost 5 million objects within the box from the most massive clusters of galaxies with masses larger than 10^{15} M_{sun} to hundreds of thousands of Milky Way-sized galaxies and millions of smaller galaxies with masses of the order of 10^{11} M_{sun}. The numerical predictions agree very well with the observed large scale structure.

One of the most intriguing mysteries in modern cosmology is the nature of the dark energy. Dark energy is the driving force which accelerates the expansion of the Universe. The accelerated expansion has been measured by the distribution of distant supernovas. To understand the nature of dark energy, one needs to measure the expansion of the Universe with high precision over a long time interval. As a standard ruler, one could use the horizon length imprinted on the baryonic acoustic oscillations. Such observations are planned for the next decade. The oscillations are very small, their change of the power is of the order of 5%. Thus the observational data need to be interpreted using high resolution cosmological simulations.

In Fig. 3, we show the ratio of the measured power spectrum to the linearly evolved power spectrum without baryons. The red line denotes the baryonic oscillations in the linear spectrum. Green circles denote the power spectrum of the halos and the blue squares the power spectrum of the dark matter particles. The baryon wiggles can be clearly seen in the distribution of dark matter as well as in the distribution of halos and thus also in the distribution of the galaxies which are hosted by those halos. This plot has been corrected according to the known deviation of the power spectrum of the given random realization of the input power spectrum and the halo distribution has been corrected by the measured bias. Fig. 3 demonstrates clearly that despite the nonlinear evolution of gravitational clustering, baryonic oscillations can be detected up to redshift z=1. They are much more pronounced at higher redshifts.

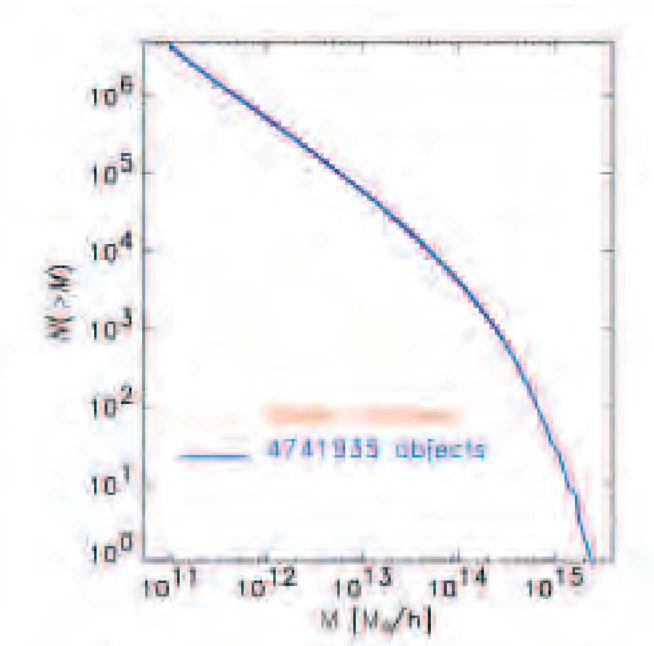


Fig. 2: Mass function at redshift z=0

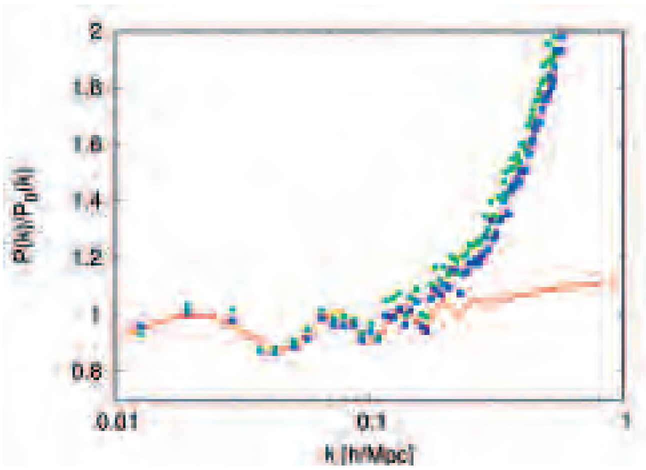


Fig. 3: Baryonic oscillations in the power spectrum at redshift z = 1

Dwarf galaxy population in Hickson compact groups

C. Maulbetsch, V. Müller

Galaxien treten typischerweise in Gruppen mit einigen hellen Objekten und einem Schwarm von Zwerggalaxien auf. Kompakte Gruppen zeigen Anzeichen von Galaxienwechselwirkungen wie Gezeitenarme und Verschmelzungsprozesse. Wir untersuchen mit dem ESO-Vielobjekt-Spektrografen VIMOS und mit Simulationen die Zwerggalaxienpopulation in Hickson-Gruppen.

Galaxy groups are important sites of galaxy interactions and of morphological transformations characterizing the modern paradigm of hierarchical galaxy formation. Hickson groups are interesting test objects for studying these processes. These compact groups are defined as conglomerates of a few spiral or elliptical galaxies in small volumes which are more or less isolated with respect to other bright galaxies. Often they show indications of tidal deformations, light from the regions between galaxies, common X-ray envelopes, nuclear activity of member galaxies and others. The abundance and luminosity distribution of group galaxies is a measure of their age. In general we expect them to transform to giant isolated ellipticals. With new observational and theoretical efforts, we are studing the number and distribution of dwarf galaxies, thereby tackling one the fundamental problems of the current standard ΛCDM model, the amount of substructures in galaxy halos similar to the local group.

Exploratory studies of four Hickson groups with the ESO 2.2m wide field imager by Krusch et al. (2005) seem to indicate a large number of dwarf galaxies characterised by their red color, so-called dwarf ellipticals. We analyse high-resolution DM simulations run with GADGET on the Linux cluster at the AIP in a 75 Mpc simulation box (1 kpc spatial resolution). The merger tree of dark matter halos (an advanced stage of a group is illustrated in Fig. 1) is coupled with our in-house semi-analytical model of galaxy formation. The theoretical colour-magnitude diagram with strong supernovae feedback shows a clear bi-modality between passive red and star-forming blue galaxies in the group (Fig. 2). The group luminosity function shows a suppression of the faint end luminosity function (Fig. 3), a clear indication of the advanced stage of galaxy merging in this group. Detailed analysis of spectroscopic and photometric data from VIMOS on the VLT are analysed in collaboration with S. Krusch, D. Rosenbaum, D. Bomans and R.-J. Dettmar (Bochum). The high-resolution simulations show weak filaments of dwarf galaxies going through the group that may explain the observed projected galaxy distribution with many red dwarfs.

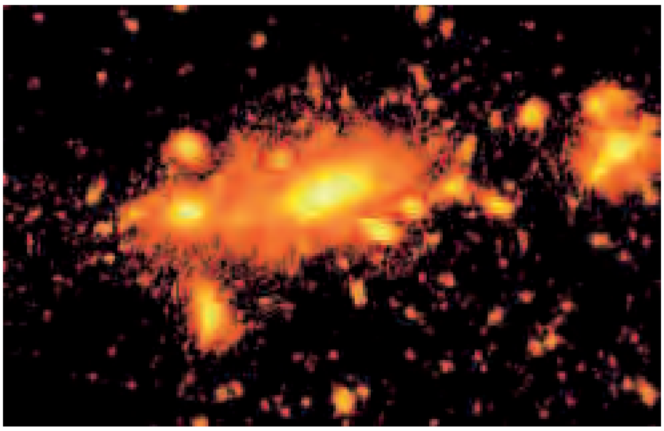


Fig. 1: Merging dark matter halos in our group simulation.

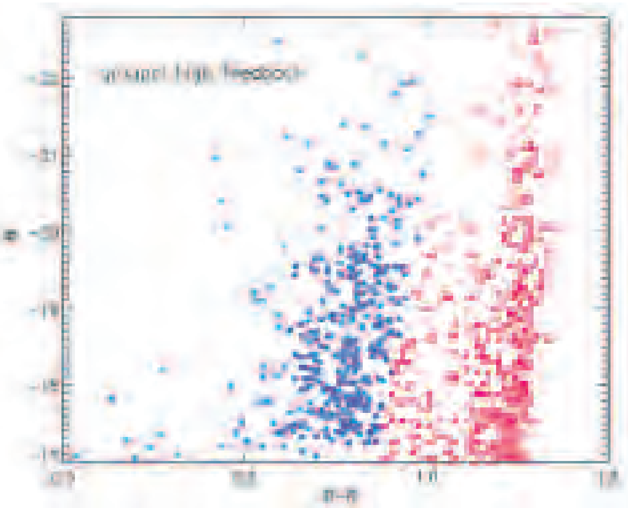


Fig. 2: Colour-magnitude diagram of simulated galaxies with a prominent red sequence and fainter blue star-forming galaxies.

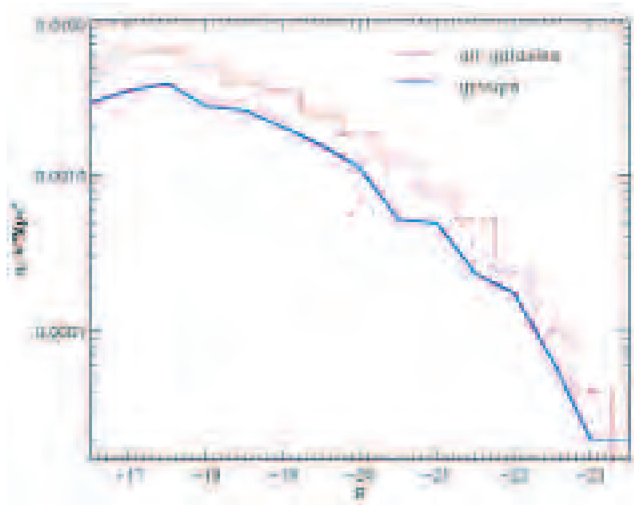
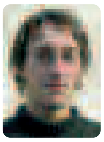
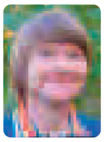
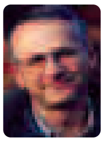


Fig. 3. Luminosity function of all galaxies (red) and reduced abundance of dwarf group galaxies (blue).

Large scale structures in the universe

S. v. Benda-Beckmann, A. Knebe, V. Müller

Die Galaxienverteilung auf großen Skalen wird im frühen Universum angelegt. Sie erlaubt eine Prüfung der grundlegenden Parameter unserer Weltmodelle und der Mechanismen der Strukturbildung. Wir identifizieren in modernen Galaxien-Katalogen Supercluster und kosmische Leerräume als größte gegenwärtig bekannte Strukturen im Kosmos.

The existence of large-scale structures in the universe has been well known since the first observations were made of extragalactic stellar systems. Galaxies form big agglomerates, from groups of galaxies to clusters and superclusters. We employ a distance-dependent weighting scheme for extracting the large scale density field uniformly throughout the 2dF galaxy redshift survey. Fig. 1 shows a slice through the north galactic pole region. Visually, one finds a coherent system of prominent overdensities surrounding dark regions without bright galaxies, often denoted as voids. The density field now allows the extraction of galaxy systems of different richness. We generate a new supercluster catalogue with 38 systems in the north and 44 systems in the south (collaboration with J. and M. Einasto, E. Tago, and E. Saar). There are hundreds of even fainter superclusters in our catalogue. Fig. 2 shows the newly derived supercluster luminosity function defined for two different threshold densities. This observational distribution can be well represented by simulated systems extracted from our own cosmological ΛCDM simulations and by an analytic description of ellipsoidal gravitational collapse. The bright end of the luminosity function shows strong scatter due to a few very prominent superclusters, demonstrating that the 2dF survey volume is still not large enough to eliminate this huge cosmic variance. At the faint end, our supercluster catalogue becomes incomplete.

Fig. 3 shows the size distribution of cosmic voids in the 2dF survey. They exhibit a clear self-similarity if void sizes D are measured by the median void diameter. The different curves stem from different volume-limited samples extracted from the 2dF galaxies. The abundance of large voids again shows a substantial scatter. The black fit stems from a new analytical void model.

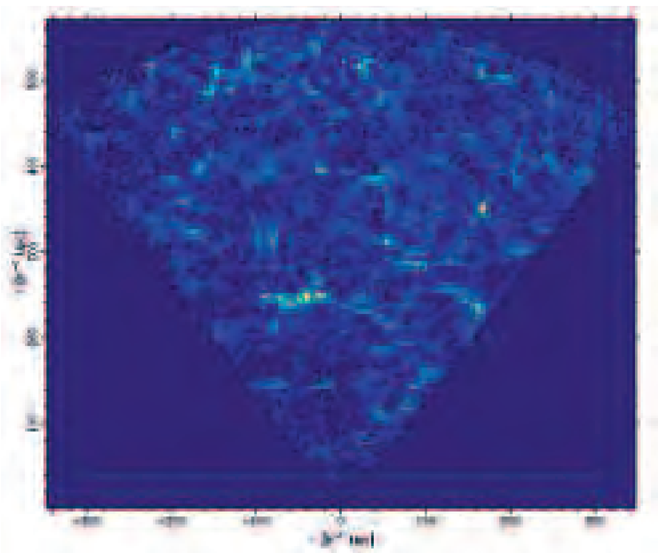


Fig. 1: 2dF redshift survey: Northern galactic pole cone diagram with the observer at the bottom.

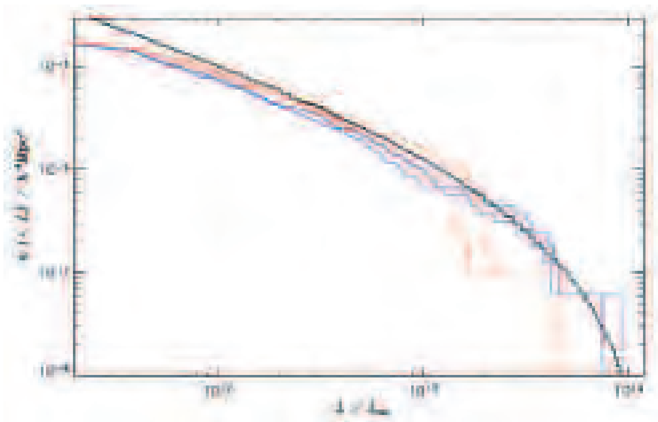


Fig. 2: Supercluster luminosity function in northern (red) and southern 2dF (blue) as compared to a collapse model (black).

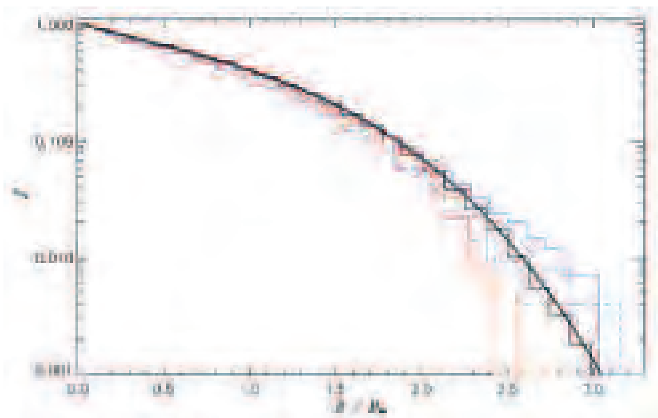
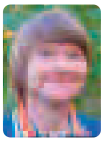
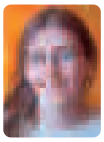


Fig. 3: Fraction f of the survey volume covered by voids of diameter D in relation to the median diameter D_{50} (colour as above). Black model curve and a histogram from simulations.

The dynamics of satellite galaxies in cosmological dark matter halos

A. Knebe, K. Warnick

Unsere Milchstraße ist umgeben von etwa einem Dutzend kleinerer Begleiter, den sogenannten Satellitengalaxien, die ein einzigartiges Laboratorium darstellen. Die Satelliten verlieren durch Gezeitenkräfte und dynamische Reibung immer mehr Masse, bis sie letztendlich aufgelöst werden. Das übrig bleibende Trümmerfeld können wir detailliert modellieren und damit Rückschlüsse auf die Entstehung und bisherige Entwicklung unserer Milchstraße ziehen. Wir stellen hier u.a. ein Verfahren vor, mit dessen Hilfe sich bereits aufgelöste Satellitengalaxien im Halo unserer Milchstraße aufspüren lassen, auch wenn sie in der räumlichen Verteilung unseren Blicken verborgen bleiben: die Methode der Bewegungsintegrale. Unter der Annahme von Energie- (E) und Drehimpuls- (L) Erhaltung erscheint das Trümmerfeld eines räumlich nicht mehr identifizierbaren Satelliten immer noch als kohärente Struktur im E-L-Diagramm.

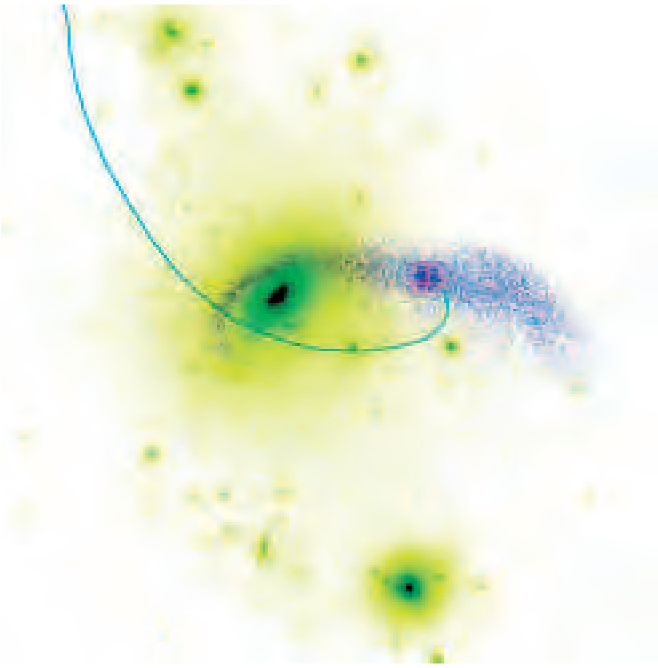


Fig. 1: A sample satellite captured by the gravitational potential of a host dark matter halo.

There is mounting evidence that the Cold Dark Matter (CDM) structure formation scenario provides the most accurate description of our Universe. Observations point towards a `standard' $\Lambda$CDM Universe comprised of 28% dark matter, 68% dark energy, and luminous baryonic matter (i.e. galaxies, stars, gas, and dust) at a mere 4%. This so-called `concordance model' induces hierarchical structure formation, whereby small objects form first and subsequently merge to form progressively larger objects. Whereas the large scale structure of our present universe can be reconstructed very well by numerical simulations, the small scale structure still poses some problems. For example, there are many more subhalos predicted by cosmological simulations than observed in nearby galaxies. The lack of observational evidence for these satellites has led to the suggestion that they are completely (or almost completely) dark, with strongly suppressed star formation due to the removal of gas from the small protogalaxies by the ionising radiation from the first stars and quasars. Others suggest that perhaps low mass satellites never formed in the predicted numbers in the first place, indicating problems with the ΛCDM model in general. Recent results from (strong) gravitational lensing statistics suggest that the predicted excess of substructure is in fact required to reconcile some observations with theory. Hence, if the lensing detection of halo substructure is correct and the overabundant satellite population really does exist, it is imperative to understand the orbital evolution of these objects and their deviation from the background dark matter distribution. In order to test the predictions of the underlying ΛCDM model, more observational tests need to be devised and we are going to present two such probes here.

We have investigated in great detail the orbital evolution of a set of satellite galaxies orbiting within a suite of nine cosmological dark matter halos. Eight of these host halos represent galaxy clusters while one is a simulation of a Milky Way type object. A visual impression of a tidally disrupted satellite orbiting within a host dark matter halo can be viewed in Fig. 1. The orbit is marked by the line and the (initially present) particles sampling the satellite are plotted as blue dots, while the host halo itself (and all other objects) is colour-coded according to the local mass density. The grid sphere in the centre of the satellite marks the radius of the satellite's remnant and encircles the gravitationally bound particles at the end-point of the orbit.

Host dark matter halos usually carry a small internal angular momentum, which is established by the transfer of angular momentum from infalling matter via tidal torques. However, halos may also obtain their spin through the cumulative acquisition of angular momentum from satellite accretion. These two descriptions are certainly linked together and mutually dependent. A detailed analysis of the orbits of satellite galaxies shows that they are directly connected to the infall pattern of satellites along the surrounding filaments. Those subhalos falling into the host at early times establish the angular momentum of the inner regions of the primary halo and are channeled into the host along the same direction as those merging at later times. This leads to the speculation that satellites are preferentially co-rotating with the host. A confirmation of this picture can be viewed in Fig. 2, where we plot the cumulative distribution of the angle between the host's angular momentum and the spin vector of the satellites' orbits. The Fig. nicely demonstrates an overabundance of prograde orbits which may (or may not) be verified observationally.

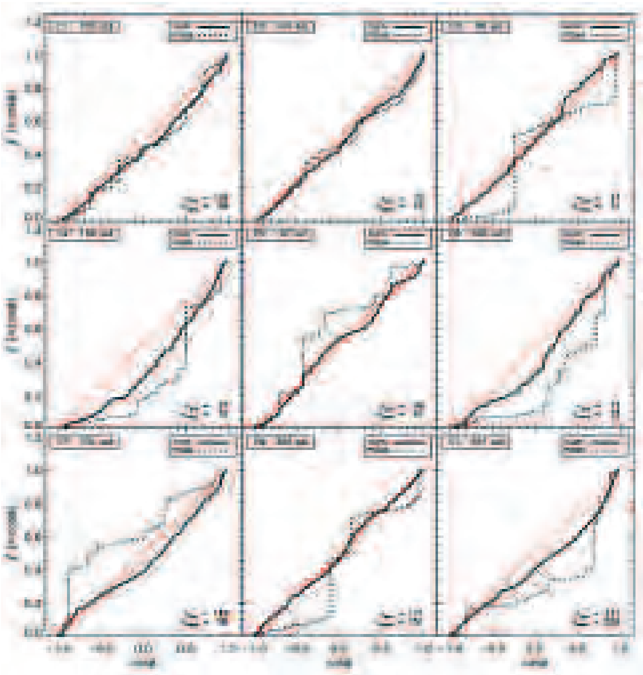


Fig. 2: Cumulative distribution of the angles between the satellite's orbital spin and the angular momentum vector of the host halo. The dotted lines represent number and the solid lines mass-weighted distributions.

While satellite galaxies are being (tidally) disrupted when orbiting within the potential of the host halo, we may anticipate conservation of energy and angular momentum of the satellites' particles, at least to some degree. This is confirmed by studies of the evolution of subhalos in (fixed) analytical host potentials. But do we expect the same behaviour in a `live' cosmological simulation? In Fig. 3 we present the evolution of eight different satellites in the energy-angular momentum (E-L) plane (also called `integral space'). Each satellite is represented by an individual colour. The left panel shows the distributions at the time the satellite enters the virial radius of its host, whereas the right panel displays the distributions at z=0. The distributions of E and L for individual satellite particles as derived from our fully self-consistent cosmological simulations show a large scatter, and have been significantly `re-shaped' over time. In addition, the mean values of E and L are also moved after the evolution. The encouraging result implied in Fig. 3, however, is that even though the integrals of motion are changing over time, satellites still appear coherent in the E-L plane. Hence, there will be a fair chance to identify tidally-induced streams (cf. Fig. 3) by ongoing and near-future observational experiments such as RAVE and GAIA.

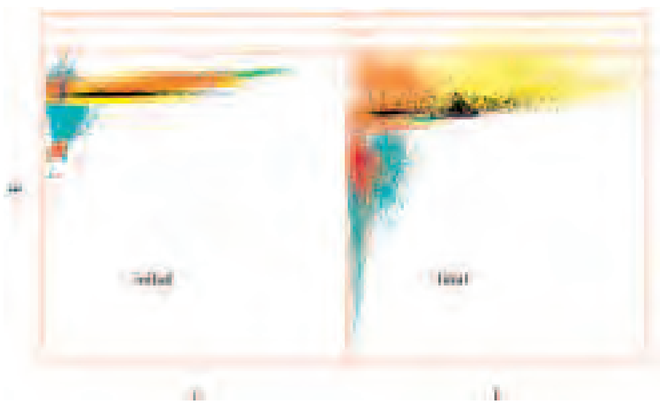
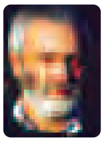
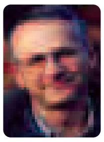


Fig. 3: The distribution of satellite particles in the E-L plane. The left panel shows the distributions at the time the respective satellite galaxy enters the virial radius of the host, whereas the right panel presents the distributions at z=0. Different colours represent particles of different satellites.

Scaling relations of galaxy clusters

Y. Ascasibar, S. Gottlöber, V. Müller

Galaxien sind zumeist nicht isolierte Objekte, sondern bilden Gruppen und Haufen, deren physikalische Eigenschaften eng mit dem Aufbau und der Entwicklung des Universums zusammenhängen. Es werden charakteristische Beziehungen zwischen Galaxiehaufenmassen, Gastemperaturen und Röntgenleuchtkräften beobachtet, die in Verbindung mit Simulationsrechnungen kosmologische Parameter einschränken.

To a great extent, the usefulness of massive galaxy clusters as cosmological probes is due to their relatively simple physics. Their gravitational potential is dominated by a dark matter halo, which accounts for about 80% of the mass, while most baryons are in the form of a diffuse ionized gas heated by gravity and shock waves to approximately the virial temperature of the halo. As long as the shape of a cluster's potential does not depend on its mass, the radial structure of the intracluster medium (ICM) ought to be scale-free, and global properties such as mass, temperature or X-ray luminosity should scale self-similarly.

In real clusters, radiative cooling, star formation and feedback may also be important, particularly for low-mass systems. Observations indeed suggest that the self-similar picture is too simplistic, since it fails to reproduce the observed scaling relations. However, the main agent responsible for the discrepancy remains as yet unidentified.

We have recently addressed this issue by means of high-resolution adiabatic gas dynamical simulations. Contrary to popular belief, we find that galaxy clusters are not expected to be self-similar, even when the only energy sources available are gravity and shock-wave heating. Theoretical predictions can be derived from a polytropic model of the ICM, taking into account the well-known relation between the mass and concentration of the dark matter halo, as well as a systematic variation of the effective polytropic index of the gas, for which we propose a phenomenological formula. An estimate of the expected scatter can be obtained from the scatter in the mass-concentration relation.

Our results suggest that, although neither the dark matter nor the gas profiles are exactly self-similar, the effects of concentration and polytropic index tend to cancel each other, leading to scaling relations whose logarithmic slopes roughly match the most basic self-similar models. However, our scheme provides not only a slope, but also a self-consistent prediction of the normalization and scatter expected for any cosmology, at any given overdensity, at any given time. In Fig. 1, we compare our prediction with the results of numerical experiments and observational data. It seems clear that cooling and star formation are important in galaxy groups. While our model provides a good fit to the adiabatic simulations, real groups seem to contain much less baryonic matter than the cosmic average, which results in a lower X-ray luminosity. For massive clusters, however, the average and scatter of the scaling relations are in excellent agreement with our model, hinting that radiative processes do not significantly affect the ICM.

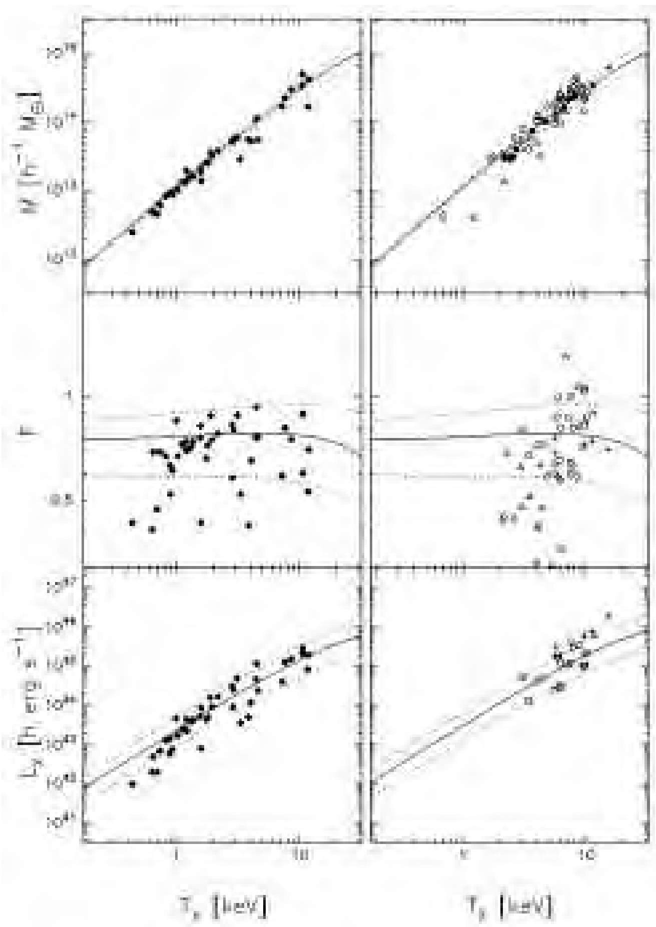
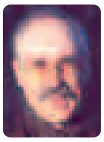


Fig. 1: Theoretical scaling relations (solid lines) of cluster mass (top panels), baryon fraction (middle panels), and X-ray luminosity (bottom panels) as a function of emission-weighted temperature. Dotted lines show the one-sigma scatter expected from the scatter in the mass-concentration relation. Symbols in the left and right panels display simulated and observed galaxy clusters, respectively.

Exploring the intergalactic medium via the cosmic microwave background



J. Mücket

Die Anisotropie der kosmischen 3-Kelvin Strahlung (CMB) gibt Auskunft über die Anfangsbedingungen der Strukturbildung im Universum. Zu späteren Zeiten können die Photonen der CMB über den inversen Compton-Effekt mit heißem Elektronengas in Galaxienhaufen und dem intergalaktischen Medium (IGM) wechselwirken, was zu spezifischen Beiträgen im Anisotropie-Spektrum der CMB führt. Der Vergleich mit Beobachtungsdaten gestattet Rückschlüsse auf den physikalischen Zustand des IGM.

During the last decade, several experiments have provided data with increasing accuracy and scale coverage for the spectrum of anisotropy distortions in the cosmic microwave background (CMB) radiation. In particular, reliable information has been obtained concerning the initial conditions for structure formation in the universe right after the epoch of recombination. At later epochs, any sufficiently hot electron gas may have impact on the CMB spectrum via the Sunyaev-Zeldovich (SZ) effect, which describes the effect of inverse Compton scattering. The thermal SZ effect causes frequency shifts of CMB photons proportional to the electron pressure integrated along the line of sight. After re-ionization, the largest fraction of hot electron gas is present in galaxy clusters at high temperatures ($T > 10^6$ K) and in the intergalactic medium (IGM) at much lower temperatures ($T \approx 10^4$ K). However, shock-heating of the IGM at low redshifts can lead to temperatures as high as $10^5 < T < 10^7$ K.

A measurable effect from the hot cluster gas on the CMB spectrum is well proven. Although the gas temperature of the IGM is much lower than in clusters the total amount of ionized gas is much higher in the IGM. Unlike in the clusters, the density distribution of the IGM is approximately log-normal. This means that we can obtain the contribution of the IGM to the anisotropy spectrum of the CMB. For model parameters in agreement with observations and for an experiment operating in the Rayleigh-Jeans regime, the largest IGM contribution corresponds to angular scales of a few arcminutes ($l \approx 2000$). The amplitude is rather uncertain and could be as large as the contribution of galaxy clusters. The actual value is strongly dependent on the gas polytropic index and the amplitude of the matter power spectrum σ_8. At all redshifts, the largest contribution comes from scales very close to the co-moving baryon Jeans length. This scale is not yet resolved in numerical simulations that follow the evolution of gas on cosmological scales. The anisotropy generated by the Intergalactic Medium could make the excess of power measured by Cosmic Background Imager (CBI) on scales of $l > 2000$ with a σ_8=0.9 compatible with results obtained from other experiments. Taking the CBI result as an upper limit, the polytropic index can be constrained to < 1.5 at redshifts $z \approx$ 0.1-0.4. With its large frequency coverage, the PLANCK satellite will be able to measure the secondary anisotropies coming from hot gas. Cluster and intergalactic medium contributions could be separated by cross-correlating galaxy/cluster catalogs with CMB maps. This measurement will determine the state of the gas at low and intermediate redshifts.

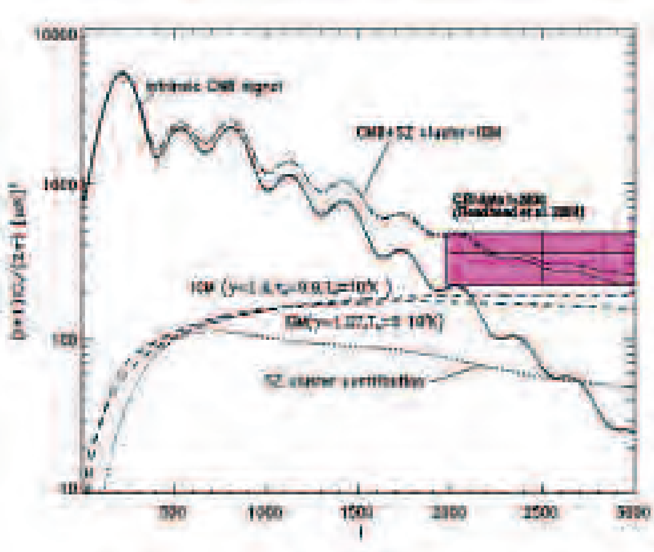
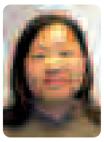


Fig.1 TSZ radiation power spectrum component from clusters (dotted line) and IGM (dashed) for two different polytropic indices, intrinsic CMB temperature anisotropies (solid) and the sum of the three components (dot-dashed). The TSZ power spectrum has been rescaled to 32 GHz. The magenta box gives the CBI data at the scales of interest.

The metallicity of the strong Ly-alpha forest at $2 < z < 3.5$



T.-S. Kim

Quasarabsoptionslinien sind ein einzigartiges Mittel, um Struktur- und Galaxienbildung bei größeren Rotverschiebungen zu studieren. Die Korrelation des Metallgehalts mit der Säulendichte von Absorptionssystemen spricht für Superwinde in Sternbildungsphasen von Galaxien.

In the current structure formation paradigm, the lower column density QSO absorption line systems, the Lyman-alpha forest, are produced by the diffuse intergalactic medium (IGM) in filamentary structures, while the higher column density QSO absorption line systems, Lyman limit systems and damped Lyman-alpha systems, are believed to be produced by intervening galaxies or halo structures where galaxies form.

In short, the higher the column density of an absorption system is, the more likely the system is closer to, and gets enriched by, nearby star-forming galaxies.

Therefore, the metallicity as a function of column density and of redshift constrains the past star formation history of galaxies closer to absorption systems and the poorly-understood feedback processes of galactic matter into the IGM. For example, we would expect a monotonic correlation between the metallicity and the absorption column density if supernovae-driven superwinds were the main mechanism. The metallicities of the damped Ly-alpha systems and sub-damped systems (the neutral hydrogen (HI) column density, N(HI) > 10^{19} cm^{-2}) are [M/H] $\approx$ -2 ~ -1 (1/100 to 1/10 solar), with a very weak redshift dependence. On the other hand, the metallicity of the weaker absorption line systems are less certain. Since the intergalactic medium is exposed to the metagalactic UV background, it is highly ionised and its metallicities need to be corrected for this ionisation effect. (Higher column density systems are self-shielded from the UV background). Assuming a homogeneous Haardt-Madau UV background, the metallicity of a typical Ly-alpha forest absorber (N(HI) ~ $10^{14\text{-}16}$ cm^{-2}) is [C/H] $\approx$ -3.5 ($\approx$1/3000 solar), with a large scatter and again with a negligible redshift dependence. Unfortunately, studies on the metallicity of absorption systems at N(HI) = $10^{15\text{-}19}$ cm^{-2} have proved to be challenging: 1) their HI lines are heavily saturated, and thus no reliable N(HI) can be derived. 2) Besides the UV background, the systems could be exposed to an additional radiation field from nearby star-forming galaxies, which makes the ionisation correction uncertain. In our first step to study the metallicity as a function of N(HI) and redshift at N(HI) = $10^{15\text{-}19}$ cm^{-2} at $2 < z < 3.5$, we concentrate on the high column density forest with N(HI) = $10^{15\text{-}17}$ cm^{-2}. We have analysed 17 high column density absorption systems towards 7 high-redshift QSOs obtained by the UVES (Ultra-Violet Echelle Spectrograph) at the VLT, Chile. The wavelength coverage down to 3050 Angstrom enables us to use the higher order Lyman series such as Lyman-beta and Lyman-gamma lines to measure a reliable N(HI) of saturated Lyman-alpha lines. We have found 3, 6 and 8 systems with no metals, CIV-only, and additional ions other than CIV (mainly SiIV), respectively. We have applied the ionisation correction assuming the Haardt-Madau UV background including both galaxies and QSOs. The photoionisation model gives median values of [C/H]=-3.03 (1/1000 solar) and -1.96 (1/100 solar) for the 6 CIV-only systems and the 8 additional ion systems respectively. When other ions are present, the [C/H] of the forest is similar to that of sub-damped Lyman-alpha systems (Fig. 1). With our current limited sample size, it is not possible to claim a simple power law between the column density and the metallicity. We are currently working with an increased sample.

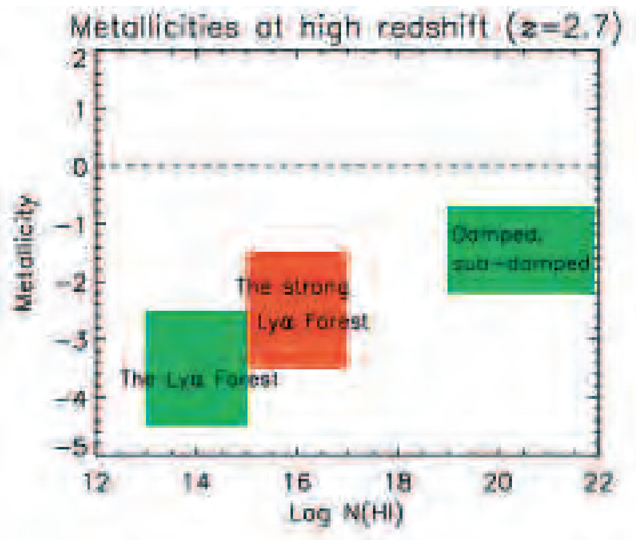
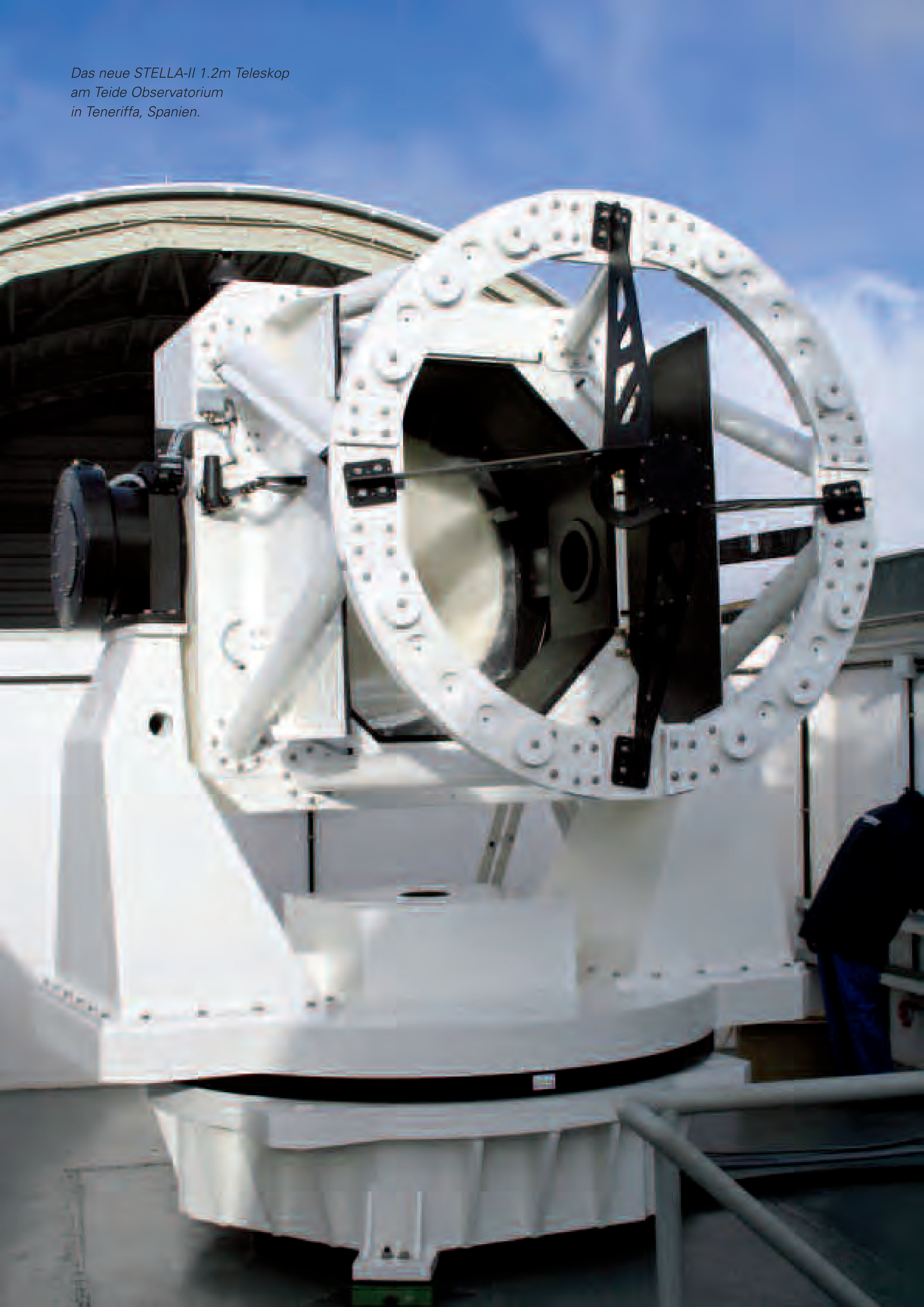


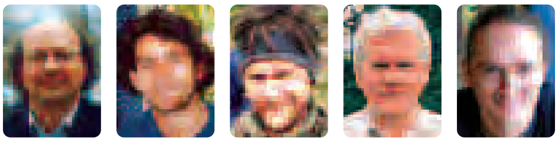
Fig. 1: The metallicity as a function of the HI column density at $z \approx 2.7$. The metallicities of damped systems, sub-damped systems and a typical Lyman-alpha forest absorber are from Prochaska et al. (2003), Dessauges-Zavadsky et al. (2003), and Schaye et al. (2003), respectively.



Das neue STELLA-II 1.2m Teleskop am Teide Observatorium in Teneriffa, Spanien.

Die Roboter-Sternwarte STELLA
The STELLA Robotic Observatory

K. G. Strassmeier, M. Weber, T. Granzer, M. Woche, J. Bartus



STELLA ist ein robotisches Observatorium mit zwei vollautomatischen 1,2m Teleskopen (STELLA-I und STELLA-II) und deren Instrumentierung für den Standort Teneriffa in Spanien. Nicht nur die beiden Teleskope sind automatisch, auch die Sternwarte selbst ist vollkommen automatisch und bedarf keiner menschlichen Präsenz, auch nicht im „remote control". Im Endausbau wird STELLA-II Sternlicht über eine Glasfaserleitung zu einem hochauflösenden Echelle-Spektrografen liefern, während STELLA-I mit einem „wide-field CCD-imaging photometer" zur Präzisionsphotometrie ausgestattet sein wird.

Robotik im praktischen Einsatz

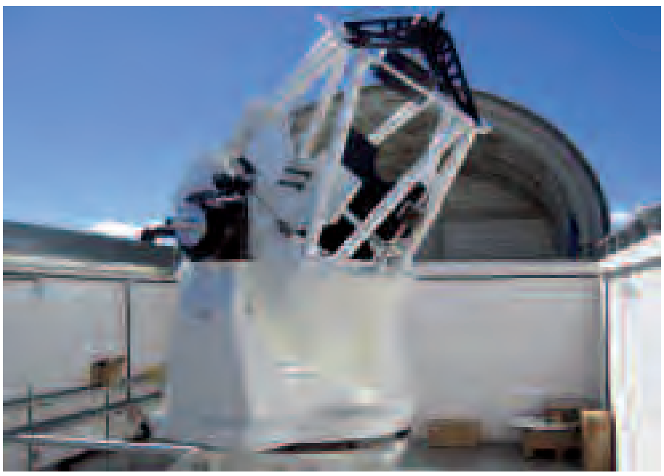
Die STELLA-Gebäudekonstruktion war bereits im Frühjahr 2002 fertig gestellt und durchlief nach Installation der Netzwerktechnik und der Computer ab Herbst 2002 eine einjährige Testphase unter realen Bedingungen. Ohne einen einzigen Ausfall hatten sich die jeweils 5 Tonnen schweren Dachhälften je nach „Anweisung" der Wetterstation abends geöffnet und morgens wieder geschlossen. Anfängliche Schwierigkeiten mit der 15kVA-USV wurden mittlerweile behoben, so dass nunmehr für etwa 20 Minuten Ausfallsicherheit besteht. Das STELLA-Gebäude wird von einer Web-Kamera am nahen VTT ständig beobachtet (siehe: http://www.aip.de/stella). Im gesamten Gebäude verteilte Sensoren sowie ein zweite Web-Kamera im Teleskopraum liefern einen aktuellen Stand über die Umweltbedingungen der Teleskope, der wissenschaftlichen

STELLA is a robotic observatory with two fully automatic 1.2m telescopes (STELLA-I and STELLA-II) for the Teide Observatory in Tenerife, Spain. Not only the telescopes are automatic, but also the entire observatory. No human presence is needed for observing – not even in remote control. In its final configuration STELLA-II supports a high-resolution, fibre-fed and bench-mounted echelle spectrograph while STELLA-I feeds a wide-field CCD imaging photometer.

Practical Robotics

The STELLA building was finished in spring 2002, and after installing the network and computer system in autumn 2002, it went through a one year test period under realistic conditions. Without a single failure the roof-halves weighting 5 tons each open in the evening, after getting permission from the weather station, and close again in the morning. The difficulties experienced in the beginning with the 15kVA UPS (uninterruptible power supply) have been fixed, so that from now on there is an approximately 20 minute safety buffer in case of a power cut. The outside of the STELLA building is observed from the close-by VTT with a web camera. This image can be accessed from http://www.aip.de/stella. Sensors, like the second web camera in the telescope room, deliver actual information on the surrounding conditions at the telescope, on the scientific equipment and on the status of the miscellaneous secondary systems. From 2006 onwards all the operational information and the scientific data will be collected in the Media and Communication Center at the AIP in Babelsberg.

Die vollautomatische Sternwarte STELLA am Teide Observatorium in Teneriffa in Spanien



Das STELLA-I 1.2m Teleskop kurz nach seiner Endmontage 2004/5

Geräte und den Status der diversen Sekundärsysteme. Alle Betriebs- und Wissenschaftsdaten werden ab 2006 im Meridian- und Kommunikationszentrum am AIP in Babelsberg zusammenlaufen.

In der Zwischenzeit wurden die beiden Wetterstationen auch benutzt, um das lokale Klima und seine Schwankungen direkt am STELLA-Standort zu messen. So wurden im Januar und Dezember 2005 die Kanaren von den stärksten je aufgezeichneten Stürme heimgesucht. Eine elektromagnetische Entladung hatte im Januar am ganzen Teide Elektronik beschädigt. Am STELLA-Gebäude trat kein großer Schaden auf, es wurden aber mehrere A/D-Wandler zerstört.

Das STELLA Kontrollsystem (SCS) ist nun in der Lage mit Hilfe eines mathematischen Modells kritische Umweltparameter wie z.B. Luftfeuchtigkeit fünf Minuten in die Zukunft vorherzusagen. Dies reicht aus, um die Dachhälften im Fall eines schnell herannahenden Sturmes sicher zu schließen ohne eine Wolke im Gebäude einzuschließen.

STELLA-I-Teleskop: Erste Himmelstests

Das erste der beiden STELLA Teleskope ist Ende November 2004 in Teneriffa installiert worden. Die anschließende „commissioning"-Phase dauerte ein Jahr und führte zu einem Austausch der gesamten M3-Einheit sowie der Motorkontroller beider Hauptachsen. Das anfängliche Oszillationsverhalten von bis zu ±2 Bogensekunden wurde mit einer Feineinstellung auf unter ±0,18 Bogensekunden gebracht. Die Frequenz dieser Schwingung ist abhängig von der Nachführgeschwindigkeit.

In the meantime both weather stations are also used to measure the local climate and its variations directly at the STELLA site. In January and December 2005 the Canary Islands were haunted by the strongest storms ever recorded. In January an electronic discharge damaged all the electronics at Teide. Fortunately, the STELLA building did not suffer much damage, but still many A/D converters burned out.

The STELLA control system uses a mathematical model to predict the critical weather parameters, like the humidity, 5 minutes into the future. This gives enough time to close the roof in the case of a rapidly approaching storm, without trapping clouds inside the building.

STELLA-I telescope: first tests on the sky

The first of the two STELLA telescopes was installed in Tenerife at the end of November 2004. The subsequent commissioning phase lasted one year and resulted in the replacement of the whole M3 unit and the motor controllers for both main axes. The fine adjustments reduced the tracking oscillation from the initial value of +/- 2 arc-seconds to +/- 0.18 arc-seconds. The oscillation frequency depends on the tracking speed.

Arrival of the spectrograph and the CCD camera

The STELLA echelle spectrograph (SES) is a modern white pupil spectrograph with high spectral resolution and a fixed wavelength format (either 430-980 nm or 390-700 nm, depending on the cross-disperser). The instrument is housed in its own room on a mechanically stabilised optical table and is connected to the telescope with 12 m long optical fibres. The

Der fasergekoppelte STELLA Echelle Spectrograph (SES) an seinem endgültigen Standort in Teneriffa.

Die Akquisitions- und Nachführeinrichtung von STELLA-I mit dem Glasfaserkabel zum SES

Ankunft des Spektrografen und der CCD-Kamera

Der STELLA Echelle Spektrograf (SES) ist ein moderner „Weißpupillen"-Spektrograf mit hoher spektraler Auflösung und einem fixierten Wellenlängen-Format (entweder 430-980nm oder 390-700nm, je nach Kreuzdispergierer). Das Instrument ist in einem eigenen Raum auf einer mechanisch stabilisierten optischen Bank montiert und wird mit einer 12m langen Glasfaser vom Teleskop mit Sternlicht versorgt. Je zwei Glasfaserkabeln mit 50µm und 100µm Kerndurchmesser ermöglichen spektrale Auflösungen von 50000 bzw. 25000 bei einer Eintrittsblende von 2,6 Bogensekunden. Das Herz des Spektrografen ist ein 31,6-Linien/mm R2-Echelle-Gitter. Zwei parabolische Off-Axis Kollimatoren, ein Faltspiegel sowie ein Prisma als Kreuzdispergierer speisen das Licht in eine f/3,4 katadioptrische Schmidt-Kamera mit einer 158mm Korrektor-Platte und einem 250 x 370mm sphärischen Spiegel. Ein E2V CCD42-40 mit 2048 x 2048 Pixel wird von einem CUO-Con-

Das 1.2m STELLA-II Teleskop kurz nach seiner Montage

fibres, 50 micrometer and 100 micrometer thick, provise resolving power of 50000 and 25000, respectively. The entrance aperture is 2.6 arc-seconds. The heart of the spectrograph is the 31.6 line/mm R2 echelle grating. Two parabolic off-axis collimators, a folding mirror, and a prism acting as a cross-disperser feed the light into a f/3.4 catadioptric folded Schmidt camera, which has a 158 mm corrector plate and a 250x370 mm spherical mirror. The detector is an E2V CCD42-40 chip with 2048x2048 pixels, and it is controlled by the CUO second generation controller. This combination gives a quantum efficiency of 90% at 630nm and 65% at both 400nm and 800nm with a read-out-noise of only 3-4 electrons. A closed cooling circuit keeps the detector at -120 degrees centigrade.

SES was delivered to Tenerife in May 2005 and it was assembled there during the next few months. The first spectrum with the calibration source was observed on the 28th of June. Only after installing the Acquisition and Guiding unit could the first stellar spectrum be obtained on the 9th of September. A 10 second exposure of a bright star, Alpha Tauri (K5II), gave a signal-to-noise ratio of 100/1 and a radial velocity precision of 440 m/s. This exposure was obtained without guiding, atmospheric dispersion correction, fine-tuning or fibre agitator. Further fine tuning of the system, like building stray light baffles, is under way.

A self-focusing Acquisition and Guiding unit for both STELLA telescopes

The acquisition and guiding unit (A&G unit) for a robotic telescope is naturally more complex than for a manual telescope. For SES it is particularly critical that the star light stays cen-

Ankunft von STELLA-II im Dezember 2005

Das erste Spektrum mit dem SES (430-980nm). 10-Sekunden Aufnahme des K5III Sternes Alpha Tauri. Jede Farbe entspricht einer von 72 Echelle Ordnungen.

troller der zweiten Generation betrieben. Diese Kombination ermöglicht bei einer Quanteneffizienz von 90% bei 650nm, sowie 65% bei 400nm bzw. 800nm, ein Ausleserauschen von nur 3-4 Elektronen. Ein geschlossener Kühlkreislauf hält den Detektor konstant auf -120 Grad Celsius. Der SES wurde im Juni 2005 nach Teneriffa überstellt und dort bis Juli aufgebaut. Ein erstes Spektrum mit der Kalibrationslichtquelle wurde bereits am 28. Juni erhalten. Erst nach Integration der Akquisitions- und Nachführeinrichtung (A&G-Einheit) am Teleskop konnte am 9. September erstes Sternlicht den Spektrografen erreichen. Eine 10-Sekunden Integration des hellen Sternes Alpha Tauri (K5III) ohne Nachführung, ohne ADC, ohne Feinjustierung und ohne Faseragitator ergab ein S/N-Verhältnis von etwa 100:1 und eine Radialgeschwindigkeitspräzision von 440 m/s. Die weitere Feinabstimmung sowie der Einbau der Streublenden ist derzeit im Gange.

Eine selbstfokussierende Akquisitions- und Nachführeinrichtung für beide STELLA Teleskope

Die Akquisitions- und Nachführeinrichtung (A&G-Einheit) für ein robotisches Teleskop ist naturgemäß komplexer als bei einem manuellen Teleskop. Für den SES ist es besonders kritisch, da das Sternlicht über lange Zeit auf einer nur 50 µm (2,6") dünnen Glasfaser zentriert und gehalten werden muß. Aus diesen Gründen wurde am AIP eine spezielle A&G-Einheit auf der Basis einer Mikrolinse konstruiert, die momentan am STELLA-I Teleskop montiert und noch getestet wird. Sie

tred on the 50 micrometer fibre core for a long time. This is realised by imaging the star on a 120 micrometer pinhole and pupil imaging with a micro-lens on the fibre core. For position control of the star on the pinhole a special A&G unit based on triple pass beamspiltter was built at AIP. At the moment this unit is being tested on STELLA-I.

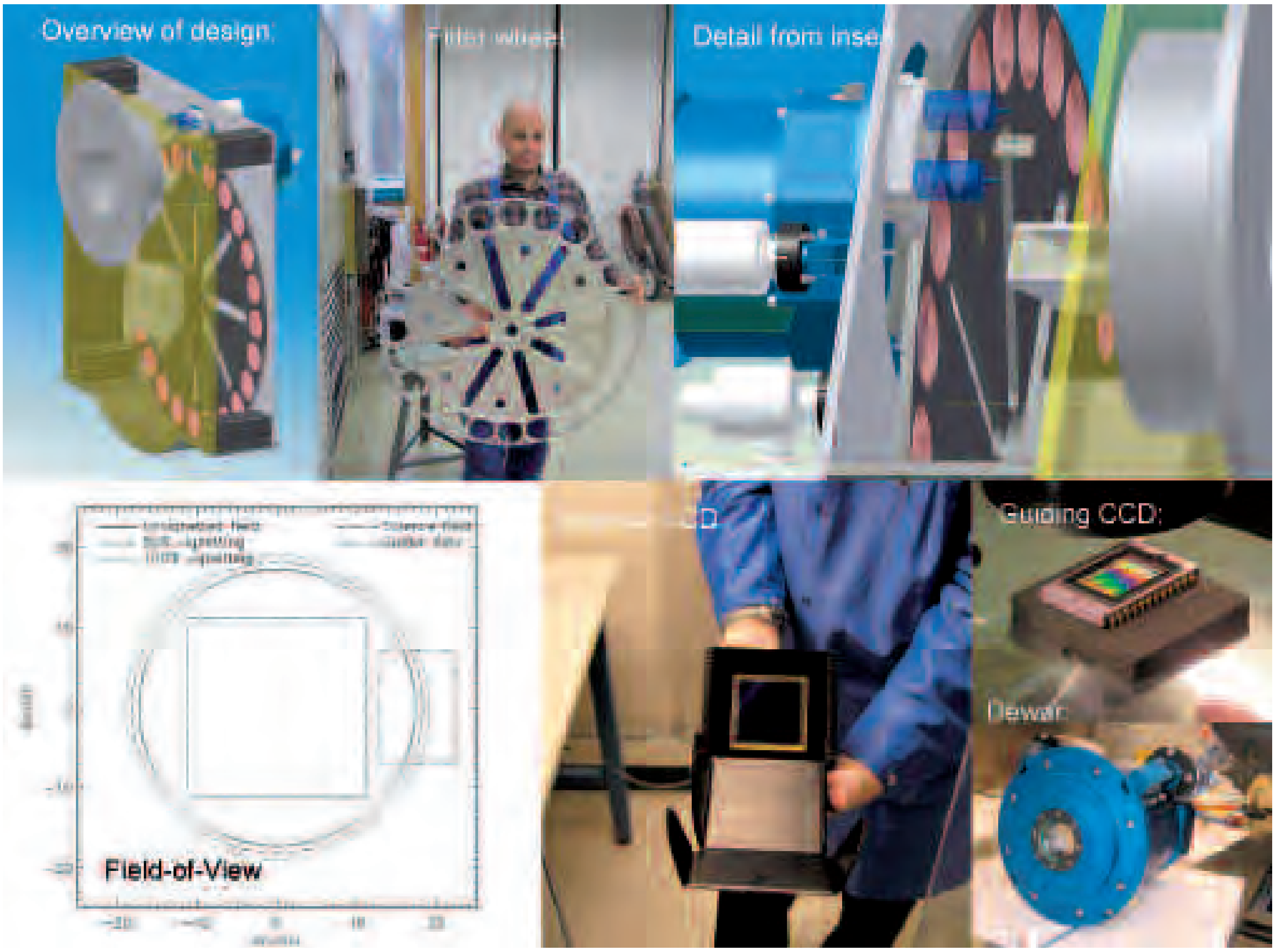
The main components of the A&G unit are a grey beam splitter and a reflecting pinhole mirror, which provide in combination with the other optical elements a well separated double image on the guiding CCD. The light for the first image comes from the 3-4% of the star light reflected by the beam splitter. The light transmitted by the beam splitter is imaged on the pinhole mirror and the science target has to be positioned exactly on the pinhole. The imaged field around the pinhole and the pinhole itself are re-imaged over the beamsplitter (by reflection and transmission) and give the second image on the guiding CCD. With these two separate images it is possible to locate the pinhole, the science target and the surrounding field. The guiding CCD is a 768 x 512 9 µm pixel Kodak KAF detector. The second STELLA-I focus, which from 2007 onwards is envisioned to have WIFSIP, will be equipped with a similar unit, but using off-axis light for guiding.

STELLA-II installed in December 2005

STELLA-II is mechanically and electronically identical to STELLA-I, but it will only have one Newton focus in use. This has the advantage of a higher efficiency in comparison to

Die Gitterhalterung des SES

Das STELLA Kontrollzentrum im MCC des AIP in Babelsberg



Übersicht über die Baukomponenten von WIFSIP, dem wide-field STELLA imaging.

basiert auf einem dichroitischen Strahlenteiler, der 3-4% des Sternlichtes ablenkt, an einem Aluminiumblättchen reflektiert, mit sich selbst überlagert, und über eine Reihe weiterer optischer Elemente auf einen 768 x 512 9µm Pixel Kodak KAF CCD-Detektor abbildet. Dies erlaubt es, das Guiding und die Fokuskontrolle mit der gleichen Taktfrequenz am gleichen CCD durchzuführen. Der zweite STELLA-I Fokus, ab 2007 für WIFSIP vorgesehen, wird mit einer ähnlichen, aber ausschließlich mit Off-Axis-Licht versorgten A&G-Einheit ausgestattet.

STELLA-I. The optics of STELLA-II are based on a high precision spherical 1.2m mirror and a focal extender with an integrated ADC (atmospheric dispersion corrector). This makes STELLA-II an ideal light collector for a spectrograph with a large wavelength coverage. The unit should be ready by the end of 2006 or early in 2007.

STELLA-II-Teleskop im Dezember 2005 installiert

STELLA-II ist mechanisch und elektrisch baugleich zu STELLA-I, jedoch wird nur ein (Newton) Fokus zur Verfügung stehen. Dies hat den Vorteil höherer Effizienz im Vergleich zu STELLA-I. Die Optik von STELLA-II basiert auf einem hochpräzisen sphärischen 1,2m-Spiegel und einem Fokalextender mit integriertem ADC (atmosphärischer Dispersionskorrektor). Dadurch eignet sich STELLA-II als idealer Lichtkollektor für einen Spektrografen mit großem Wellenlängenbereich. Das Gerät (WIFSIP: das „wide-field STELLA CCD-imaging photometer“) soll Ende 2006 bzw. Anfang 2007 einsetzbar sein. Nach Inbetriebnahme des zweiten Teleskops wird der Faseranschluss des SES von STELLA-I auf STELLA-II verlegt. Am ersten STELLA-I Fokus wird dann zusammen mit einem Bildfeldderotator ein Imaging-Photometer mit einem großen CCD-Detektor installiert (WIFSIP), während am zweiten Fokus ab 2008 eine experimentelle Adaptive-Optik zum späteren Nachrüsten mit einem NIR Instrument getestet werden soll. Als wissenschaftlicher Detektor für WIFSIP dient ein monolithischer 4096x4096 15µm Pixel, „back-illuminated“ gedünnter CCD Chip aus dem Steward-Imaging Lab. Das Photometer ist mit je einem Satz 90mm Strömgren-, einem schmalbandigen Hα-Filter, Johnson-Bessell- sowie Sloan-Filtern ausgestattet und soll eine photometrische Präzision von 1 Millimagnitude über ein Feld von 22x22 Bogenminuten bei einem Sampling von 0,3 arcsec/Pixel erreichen. Vorraussichtlicher Installationstermin ist Ende 2006. Mit beiden Instrumenten im Betrieb ist STELLA dann eine weltweit einmalige und höchst innovative Installation. Kein Bedienungspersonal wird erforderlich sein. P.I. von STELLA ist seit 2000 Prof. Klaus Strassmeier. Projektmanager ist Dr. M. Weber in Zusammenarbeit mit dem IAC in Teneriffa.

WIFSIP: the "wide-field STELLA CCD imaging photometer"

After commissioning the second telescope the fibre-feed for SES will be moved from STELLA-I to STELLA-II and the first STELLA-I focus will be used, together with an image de-rotator, for an imaging photometer with a large CCD detector (WIFSIP). In the second focus of STELLA-I, from 2008 onwards, we will test an experimental adaptive optics system, to which we will later add a NIR (near infrared) instrument. The WIFSIP science detector will be a monolithic 4096x4096 15 micrometer pixel, back-illuminated, thinned CCD chip from the Steward Imaging laboratory. The photometer will be equipped with 90 mm Stromgren filters, narrow-band Hα filter, Johnson-Bessell and Sloan filters. The instrument is envisioned to provide 1 milli-magnitude photometric accuracy over a field of view of 22x22 arc-seconds with a sampling of 0.3 arcsec/pixel. The estimated installation date is at the end of 2006.

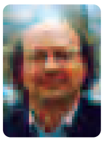
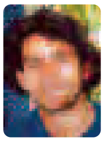
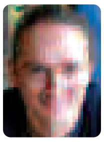
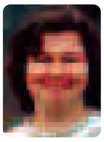
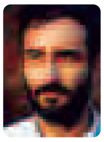
With both instruments in use STELLA will be a unique and very innovative installation, with no personnel needed on-site. Prof. Klaus Strassmeier is the PI of the STELLA project since 2000, and the project manager is Dr. Michael Weber in collaboration with IAC in Tenerife.

The STELLA team at AIP

K. G. Strassmeier, M. Weber, T. Granzer, M. Woche, S.-M. Bauer, F. Dionies, T. Fechner, J. Bartus, A. Ritter, A. Washüttl, E. Popow, J. Paschke, M. I. Andersen, H. Korhonen, A. Staude und A. Schwope.

RoboTel: ein öffentliches Roboterteleskop in Babelsberg
RoboTel: a public robotic telescope in Babelsberg

K. G. Strassmeier, M. Weber, T. Granzer, M. Woche, J. Bartus, R. v. Berlepsch, A. Schwope, A. Staude, E. Popow

RoboTel ist eine kleinere Kopie des robotischen Teleskops STELLA. Zu 50% wird das Teleskop als Testinstrument für STELLA und Robotik im Allgemeinen dienen. Die zweite Hälfte der Beobachtungszeit ist öffentlich, während der robotische Astronomie am AIP erfahrbar wird.

Eckdaten des Teleskops sind:

- 80cm Cassegrain-System
- Systemöffnungsverhältnis f/8.0
- Bildfeld mit Korrektor 30'
- Spiegelmaterial Astro-Sitall
- zwei Nasmyth-Foki nutzbar durch drehbaren Tertiärspiegel
- Positioniergeschwindigkeit bis 10°/s
- Standort: Schwarzschildhaus des AIP.

Hergestellt wurde das Teleskop für das Media- & Communication-Center (MCC) des AIP von der Firma Halfmann-Teleskoptechnik in Augsburg. Am 15. März 2005 erfolgte die Lieferung mit anschließender Installation am AIP-Schwarzschildhaus in einer 4m-Baader Kuppel. Während der ersten commissioning-Phase wurde die Pointiergenauigkeit sowie die Nachführung des Teleskop getestet und optimiert. Das RoboTel Kontrollzentrum mit allen notwendigen Peripherieeinrichtungen befindet sich im angrenzenden MCC-Gebäude. RoboTel wird zur Zeit gemeinsam mit lokalen Schülern für den regulären Betrieb als Forschungs- und Schulteleskop vorbereitet. Ab 2006/2007 werden astronomische Beobachtungen mit professionellem Anspruch vom Klassenzimmer aus möglich sein.

Bis zu 50% der Teleskopzeit sind für schulische Zwecke reserviert. Die Schüler werden dabei nicht nur mit der Astronomie aufs Engste vertraut, sondern lernen gleichzeitig die moderne Robotik-Technologie kennen. In 2006/07 wird vom AIP eine Kopie des Wide-Field-STELLA-Imaging-Photometers (WIFSIP) mit einem professionellen 2kx2k E2V CCD zur Verfügung gestellt. Ein niedrig-dispergierender Spektrograf wird derzeit von Amateur-Seite als Demonstrationsprojekt gebaut.

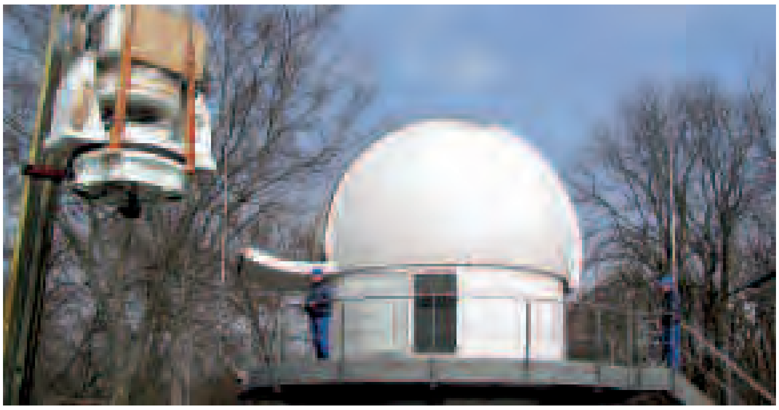
RoboTel is a scaled-down copy of the robotic STELLA telescopes. 50% of its time is used for testing STELLA instrumentation and robotics in general. The other half of its time is public and is distributed to schools for hands-on robotic astronomy.

Technical details of the telescope:

- 80cm Cassegrain system
- total aperture ratio F/8.0
- field of view with corrector 30 arcmin
- mirror material Astro-Sitall
- rotatable tertiary mirror serves two Nasmyth foci
- positioning speed 10 degrees/s
- installed in the Schwarzschild building at the AIP

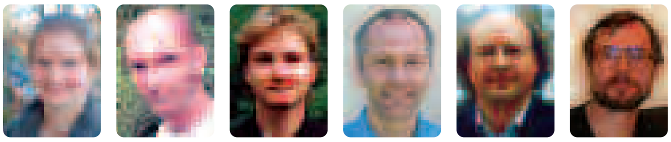
The telescope was manufactured in Augsburg by Halfmann-Teleskoptechnik company for the Media & Communication Center (MCC) of the AIP. It was installed into a 4m-Baader dome at the AIP Schwarzschild Building on March 15, 2005. During the first commissioning phase the pointing accuracy as well as the tracking of the telescope will be tested and optimised. The RoboTel control center with all necessary peripheral equipment is located in the MCC building.

RoboTel is currently being prepared for regular scientific and educational use. We are planning to start with observations in 2006/2007. The observations will be conducted by professional methods and can be operated directly from the classroom. Up to 50% of the observing time is allocated for educational purposes. The pupils will not only learn much about astronomy, but will also get in contact with modern technologies of robotics. In 2006/2007 there will be available a copy of Wide-Field-STELLA-Imaging-Photometer (WIFSIP) with a professional 2kx2k E2V CCD at AIP. A low-resolution spectrograph is being built by an amateur as a demonstration project.



The STELLA data reduction pipelines

H. Korhonen, A. Ritter, A. Staude, A. Schwope, K. G. Strassmeier, I. Ilyin



Um ein robotisches Observatorium wie STELLA mit seinen beiden 1,2m Teleskopen voll nutzen zu können, müssen die Daten automatisch reduziert und dabei einer permanenten Qualitätskontrolle unterzogen werden. Zu diesem Zweck wurden zwei voneinander unabhängige vollautomatische Reduktionsprogramme geschrieben. Erste Analysen wurden vorerst mit dem STELLA Echelle Reduktionspacket durchgeführt. Die zweite Pipeline für das STELLA-Weitfeld-Photometer ist noch in Vorbereitung.

STELLA is an observatory hosting two robotic telescopes (STELLA-I and STELLA-II) which operate in a fully robotic mode. The building itself is automatic, and the telescopes decide on the best observing strategy on the fly. STELLA telescopes fiber-feed an echelle spectrograph (SES) and host an optical wide field CCD imager and photometer (WIFSIP). To fully take advantage of this robotic observatory, automatic reduction pipelines for high-resolution spectroscopy and high precision photometry were written.

The pipeline for the STELLA Echelle spectrograph (SES) is based on the NOAO Image Reduction and Analysis Facility (IRAF). It consists of a number of IRAF-CL scripts which are invoked by a master script. The reduction process is split into two parts. First, the bad-pixel correction, bias subtraction, scattered-light subtraction, cosmic-ray correction, flat fielding and aperture extraction are done at Teide Observatory on a local computer. The relatively small one-dimensional spectra (800kB) are automatically transferred to the AIP archive, where the second step continues with Thorium-Argon emission-line identification, wavelength calibration, radial-velocity measurement and normalization. A first example of a spectrum obtained with SES and reduced with the SES pipeline is shown in Fig. 1.

The WIFSIP photometry pipeline is basically split into three modes: imaging, large-field photometry, and single-target photometry. In its current version it employs the GaBoDS image reduction package (Erben et al. 2005) for astrometrically and photometrically calibrated imaging. For photometry we are investigating the possibility of using either the Aarhus University's MOMF package (Kjeldsen & Frandsen 1992) or ISIS package (Alard 2000). The basic frame reduction is queued from a data base containing updated sky flats, biases, and darks, and is done automatically at the telescope and then transferred with lossy compression to the AIP. The original raw data (32MB per image) will be shipped regularly on DAT or similar and are then reduced again in Potsdam. In any case, a user will get pre-reduced data, but will additionally have the option to queue for re-reduction from the archive.

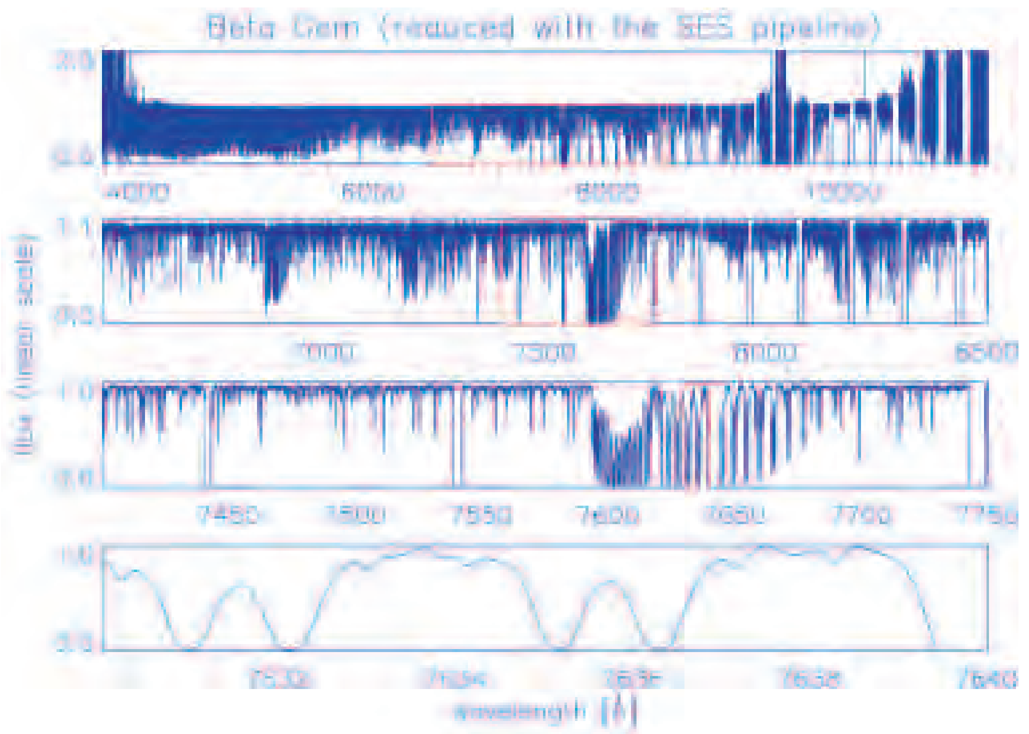
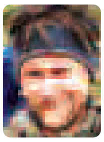
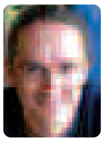
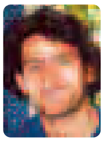


Fig. 1: β Gem spectrum observed with the SES spectrograph at STELLA and reduced with the SES pipeline.

Scheduling robotic telescopes

T. Granzer, J. Bartus, M. Weber

Robotische Teleskope sollen die Intelligenz eines menschlichen Beobachters vollständig durch Software modellieren. Ein Schwerpunkt bildet hierbei die richtige Reihenfolge der Beobachtung potenzieller Objekte. Die Mehrzahl aller weltweit betriebenen robotischen Teleskope verwendet hierfür einen als dispatch-scheduling bekannten Algorithmus, bei dem die Auswahl der Beobachtungen in situ unter Berücksichtigung der aktuellen Wetterlage erfolgt.

Dispatch scheduling implements target selection as a validation of a merit function $m(t)$:

$$m(t) = \Pi_i \, v_i \, s_i \;\; \Sigma_j \, w_j \, g_j(t)$$

Each time a target has to be selected, the individual merits of all targets within the observing pool are evaluated and the target with the highest $m(t)$ is picked. Reaction to changes in environmental conditions are algorithm-inherent, but care has to be taken if a scientific program consists of more than a single observation. In this case, dispatch scheduling tends to start different scientific programs without ever finishing any.

A way to overcome this difficulty is shown in Fig.1 for the case of phase-critical observations of a Doppler-imaging target. What one wants are observations spaced equally in terms of the rotational period of the star. Additionally, the observations can only be used if no more than a few rotations of the star occur before all individual observations have been finished. This goal is accomplished by starting with a high-frequency oscillatory function $g_j(t)$ (Fig. 1, green) and than overlaying a slowly-varying $s_i(t)$ (Fig. 1, blue) that increases the merit of the target once observation has started, but pushes it to zero once the beneficial period has passed.

The success of such an approach crucially depends on a proper choice of weights v_i, w_j to the merits. Their values can only be assigned by evaluating simulated schedules, as in Fig. 2.

Fig. 2 shows a simplified schedule, tailored to a single Doppler-imaging target, HD 82286, spanning three weeks close to opposition of the star. One can immediately see that even under perfect weather conditions it takes ten to eleven days to finish the scientific program, despite a rotational period of only 3.21d of this star. Applying random bad weather phases makes it even worse. Now 15 to 16 days are needed, an increase of 50%, though the bad weather periods were confined to only 25% of the total time. Conclusion: even highly tuned dispatch scheduling should be overseen from time to time by a human operator.

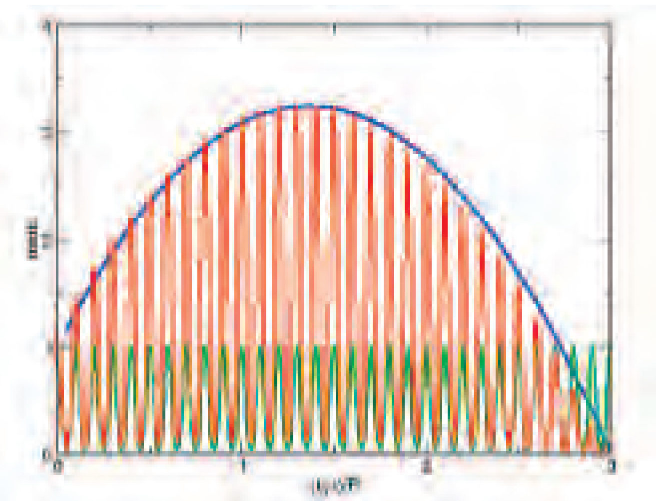


Fig. 1: The merit function of a Doppler-imaging target as a function of time. The phase-critical pick-times (green) are overlaid with a slowly-varying function (blue) to yield the total merit, shown in red.

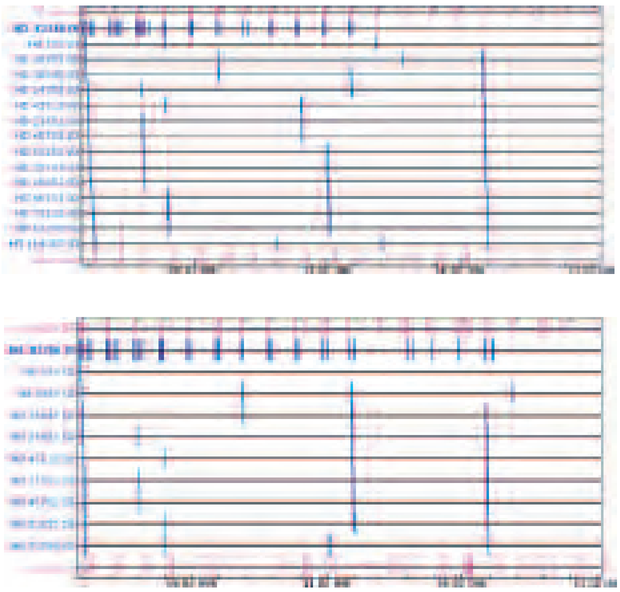
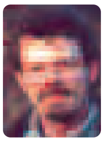
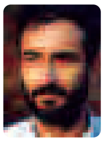


Fig. 2: Comparison of a simulated schedule without bad weather periods (top panel) and with a 25% chance of bad weather (bottom panel). The program completion time grows by 50%.

Die AGW Einheit für das Large Binocular Telescope (LBT)
The AGW units for the Large Binocular Telescope (LBT)

J. Storm, E. Popow

Der Beitrag des AIP als Partner des LBT Konsortiums ist der Bau der so genannten Erfassungs-, Nachführungs- und Wellenfrontsensoreinheit (AGW). Diese beinhaltet Optik, Mechanik, Elektronik und Kontrollsoftware.

Die AGW-Einheit ist integraler Bestandteil des Teleskops und unterstützt mehrere wissenschaftliche Geräte. Die AGW enthält eine Nachführungskamera und eine Wellenfrontsensorkamera. Mit der Nachführungskamera wird ein Stern (Referenzstern) in der Nähe des zu beobachtenden Objektes eingestellt. Je nachdem wie sich dieser Stern auf dem Detektor geringfügig durch die Ungenauigkeit der Nachführung des Teleskops verschiebt, wird sofort ein Signal zur Korrektur dieser Abweichung an das Teleskop gesendet. Dadurch wird eine hohe Stabilität des Bildes auf dem Instrument erreicht.

Andererseits benutzt die Wellenfrontsensorkamera den roten Teil des Lichtes des Referenzsterns, um die Form und Ausrichtung des Hauptspiegels des Teleskops zu analysieren. Eine Abweichung von der besten möglichen Einstellung wird sofort korrigiert, um ein möglichst scharfes Bild zu erhalten. Der Wellenfrontsensor benutzt ein sehr kleines Linsenraster.

Jede der Linsen ist nur 1/10 mm Groß und wurde von der Firma SMOS Micro-Optics in einem Ionen-Austauschprozess hergestellt. Das Linsenraster ist auf dem Bild zu sehen.

Das Linsenraster produziert ein Raster von Einzelbildern des Referenzsterns wie in Fig. 1 zu sehen ist.

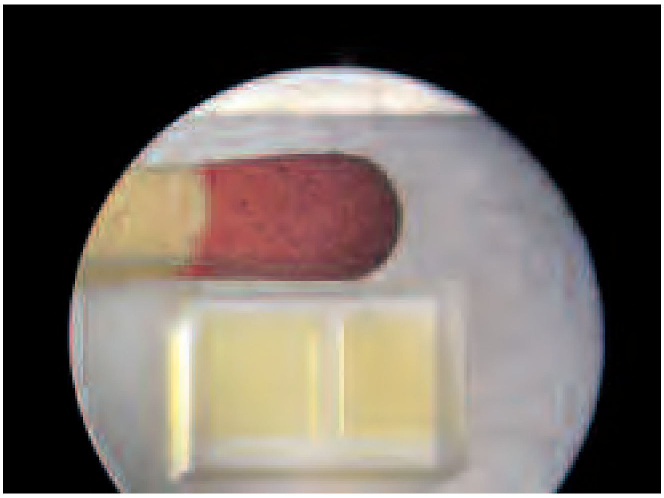


Fig. 1 Zwei Linsenraster verschiedener Linsengrößen auf einem Substrat neben einem Streichholz; die Qualität jeder Linse liegt an der optischen Auflösungsgrenze

Jeder Bildpunkt korrespondiert mit einem Bereich des Hauptspiegels des Teleskops. Wenn sich das Bild der Punkte von dem kalibrierten Bild der Punkte unterscheidet, heißt das, dass sich der dazugehörende Bereich des Spiegels nicht mehr in der besten Position befindet. Das System bestimmt dann die Korrektur der Oberfläche, die notwendig ist. Diese Korrektur übernehmen 158 Aktuatoren, die sich auf der Rückseite des Hauptspiegels befinden.

2005 absolvierte die erste AGW Einheit den Abnahmetest unter realistischen Bedingungen. Dies bedeutet Arbeitstemperaturen der Einheit bis -20 Grad C, die in der großen Kühlkammer des Institutes realisiert wurden. Ebenso wurden Verbiegungstests am Teleskopsimulator mit einem Zusatzgewicht von 2 Tonnen durchgeführt, die ein wissenschaftliches Instrument simulieren, das später an die Einheit angebaut werden wird.

The AGW units for the Large Binocular Telescope (LBT)

As a partner in the LBT consortium (LBTC), the AIP is contributing to the construction of the telescope by building the so-called Acquisition, Guiding, and Wavefront sensing units (AGW units), including optics, mechanics, electronics and control software.

The AGW units are an integral part of the telescope and will support several of the science instruments. The AIP part consists of a guide camera, and a wavefront sensing camera.

The guide camera will observe a so-called ``guide'' star close to the field observed by the science instrument. If this star moves ever so slightly on the detector due to inaccuracies in the tracking system, signals will immediately be sent to the telescope to compensate the movement. In this way

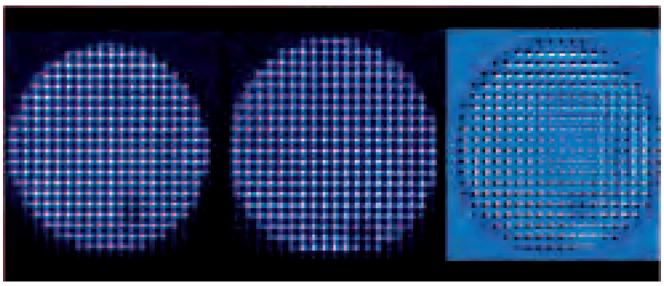


Fig. 2 Drei Bilder des Wellenfrontsensors. Im linken ist das Kalibrationsbild oder Referenzbild zu sehen. Das mittlere ist aus dem Fokus raus, so dass die Position des Sternbildes bezüglich des ersten Bildes verschoben ist. Das rechte Bild ist die Differenz zwischen beiden Bildern und zeigt den Versatz der einzelnen Bilder durch die Fokusänderung

the celestial target on the science instrument will be kept at the proper position with a very high degree of accuracy.

The wavefront sensor, on the other hand, will use the red part of the light from the guide star to analyze the shape and alignment of the main mirrors of the telescope. Any deviations from the best possible alignment and shape will immediately be corrected, thus ensuring the sharpest possible images.

The wavefront sensor uses a tiny lenslet array to split the light from different parts of the main mirror into separate images. The lenslet array is shown in Fig. 1. Each of the lenses is only a tenth of a mm wide and has been produced by the company SMOS micro-optics using a special ion-exchange process.

The lenslet array produces an array of images of the guide star as shown in Fig. 2. Each image corresponds to a certain position on the main mirror of the telescope, and if the image has moved with respect to a calibration image, it means that the corresponding part of the mirror is no longer in the best possible configuration. The system will determine the corrections to the mirror shape which are necessary and then change the shape of the main mirror through the use of 158 actuators on its back side.

Fig. 3 Die AGW Einheit am Teleskopsimulator mit dem 2 t Gewicht

In 2005 the first AGW unit passed the laboratory acceptance test after having been thoroughly tested under realistic conditions. The tests included operation at -20°C in our big refrigerator, as well as flexure tests in our telescope simulator where the unit was loaded with two ton weights to simulate the mass of the scientific instrument.

The AGW team

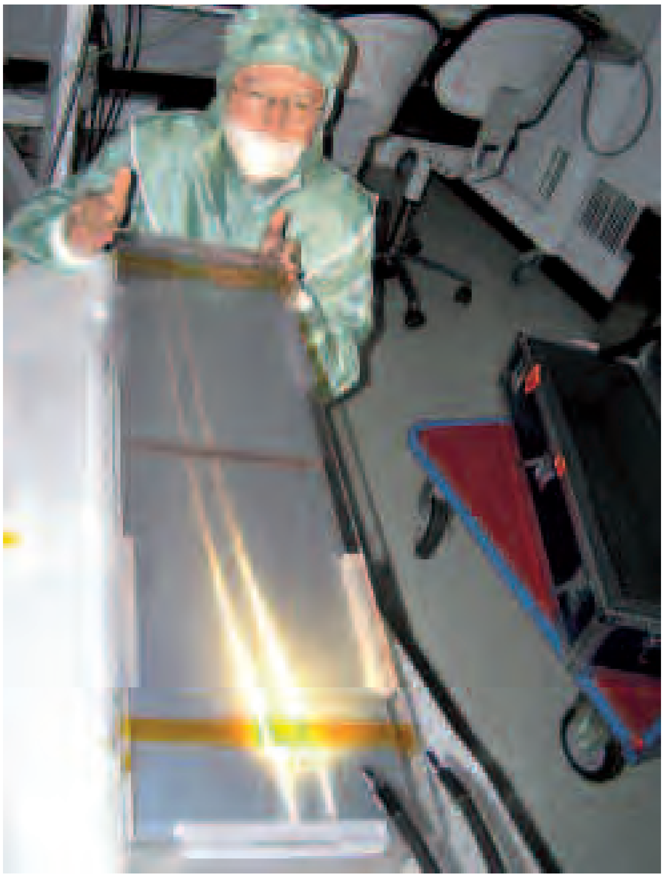
Jesper Storm (Project Manager),
Matthias Steinmetz (Member of the board of Directors),
Klaus Strassmeier (LBT project oversight),
Svend Marian Bauer (Mechanics Engineer),
Frank Dionies (Mechanics Engineer),
Thomas Fechner (Electronics engineer),
Ulfert Hanschur (Project Technician),
Felix Krämer (Software engineer),
Emil Popow (Project Engineer),
Dieter Wolter (Electronics Engineer),
Hans Zinnecker (Project Scientist)

Fig. 4 Die AGW Einheit bei der Justage der Optik

PEPSI: Das Potsdam Echelle Polarimetric and Spectroscopic Instrument

K. G. Strassmeier, M. I. Andersen, M. Woche, A. Hofmann, I. Ilyin

PEPSI ist ein hochauflösender Echelle-Spektrograf mit Polarimeter für das LBT. Je ein Polarimeter für jedes der beiden Teleskope liefert polarisiertes Licht für alle vier Stokes-Vektoren an einen gemeinsamen Echelle-Spektrografen. PEPSI soll in mindestens zwei Bereichen weltweit einzigartige neue Beobachtungen ermöglichen: Erstens, als einziges Stokes-Polarimeter hoher spektraler Auflösung an einem Großteleskop können kosmische Magnetfelder mit Hilfe des Zeeman-Effektes bis zu einer Helligkeit von V=17mag kartografiert sowie, zweitens, mit seinem adaptiven Modus im Integrallicht eine ultra-hohe spektrale Auflösung von 300000 wie sonst nur in der Sonnenphysik möglich, erreicht werden. Die Verwendung von innovativen optischen und elektronischen Komponenten (z.B. „Volume Phase Holographic Gratings" bzw. „Waveguide Image Slicers") wird es erlauben Quellen bis zu V=20mag bei R=120 000, 0.7 seeing, mit einem S/N von 10:1 bei einer Integrationszeit von einer Stunde zu beobachten.



Das 80x20cm R4 Echelle Gitter während Tests im AIP Reinraum

PEPSI is a high-resolution echelle spectrograph with two polarimeters for the LBT. It is a stabilized bench-mounted, white-pupil spectrograph with a blue and a red arm and provides a wavelength coverage from 390nm-1050nm in three exposures. Three different fibers and image slicers can be used to achieve resolutions of 40 000, 120 000 and 300 000. One polarimeter in each of the straight-through Gregorian foci selects polarized radiation in one or two of the four Stokes parameters and sends it to the spectrograph. The use of innovative optical and electronic components, e.g. volume phase holographic gratings and waveguide image slicers will allow a limiting magnitude of V=20mag with R=120,000 and a S/N of 10:1 with an integration time of 1 hour in a seeing of 0.7".

Scientific goals

Magnetic fields on the surfaces of stars like our Sun are generated by a dynamo process deep in the innermost parts of their convection zone. This insight comes from the latest helioseismological surveys, showing that possibly only a thin layer underneath the convection zone harbours this dynamo mechanism. This is an area where on the one hand magnetic flux tubes are allowed to dwell long enough to achieve the measured field strengths, and on the other hand sufficient turbulence is present to let the dynamo work. If these flux tubes are exposed to buoyancy they later become visible on the surface as bipolar sun- or starspots, respectively, i.e. a sort of dynamo fingerprint.

In the solar case the relative sunspot number determines the space weather in our planetary system, induces electromagnetic phenomena in the Earth's atmosphere, causes certain layers in the atmosphere to swell, and regulates the ocean temperature budget up to the point of tree growth.

By studying magnetic fields of other stars we hope to achieve further knowledge about our own Sun, how it was formed and how it will die, as well as what role our planetary system played and will play in that.

Arrival and integration of the first spectrograph components

2004 saw the arrival of the first critical components of the instrument. The design phase of the instrument as a whole is finished. A few component groups, like the permanent focal units or the calibration unit, are still in the detailed design phase, partly in collaboration with the suppliers, since they depend on availability of special glass and so on. Further critical components like the two cameras, the collimator

Wissenschaftliche Zielsetzung

Magnetfelder an der Oberfläche von Sternen wie unserer Sonne werden tief im Inneren ihrer Konvektionszone von einem Dynamoprozess erzeugt. Die Basis dieser Erkenntnis stellen neueste helioseismologische Untersuchungen dar, die zeigen, dass womöglich nur eine dünne Schicht unterhalb der Konvektionszone diesen Dynamomechanismus beherbergt. Es ist dies eine Zone, wo magnetische Flußröhren einerseits lang genug verweilen können, um die gemessenen Feldstärken zu erlangen, sowie genug Turbulenz vorhanden ist, um den Dynamo überhaupt funktionieren zu lassen. Erfahren diese Flußröhren einen Auftrieb, sind sie später an der Oberfläche als bipolare Sonnen- bzw. Sternflecken sichtbar, also eine Art Fingerabdruck des Dynamos.

Bei der Sonne bestimmt diese relative Fleckenzahl u.a. das Weltraumwetter in unserem Planetensystem, erzeugt elektromagnetische Erscheinungen in der Erdatmosphäre, lässt bestimmte Schichten in der Erdatmosphäre aufblähen und reguliert den Temperaturhaushalt der Meere bis hin zum Wachstum unserer Bäume.

Durch das Studium von Magnetfeldern anderer Sterne erhoffen wir uns weitere Erkenntnisse über unsere eigene Sonne, wie sie entstanden ist, wie sie sterben wird und welche Rolle dabei unser Planetensystem spielte und noch spielen wird.

Ankunft und Integration erster Baukomponenten des Spektrografen

2004 sah die Ankunft erster kritischer Baukomponenten des Instruments. Die Designphase des Instrumentes als Ganzes ist abgeschlossen. Einzelne Baugruppen wie z.B. die permanenten Fokaleinheiten oder die Kalibrationseinheit sind nach wie vor noch im Stadium des Detaildesigns, zum Teil gemeinsam mit den Lieferfirmen, da die Finalisierung von der Verfügbarkeit spezieller Gläser o.ä. abhängt. Weitere kritische Baukomponenten wie die beiden Kameras, die Kollimatoroptik oder die Kreuzdispergierer sind entweder bestellt bzw. Anfang 2006 kurz vor der Bestellung. Das Kernstück des Spektrografen, das R4-Echelle-Gitter, wurde von C3-Analysentechnik nach 14 Monaten Bauzeit im Juni 2004 geliefert. Das Testergebnis übertraf unsere Spezifikationen bzgl. Auflösung um beinahe 50%, das Gitter liefert eine Wellenfront entsprechend $\lambda/\Delta\lambda \approx 1{,}25$ Millionen! Die mechanische Halterung des Gitters wurde in Brandenburg nach unserem Design gefertigt und mittlerweile ebenfalls geliefert. Die kinematische Aufhängung mit Hilfe von Invar-Platten und Gegengewichten ist derzeit noch im Bau.

optics, or the cross-disperser have either been ordered or are about to be ordered as of early 2006. The core of the spectrograph, the R4 echelle grating, was delivered by C3-Analysentechnik after 14 months of construction in June 2004. Resolution test results exceeded our specifications by almost 50%; the grating provides a wavefront corresponding to $\lambda/\Delta\lambda \approx 1.25$ million! The mechanical housing for the grating was manufactured in Brandenburg following our design and has also been delivered. The kinematic mount based on Invar pads and counterweights is at present still under construction.

The collimator optical design (three spherical mirrors, three Maksutov correctors, the field lens, as well as two dichroics) was optimized and made ready for production together with the French manufacturer from March to December 2004, and is expected in January 2006. Camera optical details could not be finalized in 2004 due to uncertainty in the collimator production. A R&D assignment rendered an alternative design for the 'red' camera. Both camera systems are being built by FISPA in Switzerland at the time of writing. The high-precision mechanical housings for the collimator optics have already been finished in the AIP workshop.

The polarimeter: still being tested

The optical core of the polarimeter, the combined $\lambda/4$ retarder, was already seen as completed when an asymmetric alteration of both outer double refraction layers was detected in November 2004. This was repaired by the manufacturing company Berliner-Glas. However, laboratory tests at the Einstein Tower detected retardation effects which are no longer reversible and still not understood.

The ASTROPRIBOR Plastic Retarder used in the GREGOR polarimetric calibration was adopted for PEPSI purposes and tested as alternative. It yielded partly better results than the combined retarder.

The AGW units for PEPSI

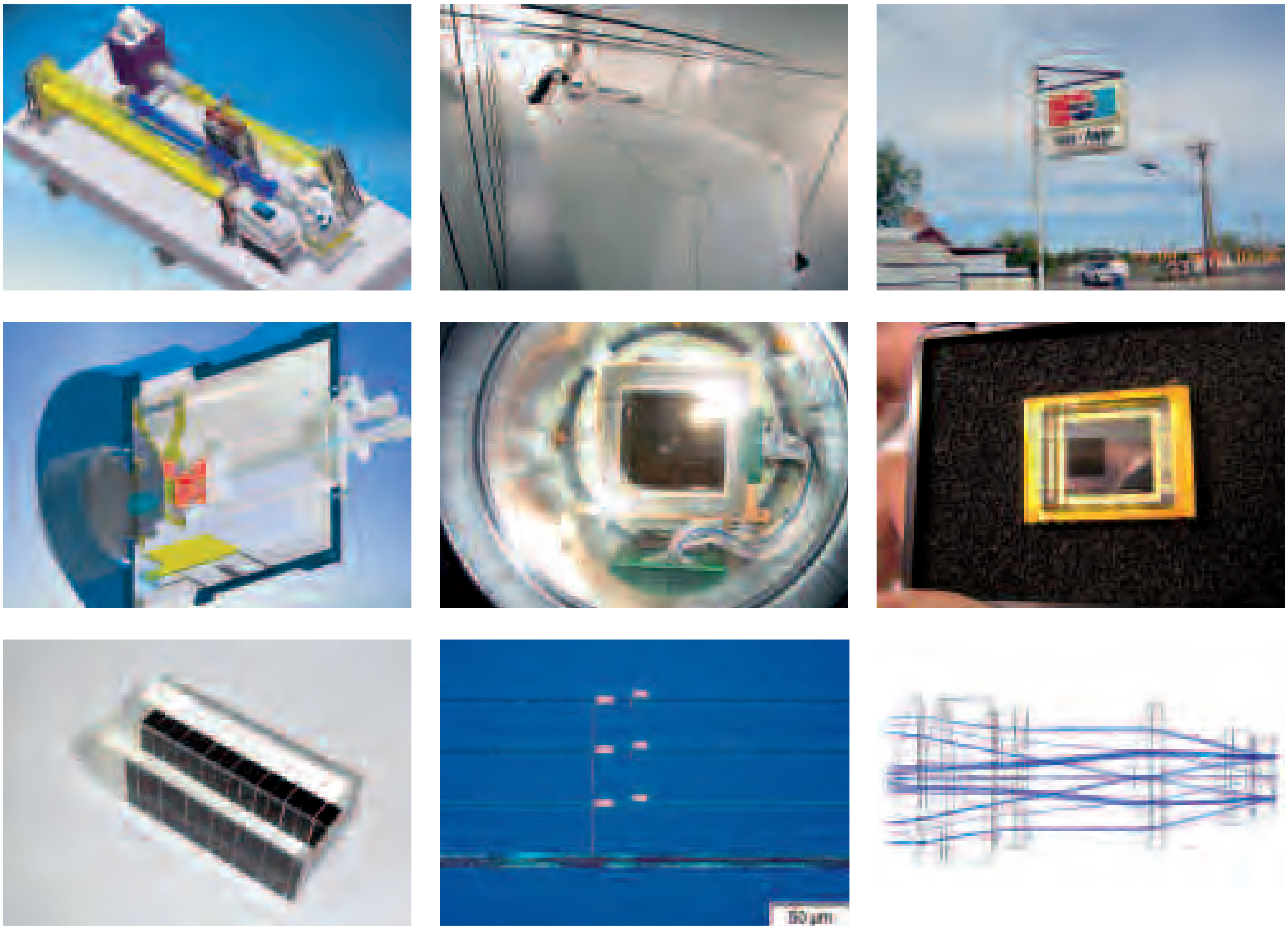
The off-axis AGW mechanics has been delivered, and the electronics has been finished at the AIP. Both have been tested at -15 degrees Celsius in the cold room and found satisfactorily functional. The 10 CCD guider cameras including interfaces for the PEPSI AGWs were ordered from Prof. M. Lesser at the University of Arizona Imaging Technology Lab, and not produced at the AIP itself, following a detailed price comparison. The required 10 guiding CCDs were ordered from E2V and delivered in March 2005. Four of these CCDs are now being furnished with the Shack-Hartmann Sensors

Das optische Design des Kollimators (drei sphärische Spiegel, drei Maksutov-Korrektoren, die Feldlinse, sowie zwei Dichroide) wurde in der Zeit von März bis Dezember 2004 gemeinsam mit dem Hersteller in Frankreich zur Produktionsreife optimiert und wird im Januar 2006 erwartet. Optische Details der beiden Kameras konnten wegen der Unsicherheit der Kollimatorproduktion 2004 noch nicht finalisiert werden. Ein F&E-Auftrag erbrachte ein Alternativdesign für die „rote“ Kamera. Beide Kamerasysteme werden momentan bei FISPA in der Schweiz produziert. Die hochpräzisen mechanischen Halterungen der Kollimatoroptik sind bereits in der AIP Werkstatt gefertigt.

and built into four of the 10 AGW cameras. For immersion of the atmospheric dispersion corrector (ADC) as well as the beam splitter in front of the fibre entrance to the AGWs, dichroics (6 per unit) have been ordered, and the glass was delivered late 2004.

First spectrograph pressure chamber tests

The last major parts of the spectrograph chamber have been delivered and assembled in the AIP integration hall. Pressure and temperature tests of the entire chamber (9 m by 4 m by 3.5 m) revealed that the chamber door delivered by Branco was not airtight. It was replaced by an in-house construction.



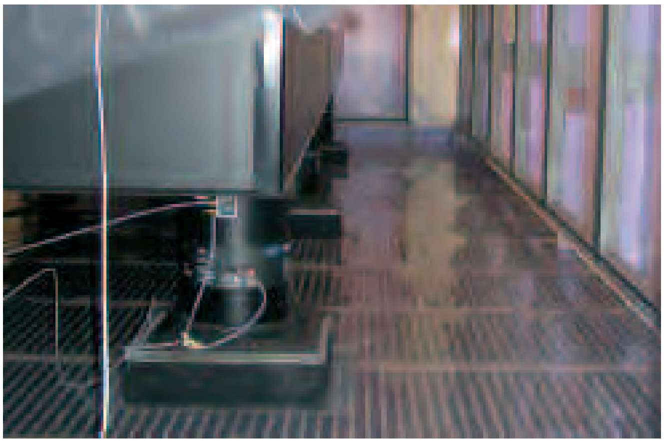
Oben links nach rechts unten: Optomechanisches Design des Spektrografen; Spektrografengehäuse in der PEPSI-Druckkammer; die PEPSI „Hide-Away Lounge“ am Fuße des Mt. Graham in Safford, U.S.A.; Design des CCD Dewars; erster CCD chip während der Tests; der AGW „frame-transfer“ CCD von E2V für die PEPSI Einheiten; Prototyp des 7-fach „image slicers“; Schnitt durch die „waveguides“ eines der PEPSI image slicers; optisches Design einer der beiden Spektrografenkameras.

Das Polarimeter: noch in der Testphase

Das optische Kernelement des Polarimeters, der kombinierte $\lambda/4$-Retarder, war bereits als abgeschlossen betrachtet, als im November 2004 eine asymmetrische Veränderung der beiden äußeren Doppelbrechungsschichten entdeckt wurde. Dies wurde mittlerweile von der Herstellerfirma Berliner-Glas repariert, doch zeigten sich bei Labortests am Einsteinturm nunmehr irreversible Retardationseffekte, die noch immer unverstanden sind. Als Alternative wurde nunmehr der ASTRO-PRIBOR Plastik-Retarder der GREGOR-Polarimeterkalibration für PEPSI Zwecke adaptiert und getestet und lieferte zum Teil bessere Ergebnisse als der kombinierte Retarder.

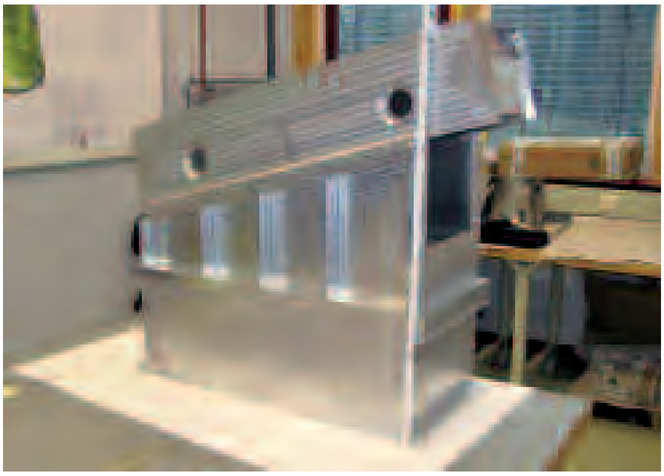
A Mpx/s CCD controller

The CCD camera design of both scientific cameras is finished, and the first one is being constructed at the AIP. The detector head for the 64 mm 4k by 4k detectors is an all-AIP new development. The chip is cooled to -160 degrees Celsius in the cryogenic Dewar by a closed cooling circuit. The CCD controller, as well as other mechanical and electronic components, are in the finishing or test stages, using a Magellan design modified by T. Fechner. We expect read-out rate of over 1 Mpx/port/sec (corresponding to 4 sec read-out time with four amplifiers). The two 4096 by 4096 15-micrometre pixels 4-phase CCDs were delivered from the University of Arizona Imaging Technology Lab late December 2004 (follo-



Die Heizung der PEPSI-Druckkammer, im Vordergrund der optische Tisch

Mechanische Komponenten der Kollimatorspiegel in der AIP Werkstätte



Die große Gitter-Montierung

Das PEPSI Kontrollzentrum während des Aufbaus am Standort

Die AGW-Einheiten für PEPSI

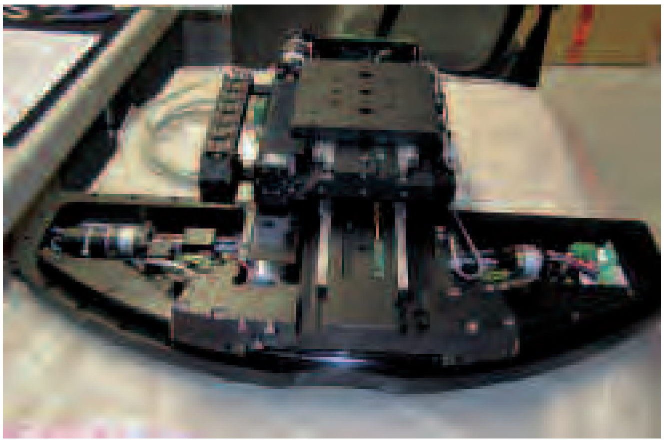
Die Off-Axis AGW-Mechanik und Elektronik wurde mittlerweile geliefert bzw. am AIP gefertigt und in der Kühlkammer zu unserer Zufriedenheit auf Funktionstüchtigkeit bei 15 Grad Celsius getestet. Nach einem detaillierten Kosten-Aufwands-Vergleich wurden die 10 CCD-'Guider'-Kameras für die PEPSI-AGWs inklusive Interfaces bei Prof. M. Lesser am Imaging Technology Lab der Univ. of Arizona bestellt, und nicht etwa am AIP selbst produziert. Die nötigen Guiding-CCDs wurden bei E2V bestellt und im März 2005 geliefert. Vier dieser CCDs werden nunmehr mit den Shack-Hartmann-Sensoren versehen und in vier der 10 AGW-Kameras eingebaut. Für die Immersion des atmosphärischen Dispersionskorrektors (ADC), sowie der Stahlteiler hin zu den AGWs in den permanenten Fokaleinheiten, wurden die Dichroide (6 pro Einheit) bestellt und die Gläser Ende 2004 geliefert.

Erste Tests der Spektrografen-Druckkammer

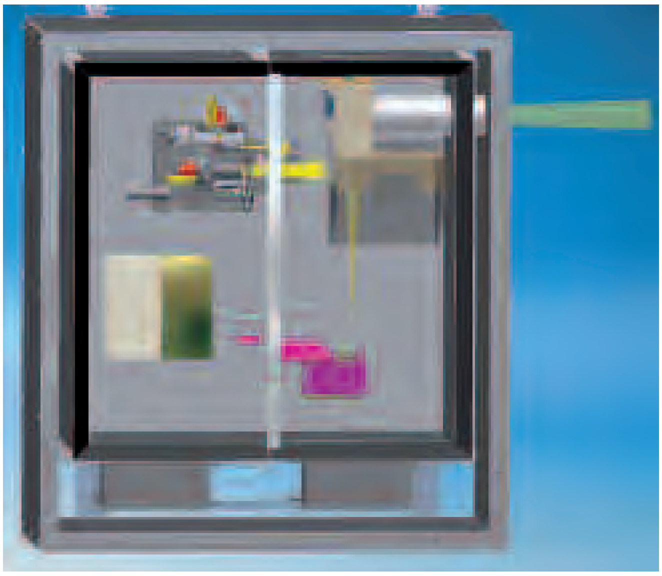
Die letzten großen Baukomponenten für das Spektrografengehäuse wurden ebenfalls geliefert und in der Montagehalle des AIP integriert. Die thermische Isolierung aus mit Aluminiumplatten geschachteltem Jakodur wurde mit Heizungsfolien untersetzt. Druck- und Temperaturtests des gesamten Gehäuses (9mx4mx3.5m) ergaben, dass die von der Firma Branco gelieferte Rauchsicherheitstüre nicht luftdicht ist und durch eine Eigenkonstruktion ersetzt werden musste.

Ein CCD-Kontroller auf Mpx/s-Basis

Das CCD-Kamera Design der beiden wissenschaftlichen Kameras ist abgeschlossen und die erste der beiden Kameras befindet sich am AIP in Bau. Der Detektorkopf für die 64mm großen 4kx4k Detektoren ist eine vollständige Neuentwicklung des AIP. Im kryogenischen Dewar wird mit einem geschlossenen Kühlkreislauf über einen extrabreiten Kältefinger aus geflochtenem Kupfer der Chip auf -160 C gekühlt. Der CCD-Kontroller als auch andere mechanische und elektronische Komponenten befinden sich ebenfalls bereits in der Fertigung bzw. im Teststadium. Dabei kommt ein von T. Fechner modifiziertes Magellan-Design zum Einsatz. Wir erwarten eine Auslesegeschwindigkeit von über 1 Mpx/port/sec (entsprechend einer Auslesezeit von 4 Sekunden bei vier Verstärkern). Die zwei 4096 x 4096 15µm-Pixel 4-Phasen CCDs wurden Ende Dezember 2004 vom Imaging Technology Lab der Universität von Arizona geliefert (nach zweijähriger Bauzeit bei STA, Silicon Valley). Beide CCDs – ein blau- und ein rot-optimiertes – haben die Spezifikationen des Ausleserauschens um einen Faktor 2 übertroffen (gemessene 3 Elektronen!) und haben eine maximale Quantenausbeute von 92.5%! Weitere CCD-Tests sind in Vorbereitung sobald die Kamera und der Kontroller



Eine der beiden AGW-Einheiten für die permanenten Foki



Ständig am LBT angeschlossene Fokaleinheit für PEPSI

wing two years of construction at STA, Silicon Valley). Both CCDs - one blue and one red optimised - exceeded read-out noise specifications by a factor 2 (3 electrons were measured!) and have maximum quantum efficiency of 92.5%! Further CCD tests are being prepared for when the camera and the controller are ready for use.

A state-of-the-art waveguide image slicer

Prototype development for a novel image slicer was carried out in collaboration with the Fraunhofer Institute for Applied Optics in Jena. Three waveguide slicers have been built and subsequently tested at the AIP. Astoundingly, all three prototypes turned out to be working at the diffraction

PEPSI AGW guider cameras

einsatzbereit sind. Die Entwicklung eines neuartigen 'Image Slicer'-Prototyps wurde gemeinsam mit dem Fraunhofer-Institut für Angewandte Optik in Jena abgeschlossen. Drei sog. 'Waveguide Slicer' wurden produziert und am AIP getestet. Dabei ergab sich das erstaunliche Resultat, dass alle drei Prototypen am Beugungslimit arbeiten (d.h. keine messbare 'focal ratio degradation' zeigen) jedoch die Planparallelität der einzelnen 'slices' noch nicht gut genug ist. Der erste wissenschaftlich-verwendbare Slicer wird in 2006 zum Einsatz im STELLA-Spektrografen erwartet. Die Einkoppelung der Glasfasern erfolgt über eine Saphirkugellinse in einem immersierenden Ölbad. Alle Glasfasern, inklusive der großen 600µm Kalibrationslichtfaser, wurden noch Ende 2003 geliefert. Der voraussichtliche Liefertermin für PEPSI in der ersten Ausbaustufe (d.h. ohne Polarimeter und nur für den Modus mit R=120000) ist nunmehr für Ende 2007 geplant, volle Wellenlängenabdeckung und die UHR-Option erst ab 2008. PI von PEPSI ist Prof. Klaus G. Strassmeier. Projektmanager ist Dr. M. I. Andersen.

Die BMBF-Verbundforschung fördert das
PEPSI Vorhaben für den Zeitraum 2002-2006.

limit (i.e. no focal ratio degradation could be measured), although the individual slices are not yet acceptably plan parallel. The first science quality slicer is expected to be put in use in the STELLA spectrograph in 2006.

The optical fibres are connected to the ball lens immersed in an oil bath. All optical fibres, including the 600-micrometre calibration fibre, were delivered late 2003.

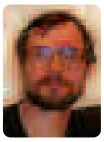
Anticipated first construction step (i.e. without polarimeter and with only R = 120000 mode) PEPSI delivery is now late 2007. Full wavelength coverage and the UHR mode are expected by 2008. The PEPSI P.I. is Prof. Klaus G. Strassmeier. The project manager is Dr. M. I. Andersen.

The PEPSI project has been supported by the
'BMBF-Verbundforschung' during 2002-2006.

The PEPSI team at AIP

K. G. Strassmeier, M. I. Andersen, M. Woche, I. Ilyin, A. Hofmann, E. Popow, F. Dionies, S.-M. Bauer, T. Fechner, D. Wolter, W. Bittner, A. Järvinen, F. Krämer and J. Storm

PEPSI data reduction and control system

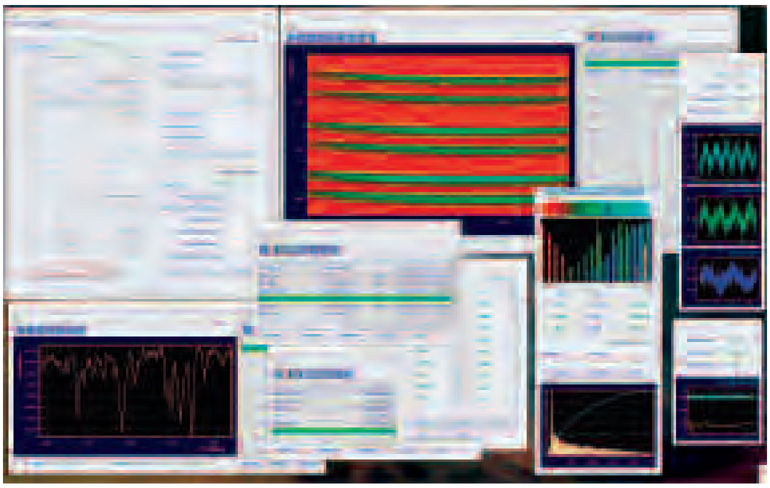


I. Ilyin

Software ist eines der Schlüsselprobleme des modernen (astro)physikalischen Instrumentenbaus. Die Steuerung der hochpräzisen mechanischen und optischen Elemente, z.B. des PEPSI Spektrografen, erfordern ein Zusammenspiel von Echtzeit-Datenverbindungen mit objektorientierten logischen Schaltkreisen und der LBT-Teleskopsteuerung. Auch die Aufbereitung (Datenreduktion) der komplexen spektralpolarimetrischen CCD Daten stellt höchste Ansprüche an die eingesetzte Software.

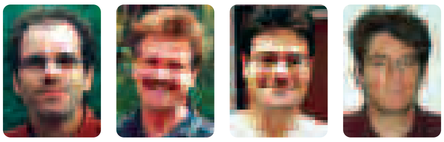
The high resolution echelle spectropolarimeter PEPSI at LBT is expected to be a major breakthrough facility to study magnetic fields in astrophysics. It will offer a number of resolving power modes. One of them is dedicated to record detailed Zeeman features in spectral lines with high relative accuracy, comparable to solar observations. In conjunction with sufficient efficiency and temporal stability, the instrument will address a number of unresolved astrophysical problems. The control software and the automatic data reduction for the instrument are in the process of careful design and development to pursue the outlined demands. Object-oriented C++ classes are used to achieve a higher and more logical integration of the upper layer of the user interface by omitting unnecessary details of its implementation. Efficiency, flexibility, and adaptivity are the major concerns of the software design for PEPSI. The user interface will provide everything necessary for efficient observations and will include the control panel of the spectrograph, which allows one to monitor and control the status information of the numerous devices of the instrument, e.g. the fiber and spectral settings selection, polarization optics configuration, as well as the CCD status and spectrograph chamber environmental information. The real-time image data display allows for quick examination and quality control of the collected exposures and incorporates a FITS image table browser to allow access to the database of observations. Information concerning instrument settings, observing targets, etc. are all stored as browseable FITS binary tables and can be easily displayed and modified. The observational schedule planned integrates the above components to facilitate the program makeup.

One other integral part of the control system is to be the interface to the LBT, which provides the target pointing, parallactic angle control for the linear polarimetry, focus adjustment, and most importantly the proper setting of the star on the entrance fiber, with the subsequent control of its best position during the exposure. This is all achieved by sending the commands to the telescope via an instrument interface layer. The integration of numerous processes and communication between them is achieved with a multi-thread approach which allows one to run several processes in parallel with no interference between them. The expected excellence in optical design and its implementation should significantly reduce the number of instrumental effects to be eliminated during data reduction of the echelle spectra. Nevertheless, the specific instrumental solutions, like obliquity of the image slicer components, will require a special treatment to calculate the intensity at every wavelength pixel. As usual, the intensity transformation during data reduction is accompanied by the error propagation of pixel intensity at every stage: the knowledge of the error bars in the resulting spectra is essential for the further quantitative analysis and proper fits to the models. Implementation of automatic data reduction requires a proper link between the scientific exposures and calibration images to be established during observations.



Control screen

Wide Field 3D Spectroscopy using PMAS



A. Kelz, M. M. Roth, S. F. Sanchez, M. Verheijen

Mit dem am AIP entwickelten Potsdamer Multi-Aperture Spektrophotometer (PMAS) und dem zusätzlich eingebauten optischen Glasfaserbündel (PPak) ist es möglich, ausgedehnte astronomische Objekte mit einem weltweit einzigartig großen Gesichtsfeld zu spektroskopieren. Dabei können in nur einer Belichtung Hunderte von Spektren, sowie Bilder gleichzeitig aufgenommen werden. Diese Feld- oder 3D-Spektroskopie genannte Technik eignet sich vor allem für komplexe Objekte, wie diffuse Nebel, Jets, Galaxien oder Haufen.

3D Spectroscopy (sometimes also called Imaging- or Integral-Field Spectroscopy) is a novel technique providing spectra for each point of a 2-dimensional image, rather than only along a traditional 1-dimensional spectrograph slit. Three dimensions, x and y on the sky and one wavelength direction, are recorded simultaneously, resulting in a 3D datacube. As all of the information is taken at the same time, 3D spectroscopy is insensitive to changes in the atmospheric conditions. Additionally, it avoids losses caused by atmospheric dispersion or pointing inaccuracies.

Since 2001, the AIP has successfully operated PMAS, the Potsdam Multi-Aperture Spectrophotometer, at the German-Spanish Calar Alto Observatory (Fig. 1, left). While PMAS covers a wide wavelength range (from the ultraviolet to the near infrared) and can record 256 spectra at the same time, its integral field-of-view as projected on the night sky was limited to 16 x 16 arc-seconds.

Driven by the `Disk Mass Project', which requires imaging spectroscopy at intermediate spectral resolution of nearly face-on spiral galaxies, a specialized fiber-bundle, called PPak (PMAS fiber Pack, Fig. 1, right), was built at the AIP and integrated into the PMAS instrument. With a field-of-view of 74 x 64 arc-seconds, PPak currently is the world's widest integral field unit (IFU) that provides a semi-contiguous regular sampling of extended astronomical objects.

As an example, to demonstrate the power of the 3D technique, the planet Jupiter was observed by AIP astronomers during a cloudy weather period. The PMAS instrument features two cryogenically cooled CCD cameras in parallel: a Spectrograph Camera, collecting up to 382 spectra simultaneously in one exposure, and an A&G Camera, which is used for faint target acquisition and guiding. The A&G Camera pro-

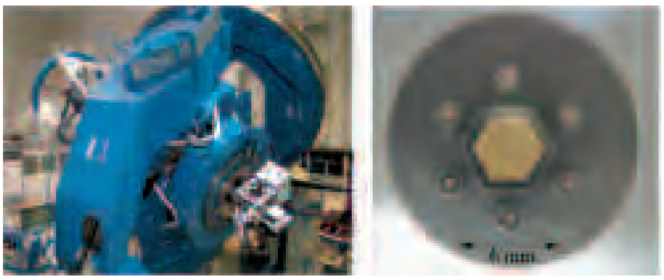


Fig. 1: Left: The PMAS instrument, attached to the Cassegrain focus of the 3.5 m telescope on Calar Alto, Spain, allows the observer to obtain images and spectra simultaneously. This is done using optical fibers that guide the light from the telescope focal plane to a high-performance spectrograph. Right: Top view onto the PPak fiber bundle. 331 densely packed fibers form the integral field unit of the central hexagonal. An additional 36 sky fibers are surrounding the central field. While the physical dimension of the array is just 6 mm, its coverage on the sky is more than 1 arc-minute.

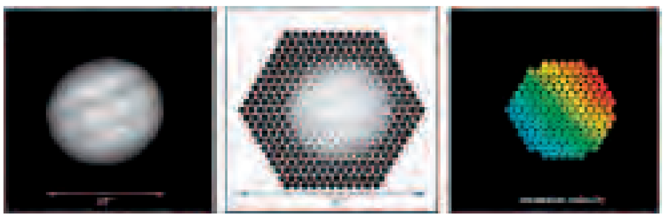


Fig. 2: Left: The picture of Jupiter was taken on March 21, 2004, using the PMAS acquisition camera with an exposure time of 0.5 sec and a narrow-band filter (central wavelength 509 nm, FWHM 10 nm). Orientation: North is up, East is left. Center: Reconstructed image of Jupiter as seen by the PPak fiber bundle. Despite the rather coarse sampling, the cloud bands of Jupiter can be seen clearly. The apparent diameter of Jupiter of 40'' at the time of the observation illustrates the wide field-of-view that is now available with PPak. Right: After the spectra have been analyzed for the Doppler-shift of a reflected solar absorption line, a velocity map of Jupiter was constructed. The rotation of the planet (blue colour for the approaching, red for the receding side) can be easily measured.

duced the direct image of Jupiter (Fig. 2, left), while the light sampled by the PPak unit (Fig. 2, center) is dispersed by the spectrograph to obtain velocities (Fig. 2, right).

The combination of fibers with large grasp and the PMAS spectrograph with high efficiency and wide wavelength coverage, makes PPak a powerful tool for the study of extended low-surface brightness objects, which require a high light collecting power and a large field-of-view. For the Disk Mass project, the galaxy UGC 463 was observed (amongst many others) to measure the vertical velocity dispersion of the stars in the faint outer disk of the galaxy. Despite the rather crude sampling of the fibers, the basic morphological structures (spiral arms, star clumps) of the galaxy seen in the POSS-II image (Fig. 3, left), are clearly visible in the PPak reconstructed image (Fig. 3, right). Apart from the ability to create mono- and polychromatic images from the resulting data, one exposure with PPak yields 331 spatially resolved spectra of the target. The high number of fibers covering the outer and fainter parts of the galaxy offers the observer the option to adaptively bin spaxels so as to increase the signal-to-noise further.

During another campaign (by Sanchez, Cardiel, Verheijen and Benitez), the rich galaxy cluster Abell 2218 was observed. The spectrograph covered a wavelength range between 469-806 nm, while the PPak bundle was dithered between 3 pointings, to fill the gaps between the fibers. From the resulting spectroscopic data, a broadband (VRI) image was reconstructed. In Fig. 4 (left panel) a 6 hour exposure taken with PPak is compared with an image taken by the Hubble Space Telescope (right panel) with a 3 hour exposure time. Despite the differences in sampling and resolution, the similarities in both images are striking, even if many galaxies are strongly blended in the PPak data. However, the real power of 3D-spectroscopy lies not in image reconstruction, but in the fact that 1000 spectra were obtained of the region, allowing detailed analyses of individual redshifts, ages and metalicities of the galaxies.

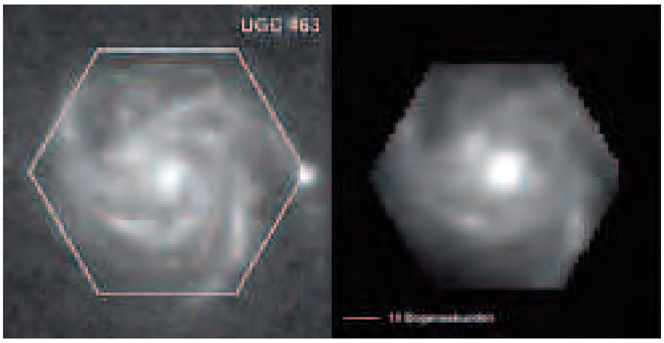


Fig. 3: Comparison between the POSS-II R-band image (left panel) and the PPak reconstructed image of the spiral galaxy UGC 463 (right panel). The PPak data was reduced and visualized using the E3D software which was developed within the Euro3D project at AIP. The 2D image was produced by co-adding the flux in the wavelength range between 450 and 600 nm and by spatially interpolating to a common grid of 1''.35/pixel.

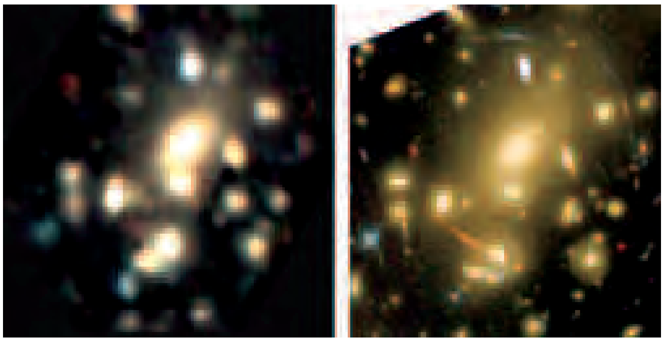
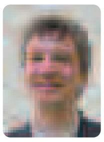
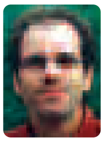


Fig. 4: Left: Three-color image (size: 1 arc-minute) of the galaxy cluster Abell 2218, created by co-adding the flux of the PPak data-cube in three broad-bands corresponding approximately to V ,R, and I, and re-scaling it to 1''/pixel.
Right: For comparison, a F850LP-band image of 3 hours exposure time taken with the HST/ACS, obtained from the HST archive.

MUSE: a powerful 3D spectrograph for the ESO-VLT

M. M. Roth, M. Steinmetz, A. Kelz

Mit einer mehr als 15 Jahre zurückreichenden Erfahrung in der Prototypenentwicklung für die neue Technik der Integralfeld-Spektroskopie haben sich Europäische Gruppen eine weltweit führende Stellung in dieser Technologie erarbeitet. ESO hat dieser Führungsrolle – und insbesondere dem Potenzial dieser neuen Technik – durch die Entscheidung Rechnung getragen, einen extrem leistungsfähigen 3D Spektrografen für die zweite Instrumentengeneration am VLT entwickeln zu lassen: MUSE, den "Multi Unit Spectroscopic Explorer". Die Inbetriebnahme soll im Jahre 2012 erfolgen.

Aufbauend auf seiner Erfahrung im Bau von 3D Instrumentierungen (PMAS am Calar Alto) sowie seiner wissenschaftlichen Nutzung (Euro3D Netzwerk) nimmt das AIP als einer von 7 Partnern in einem internationalen Konsortium unter der Federführung von CRAL (Lyon) an der Entwicklung von MUSE teil.

Das Vorhaben befindet sich gegenwärtig in der Design-Phase, die Preliminary Design Review ist für Anfang 2007 geplant. Nach seiner Fertigstellung wird mit MUSE ein außergewöhnlich leistungsfähiger Integralfeld-Spektrograf zur Verfügung stehen, der durch eine neue adaptive Optik des VLT unterstützt wird. Mit jeder Belichtung wird MUSE einen dreidimensionalen Datenkubus erzeugen, der aus insgesamt 90000 Spektren mit einem spektralen Auflösungsvermögen von R=3000 besteht, von denen jedes ein Wellenlängenintervall von 465-930 nm überdeckt. Im Normalmodus wird ein Gesichtsfeld von 1x1 $arcmin^2$ mit einer Rate von 0,2 arcsec pro Auflösungselement ("spaxel") abgetastet. Im hochauflösenden Modus wird die Abtastrate noch auf 0,025 arcsec/spaxel gesteigert, so dass mit MUSE beugungsbegrenzte Aufnahme gemacht werden können.

Der Aufbau von MUSE beruht auf 24 identischen Spektrografen, die, jeder für sich genommen, einem vollständigen VLT-Instrument der ersten Generation entsprechen. Die Spektrografen besitzen jeweils einen Präzisions-Imageslicer, mithilfe dessen die bildgebende Eigenschaft des Instruments realisiert wird. Die optisch-mechanische Stabilität ist extrem hoch, unter anderem wegen der konsequenten Vermeidung beweglicher Baugruppen. Diese Eigenschaft wird es erlauben, ein große Zahl von Einzelaufnahmen, d.h. das Äquivalent einer außergewöhnlich tiefen Belichtung, aufzusummieren. In Verbindung mit einer sehr hohen Effizienz wird MUSE eine extrem hohe Empfindlichkeit besitzen, die es erlaubt, die schwächsten Objekte zu spektroskopieren.

Aufgrund seiner innovativen Eigenschaften ist zu erwar-

With more than 15 years of experience of prototyping the novel observing technique of integral field (3D) spectroscopy, European groups have become the world-wide leading experts in this area of technology. In recognizing both this leadership and the enormous potential of 3D spectroscopy, ESO has decided to pursue the development of a powerful 3D instrument as a 2nd Generation VLT instrument, to be installed at Paranal in 2012: MUSE, the "Multi Unit Spectroscopic Explorer".

Building on its expertise in the development of 3D instrumentation (PMAS at Calar Alto) and its scientific use (the Euro3D network), the AIP is participating in the development of MUSE as one of 7 participants in an international consortium, led by CRAL in Lyon.

The project is presently in its design phase, with the preliminary design review scheduled for early 2007. When finished, MUSE will be an extraordinarily powerful integral field spectrograph, fed by a new adaptive optics system on the VLT. In any single observation, MUSE will produce a 3-dimensional data cube consisting of 90000 spectra with a spectral resolving power of R=3000, each covering the wavelength range of 465-930 nm, and fully sampling a contiguous 1x1 $arcmin^2$ field-of-view with a spatial sampling of 0.2 arcsec. A high-resolution mode will increase the spatial sampling to 0.025 arcsec per spatial element (''spaxel''). MUSE is built around a novel arrangement of 24 identical spectrographs, each comparable to a 1st generation VLT instrument, which are fed by a set of 24 precision image slicers. MUSE is designed for extreme stability, with no moving parts, allowing very long exposures to be accumulated. Together with high throughput, this ensures that MUSE will have an extremely high sensitivity, suitable for the observation of the faintest objects.

Based on its innovative capabilities, MUSE will have a major impact on a broad range of astrophysical problems, from studies of the most distant Universe to observations within the Solar System. MUSE is uniquely well suited to the study of faint galaxies in the early Universe, and will be able to detect the small progenitors of the Milky Way galaxy at high redshift, thus providing a map of the mass assembly of galaxies at early epochs. It will also give new insights into the physical processes operating within young galaxies, and into the feedback mechanisms that control their development. In the nearby Universe, MUSE will enable studies of the complex environments in galaxies with unprecedented detail, including those in star-forming regions and around the central black holes, sharpening our observational picture of the co-evolution of stars and black holes.

ten, dass MUSE für einer Vielzahl von astrophysikalischen Problemen einen wesentlichen Fortschritt erbringen wird, die vom weit entfernten Kosmos bis hin zum Sonnensystem reichen. MUSE ist gut gerüstet, die schwachen Galaxien im frühen Universum zu studieren, und wird in der Lage sein, die kleinen Vorgängergalaxien der Milchstraße bei hohen Rotverschiebungen zu finden. Damit wird es möglich sein, den typischen Massenaufbau von Galaxien in frühen Epochen des Universums zu verstehen. Die Beobachtungen werden ferner Einblick in die physikalischen Prozesse in jungen Galaxien verschaffen, sowie in die Rückkopplungsmechanismen, die einen Einfluss auf ihre Entwicklung haben. Im nahen Universum wird es MUSE ermöglichen, die komplexen Regionen in Galaxien mit noch nie dagewesener Detailfülle zu spektroskopieren, z.B. in Sternentstehungsgebieten oder in der Umgebung von schwarzen Löchern, um damit Aufschluss über die gleichzeitige Entwicklung des Schwarzen Lochs und der Sternpopulation in seiner Nachbarschaft zu gewinnen.

Neue Techniken der digitalen Bildverarbeitung werden es ermöglichen, Algorithmen einzusetzen, die in ähnlicher Weise seit langer Zeit schon erfolgreich in der CCD Photometrie Verwendung finden, um damit Spektroskopie in dicht bevölkerten Sternregionen zu ermöglichen ("Crowded-field 3D Spectroscopy"). Innerhalb unserer Milchstraße wird man mit MUSE zu einem neuen Verständnis von protostellaren Objekten kommen, von stellaren Populationen in dicht bevölkerten Feldern, z.B. im Bulge der Milchstraße, oder in Sternhaufen. Mit einer engen Beziehung zum zukünftigen Weltraum- Observatorium GAIA, oder zum gegenwärtig laufenden RAVE Survey (Federführung am AIP), wird diese Fähigkeit neue Wege zur massiven Spektroskopie in dichten Sternfeldern eröffnen – ein Ziel, das mit konventionellen Technologien unerreichbar wäre. Schließlich wird MUSE auch die Überwachung von Körpern des Sonnensystems erlauben, und zwar mit hoher spektraler Auflösung über ausgedehnte Zeiträume hinweg.

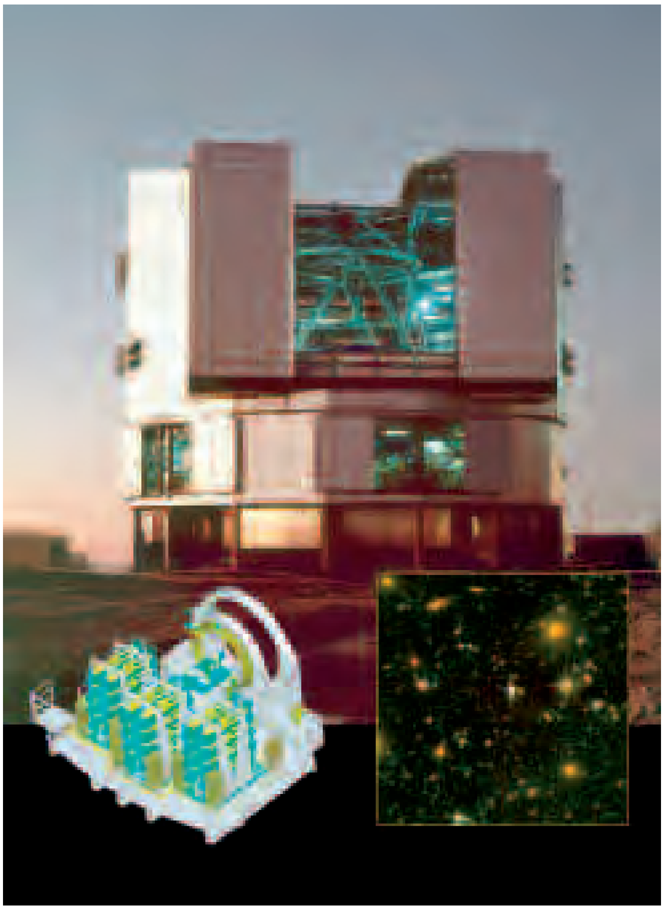
Im Rahmen des MUSE Konsortium hat das AIP die Verantwortung für die Entwicklung der Datenredutionssoftware und der Kalibriereinheit übernommen, sowie für die Vorbereitung und Durchführung eines ausführlichen Testprogramms für die Abnahme der 24 vormontierten IFU/Detektor-Baugruppen.

The MUSE team at AIP

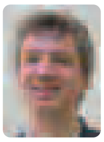
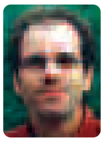
M. M. Roth, M. Steinmetz, A. Kelz, P. Weilbacher, J. Gerssen, S.-M. Bauer, P. Böhm, T. Hahn, E. Popow

New image processing techniques will allow one to employ similar algorithms to the ones which are used very successfully for CCD photometry, and perform what is presently being introduced as "Crowded-field 3D Spectroscopy". Within our own Galaxy, MUSE will produce new understanding of proto-stellar objects, star-formation, and stellar populations in crowded fields, e.g. the galactic bulge, or in densely populated star clusters. With strong links to the future GAIA observatory and the presently conducted RAVE survey (PI: AIP), this capability will offer new avenues for massive stellar spectroscopy in crowded fields, which would otherwise be impossible to achieve with conventional techniques. Finally, MUSE will allow synoptic monitoring of solar system bodies at high resolution over extended periods of time.

The AIP responsibilities within the MUSE Consortium are focused on the development of the data reduction software, of the Calibration Unit, and the preparation and execution of an extensive test programme for the acceptance tests of the 24 preassembled IFU/Detector subsystems.



VIRUS – Measuring dark energy in the universe

M. M. Roth, M. Steinmetz, A. Kelz

Als eine der vielleicht aufregendsten Entdeckungen der aktuellen Forschung kann gelten, dass sich im Ergebnis verschiedener voneinander unabhängiger Experimente erwiesen hat, dass die Energiebilanz des Universums von einer Vakuumenergie, einer mysteriösen "Dark Energy", dominiert wird. Unter mehreren konkurrierenden Gruppen weltweit, die an Messungen zur Einschränkung der Eigenschaften von Dark Energy arbeiten, verfolgt ein Team in Austin, Texas, ein besonders ehrgeiziges Vorhaben, das HETDEX Experiment. Mit seiner Expertise in der Entwicklung von faseroptischen IFUs wurde das AIP zur Mitwirkung an der Entwicklung des VIRUS 3D Spektrografen für das 9,2m Hobby Eberly Telescope, Texas, eingeladen, mit dem der HETDEX Survey durchgeführt werden soll.

Die fundamentale Beobachtungsgröße zur Einschränkung der Eigenschaften von Dunkler Energie sind die sog. "baryonischen Oszillationen", die im Baryonen-Photonen-Plasma kurz nach dem Big Bang entstanden sind, und deren Signatur auch heute noch in der großräumigen Verteilung von Galaxien sichtbar wird. Diese Oszillationen können im Fourierspektrum der räumlichen Verteilungsfunktion einer (sehr) großen Anzahl von Galaxien gemessen werden, deren Entfernung von uns sehr genau aus ihrer Rotverschiebung ermittelt werden kann. Die HETDEX Durchmusterung wird ein Gebiet mit einer Größe von 200 Quadratgrad über das Rotverschiebungsintervall $1{,}8 < z < 3{,}7$ abdecken, was zusammen einem Gesamtvolumen von 5.2 Gpc^3 entspricht. Dieses Volumen ist 10fach größer als das im SLOAN-Survey erfasste. Ein herausragendes Merkmal von HETDEX wird sein, dass die baryonischen Oszillationen in 3 Dimensionen gemessen werden – nicht nur, wie sonst, in z-Richtung. Dieses Ziel lässt sich nur durch eine quasi-kontinuierliche räumliche Abtastung realisieren, was letztlich eine enorm große Integral Field Unit (IFU) erforderlich macht.

Im gegenwärtigen konzeptionellen Design besteht die VIRUS IFU aus 144 identischen, modular aufgebauten Faserbündel IFUs. Diese enthalten jeweils insgesamt 246 Fasern pro Bündel, das in einem rechteckigen Format aufgebaut ist, und jeweils an einen eigenen Spektrografen angekoppelt wird. Das Gesamtgesichtsfeld pro Einzelaufnahme besitzt eine Größe von 29'x29' und produziert insgesamt 35000 Spektren pro Belichtung. Die Machbarkeit des Projekts beruht auf einem hochgradig modularen Konzept, das die kostensparende Herstellung der reproduzierbaren Baugruppen mit Methoden der industriellen Serienfertigung gestattet. Zur Demonstration der Machbarkeit dieses Konzepts wird gegenwärtig ein Prototyp für eines der 144 Subsystem

Among the important findings in modern Astrophysics, the recent discovery of "Dark Energy" is perhaps the most exciting one. Various independent experiments have shown that there is a mysterious non-negligible vacuum energy, which in fact dominates the total energy content of the universe. One of several competing groups worldwide which are trying to constrain the properties of Dark Energy through a variety of experiments, a team at the University of Texas, Austin, U.S.A., is undertaking a particularly ambitious endeavour: the HETDEX experiment. Based on its fiber optical expertise, the AIP was invited to participate in the development of the VIRUS 3D Spectrograph for the 9.2m Hobby Eberly Telescope, Texas, which shall be used to perform the HETDEX survey.

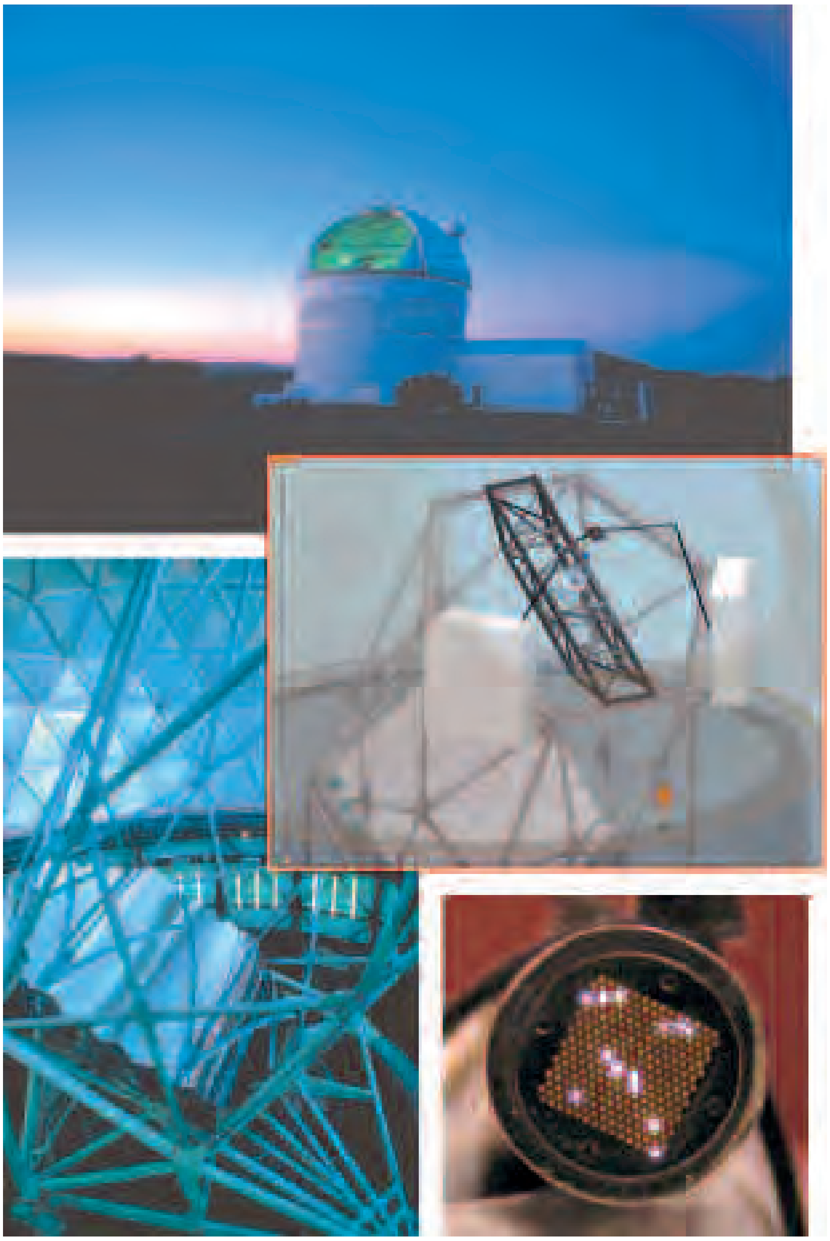
The fundamental observable which will be used to derive constraints on Dark Energy properties are the baryonic oscillations, which were formed in the baryon-photon plasma shortly after the Big Bang, and which are still visible today in the large scale distribution of galaxies. These oscillations can be measured in the power spectrum of the spatial distribution of a huge number of galaxies, whose distance from us will be accurately known through the measurement of their redshift. The HETDEX survey will cover a very large area on the sky (200 $degrees^2$) over the redshift range of $1.8 < z < 3.7$, corresponding to a total volume of 5.2 Gpc^3. As this volume is 10 times larger than that of the Sloan-Survey, a unique feature of HETDEX will be the detection of baryonic oscillations in three dimensions, rather than only in the z direction. This goal can only be accomplished by ensuring a quasi-contiguous spatial coverage, requiring a huge integral field unit (IFU).

In the present conceptual design, the VIRUS IFU will consist of 144 modular fiber bundle IFUs, which are all identical, consist of a total of 246 fibers per bundle, which present a rectangular footprint, and each of which is coupled to its own associated spectrograph. The total area covered in any single exposure is 29' x 29', producing altogether ~ 35 000 spectra per exposure. The feasibility of the project rests entirely on a highly modular concept, allowing cost effective industrial production of replicable subsystems. In order to demonstrate the feasibility, a single-unit prototype is presently being built for operation at the McDonald Observatory 2.7m Telescope, Texas. The prototype fiber optics subsystem is designed, built, and tested at AIP. The development of this IFU builds strongly on the expertise gained with the PMAS instrument, which is successfully in regular operation at the Calar Alto 3.5m Telescope in Andalucia, southern Spain, since 2001. PMAS was entirely built in-house AIP, with funding from the Verbundforschung of the German BMBF, and from the Land Brandenburg.

aufgebaut. Der Prototyp wird am 2,7m-Teleskop am McDonald Observatory in Texas zum Einsatz kommen. Die Faseroptik dazu wird in Eigenregie am AIP entworfen, aufgebaut und getestet. Die Entwicklung dieser IFU beruht weitgehend auf der Expertise, die mit dem PMAS Instrument gewonnen wurde, das gegenwärtig am Calar Alto 3,5m-Teleskop in Andalusien, Südspanien, erfolgreich im Einsatz ist. PMAS ist vollständig am AIP entwickelt worden und wurde finanziert durch die Verbundforschung des BMBF, sowie durch das Land Brandenburg.

The VIRUS team at AIP

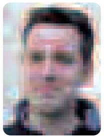
Matthias Steinmetz (CoI), Martin Roth (Project Manager)
Andreas Kelz (Fiber Optics), Emil Popow (Fiber Optics)
Svend-Marian Bauer (Mechanical Design)
Jens Paschke (Manufacture)
Peter Weilbacher (Data Reduction Software)
Joris Gerssen (Data Reduction Software)
Petra Böhm (Data Reduction Software)
Ute Tripphahn (Fiber Optics, Support)



Das 9,2m Hobby-Eberly-Telescope am McDonald Observatory, Texas, früher auch einmal bekannt als das "Spectroscopic Survey Telescope", wird mit minimalem Kostenaufwand als Primärfokus-Teleskop betrieben, etwa in der Art des Arecibo-Radioteleskops. Dazu besitzt das Teleskop eine Linearnachführung in der Fokalebene, sowie ein optisches Korrektorsystem. Die VIRUS IFU wird an dieser Stelle montiert. Das dort aufgefangene Licht wird mittels optischer Lichtleitfasern von der Fokalebene zu den insgesamt 144 Spektrographen geleitet, die in zwei Behausungen am Frontring des Teleskops montiert werden sollen. Ein einzelnes Faserbündel bildet einen IFU-Kopf wie im Bild unten rechts gezeigt (VIRUS prototype IFU, hergestellt am AIP)

The 9.2m Hobby-Eberly-Telescope at McDonald Observatory, Texas, formerly also known as the Spectroscopic Survey Telescope, is operated in a low-cost fashion like an Arecibo-type prime focus telescope with a focal plane tracker and an optical corrector. The VIRUS IFU will be mounted at this location, coupling light by means of optical fibers from the focal plane to a total of 144 spectrographs, which are mounted in two banks near the front ring of the telescope structure. A single fibe bundle forms an IFU head as shown in the picture to the lower right (VIRUS prototype IFU, manufactured at AIP)

IFU observations of the early universe



J. Gerssen

Gesamtfeldspektroskopie (IFU) erweist sich als wertvolles Instrument zur Beobachtung des Universums bei großer Rotverschiebung. Unsere Arbeit an der Eingrenzung der feedback-Mechanismen, die einen wesentlichen Teil der Modelle zur Galaxienbildung darstellen, zeigt das Potenzial der IFU auf diesem Feld und legt die Basis für zukünftige Forschung mit MUSE, der nächsten Generation der IFU. Das AIP ist ein Hauptakteur bei der Entwicklung dieses einzigartigen Instruments.

Integral Field Spectroscopy is proving to be a very valuable new tool for observing the high redshift Universe. Our work in obtaining constraints on feedback mechanisms, an essential part of galaxy formation scenarios, demonstrates the potential of IFUs in this field and lays the groundwork for future research using MUSE, the next generation IFU. The AIP is a key player in the development of this unique instrument.

Although rapid advances are now being made in our understanding of the observable Universe, the formation of galaxies is still an outstanding difficulty. Their formation requires gas to cool in the halos of dark matter that collapse under gravity. However, cooling alone would produce far too many bright galaxies at present day. The rate of cooling therefore has to be balanced by the injection of energy. An often invoked scenario to terminate star formation in the most massive galaxies and to deposit heavy elements in the intergalactic medium is a galactic outflow of baryons ("superwind" feedback) driven by SNe and AGN. While this idea is widely accepted, the actual mechanism is poorly understood and even more poorly constrained observationally.

Using the SAURON Integral Field Unit (a direct precursor to MUSE) we found the most direct evidence to date for a feedback process operating in the early Universe. We observed the system LAB-2 in the protocluster SSA22 at z=3.09 (implying a look-back time of 11.5 Gyr). Here, we discovered the aftermath of a several 100 million year old superwind outflow in the form of a 100 kpc scale shell of absorbing HI covering the entire Ly-alpha emission (Wilman, Gerssen et al. 2005).

A schematic representation of the data is shown in Fig. 1. Unlike imaging or spectroscopy, high-z IFU observations are volumetric in nature. Such data can thus also be used to efficiently search for serendipitous Ly alpha emitters in a volume of space. Recently, Adelberger et al. (2003) compared the redshift distribution of these emitters with the distribution of neutral hydrogen (deduced from QSO absorption lines). They find a surprising anti-correlation on the smallest scales. The most plausible explanation for this so-called proximity effect is again a super-wind that has swept the surrounding region clean of hydrogen.

In collaboration with the astronomy group in Durham we have obtained several SAURON and VIMOS IFU data sets of QSOs in the redshift range 3 to 4. These data were obtained for the express purpose of constraining the number density of Ly-alpha emitters and to correlate their properties with the QSO spectra. Our preliminary results indicate that the number of serendipitous detections is in line with theoretical predictions and that IFUs are indeed capable of working at very faint flux levels.

Exploring the high redshift Universe is one of the main science drivers behind the MUSE collaboration. The AIP is an essential part of this network, and the experience we gain working with pre-MUSE data and the tools we are developing to do so will be extremely beneficial to development of MUSE, and will help us to maximize the scientific return of this instrument.

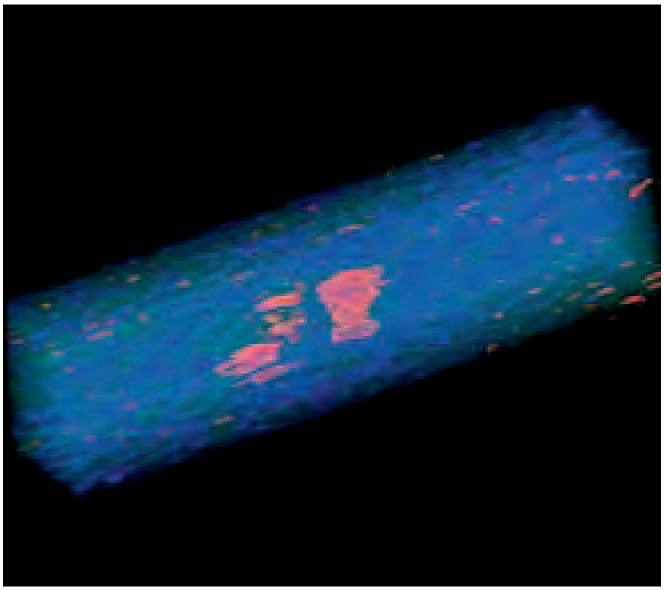
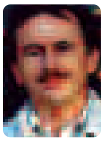


Fig. 1: The data-cube of the z=3.09 protogalaxy LAB-2 observed with the SAURON IFU showing the Ly alpha emission (red). A data-cube is a three dimensional representation of data obtained with an IFU. Here, the long axis corresponds to the wavelength range. The spatial dimensions (x,y) are approximately square in this data cube. With visualization software, a data-cube representation can provide useful qualitative insights into complex data sets.

Das Zentrum der Michstraße

Information technology



D. Elstner

Die Anforderungen der modernen astrophysikalischen Forschung verlangen eine hochleistungsfähige Informationstechnik, um die kontinuierlich wachsenden Datenmengen zu verarbeiten. Mit der Entwicklung moderner Computertechnik ist auch die numerische Simulation komplexer astrophysikalischer Vorgänge ein integraler Bestandteil der Forschung. Dazu werden Rechner an der Grenze des technologisch Möglichen benötigt. Neben der Nutzung von Höchstleistungsrechnern an den zentralen Rechenzentren im In- und Ausland für augewählte Probleme sind auch vor Ort entsprechende Ressourcen notwendig.

Das AIP betreibt zentrale Computer-Cluster mit bis zu 256 Prozessoren. Der Einzug der 64bit-Architektur ermöglicht heute, mit diesen Systemen große Datensätze zu verarbeiten. Die anfallenden Datenmengen werden im AIP auf zentralen Raid-Systemen gespeichert, die einen schnellen Zugriff auf die Daten ermöglichen. Sicherungskopien und Langzeitarchivierung von großen und nicht reproduzierbaren Daten werden auf Magnetbändern gespeichert.

Die Arbeitsplatzcomputer werden von den Mitarbeitern der IT-Technik zentral verwaltet. Neben typischen Office-Anwendungen, wie Textverarbeitung, Email, Präsentationserstellungen werden die Arbeitsplätze der Wissenschaftler zum großen Teil für die Auswertung von Daten, kleineren Simulationsrechnungen und Softwareentwicklung genutzt.

Durch die IT-Infrastruktur des AIP werden zentrale Dienste wie Mailservice, WWW-Server, FTP-Server, Printserver und institutsweite Fileserver angeboten. Das Netzwerk des AIP besteht aus einem Gbit-Ethernet Backbone mit 100Mbit Anbindung der Arbeitsplatzrechner. Es ist über Switche und Subnet-

Einweihung des Supercomputers Sanssouci am 15.1.2004

The requirements of modern astrophysical resarch demand a powerful information technology with a structure in order to handle the continously growing amount of data. With rapidly developing computer technology, the numerical simulation of complex astrophysical processes has become an integral part of research. Supercomputers at the limit of technological feasibility are necessary. Beside the use of supercomputers at national and international computing centers for special projects, local resources also have to be installed.

The AIP operates a central computer cluster with up to 256 processors. 64bit technology now allows the processing of huge data sets. Data produced at the AIP are stored on central RAID systems, which allow rapid data access. Backups and long term archiving of huge and non-reproducible data are saved on magnetic tapes.

The workstations for the scientists are centrally administrated by the IT staff. Beside typical office applications, like text processing, email and preparation of presentations, the scientists use their workstations mostly for data reduction, small simulations and software development.

35TB diskspace in the new fileserver luise ze strukturiert, die dem Netzverkehr angepasst sind. Auch sicherheitsrelevante Maßnahmen haben zunehmend Einfluss auf die Netztopologie.

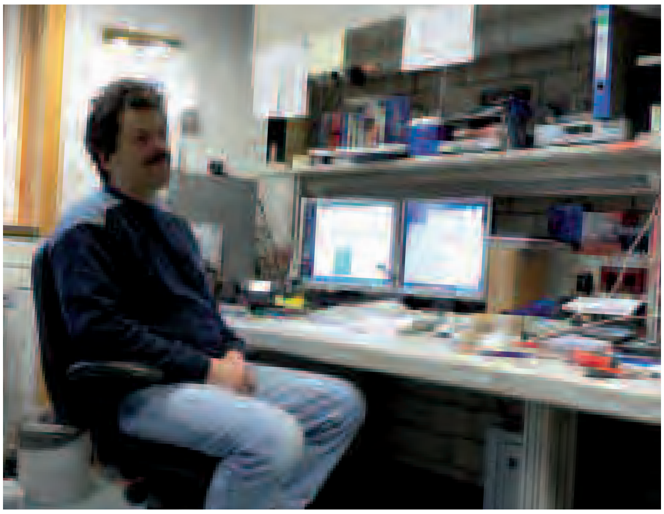
Einen höheren Aufwand erfordern Sicherheitsmaßnahmen im AIP-Netzwerk gegen Hackerangriffe, Spam-Attacken und Viren. Das wird unter anderem durch ständige Aktualisierung der Betriebssysteme, zentrale Virenüberprüfung von eingehenden Emails und lokalen Virenscannern auf den Arbeitsplatzrechnern gewährleistet.

The IT infrastructure also provides central services like email, webserver, FTP server, printserver and fileserver. The network of the AIP consists of a Gbit Ethernet backbone with fast Ethernet connection of the workstations. It is structured for an optimal network traffic. Also, security requirements influence the net topology more and more. An increasing amount of effort has to be spent on security tasks which defend against hackers, spam attacks and viruses in the AIP network by continous patching of the operating systems and scanning of workstations and emails for viruses.

Video-conference systems and IP phones are maintained by the IT staff supporting external telescope operation and national and international collaboration.

Computational Cluster Sanssouci

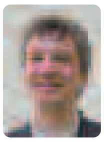
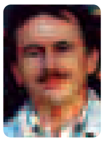
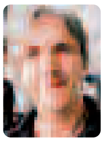
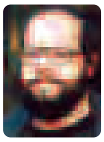
The central network switch at AIP



Mario Dionies in the PC lab

IT staff

eScience in der Astronomie
eScience in Astronomy

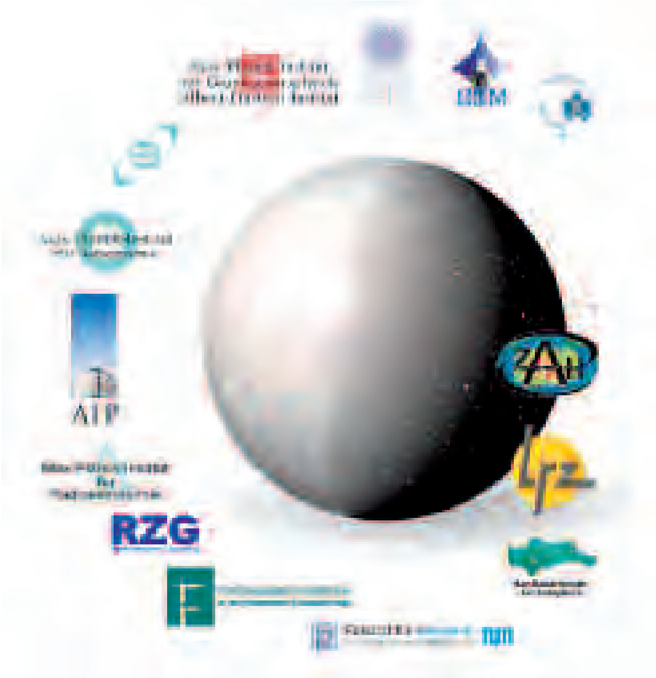





M. Steinmetz, D. Elstner, H. Enke, A. Saar

Unter dem Begriff eScience wird jede Form der computer-gestützten, kooperativen Forschung verstanden. Das AIP ist als aktiver Partner an der Entwicklung der eScience in Deutschland beteiligt. Zusammen mit anderen führenden astronomischen Forschungsinstituten, Forschungsgruppen der Informatik sowie einigen Hochleistungsrechenzentren hat das AIP das Verbundvorhaben AstroGrid-D als interdisziplinäres Projekt begonnen. Das Ziel ist die Schaffung einer bundesweiten Infrastruktur in der Astronomie für die gemeinsame Nutzung von Ressourcen wie Hochleistungsrechnern, Beobachtungs- und Simulationsdaten und Teleskopen. Zusammen mit anderen Community-Projekten soll im Rahmen des D-Grid eine bundeseinheitliche Forschungsstruktur für verteiltes gemeinschaftliches Arbeiten mit Hilfe innovativer Grid-Technologie entstehen. Durch die Beteiligung am GAVO-Projekt unterstützt das AIP die weltweiten Bemühungen, funktionsfähige Verknüpfungen der astronomischen Datenarchive herzustellen. Es wurden Datenarchive in einem VO-konformen Standard neu aufgebaut und vorhandene überführt. Das erfordert auch ein leistungsfähiges Netzwerk. Der Ausbau der Netzwerkinfrastruktur am AIP und im Raum Potsdam dient auch als Testrahmen für die Gewinnung von technologischem und organisatorischem Know-how.

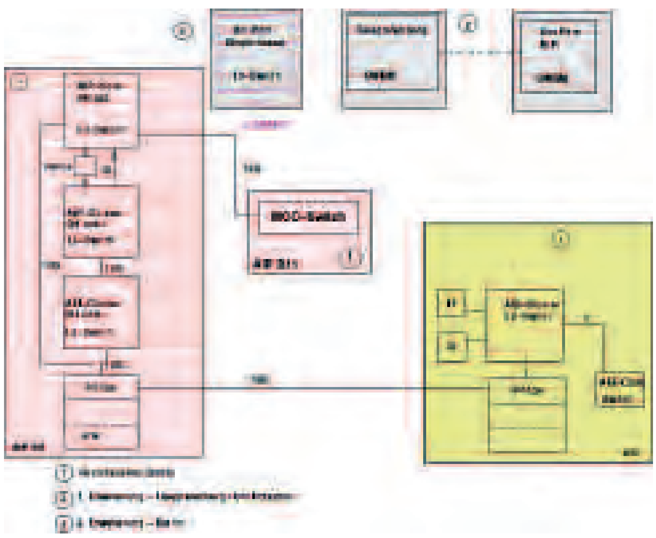
Moderne Teleskope und Empfänger erhöhen tagtäglich Genauigkeit und Details unseres Wissens über das Universum durch Anwendung neuester Technologie und geben dabei eine Fülle von Rohdaten, die schneller wächst als die verfügbaren Speicheranlagen. Neue Instrumente werden in einer einzigen Beobachtungsnacht Rohdaten von einigen Terabyte liefern. Die Verteilung dieser Datenmenge über das allgemeine Internet würde Tage beanspruchen. Mit modernen Grid-Methoden können Auswertungsprozeduren der Astronomen zu den Daten gesandt werden und bei einer deutlich reduzierten Netzbelastung werden nur noch die Resultate an den Astronomen zurückgeschickt. Mit der wachsenden Anzahl und Qualität von Online-Archiven mit standardisierten Schnittstellen wird in Zukunft die Datengewinnung aus astronomischen Archiven eine mächtige Quelle wissenschaftlicher Erkenntnis. Werkzeuge zur Datengewinnung zusammen mit wachsenden Datensätzen stellen höhere Anforderungen an die verfügbaren Rechner und Datenspeichergeräte. Die Zusammenführung von

The idea of eScience is any form of computer aided cooperative research. The AIP participates as an active partner in the development of eScience in Germany. It started the interdisciplinary project AstroGrid-D together with other astronomical research institutes, research groups of informatics and some supercomputing centers. The aim is the creation of a national infrastructure in astronomy in order to share resources like supercomputers, data from observations, or simulations and telescopes. Together with other community projects a national research structure for collaborative work with the aid of innovative grid technology will emerge in the framework of the D-Grid. The AIP supports the worldwide efforts to create interoperability of astronomical data archives with its participation in the German Astrophysical Virtual Observatory (GAVO). Data archives have been transformed and new ones created which are consistent with the standards of the Virtual Observatory (VO). A powerful network will be necessary. The upgrade of the network infrastructure at the AIP and in the Potsdam area also serves as a testbed for the acquirement of technological and organisational know how.



The AstroGrid-D logo showing the participating partners

Rechen- und anderen Ressourcen in einen einheitlichen Grid-Rahmen mit standardisierten Nutzerschnittstellen und Zugriffsmethoden wird helfen, diese Anforderungen zu erfüllen. Der Fortschritt in der Astronomie und Astrophysik ist mit der Entwicklung der Informatik und Computertechnologie auf unterschiedliche Weise verbunden. Numerische Simulationen auf Höchstleistungsrechnern, die auf dem gegenwärtigen Verständnis der physikalischen Gesetze basieren, geben unschätzbare Einsicht in die kosmischen Prozesse. Die Integration von Hochleistungsrechnern in das Grid öffnet neue Dimensionen für den Vergleich der Resultate von Modellrechnungen mit Beobachtungsdaten. Das LOFAR Radioteleskop ist ein Software-Teleskop, das über Netzwerkverbindungen mit hoher Bandbreite und mit Hochleistungsrechnern geografisch verteilte Antennenfelder kombiniert, die den Radiohimmel beobachten. Dabei werden einige hundert Terabyte Daten pro Tag produziert. Diese Daten werden durch einen der weltweit leistungsfähigsten Supercomputer reduziert. Die Resultate dieses Prozesses werden an verschiedene Wissenschaftszentren verteilt, wo sie archiviert und analysiert werden. Hier werden Methoden der Verarbeitung von verteilten Daten verwendet, welche im Rahmen des Grid entwickelt wurden. Ein anderes



Network scheme of the 10Gbit ethernet backbone

Modern telescopes and detectors are increasing the accuracy and the details of our knowledge of the universe day by day by using the most advanced technology, resulting in a wealth of raw data that grows even more rapidly than the fast increase of available storage facilities. New instruments are expected to generate raw data to the order of several terabytes during one night of observing time. Distributing this amount of data via the common internet would take days. With modern grid-methods the astronomer's data analysis tools and programs could be sent to the raw data, and only results would be reported back to the astronomer, thus reducing the network load.

Datamining of astronomical archives becomes a more powerful source of scientific knowledge with the increasing number of online archives and standardized interfaces and quality. Datamining tools together with the growing data sets impose more demands on available computational resources and storage facilities. Integrating computational and other resources into a coherent grid framework with standardized user interfaces and access methods would help to meet these demands.

Progress in astronomy and astrophysics is connected to development of informatics and computer technology in many ways. Numerical simulations on supercomputers based on our current understanding of the laws of physics provide invaluable insight into cosmic processes. The integration of supercomputers into the Grid opens new dimensions to compare results of simulations with observational data.

The LOFAR radio telescope is a software telescope, where high bandwidth network connections and supercomputing facilities combine geographically distributed arrays of antennae, which produce several hundreds of terabytes a day. This data is integrated by one of the most powerful supercomputers in the world. The results of this processing are distributed to Science Centers where they are further archived and analyzed. Methods of working with distributed data will be employed here, which have to be provided within the Grid. Developing a framework, where simultaneously observing rare events like gamma ray bursts or supernovae with instruments operating in different wavelengths, or coordinating a network of robotic telescopes to observe objects continuously for days is another field for grid based methods.

Feld für Grid basierte Softwaretechnologie ist die Entwicklung von Systemen die mit Teleskopen für unterschiedliche Wellenlängenbereiche koordiniert auf seltene Ereignisse wie "gamma ray bursts" oder Supernovae reagieren, oder der Betrieb von Netzwerken robotischer Teleskope, die kontinuierlich Objekte über Tage beobachten. Das AIP ist aktiv in der eScience, beim Aufbau von Netzwerken für interaktive Zusammenarbeit und einer computergestützten Forschungsinfrastruktur. Das AIP beteiligt sich am GAVO-Projekt und unterstützt das weltweite Bemühen, die astronomischen Datenarchive über standardisierte Schnittstellen zugänglich zu machen. Die Entwicklung einer Software-Infrastruktur zur Spiegelung der RAVE-Website an verschiedene Orte der Erde und die Bereitstellung einer zum Virtuellen Observatorium (VO) kompatiblen Schnittstelle erlaubt bereits die Zusammenarbeit mit anderen VO-Werkzeugen und VO-Archiven. Das AIP unterstützte frühzeitig die D-Grid-Initiative. Das AstroGrid-D Projekt, das im September 2005 startete und vom AIP koordiniert wird, vereint wichtige deutsche astronomische Institute, Grid-orientierte Arbeitsgruppen aus der Informatik und Hochleistungsrechenzentren um eine Grid Infrastruktur für die deutsche Astronomie innerhalb des D-Grids aufzubauen. Die Hauptgebiete der Arbeit des AIP für das AstroGrid-D sind Grid-basierte astrophysikalische Simulationen, Visualisierung und die Einbeziehung robotischer Teleskope in das Grid-Netzwerk. Obwohl die neuen Technologien schon eine effizientere Nutzung der Rechen- und Datenressourcen ermöglichen, ist auch ein Hochgeschwindigkeitsnetzwerk erforderlich. Dazu hat das AIP jetzt ein 10Gbit Basisnetz mit modernen leistungsfähigen Switches, das die Supercomputer und Fileserver im AIP verbindet. Eine 10Gbit/s Datenleitung zwischen AEI und AIP vernetzt die Cluster beider Institute für gut parallelisierbare Grid-Anwendungen. In Abbildung 2 ist das Netzwerkschema in einem Blockdiagramm dargestellt. Die gemessene Latenz zwischen AIP und AEI beträgt 0,2 ms. Die Untersuchung der Wirkung von Netzwerkparametern, wie Bandbreite, Signalverzögerung und Fehlerrate dieser Datenverbindung auf das Laufzeitverhalten von Anwendungen, wird helfen, die wissenschaftlichen Simulationen und Werkzeuge zur Datenanalyse zu optimieren. Diese Netzwerkverbindung könnte ein Kernteil für ein Hochgeschwindigkeitsnetz im Raum Potsdam bilden, um wissenschaftliche Institute und die Universität zu verbinden. Der Anschluss des Potsdamer Netzes nach Berlin über BRAIN (Berlin Research Area Information Network) oder der geplante DFN-X-WIN Knoten auf dem Telegrafenberg könnte die notwendigen Datenverbindungen für LOFAR bereitstellen und die Zusammenarbeit mit dem "Climate-Community Grid" über das Potsdamer Institut für Klimafolgenforschung fördern.

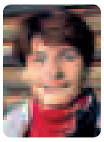
The AIP is actively supporting eScience, the building of networks for interactive collaborations and computerbased research infrastructure.
The AIP joined the GAVO project, supporting the worldwide efforts to make astronomical data archives available through standardized interfaces. Developing software infrastructure to allow mirroring of the RAVE website at different locations across the globe and providing a Virtual Observatory-compliant interface for the RAVE archive already enables the collaboration to work with other VO-tools and VO-archives. Within the GAVO project, the AIP piloted studies of astrophysical simulation codes running on a grid of workstations.

The AIP supported the D-Grid Initiative from early on. The AstroGrid-D project, started in September 2005 and coordinated by AIP, joins major German astronomical institutes, grid-oriented research groups from informatics and supercomputing centers to build a grid-infrastructure for German astronomy within D-Grid. The AIP's main areas of work for AstroGrid-D are grid-based astrophysical simulations, visualization and inclusion of robotic telescopes into the grid-framework.

Although the new technologies make more efficient use of computing and data resources, the availability of a high-performance network infrastructure is required. Therefore the AIP now has a 10Gbit Ethernet backbone connecting supercomputers and fileservers at the AIP based on powerful state of the art switching devices. A 10Gbit/s data link between the AEI and AIP connects the high-perfomance clusters of both institutes for running highly parallel grid applications. A block diagram of the network scheme is shown in Fig. 2. The measured latency between AEI and AIP is about 0.2 ms.

Studying the impact of the network parameters, eg. bandwidth, signal delay and error rate, of this data link on application performance will help to optimize scientific simulations and data analysis tools. Since emerging Grid technologies lead to new requirements for network management software and policies, this data link is well suited as a testbed for operating future scientific networks. This network link could be a core part of a high-speed scientific network infrastructure in the Potsdam area, connecting scientific institutes and the University. Linking the Potsdam net to Berlin via BRAIN (Berlin Research Area Information Network) or a planned DFN-X-WIN node at the Telegraphenberg would provide the necessary data links for LOFAR as well as facilitate collaboration with the Climate Community Grid via the Potsdam Institute for Climate Research.

Virtual Observatory: Incorporation of the Potsdam Plate Archive

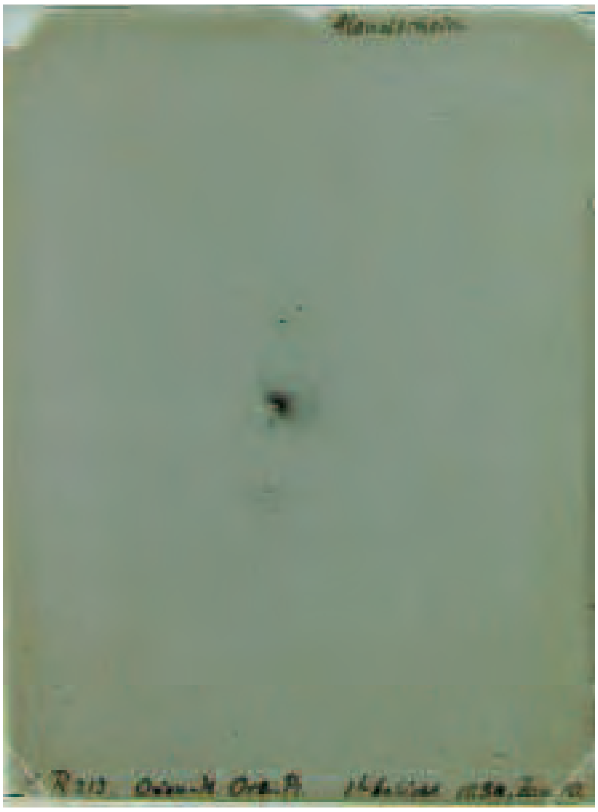


P. Böhm

Als „Virtuelles Observatorium“ (VO) bezeichnet man eine globale Netzwerkplattform mit schnellem und einfachem Zugriff auf verteilte astronomische Datenarchive in aller Welt über einheitliche Schnittstellen und ein gemeinsames Datenmodell. Ziel unseres Deutsch-Bulgarischen DFG-Projektes ist es, die historischen Weitwinkel-Fotoplatten des Potsdamer Observatoriums in die Archive des GAVO, dem Deutschen Beitrag zum VO, zu integrieren.

The Potsdam collection of wide-field plates consists of 11 archives, obtained from 1879 to 1970 (see Catalogue of Wide-Field Plate Archives, version 5.0, March 2005, http://www.skyarchive.org/catalogue.html), with a total number of about 10000 plates and films stored not only in Potsdam but also in Leiden and Sonneberg. Apart from the long timeline provided for the observed objects, the archives reflect the history and development of the Potsdam observatory and of astronomical photography as well.

The first astronomical photographs represent a scientific treasure. In Potsdam the oldest astronomical photographs are stored obtained by Oswald Lohse with his self-made camera, as well as historical photographic surveys, including the Potsdam part of the Carte du Ciel survey, the first astrographic catalog observed from 1893 to 1900, and the Pleiades survey by Hertzsprung. These plates offer the possibility to follow the photometric behavior of astronomical objects for about 120 years. This information is unique, because it is no longer reproducible. Our aim is to digitize the old plates as long as their physical state still allows it. The work is done in collaboration with the team of Milcho Tsvetkov, Institute of Astronomy BAS, Sofia.

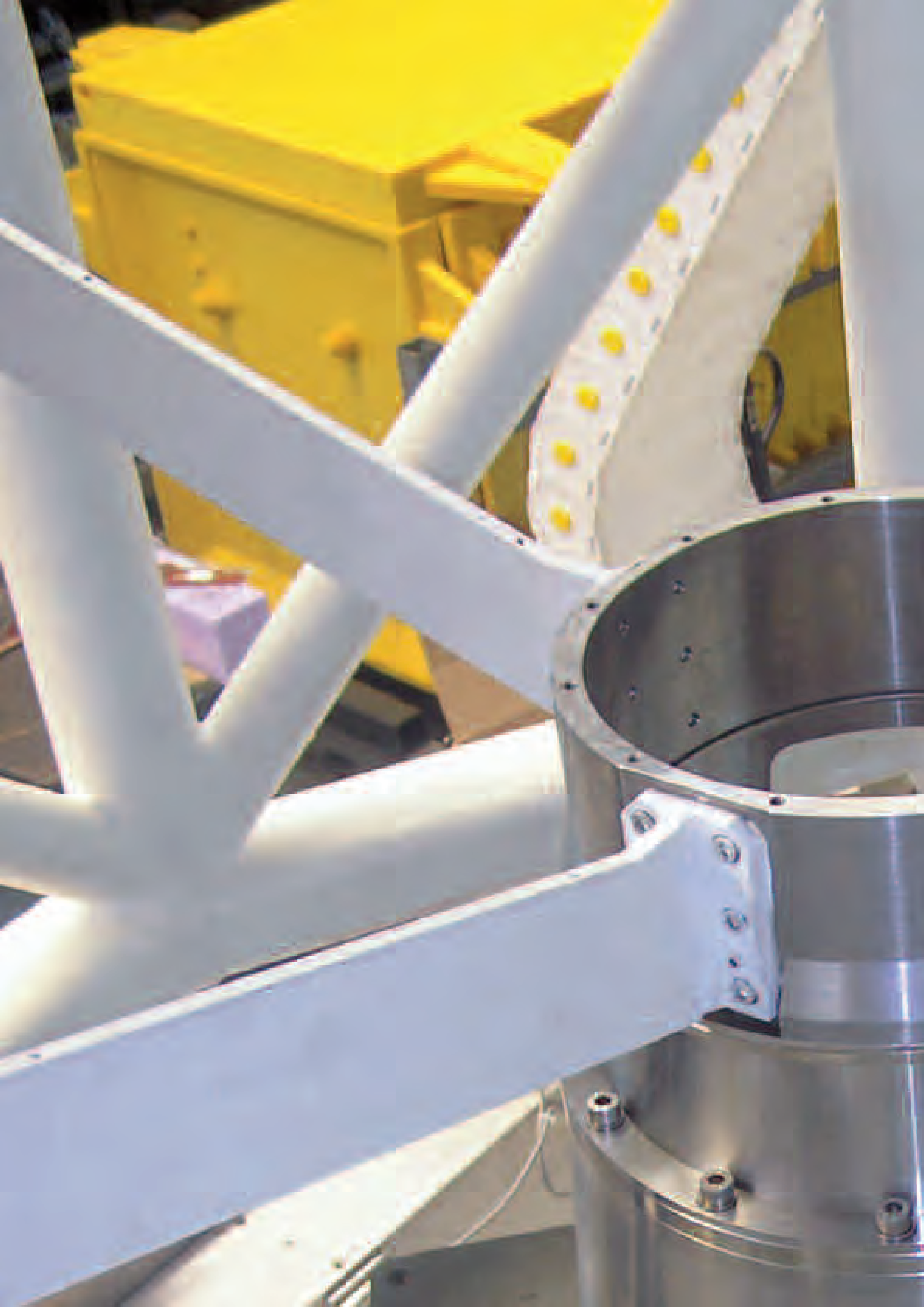


The Fig. shows one of the oldest photographic plates – a 60 min exposure of Orion Nebula, observed by Lohse on January, 10th, in 1889. Lohse used a 13 cm heliographic objective with 1.36 m focal length and 152"/mm scale, attached to the 30 cm refractor on Telegrafenberg, which was called "Großer Refraktor" in the period of 1879 -1899, before the 80 cm refractor was mounted.

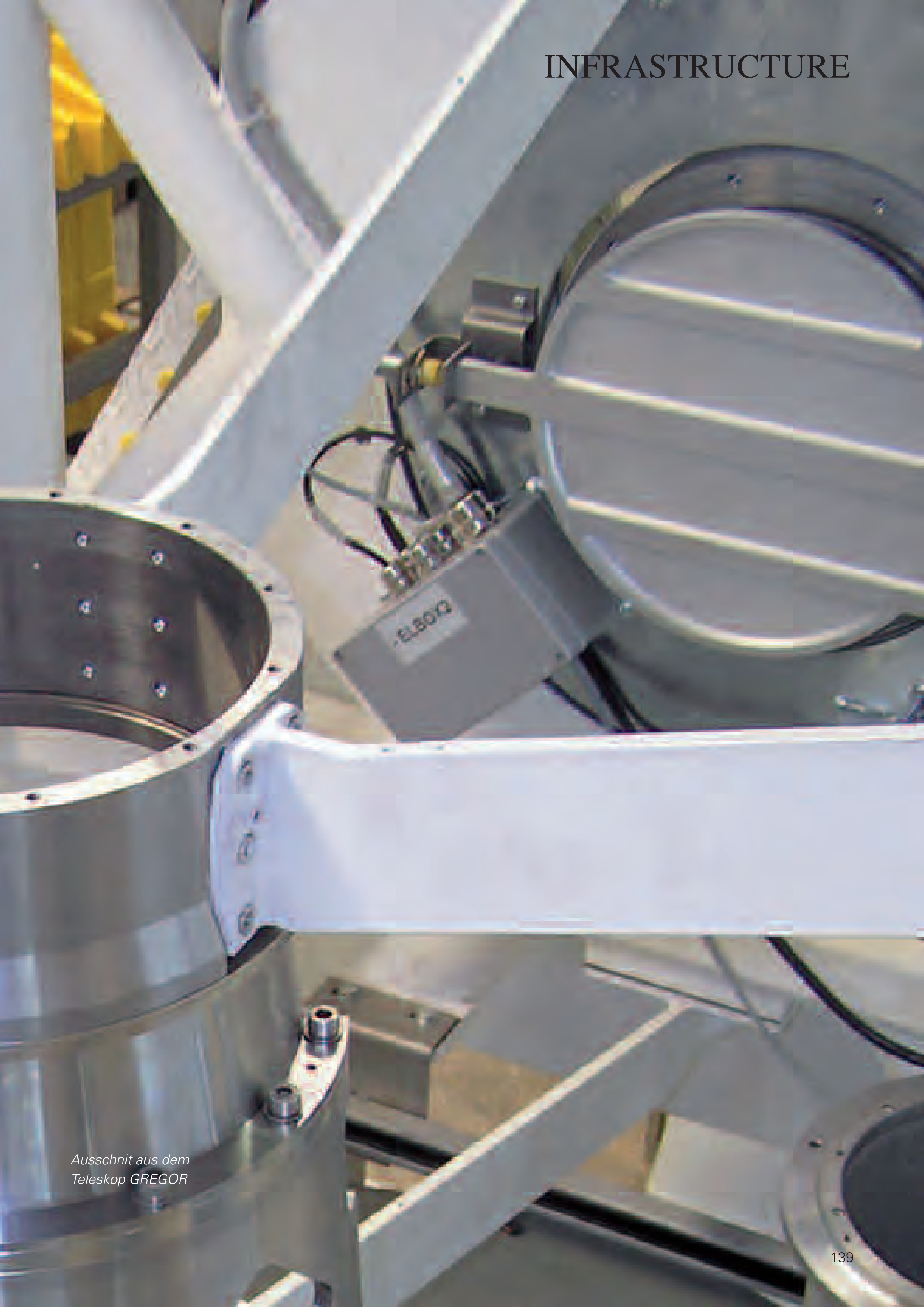
Identifier WFPDB(1)	Type	Aperture (m)	Foc.Len. (m)	Scale ("/mm)	FoV (sq.deg)	in Operation (from - to)	Plates (number)
POT013A	Rfr	0.13	2.10	98		1879 - 1908	
POT013B	Rfr	0.13	1.36	152	5.0	1888 - 1889	15
POT015	Cam	0.15	1.50	137	7.6	1908 - 1948	3000
POT020	Rfr	0.20	3.40	61	1.5	1879 - 1908	68
POT025	Sch	0.25/0.3	0.75	275	6.8	1949 - 1967	405
POT030A	Rfr	0.30	5.40	38	1.2	1879 - 1930	52
POT030B	Rfl	0.30	0.90	229		1906 - 1930	1500
POT032	Rfr	0.32	3.40	61	2.7	1889 - 1928	3000
POT040A	Rfr	0.40	5.50	38	1.7	1917 - 1938	1436
POT040B	Rfl	0.40	0.90	229		1932 - 1948	
POT050	Sch	0.5/0.7	1.72	122	4.5	1952 - 1970	507

(1) WFPDB = Wide-Field Plate DataBase: see http://www.skyarchive.org

Table: Current status of the Potsdam archives of photographic wide-field plates (wide-field is defined as FoV = Field of View ≧ 1 square degree) achieved in Potsdam/Telegrafenberg (except POT040A, belonging to Babelsberg) from 1879 to 1970 with different types of instruments: Rfr = refractor, Cam = Camera, Sch = Schmidt telescope, Rfl = Reflector.

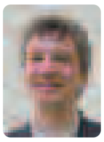


INFRASTRUCTURE



Ausschnit aus dem Teleskop GREGOR

Ein Teleskop sieht Licht
A telescope sees light



Matthias Steinmetz und das AIP-LBT team

Ein Teleskop entsteht

3200m über dem Meeresspiegel nahe der Spitze des Mt Graham in Arizona wird zur Zeit von einem Konsortium aus amerikanischen, deutschen und italienischen astronomischen Instituten (darunter das AIP) das größte optische Teleskop der Welt errichtet, das Large Binocular Telescope (LBT). Wie der Name verrät, besteht es aus zwei gewaltigen Spiegeln mit je 8,4m Durchmesser auf einer gemeinsamen Montierung. Jeder dieser beiden Spiegel für sich ist bereits der größte optische Einzelspiegel der Welt. Die Spiegel können parallel verwendet werden, oder aber auch kombiniert werden zu einem Teleskop mit einer effektiven Lichtsammelfläche eines 11,8m-Teleskops oder, über Interferometrie, zu einem Teleskop mit der Auflösung eines 22,8m-Teleskops. Das LBT ist so nicht das letzte der gegenwärtigen Teleskope der 8-10m-Klassen, sondern der Pfadfinder hin zur nächsten Generation der 20-50m Teleskope, wie sie zurzeit für die Mitte des nächsten Jahrzehnts geplant werden.

Während seit dem Baubeginn Mitte der 90er weitgehend die Errichtung des großen Schutzgebäudes im Vordergrund stand, sahen die letzten beiden Jahre die Ankunft und den Zusammenbau des Teleskops. So war bereits im Frühsommer 2004 die Teleskopstruktur errichtet, der erste Hauptspiegel integriert und das erste Instrument, eine optische Kamera (die Frontlinse übertrifft mit ihrem Durchmesser von 90cm die Apertur des Großen Refraktors auf dem Telegraphenberg!), installiert. Alles war somit vorbereitet für das erste noch einäugige Licht. Dem Anlass entsprechend wurde auch eine Einweihungszeremonie für Oktober 2004 vorbereitet, für die sich hochrangige Gäste, darunter die italienische Forschungsministerin Letizia Moratti, angemeldet hatten.

Feuer!

Am 4. Juli 2004, dem amerikanischen Unabhängigkeitstag, kam jedoch eine Schreckensmeldung. In der Nähe des LBT hatten sich durch Gewitter zwei Buschbrände entzündet, die sich zu vereinigen drohten und Richtung auf das LBT nahmen. Die Lage war zeitweise so dramatisch, dass den Löschkräften am Berg mitgeteilt wurde, dass in etwa einer Stunde das Feuer über das Teleskop laufen würde, und sie den Berg zu evakuieren hätten. Glücklicherweise drehte kurz davor der Wind, und gab der Löschmannschaft, zeitweise bestehend aus über 700 Feuerwehrleuten sowie mehreren Löschflugzeugen und Löschhubschraubern, die notwendige Zeit, Gegenmaßnahmen zu treffen und das Teleskop abzusichern. Am Ende verbrannten in drei Wochen auf dem Mt Graham knapp 100 qkm Wald, das LBT blieb aber unbeschädigt. Ende Juli konnten die Arbeiten wieder aufgenommen werden. Der ehrgeizige Plan des first light vor der Einweihung war aber nicht mehr zu verwirklichen.

A telescope takes shape

3200m above sea level, near the top of Mt Graham in Arizona, a consortium of American, German and Italian astronomical institutes (among them the AIP) is building the largest optical telescope in the world, the Large Binocular Telescope (LBT). As the name suggests, it consists of two enormous mirrors (each 8.4m in diameter) on a common mounting. Each of these mirrors is in itself already the largest one-piece mirror in the world. The mirrors can be used in parallel or they can be combined to form a telescope with a total light collection area that corresponds to a 11.8m telescope or, via interferometry, to a telescope with the resolution of a 22.8m telescope. Thus, the LBT is not the last of the present telescopes of the 8-10m class, but the pioneer for the next generation of 20-50m telescopes as they are currently planned for the middle of the next decade. While the construction of the giant shelter was the inital focus following the start of construction in the mid-nineties, the last two years focused on the arrival and assembly of the telescope. In early spring 2004, the telescope structure was already assembled, the first main mirror integrated and the first instrument, an optical camera (the front lens with its 90cm diameter exceeds the one of the great refractor on the Telegraphenberg!) was installed. Thus everything was prepared for the first, still one-eyed light. To mark the occasion, an inauguration ceremony was prepared for October 2004, for which high-ranking guests like the Italian minister of research, Letzia Moratti, had been invited.

Fire!

On July 4, 2004, the American Independence Day, a frightening report arrived: close to the LBT, two wildfires had been caused by lightning which were on the verge of uniting and spreading towards the LBT. At times, the situation was so dramatic that fire-fighters on the mountain were told that the fire would reach the telescope in about one hour and that they had to evacuate the mountain. Luckily, the wind turned shortly before and provided the fire-fighter team, at times consisting of over 700 firemen as well as several fire-fighting planes and helicopters, with the necessary time to take counteractive measures and secure the telescope. In the end, during three weeks, approximately 100 square kilometres of forest burnt around Mt Graham, but the LBT was left unharmed. At the end of July, work was resumed. The ambitious plan for first light before the inauguration could no longer be realised.

The inauguration

The solemn inauguration of the LBT took place on the evening of October 15 in Tucson, followed by a tour to Mt Graham with a visit to and demonstration of the telescope on October 16,

Die Einweihung

Die feierliche Einweihung des LBT fand dann am Abend des 15. Oktober in Tucson statt, gefolgt von einer Tour zum Mt Graham mit einer Besichtigung und Vorführung des Teleskops am 16. Oktober 2004. Am Teleskop wurde dann auch eine Tafel, die die internationale Kooperation würdigt, enthüllt. Von deutscher Seite waren der Präsident der Leibniz-Gemeinschaft, Prof. Hans-Olaf Henkel und der Vizepräsident der Max-Planck-Gesellschaft, Prof. Kurt Mehlhorn, von Brandenburger Seite die Vorsitzende des Kuratoriums des AIP, Frau Konstanze Pistor zugegen.

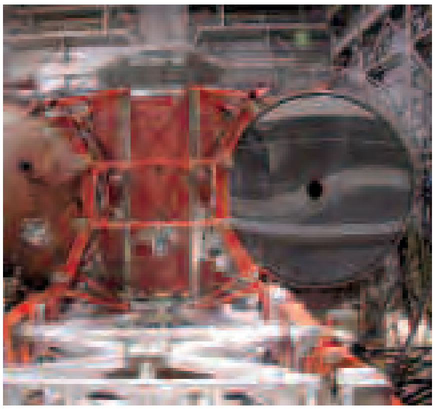
Nach den Einweihungsfeierlichkeiten wurden sofort weitere Schritte zur Inbetriebnahme des Teleskops unternommen, insbesondere stand die Aluminisierung des ersten Hauptspiegels an. Ein früher und heftiger Wintereinbruch auf dem Mt Graham mit zeitweise bis zu zwei Metern Schnee erlaubten eine Verspiegelung erst im Frühjahr 2005, die Zeit dazwischen konnte aber für Funktionsprüfung und Kalibrierung der Teleskopmechanik genutzt werden.

2004. A plaque which acknowledges the international cooperation was unveiled. From Germany, the President of the Leibniz-Gemeinschaft, Prof. Hans-Olaf Henkel and the Vice President of the Max-Planck-Gesellschaft, Prof. Kurt Mehlhorn, and from Brandenburg, the chairwoman of the board of trustees of the AIP, Mrs Konstanze Pistor, were present.

After the inauguration ceremony several further steps for the commissioning of the telescope were taken, particularly the aluminization of the first main mirror. An early and fierce winter on Mt Graham, with two meters of snow at times, delayed this to spring 2005, but the time in between could be used for tests and the calibration of the telescope mechanics.

The adaptive secondaries, a delicate piece of glass

It is natural for a project of this size to encounter setbacks from time to time. The most dramatic setback happened during the production of the first secondary mirror in May 2005. The LBT is equipped with so-called adaptive secondary mirrors. These glass shells, 90cm in diameter but only 1.7mm



Scherben bringen Glück?

Ein Projekt dieser Größe kann von Zeit zu Zeit auch Rückschläge erfahren. Der vorerst dramatischste war im Mai 2005 bei der Herstellung des ersten Sekundärspiegels. Das LBT ist mit so genannten adaptiven Sekundärspiegeln ausgestattet. Diese 90cm großen aber nur 1,7mm dicken Glasschalen werden über 672 Aktuatoren so in Form gebracht, dass sie die Turbulenz in der Erdatmosphäre ausgleichen. Dies geschieht mehrere hundertmal pro Sekunde! Mit Hilfe dieser adaptiven Optik erreicht das LBT erst sein volles Auflösevermögen, das im Infraroten das des Hubble-Weltraumteleskops um einen Faktor 10 übertrifft. Bei der Herstellung dieser sehr zerbrechlichen Glasschale verkantete das Schleifwerkzeug und brach die äußere Kante. Der Sekundärspiegel kann zwar noch für Testzwecke verwendet werden, ist aber für den Wissenschaftsbetrieb unbrauchbar, ein weiterer Sekundärspiegel muss hergestellt werden. Die Ironie der Geschichte ist, dass dieses Unglück keineswegs bei der technologisch herausfordernden Teil der Herstellung passierte, sondern in einem eher unkritischen Teil.

Das erste Licht

Am 12. Oktober 2005 war es dann soweit: Das lange erwartete, erste wissenschaftlich nutzbare Bild mit dem noch einäugigen LBT konnte aufgenommen werden. Im Visier stand die Galaxie NGC801 im Sternbild Andromeda, eine Galaxie, die nicht nur ästhetisch anregend, sondern auch wissenschaftlich hoch interessant ist, da ein sich über die ganze Galaxie erstreckender Sternbildungsausbruch das interstellare Gas und den Staub mächtig aufrührt. Weiter finden sich im Hintergrund zahlreiche kleinere, weiter entfernte Galaxien. Die erste Aufnahme wurde im blauen Spektralbereich mit der Large Binocular Camera gemacht (B-Filter). Diese Kamera besteht aus einem Detektor aus 4 CCDs in der Fokalebene, die jeweils 2048x2048 Pixel groß sind.

Das LBT wird zum Binokular

Wie der Name sagt, wird das Teleskop erst durch den zweiten Hauptspiegel zum LBT. Der zweite Hauptspiegel wurde 2002/3 gefertigt, 2004 poliert und dann im Sommer 2005 auf den Mt Graham transportiert und im Teleskop installiert. Im Januar 2006 fand schließlich die Aluminisierung des zweiten Hauptspiegels statt, so dass zum Zeitpunkt der Drucklegung dieses Berichts in der Tat ein Binocular Telescope auf dem Mt Graham zu finden ist. Zweites Licht ist nun für Sommer 2006 geplant.

thick, are put in shape by 672 actuators in such a way as to allow them to compensate for the image distortion caused by turbulence in the Earth's atmosphere. This happens several hundred times per second! These adaptive optics allow the LBT to achieve its full resolution, which in the infrared is about 10 times better than the Hubble Space Telescope. During the production of this very fragile glass shell, the grinding tool jammed and broke the outer edge. Although the secondary mirror can still be used for test purposes, it is useless for scientific operations and another secondary mirror had to be produced. The irony of this story is the fact that this accident did not happen during the technologically very demanding part of production but in a rather uncritical part.

First light

On October 12, 2005 it happened: the long-awaited, first scientifically usable picture with the still one-eyed LBT could be taken. The target was the galaxy NGC801 in the constellation Andromeda, a galaxy which is not only aesthetically but also scientifically very interesting, since a starburst covers the whole galaxy and jumbles interstellar gas and dust. In the background, there are numerous smaller, more distant galaxies. The first light image was taken in the blue spectral band with the Large Binocular Camera (B-band). This camera has a detector of 4 CCDs in the focal plane, with 2048x2048 pixels each.

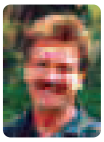
The LBT becomes a binocular

As the name suggests, the telescope becomes the LBT only after the installation of the second main mirror. The second primary mirror was produced in 2002/3, polished in 2004 and transported to Mt Graham and installed in the telescope in summer 2005. In January 2006, the second main mirror was aluminized. Thus, as this report goes into print, a binocular telescope can indeed be found on Mt Graham. Second light is now planned for summer 2006.

The LBT team at AIP:

M. Steinmetz (board member), K.G. Strassmeier (PI Pepsi),
P.A. Stolz und H. Klein (financial affairs),
J. Storm (PM AGW-units), H. Zinnecker (LBTI-scientist),
M.I. Andersen (PM Pepsi), E. Popow (Technology Division)

Technologietransfer – OptecBB



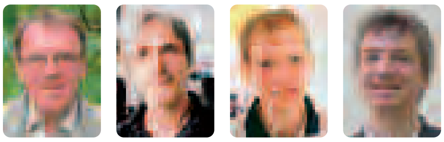
M. M. Roth

Aufgrund seiner Stiftungssatzung ist das AIP an erster Stelle der astrophysikalischen Forschung verpflichtet, also im Unterschied zu angewandter Forschung oder den Ingenieurwissenschaften einem Gebiet der Grundlagenforschung. Nichtsdestoweniger resultiert F+E in der Grundlagenforschung häufig in Innovationen, die sich nachträglich als wirtschaftlich erfolgreiche Produkte zum Nutzen einer ganzen Volkswirtschaft vermarkten lassen. In der Astronomie war die Entdeckung der besonderen thermischen Eigenschaften von Glaskeramik (ZERODUR), die ursprünglich von Schott für den Bau der Optiken großer Spiegelteleskope entwickelt wurde, auch ein großer wirtschaftlicher Erfolg, um nur eines von vielen Beispielen herauszugreifen: Das CERAN Kochfeld einer modernen Küche ist heute für jeden ein Begriff! Die Nachfrage nach hochwertigen Produkten aus Labors, die sich mit der Entwicklung astronomischer Instrumentierungen befassen, hat wichtige Auswirkungen auf lokale Hochtechnologie-Branchen, besonders insofern, als kleine und mittelständische Unternehmen (KMU) betroffen sind. Existierende internationale Verbindungen, die in der modernen Astrophysik Tradition haben und dort unerlässlich sind, können auch durchaus hilfreich zum Knüpfen erster Kontakte für neue Industriepartnerschaften sein. Schließlich ist auch das positive Image der Astronomie in der Öffentlichkeit, besonders im Bereich von Hochtechnologie wie etwa Supercomputern, Optik, Elektronik, Präzisionsmechanik und anderen Technologien, hilfreich für das Standortmarketing einer Industrieregion. Aus allen diesen Gründen ist eine enge Zusammenarbeit zwischen Industrie und akademischer Forschung von wachsender Bedeutung für jede moderne Industriegesellschaft. Das AIP ist daher bemüht, gute Kontakte zu örtlichen KMUs und anderen Unternehmen zu unterhalten und ist in diesem Zusammenhang auch als Mitglied in dem OpTecBB Netzwerk engagiert (Optische Technologien in Berlin und Brandenburg). Das AIP nimmt in diesem Zusammenhang regelmässig an Workshops, Netzwerkveranstaltungen und Veranstaltungen für die Öffentlichkeit teil.

First and foremost, the objective of the AIP is to provide scientific advances in the field of astrophysics, i.e. a field of fundamental science, as opposed to applied research and engineering. However, R&D for fundamental science often produces innovations, which can then be well exploited in industrial applications for the benefit of the whole economy of a country. In astronomy, the discovery of the unique thermal properties of glass ceramics (ZERODUR) for the purpose of developing superior mirrors for large optical telescopes would be only one such example – also known as CERAN cooktop panels in almost any modern household. The demand for high quality engineering products from laboratories developing astronomical instrumentation, also has an important impact on local high-tech clusters, in particular as far as small and medium size enterprises (SME) are concerned. Long-standing international contacts, which are necessarily common-place in astrophysics, sometimes help to establish new industrial partnerships between enterprises in foreign countries. Last but not least, the positive image of astronomy held by the general public, associated with high-tech in computation, optics, electronics, precision mechanics, and other technologies, has a favourable influence on the marketing potential of the local industrial area. For all of these reasons, a tight relation between industry and academia is of ever-growing importance in any modern industrial society. Therefore, the AIP maintains good contacts with local SMEs and other industrial partners, e.g. as a member in the OpTecBB Network (Optische Technologien in Berlin-Brandenburg), and participates on a regular basis in workshops, network events, and presentations for the general public.

Besuch einer Wirtschaftsdelegation aus dem Optik-Cluster Tucson mit Walter Momper, Präsident des Berliner Abgeordnetenhauses am 3.6.2005, hier mit Prof. Steinmetz und Dr. Roth. Das Treffen diente der Vorbereitung von Wirtschaftskooperationen zwischen Unternehmen der Optikindustrie in Berlin und Tucson.

Solar Radio Astronomy with the Low Frequency Array (LOFAR)



G. Mann, H. Enke, C. Vocks, M. Steinmetz

LOFAR ist ein neuartiges Radioteleskop für den Frequenzbereich 30-240 MHz. Es besteht aus einem zentralen Kern und entfernten Stationen. Jede Station besteht aus einem Feld einfacher Dipolantennen, deren Signale digitalisiert und im Rechenzentrum in Groningen, Niederlande, verarbeitet werden. LOFARs wissenschaftliche Ziele decken einen weiten Bereich vom frühen Universum über Galaxien, stellare Astrophysik bis zur Sonnenphysik ab. Es ist geplant, am AIP eine LOFAR-Station einzurichten sowie ein Solar Science Data Center zu etablieren. Die zu bewältigenden Datenmengen erfordern eine Einbindung des Projekts in die GRID-Infrastruktur.

The Low Frequency Array (LOFAR) is a novel radio telescope that operates in the frequency range of 30 -- 240 MHz. It is a radio interferometer consisting of 77 stations in a central core at Exloo (Netherlands) and remote stations. Fig. 1 shows a sketch of the network of LOFAR remote stations in Europe.

A station consists of dipole antennae for low and high frequencies that are spread out over areas of 60 m x 60 m. Fig. 2 shows a sketch of a LOFAR station. The antenna signals are digitized and sent to the Central Processing System (CPS) at Groningen. This novel approach provides LOFAR with a high flexibility and the possibility of directing up to eight beams at different sources in the sky so that it can be used by a corresponding number of concurrent users. LOFAR's scientific objectives cover the early universe, cosmology, galaxies, stellar physics as well as solar physics. The CPS does no scientific data analysis, but sends the data products to specialized Science Data Centers.

German institutions interested in a LOFAR collaboration have founded the German Long Wavelength (GLOW) consortium. The AIP will build a LOFAR station at the Observatory for Solar Radioastronomy at Tremsdorf.

The AIP plans to establish a Solar Science Data Center that will be responsible for developing solar observation programs, performing the observations as well as archiving the data and disseminating them to the scientific community. The amount of data and the necessary computing resources require its integration into the GRID infrastructure.

Solar radio emission in the LOFAR frequency range originates from the upper solar corona. LOFAR observations will greatly increase our knowledge about solar activity and its impact on Earth, usually referred to as Space Weather. Fig. 3 demonstrates the great progress in solar radioastronomy that LOFAR's imaging capabilities make available.

Fig. 1: Sketch of the structure of LOFAR and the remote stations in Europe.

Fig. 2: A LOFAR antenna field.

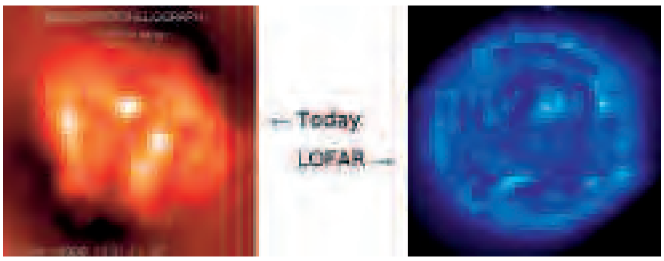
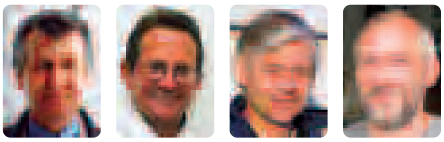


Fig. 3: Nancay radioheliograph and EIT/SOHO images of the Sun. LOFAR will observe the solar corona with similar resolution as EIT.

Sonnenobservatorium Einsteinturm
Ein Labor für Spektralpolarimetrie
Solar Observatory Einstein Tower
A laboratory for spectro-polarimetry



A. Hofmann, K. Arlt, H. Balthasar, J. Rendtel

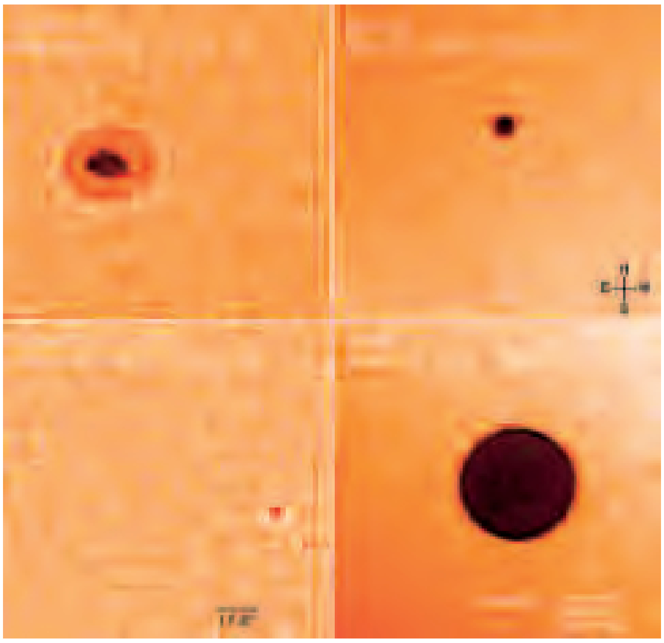
Im Einsteinturm befindet sich eine leistungsfähige Sonnenforschungsanlage, bestehend aus dem Turmteleskop mit 63 cm Öffnung und dem langbrennweitigen Spektrograf. Die modernisierte optische und mechanische Ausrüstung erlaubt eine spektrale Auflösung von 10^6. Bei guten Bedingungen kann eine Bildauflösung von 1"- 2" erreicht werden.

Schwerpunkt der Beobachtungen sind spektralpolarimetrische Messungen in Sonnenfleckengruppen. Die Polarisationsanalyse des Lichtes gestattet Rückschlüsse auf das Magnet- und Geschwindigkeitsfeld an der Oberfläche der Sonne.

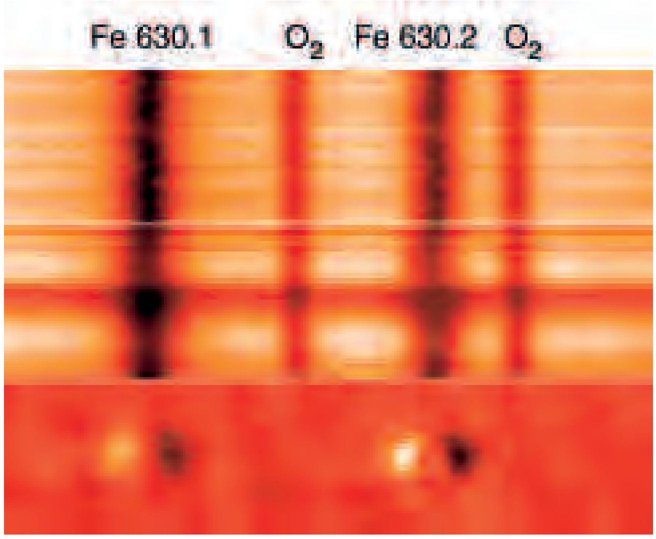
Die ständige Verfügbarkeit des Instruments mit seinem Labor spielt bei der Ausbildung des wissenschaftlichen Nachwuchses sowie Entwicklung und Tests neuer spektralpolarimetrischer Fokalinstrumente für den Einsatz an Großteleskopen eine bedeutende Rolle. Der Einsteinturm ist daher eine wichtige Ergänzung zu den großen Teleskopen auf Teneriffa.

The Einstein Tower houses a very efficient 63cm telescope combined with a long-focus spectrograph. Under favourable conditions the instrument reaches a spatial resolution of 1"-2". The modernised mechanical and optical equipment allows a spectral resolving power of 10^6. Observations focus on spectral-polarimetric measurements in solar active regions. The analysis of the polarisation of the light allows one to determine the magnetic field and radial velocities on the surface of the Sun.

The permanent availability of this large telescope, spectrograph and associated laboratory facilities is important for the education of young scientists as well as the development and testing of new spectro-polarimetric equipment for subsequent use at other large telescopes. In this sense, the Einstein Tower is an indispensable complement to the German solar telescopes at Tenerife.



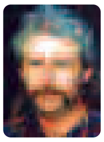
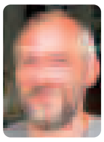
Beobachtungen mit dem Turmteleskop. Rechts: Die Planeten Merkur (oben) und Venus (unten) vor der Sonnenscheibe. Links: Als Vergleich ein mittelgroßer Fleck (oben) bzw. kleine magnetische Poren (unten) auf der Sonne. Es ist die granulare Struktur der Sonnenoberfläche zu erkennen. Der Balken im linken unteren Bild entspricht dem Erddurchmesser (ca. 12750 km).



Spektralpolarimetrische Beobachtungen bei 630 nm. Die Spektren zeigen zwei solare Eisenlinien und zwei Sauerstofflinien der Erdatmosphäre. Oben: Spektrum der ungestörten Sonne. Die sägezahnartige Struktur der Eisenlinien wird durch turbulente Bewegungen in der Sonnenatmosphäre verursacht. Mitte: Spektrum einer magnetischen Pore, erkennbar an dem dunklen Streifen quer über das Spektrum. Durch das Magnetfeld der Pore sind die beiden Eisenlinien verbreitert. Unten: Zirkular polarisierter Anteil des mittleren Spektrums. Die Aufspaltung zwischen den entgegengesetzt polarisierten Linienanteilen ist proportional zur Magnetfelddichte in der Pore.

Die automatische Aussenstelle Radiosonne des AIP
The remotely controlled solar radio burst patrol



G. Mann, H. Aurass, U. Hanschur, J. Rendtel

Im Observatorium für solare Radioastronomie arbeitet ein Radiospektralpolarimeter, bestehend aus einem System von vier Sweepspektrografen und zwei Spektrallupen im Frequenzbereich 40-800 MHz. Mit dem Gerät wird der Ramaty High Energy Spectroscopic Imager (RHESSI) der US-amerikanischen Weltraumbehörde NASA bodengebunden begleitet. In den Jahren 2004 und 2005 konnten dank finanzieller Unterstützung durch die US Air Force (Geophysics Laboratory und EOARD) weitere Komponenten modernisiert werden. Die Daten werden kontinuierlich in den NOAA Solar Geophysical Data publiziert und stehen online auf der AIP Webseite zur Verfügung. Auf dem Observatoriumsgelände wurden im Jahre 2005 Voruntersuchungen für den Aufbau einer LOFAR-Station durchgeführt. Dies ist Voraussetzung für die Errichtung des Kompetenzzentrums "Sonnenphysik mit LOFAR" am AIP.

The radio observatory of the AIP records solar flare emission in the frequency range between 40 and 800 MHz. The entire system consists of four automatically running sweep spectrometers, combined with two multichannel magnifiers (working as polarimeters in a narrow sub-frequency band). Parts of the mechanics and electronics were renewed in 2004 and 2005, thanks in part to funding by the Geophysics Laboratory and the EOARD of the US Air Force. The data are used for the diagnosis of plasma processes in the solar corona with special regard to electron acceleration at coronal shock waves. They are also an important ground based support for solar space missions, now especially the Ramaty High Energy Spectroscopic Imager (RHESSI). The solar radio burst event listings are routinely published in NOAA Solar Geophysical Data and are available online on the AIP webpage. Fig. 1 shows the antennae recording the range between 100 and 800 MHz.

Solar radio burst emission is excited by energetic electrons in the solar corona. As an actual example, the radio spectrum of an event occurring on 14 November 2005 (Fig. 2) shows the emission signature of shock-accelerated electrons. Informative details are visible of the band split pattern emitted by the propagating shock front. The observations are studied paying special attention to the sometimes visible radio signature of the standing shock waves formed at the reconnection outflow termination during solar flares. This research is important for understanding energetic particle acceleration in cosmic plasmas and for space weather applications.

At the aerial site of the observatory, initial investigations have been carried out for installing a low frequency array station as part of the international LOFAR project. This is part of the intended formation of a competence center "Solar physics with LOFAR" at the AIP.

Fig. 1: Die 7,5 und 10 m Durchmesser-Antennen des Observatoriums fuer den Frequenzbereich zwischen 100 und 800 MHz.

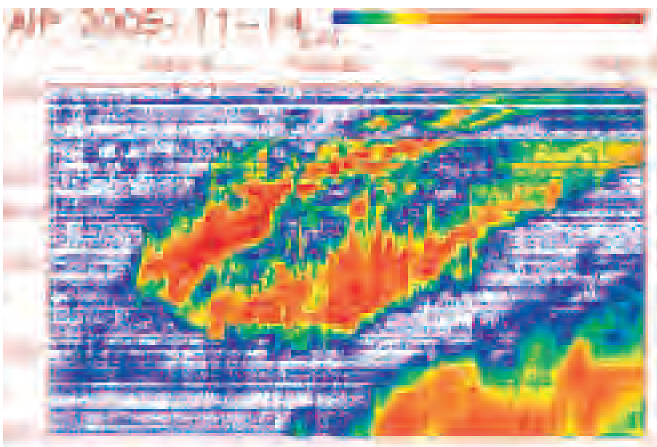
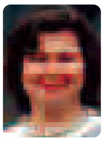


Fig. 2: Ausschnitt aus dem Typ II Burst-Spektrum vom 14. November 2005.

Wissenschaftliches Dokumentationszentrum
Science documentation centre



R. v. Berlepsch

Die Geschichte der Naturwissenschaft ist, je weiter man zurückgeht, zunehmend identisch mit der Geschichte der Astronomie. Dementsprechend umfangreich und von weltweitem Interesse ist der historische Buchbestand einer mehr als 300 Jahre alten Bibliothek. Zu den wertvollsten Büchern gehören die Alfonsinischen Tafeln (Ausgabe von 1483).

Im Zuge der Erfassung der Bibliotheksbestände wurde auch schon ein großer Teil des wertvollen Bestandes bibliothekarisch erfasst und ist über den Online-Katalog recherchierbar. Durch die Anschaffung eines Buchscanners konnte nun auch die inhaltliche Erschließung in Angriff genommen werden. Für die Erfassung des wertvollen Fotoplattenbestandes ist die Anschaffung eines Scanners geplant.

Die Bibliothek des AIP ist als offene Freihandbibliothek organisiert; ihre Dienstleistungen orientieren sich an der Struktur und den Inhalten der Institutsforschung, werden aber auch externen Nutzern/innen angeboten. Der Präsenzbestand umfasst ca. 75000 Bestandseinheiten, 500 Atlanten mit ca. 7000 Himmelskarten sowie 19000 Fotoplatten. Darüber hinaus gehören zum Bestand der Bibliothek ca. 12000 ungebundene Sternwartenveröffentlichungen von 300 Observatorien seit dem 17. Jh. und die Schriften und Reihen von 100 Akademien und Gesellschaften. Der Nachweis der Bibliotheksbestände erfolgt zu 20% über einen Online-Katalog. Außerdem werden der Zugang zur elektronischen Zeitschriftenbibliothek, Fachdatenbanken und Fachrecherchen angeboten. Durch Netzwerkbildungen wie den Arbeitskreis der Leibniz-Bibliotheken und das Library and Information Services in Astronomy (LISA) Netzwerk konnte die Literatur- und Informationsbeschaffung deutlich verbessert werden. Im Berichtszeitraum konnte die Anzahl der Online-Zeitschriften durch Konsortialbildungen innerhalb der Leibniz-Gemeinschaft, wie das Blackwell-Konsortium, deutlich erhöht werden. Die Bibliothek hat 100 Periodika im Abonnement und bietet Zugriff auf ca. 400 eJournals. Alle diese Serviceleistungen der Bibliothek sind auf den Bibliothekswebseiten (http://www.aip.de/groups/bib/lib.html) dargestellt und abrufbar.

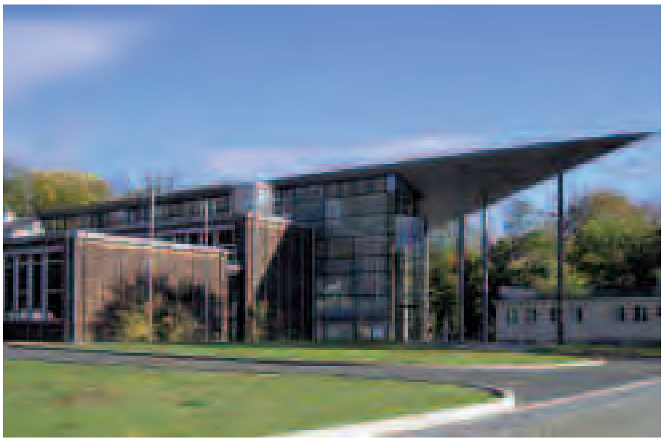
Ein Höhepunkt im Berichtszeitraum war die 5. Arbeitstagung des Arbeitskreises „Bibliotheken und Informationseinrichtungen der Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz", die vom 27. – 29. Oktober 2004 am Astrophysikalischen Institut Potsdam (AIP) stattfand. Die 70 Vertreter der bundesweit verteilten Bibliotheken der Leibniz-Gemeinschaft hatten Gelegenheit, sich im Rahmen eines Empfanges in der Bibliothek umzuschauen, bevor am nächsten Tag die Vorträge begannen. Hauptanliegen der alljährlichen dreitägigen Tagung war ein aktiver Gedankenaustausch, mit dem Ziel, die Zusammenarbeit untereinander intensiver zu gestalten und zu festigen.

The further you go back in time the more identical the history of science is to the history of astronomy. Accordingly, the considerable historical book stock of a 300 year old library is of worldwide historic interest. One of the most valuable books is "The Alfonsinischen Tafeln" (1483).

In the course of the documentation of the library stock, a large part of the valuable collection has already been documented and can be found in the online catalogue. The purchase of a book scanner has allowed us to make a start at subject indexing. Documentation of the valuable collection of photo plates is planned. Today, the library of the AIP is an open access library. Services are oriented at the structure and contents of research within the institution. However, the facilities are also offered to external users. The open access holdings include about 75000 inventory units, 500 atlases containing 7000 star charts as well as 19000 photo plates. Moreover, approximately 12000 unbound observatory publications from 300 observatories dating from the 17th century and writings and periodicals of 100 academies and societies are part of the collection. The library stock is listed in the online catalogue. Furthermore, we offer access to our electronic library of journals, scientific databases and subject-matter search. By creating networks like the working group of libraries of the Leibniz Association and the network of Library and Information Services in Astronomy (LISA), literature acquisition and the provision of information improved remarkably. During the reference period, the number of electronic journals increased by the formation of consortia, for example the Blackwell consortium within the Leibniz Association. The library subscribes to 100 periodicals and give access to approximately 400 electronic journals. All services can be found on the library website (http:// www.aip.de/groups/bib/lib.html).

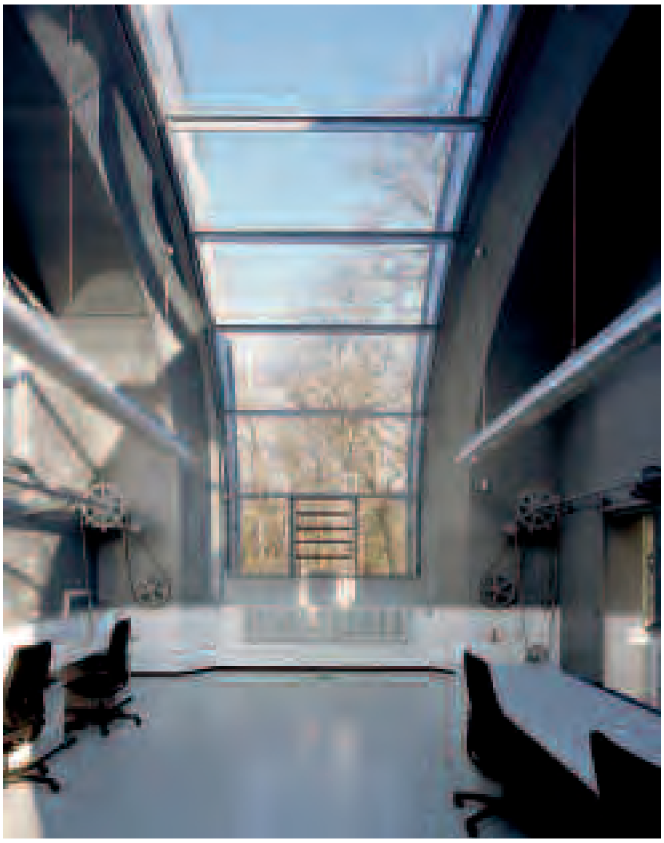
A highlight in the reported time span was the 5th workshop of the working group "Bibliotheken und Informationseinrichtungen der Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz" which took place from the 27th to the 29th October 2004 at the Astrophysical Institute Potsdam. 70 representatives of the libraries of the Leibniz Association from all parts of Germany had the chance to look around the library during the reception before the talks started the next morning. The primary objective of the annual workshop lasting three days was an active exchange of ideas with the goal to intensify and consolidate the cooperation.

Der Forschungscampus Babelsberg



Schwarzschildhaus: Das Schwarzschildhaus ist das Technologiegebäude des AIP. Es wurde im Jahre 2000 eingeweiht und beherbergt heute eine Integrationshalle mit Teleskopsimulator und mehrere Forschungsgruppen, Labore und Werkstätten.

Hauptgebäude: Die 1913 errichtete Sternwarte ist das zentrale Gebäude und bietet Platz für Forschungsgruppen des Bereichs Kosmische Magnetfelder und die Administration. In der großen Kuppel befindet sich der alte Refraktor, die Teleskope in den kleineren Kuppeln werden auch heute noch genutzt.



Bibliothek: Ursprünglich beherbergte die große Bibliothekskuppel eines der größten Fernrohre der Welt, ein 122-cm-Spiegelteleskop; das neue Kuppelgebäude wurde 2002 der Bibliothek des AIP zur Nutzung übergeben.

Meridianhäuser (MCC): Die ehemaligen Meridianhäuser sind heute das Medien- und Kommunikationszentrum des AIP, in dem die Datenströme der robotischen Teleskope und ferngesteuerten Instrumente zusammenlaufen.

Container: Das Bürogebäude neben der Bibliothek wird von den Arbeitsgruppen Solare Radioastronomie und Kosmologie genutzt.

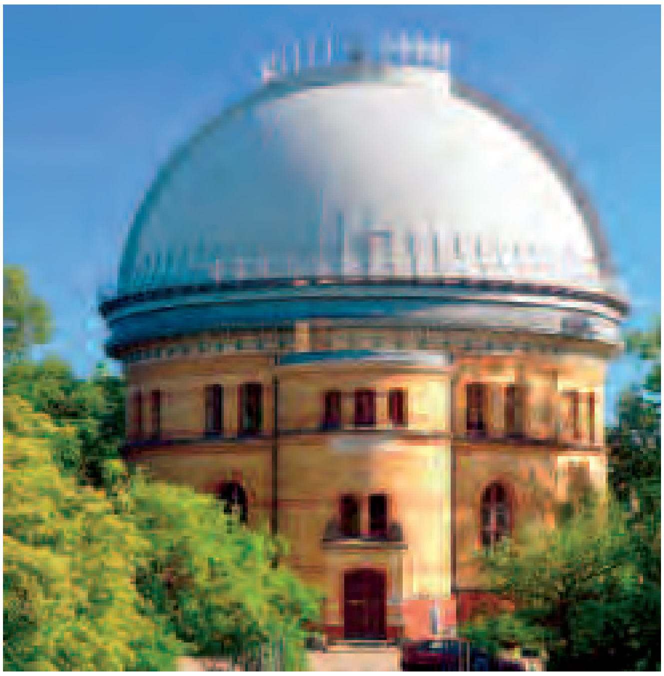
Merzrefraktor: Kuppel des ehemaligen Merz-Refraktors, später beherbergte sie ein 50-cm-Schmidt-Teleskop. Heute ist das Gebäude nicht mehr in Betrieb.

Direktorenhaus: Das Gebäude wurde für den Direktor der Sternwarte Babelsberg, Hermann Struve errichtet. Heute hat das Haus Büros für die Wissenschaftler der Abteilungen stellare Physik und Magnetohydrodynamik.

Persiushaus: Das Gebäude wird dem Architekten Reinhold Ernst Ludwig Persius (1835-1912) zugeschrieben und umgangssprachlich als Persiushaus bezeichnet. Nach einer Sanierung wird dieses Gebäude für Zwecke des Instituts zur Verfügung stehen.

Observatorium für solare Radioastronomie: Das Observatorium für solare Radioastronomie befindet sich bei Tremsdorf südlich von Potsdam und überwacht mit Antennen für verschiedene Frequenzbereiche automatisch die Radiostrahlung aus der Sonnenkorona.

Einsteinturm: Der Einsteinturm ist das erste bedeutende Bauwerk des bekannten Architekten Erich Mendelsohn. Es wurde in den Jahren 1919 bis 1924 entworfen und fertig gestellt, wobei der Rohbau bereits seit 1921 besteht. Der Einsteinturm ist ein Zweckbau, ein Sonnenobservatorium, das bis zum zweiten Weltkrieg auch wissenschaftlich das bedeutendste Sonnenteleskop in Europa war. Der Einsteinturm wurde ab November 1997 grundlegend renoviert. Die Wiedereröffnung fand am 1. Juli 1999 mit einem Festakt statt.



Großer Refraktor: Der Große Refraktor ist ein Doppelfernrohr auf dem Gelände des ehemaligen Astrophysikalischen Observatoriums Potsdam und wurde 1899 der Nutzung übergeben. Nach umfassender Restaurierung kehrte der Große Refraktor am 17.6.2005 auf den Telegrafenberg zurück.

Astronomische Nachrichten
Astronomical Notes

K. G. Strassmeier und das AN-Team

Das AIP ist als Nachfolger der Berliner Sternwarte und des Astrophysikalischen Observatoriums Potsdam der Herausgeber der im Jahr 1821 durch H.C. Schumacher gegründeten und damit weltweit ältesten noch periodisch erscheinenden astronomischen Zeitschrift, der Astronomischen Nachrichten/Astronomical Notes (AN).

Die neu eingeleiteten Änderungen des Layout und die verstärkte Nutzung elektronischer Medien zeigen mittlerweile Wirkung. So haben sich alle Kenngrößen des Journals positiv entwickelt. Das betrifft die Anzahl der eingereichten und publizierten Arbeiten, den Seitenumfang des Journals, die Zahl der Autoren und standardisierte Werte wie z.B. den vom ISI generierten Journal Impact Factor. Im Berichtszeitraum wurden 18 Bände mit 328 Originalartikeln und einer Gesamtseitenzahl von 679 im Jahre 2004 und 1071 im Jahre 2005 editiert und bei Wiley-VCH in Berlin verlegt.

Astronomische Nachrichten/Astronomical Notes (AN), founded in 1821 by H.C. Schumacher, remains the oldest astronomical journal in the world still being published. New changes and face lifts occurred with the aim to improve the visibility and acceptance of the journal by the international astronomical community. These actions achieved their aims in general terms. All benchmark figures of the journal saw a very positive development. The number of submitted and published papers, the number of pages per year and the number of authors grew considerably. This applies also to standardised benchmarks, e.g. the Journal impact factor generated and published by the ISI. In the reported period, 18 volumes with 328 original articles and a total number of 679 pages in 2004 and 1071 pages in 2005 have been edited and were published by Wiley-VCH in Berlin.

Special Issues in 2004/2005 were:

Issue 2-2004:
Euro 3D Science Workshop Proceedings
in Potsdam, Germany

Issue 6/8-2004:
Proceedings of the 3rd Potsdam ThinkShop "Robotic Astronomy"
in Potsdam, Germany

Issue 7-2005:
Proceedings of the 79th regular meeting of the General Assembly of the Deutsche Astronomische Gesellschaft,
in Cologne, Germany

Issue 8-2005:
Proceedings of the "Quasi Periodic Oscillations in Black hole and Neutron Star sources" meeting
at Nordita, Copenhagen, Denmark

Issue 10-2005:
Proceedings of the "Ultra-low-mass star formation and evolution" workshop
in La Palma, Spain

The AN Team
G. Rüdiger, D. Schönberner, A. Schwope, K. Fritze, M. Krumpe, W. Thänert

Lectures

Vorlesungen WS 03/04

Universität Potsdam

- Hamann (Univ. Potsdam), Staude, J.: Astrophysikalisches Praktikum
- Klessen: Kugelsternhaufen – Laboratorien für stoßdominierte Stellardynamik
- McCaughrean: Modern telescopes and their instrumentation
- Mann: Einführung in die kosmische Plasmaphysik
- Steinmetz/Lamer: Einführung in die Astronomie und Astrophysik I, mit Übungen
- Strassmeier: Die `solar-stellar connection'
- Wisotzki: Quasar-Absorptionslinien und das Intergalaktische Medium

Humboldt-Universität zu Berlin

- Staude/Balthasar: Einführung in die Astronomie und Astrophysik I, mit Übungen

MINTEC – Verein mathematisch-naturwissenschaftlicher Excellence – Center an Schulen e.V.

- Schwope/Krumpe: Schülerlaborpraktikum, März 2004

Vorlesungen SS 04

Universität Potsdam

- Klessen: Kugelsternhaufen II
- Mann: Einführung in die Radioastronomie
- Schönberner: Aufbau und Entwicklung der Sterne, mit Übungen
- Staude: Astrophysikalisches Praktikum
- Steinmetz/Jahnke: Einführung in die Astronomie und Astrophysik II, mit Übungen

Humboldt-Universität zu Berlin

- Staude/Balthasar: Einführung in die Astronomie und Astrophysik II, mit Übungen

Technische Universität Berlin

- Schwope: Röntgenastronomie

Vorlesungen WS 04/05

Universität Potsdam

- Klessen: Physik der Sternentstehung
- Strassmeier: Exotische Himmelsobjekte
- Wisotzki/Steinmetz: Galaktische und Extragalaktische Astrophysik, mit Übungen
- Rüdiger: Cosmic magnetism

Technische Universität Berlin

- Schwope: Strahlungsprozesse in der Astrophysik

Vorlesungen SS 05

Universität Potsdam

- Klessen, Kitsionas: Seminar – Spezielle Themen in der Sternentstehung
- Steinmetz/Knebe: Kosmologie und frühes Universum
- Strassmeier: Kosmische Magnetfelder
- Wisotzki/Jahnke: Aktive Galaxien, Quasare, Schwarze Löcher

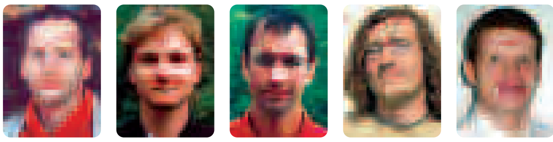
Technische Universität Berlin

- Liebscher: Relativitätstheorie und Geometrie

Univ. of Canterbury, Christchurch, Neuseeland

- Zinnecker: Pre-Main Sequence Stellar Evolution (17. Feb - 28.April)

Das 70cm Teleskop in Potsdam-Babelsberg
The 70cm telescope at Potsdam-Babelsberg



A. Schwope, A. Staude, R. Schwarz, J. Vogel, M. Krumpe

Das 70cm Teleskop des AIP ist in der Westkuppel des Hauptgebäudes untergebracht. Die Steuerung der Messungen und das Nachführen des Teleskops werden von einem separaten Kontrollraum vorgenommen. Das Teleskop ist mit einer Stickstoff gekühlten CCD-Kamera ausgestattet. In den Jahren 2004-05 wurde das Teleskop in etwa 40 Nächten für astronomische Beobachtungen eingesetzt. Diese umfassten rein wissenschaftliche Arbeiten, die Studentenausbildung in Zusammenarbeit mit der Universität Potsdam und Beobachtungen für populärwissenschaftliche Zwecke.

Schwerpunkt der wissenschaftlichen Arbeiten sind kataklysmische Veränderliche, das sind sehr enge, wechselwirkende Doppelsterne. Primäres Ziel der Beobachtungen am 70cm Teleskop ist die Bestimmung der Bahnumlaufsperioden neu gefundener Sterne, die Überwachung bekannter Objekte zur Suche nach Ausbrüchen sowie begleitende optische Beobachtungen zu Röntgenbeobachtungen mit XMM-Newton. Ein Beispiel dafür ist in der Abbildung 2 gezeigt, in der die gleichzeitig mit dem 70cm Teleskop im roten Spektralbereich sowie mit den Ultraviolett- und Röntgenkameras auf XMM-Newton gewonnenen Beobachtungsdaten dargestellt sind.

The 70cm telescope of the AIP is located in the Western dome of the main building of the AIP. Astronomical observations are controlled from a separate room. It is equipped with a nitrogen-cooled CCD camera and a Johnson-Cousins filter set. With this configuration, it is possible to get accurate time resolved photometry in different wavelength bands for objects of up to 19th magnitude, despite the bright night sky in the Potsdam area. In 2004-05, the telescope was used on about 40 nights for astronomical observations, focusing on student education, monitoring programs and for public outreach.

The celestial objects which received most attention at the telescope are cataclysmic variable stars. These are short-period close binaries: the whole system would fit completely within our Sun. Scientific observations of these stars are focusing on the determination of periodicities of newly detected sources, monitoring of well-known sources and ground-based coverage while observing with a satellite from space. An example is given in Fig. 2. Data are shown which were obtained simultaneously with the 70cm telescope in the optical, and the OM and EPIC cameras on the spacecraft XMM-Newton in the ultraviolet and X-ray spectral ranges.

Fig. 1: Das 70cm Teleskop in der Westkuppel des Hauptgebäudes im „gläsernen" Dom

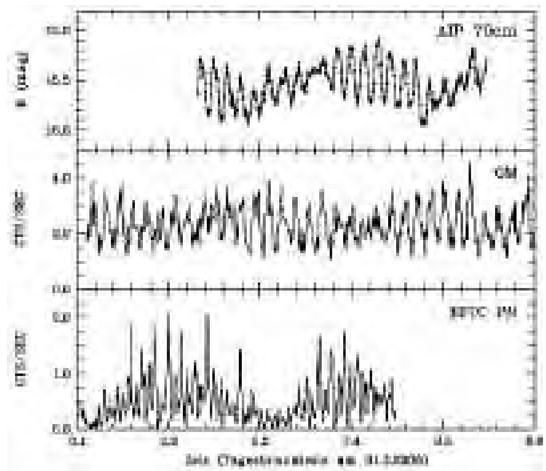
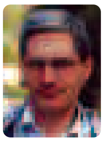
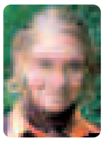
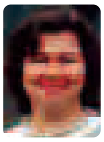
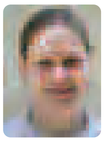


Fig. 2: Simultanbeobachtung mit dem 70cm Teleskop und dem Röntgensatelliten XMM-Newton (ESA) des Doppelsterns 1RXS J062518.2+733433. Dargestellt sind optische, ultraviolette und Röntgenlichtkurven. Das unterschiedliche Zeitverhalten in den verschiedenen spektralen Fenstern gibt Aufschluss über den Ursprungsort und die Reprozessierung der primären Röntgenstrahlung.

Öffentlichkeitsarbeit
Public Relations

D. E. Liebscher, S. Scholz, R. v. Berlepsch, S. Bonatz

Astronomie und Astrophysik stoßen auf großes Interesse in der Öffentlichkeit und den Medien. Die Wissenschaftler des AIP haben sich zum Ziel gesetzt, interessante und spannende Angebote zu präsentieren und die eigene Forschung wie auch das Wissenschaftsgebiet im Ganzen anschaulich werden zu lassen. Das AIP öffnete seine Türen für eine Vielzahl von Veranstaltungen mit Besucherzahlen zwischen 15 und 2.000: so zur Langen Nacht der Sterne 2004 und 2005, zur Schaustelle Berlin, während des Venustransits 2004, zum bundesweiten Zukunftstag (22.4.2004, 28.4.2005). Auch ist das Institut mit einem Informationstisch zu Gast bei anderen Veranstaltungen, speziell der OptecBB (Optische Technologie in Berlin und Brandenburg).

Im Berichtszeitraum konzentrierte sich Vieles auf die Vorbereitung und Realisierung eigener Beträge zum Einstein-Jahr 2005: Das Vortragsangebot wurde entsprechend erweitert, Ausstellungen mitgestaltet und verschiedene Poster und Informationsblätter entwickelt, die sich bei Lehrern und Schülern wachsender Beliebtheit erfreuen. Speziell zum Wissenschaftssommer 2005 wurde ein Stand auf dem Wissenschaftsmarkt gestaltet und öffentliche Vorlesungen gehalten. Die Rückkehr des Großen Refraktors war ein besonderes Ereignis. Die Wiedereinrichtung des Michelson-Kellers auf dem Telegrafenberg wurde begleitet. Darüber hinaus wurden verschiedene Aussteller beraten und zahlreiche Exponate verliehen.

Astronomy and Astrophysics are subject of an increasing interest in the media and to the public. Therefore we try to offer interesting and exciting events and to make our science and our addiction vivid and understandable. The events in the institute attracted between 15 and 2000 visitors: the Long Night of Stars 2004 and 2005, the *Schaustelle Berlin* , the Venus transit in 2004, the Future Day (Girl's Day) are only a few examples. We took part with information desks in other events, in particular in the OptecBB (Optical technology in Berlin and Brandenburg). Visitors of all ages follow our invitations to get captured by the fascination of the starred sky in guided tours, lectures and observations. In the two years covered by this report, many activities were centered on the preparation and realisation of our own contributions to the Einstein Year (World Year of Physics) 2005. The list of lectures was enlarged, exhibitions were supported and designed, and various poster and handouts were prepared, which attracted both teachers and pupils. During the Science Summer 2005, an exhibition was presented at the Science Fair in Potsdam, many public lectures were given, the return of the Great Refractor was celebrated, and the reinstallment of the Michelson Cellar in the building of the former AOP was supported. Various other exhibitions were supported.

The Public Relations group is open for all questions which concern the work of the institute. A list of lectures for schools was published and is often used (http://www.aip.de/pr/vor-

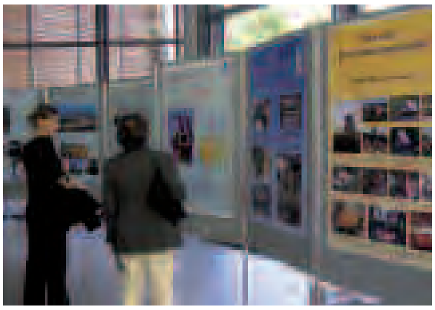


Zukunftstag 2005: Besichtigung der Feinmechanikwerkstatt und des Optiklabors

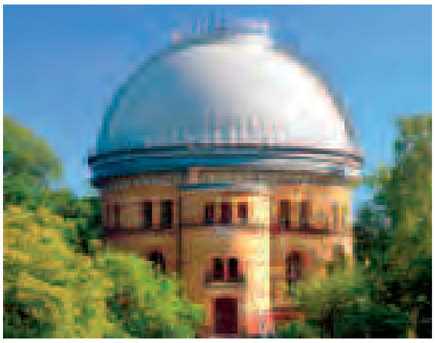
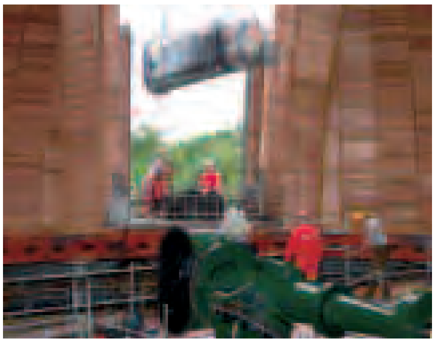
Die Presse- und Öffentlichkeitsarbeit steht als Ansprechpartner für alle Fragen zur Verfügung, die die Arbeit des Instituts betreffen. Das Institut hat ein Vortragsangebot für Schulen entwickelt, das regelmäßig abgerufen wird (http://www.aip.de/pr/vortragsangebot.html). Für neugierige Besucher steht mit dem Langen Donnerstag, dem jeweils dritten Donnerstag des Monats, ein regelmäßiger Termin fest, an dem das Institut ohne Voranmeldung besucht werden kann. Nicht zuletzt durch die persönliche Ansprache der verantwortlichen Redakteure der lokalen Medien verzeichnen diese Abende bis zu 60 Besucher.

Filmteams besuchen das Institut regelmäßig, sie schätzen besonders die historischen Anlagen des AIP. Ihnen wird bei Bedarf ein Interviewpartner vermittelt und eine Betreuung während der Dreharbeiten angeboten. Printmedien, Fernsehen und Hörfunk erwarten von uns und den Mitarbeitern des Instituts in zunehmendem Maße Stellungnahmen und Interviews zu wissenschaftlichen und anderen Fragen. Die Sendungen haben im Allgemeinen zur Folge, dass Hörer im Institut anrufen und weitere Aufklärung verlangen. Antworten prinzipiellerer Natur werden ins Netz gestellt. Die folgenden Bilder sollen die Vielfalt der Bemühungen darstellen.

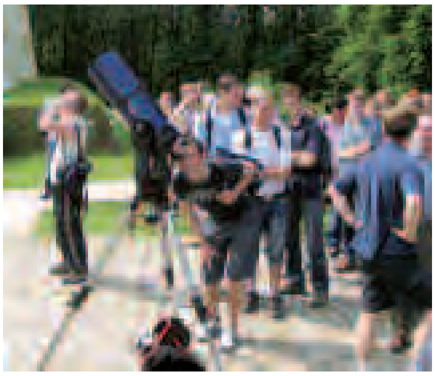
tragsangebot.html). The institute can be visited unannounced every third Thursday of the month, for a lecture and observations at our telescopes. Due to the direct interaction with the local media, these evenings draw up to 60 visitors. Movie producers visit and use the institute rather often. They appreciate the historical buildings and instruments of the institute. They find partners for interviews and support during the stay. Print media, TV and Radio expect comments and statements from us about scientific and other topics. After the broadcast, we receive additional questions from the public asking for supplementary information and explanations. General questions and answers are published on the net. The following images illustrate some of our efforts.



Lange Nacht der Sterne 2004


Rückkehr des Großen Refraktors: Ministerin Prof. Wanka begrüßt die Gäste, Prof. Steinmetz erläutert die Probleme



Beobachtung des Venustransits vor dem Einsteinturm

Lange Nacht der Sterne 2005



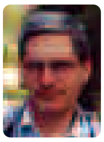

Wissenschaftssommer 2005 in Potsdam


Ausstellungsstand in der URANIA Berlin zur Physikertagung 2005

Besuch der Technologiestiftung Berlin im Media and Communications Center des AIP

Zum Einsteinjahr 2005 wurde eine Reihe von didaktischen Postern entwickelt, von denen diese beiden einen Eindruck vermitteln.

Fresnel's paradox, the Michelson experiment, and Einstein's axiom



Dierck-E. Liebscher

Üblicherweise wird das Michelson-Experiment als erste Grundlage der Relativitätstheorie gesehen. Zu dieser Grundlage wurde es aber erst nach Konstruktion der Relativitätstheorie. Es wird daran erinnert, dass der Michelson-Versuch zunächst das Fresnelsche Paradoxon der Aberration der Wellenfronten neu konstatierte.

Wellenfronten zeigen bei universell definierter Gleichzeitigkeit keine Aberration. Es war dieses Paradoxon, das Fresnel zwang, sich mit der Aberration von Wellengruppen zu begnügen. Diese Aberration von Wellengruppen erforderte allerdings wegen des Relativitätsprinzips die Existenz eines Äthers, der frei durch alle Materie strömte. Michelsons Experiment zeigte jedoch, dass dieser Äther von der Erde wie eine Atmosphäre mitgenommen wird. Erst Einsteins Axiom der Unabhängigkeit der Lichtgeschwindigkeit von der Bewegung des Messgeräts implizierte eine Aberration der Wellenfronten und machte Fresnels Konstruktion überflüssig. Deshalb wurde in der Folge das Ergebnis des Michelson-Experiments (gegen die begründeten Einwände Michelsons) als elementare Bestätigung des Einsteinschen Axioms angesehen.

In general, the result of the Michelson experiment is interpreted as the first foundation of the theory of relativity. This interpretation, however, is post festum. The experiment was designed to test the consequences of the effect of aberration in the wave picture of the propagation of light. When Young and Fresnel replaced the emanation picture with the wave picture, Fresnel found that there was no longer a way to produce an aberration of light wave-fronts. This was the only drawback of the wave picture of light propagation.

Fresnel explained the observable aberration as an effect on a wave group, and the aberration of wave-fronts is pushed into the unobservable background. The aberration of wave groups, nevertheless, requires a unique reference system of isotropic light propagation, and in order not to give up relativity, it must be material, i.e. some ether. This ether must be freely floating (just as an abstract reference system does with ease), and it was hard for Fresnel to convince his contemporaries of such a concept, given the fact that Copernicus had to convince people about the inverse, namely that the earth drags its atmosphere along while orbiting the sun.

Material or not, Fresnel's explanation implies anisotropic light propagation for the moving earth, and Michelson was the first to be able to measure this anisotropy with his interferometer. His conclusion was that Fresnel's explanation is wrong and that the ether is dragged along by the earth like an atmosphere. The paradox of aberration rose from the ashes.

With this interpretation, the experiment was just one of many, and there was no need for Einstein to cite it in particular when he found out that the axiom of an observer-independent velocity of light solves the known problems of electrodynamics in general and wave propagation in particular. There is no contradiction to his later attitude to see in the result of the Michelson experiment a basic backing of his axiom (although Michelson's experiment does not imply or prove the axiom, of course).

The aberration is a simple fact of the geometry of space-time, and the consequence of the aberration of wave-fronts is the relativity of simultaneity (Fig. 1).

Fig.1 Aberration. A wave front is moving in the y direction, together with embedded particles. While the aberration of the particles depends on the behaviour of the projections of the particles' world-lines, the aberration of the wave-fronts depends on the behaviour of the intersections of the wave's trace. There is no aberration of the wave-front without relativity of simultaneity. The demand of equal aberration of wave-fronts and particles implies the Lorentz group.

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First picture taken by the LBT

Wissenschaftliche Veröffentlichungen
Scientific Publications

2004 – In Zeitschriften
2004 – In Journals

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2004 – Wissenschaftliche Vorträge
2004 – Scientific Talks

Arlt, R.: **Magnetorotational instability in Ap star envelopes.** Poprad, Slowakei

Arlt, R.: **Magnetic shear-flows in stars.** Catania, Italien

Arlt, R.: **Magnetic-shear versus vertical-shear instability.** Schloß Ringberg

Arlt, R.: **Global simulations of the magnetic-shear and vertical-shear instabilities.** MPIA, Heidelberg

Arlt, R.: **Magneto-rotational instability in the solar core and Ap star envelopes.** Cambridge, UK

Arlt, R.: **New results on the magneto-rotational instability in stars.** TU Ilmenau

Auraß, H.: **Radio Pulsations - State of the Art and Summary of Working Group Activities.** CESRA Conference, Sabhal Mor Ostaig, UK

Auraß, H.: **On the Radio Evidence for Reconnection Outflow Termination Shocks.** SOHO-TRACE-RHESSI Workshop, Sonoma (CA), USA

Baumgärtel, K.: **Solitons and magnetic decreases in collisionless plasmas - key for understanding magnetic holes?** Workshop on Nonlinear Plasma waves, solitons, periodic waves and oscillitons in diverse space plasma environments, March 21 to 26, International Space Science Institute (ISSI), Bern, Schweiz

Böhm, P.: **3D Spectrophotometry with PMAS.** 4th Serbian-Bulgarian Astronomical Conference, Belgrad, Serbien

Dziourkevitch, N.: **Magneto-rotational instability for galactic disks: 3D global MHD simulations.** TU Ilmenau

Dziourkevitch, N.: **Interstellar turbulence driven by the magnetorotational instability**. Kopenhagen, Dänemark

Dziourkevitch, N.: **The dispersion and symmetry characteristic of MRI-driven turbulence in ISM.** Krakow, Polen

Egorov, P.: **Numerical study of eddy viscosity in the convective zone with NIRVANA.** 7. MHD-Tage, Ilmenau

Elstner, D.: **Sanssouci – ein Opteron-Cluster für die Astrophysik.** AEI Potsdam

Elstner, D.: **Sanssouci – ein Opteron-Cluster für astrophysikalische Simulationen am AIP.** ZKI Stuttgart

Elstner, D.: **Magnetic fields and spiral structure.** Krakow, Polen

Geppert, U.: **Temperature distribution in crusts of isolated cooling neutron stars.** Colloquium, MPE Garching

Geppert, U.: **Magnetic field effects on to the temperature distribution in neutron stars.** NATO Advanced Study Institute, Marmaris, Türkei

Gottlöber S.: **The lighthouses and deserts of the Universe.** (Structure formation from galaxy clusters to voids.) Colloquium, Granada, Spanien

Gottlöber S.: **The structure of dark matter halos.** KITP seminar, Santa Barbara, USA

Gottlöber S.: **Modeling galaxy formation with high-resolution simulations.** 6th Sino-Germany Workshop on Cosmology and galaxy formation, Tunxi Anhui, China

Granzer, T.: **Thin flux tube models for cool stars.** Colloquium of the Astronomical Institute of the University of Vienna, Wien, Österreich

Granzer, T.: **What makes an automated telescope robotic?** 3rd Potsdam Thinkshop on Robotic Astronomy, Potsdam

Granzer, T: **The STELLA observatory.** Colloquium Kiepenheuer Institut, Freiburg

Jahnke, K.: **AGN host galaxies from $0.05 < z < 2.75$: young stars and mergers?** Ringberg Workshop on AGN physics, Schloß Ringberg

Jappsen, A.-K.: **Angular momentum evolution of protostellar cores during clustered star formation.** Astrofest 2003, Department of Astronomy, Columbia University, New York, USA

Jappsen, A.-K.: **Non-isothermal gravoturbulent fragmentation: Effects on the IMF.** Workshop on Astrophysical Fluid Dynamics. Max-Planck-Institut für Astronomie, Heidelberg

Jappsen, A.-K.: **Non-isothermal graviturbulent fragmentation: Effects on the IMF.** Conference on Brown Dwarfs and Low Mass Stars. Volterra, Italien

Jappsen, A.-K.: **Mass spectra from gravoturbulent fragmentation cores to clusters.** Porto, Portugal

Kelz, A.: **Two years of PMAS operations at the Calar Alto telescope.** Annual Calar Alto Colloquium, IAA, Granada, Spanien

Kelz, A.: **3D spectroscopy of Interacting Galaxies.** Jahrestagung der Astronomischen Gesellschaft, Prag, Tschech. Republik

Kitchatinov, L.L.: **Stellar dynamos and differential rotation: what to observe?** Potsdam Thinkshop

Klessen, R. S.: **Star Formation.** Conference `Role of Mergers and Feedback in Galaxy Evolution', Schloß Ringberg

Klessen, R. S.: **Numerical Methods in Star-Formation Research.** Workshop `Frontiers in Computational Astrophysics', Wengen, Schweiz

Klessen, R. S.: **Gravoturbulent Star Formation. Splinter Meeting `Astrophysical Turbulence',** Jahrestagung der Astronomischen Gesellschaft, Prag, Tschech. Republik

Klessen, R. S.: **Star Formation.** Helmholtz School on Computational Physics, Potsdam

Klessen, R. S.: **SPH in Star-Formation Theory.** Tübingen/Heidelberg Workshop on Astrophysical Fluid Dynamics, Heidelberg

Klessen, R. S.: **The IMF from Gravoturbulent Cloud Fragmentation.** Dutch Astronomy Conference 2004, celebrating the 90th birthday of Prof. Adriaan Blaauw, Vlieland, Niederlande

Klessen, R. S.: **Mass Spectra from Gravoturbulent Fragmentation.** International Conference `50 Years of Stellar Initial Mass Function', Spineto, Italien

Klessen, R. S.: **The Initial Conditions of Star-Cluster Evolution.** MODEST-4 Workshop: `Modelling Dense Stellar Systems', Genf, Schweiz

Klessen, R. S.: **Theorie der Sternentstehung.** Institut für Theoretische Physik und Astrophysik, Kiel

Klessen, R. S.: **Sternentstehung.** Institut für Theoretische Astrophysik, Heidelberg

Klessen, R. S.: **Star-Formation Theory.** Niels Bohr Institute, Kopenhagen Dänemark

Klessen, R. S.: **Gravoturbulent Star Formation.** University of California at Berkeley, USA

Klessen, R. S.: **The Relation between Interstellar Turbulence and Star Formation.** University of California at Santa Cruz, USA

Klessen, R. S.: **Star Formation.** American Museum of Natural History, New York, USA

Klessen, R. S.: **The Formation of Stars.** Leicester University, UK

Klessen, R. S.: **Star Formation.** Universität Jena

Klessen, R. S.: **Gravoturbulent Star Formation.** Observatoire de Geneve, Schweiz

Klessen, R. S.: **Dynamical Processes in Astrophysics.** University of Hertfordshire, Hatfield, UK

Klessen, R. S.: **Star-Formation.** Max-Planck-Institut für Astrophysik, Garching

Klessen, R. S.: **Theory of Star Formation.** Max-Planck-Institut für Radioastronomie, Bonn

Klessen, R. S.: **Star Formation in Turbulent Interstellar Gas.** Leicester University, UK

Klessen, R. S.: **Polarlichter.** Universität Potsdam

Kliem, B.: **The kink instability in solar eruptions.** Ruhr-Uni Bochum, SFB 591

Kliem, B.: **TRACE, SOHO and RHESSI observations of erupting core flux in the solar X flare on 2002 April 21.** University of St. Andrews, UK

Kliem, B.: **Solar flares: from theory to reality.** PLATON network final meeting, Strasbourg, Frankreich

Kliem, B.: **Flare/CME Relationship.** 35th COSPAR Scientific Assembly, Paris, Frankreich

Kliem, B.: **Some open problems for magnetic reconnection in solar flares.** University of Cambridge, UK

Korhonen, H.: **Surface differential rotation on FK Com Cool Stars 13.** Hamburg

Korhonen, H.: **Flip-flop Phenomenon: Observations and Theory.** Dynamos of the Sun, Stars and Planets, Freiburg

Küker, M.: **Differential rotation of late-type stars.** Hamburg

Küker, M.: **Solar and stellar differential rotation.** KIS Freiburg

Küker, M.: **Stellar differential rotation and advection-dominated dynamo models.** Leeds, UK

Lodieu, N.: **A photometric study of the young open cluster Collinder 359.** XXIVth Moriond Astrophysics Meeting, the `Young Local Universe', La Thuile, Aosta Valley, Italien

Mann, G.: **LOFAR - Importance of low Frequency Observation of the Solar Radio Radiation.** LOFAR Meeting, Bremen

Mann, G.: **RHESSI Results - Generation of Energetic Electrons at the Termination Shock During Solar Flares.** AEF Frühjahrstagung, Kiel

Mann, G.: **ISSI Workshop - CME, Working Group F, CME - Related Coronal Phenomena.** ISSI Workshop on CMEs, Bern, Schweiz

Mann, G.: **On the Behaviour of the Alfvén Velocity in the Solar Corona.** ISSI Workshop on CMEs, Bern, Schweiz

Mann, G.: **RHESSI Results - Generation of Energetic Electrons at the Termination Shock During Solar Flares.** RHESSI Topical Workshop, Glasgow, UK

Mann, G.: **RHESSI Results - Generation of Energetic Electrons at the Termination Shock During Solar Flares.** EGS General Assembly, Nice, Frankreich

Mann, G.: **Electron Acceleration of Shock Waves in the Solar Corona.** EGS General Assembly, Nice, Frankreich

Mann, G.: **RHESSI Results - Generation of Energetic Electrons at the Termination Shock During Solar Flares.** CESRA Workshop 2004, Isle of Skye, UK

Mann, G.: **CESRA - Workshop, Working Group 2, Large-scale Disturbances Their Origin and Consequences.** CESRA Workshop 2004, Isle of Skye, UK

Mann, G.: **EIT Waves and Coronal Shock Waves.** AGU Chapman Conference, Turku, Finnland

Mann, G.: **The RHESSI Mission - The Sun in the Hard X-ray Light.** Royal Astronomical Observatory, Brüssel, Belgien

Mann, G.: **Flare Waves in the Solar Corona.** U.R.S.I. Committee of Belgium, Brüssel, Belgien

Mann, G.: **Generation of suprathermal electrons in the quiet solar corona and wind.** University of Leuven, Brüssel, Belgien

Mann, G.: **Solar Physics with LOFAR.** Jahrestagung des U.R.S.I.-Landesausschusses

Mann, G.: **RHESSI Results:Generation of Energetic Electrons at the Outflow Termination Shock During Solar Flares.** 6th European Workshop on Collisionless Shocks, Paris, Frankreich

Mann, G.: **Solar Physics with LOFAR.** Bonn

McCaughrean, M. J.: **Chandra Orion Ultradeep Project: Brown dwarfs.** COUP collaboration team meeting, Bonn

McCaughrean, M. J.: **The low-mass end of the IMF in star-forming regions.** `IMF@50: The Initial Mass Function 50 Years Later' conference, Spineto, Italien

McCaughrean, M. J.: **Future facilities with relevance to the IMF: Shortward of 30 micron,** `IMF@50: The Initial Mass Function 50 Years Later' conference, Spineto, Italien

McCaughrean, M. J.: **Birth of stars and planetary systems** American Astronomical Society Meeting, session on `JWST Science', Atlanta, USA

McCaughrean, M. J.: **Space infrared astronomy Lecture series at the XV Canary Islands Winter School of Astrophysics,** `Payload and mission definition in space sciences', Tenerife, Spanien

McCaughrean, M. J.: **Standing on the shoulders of giants: star and planet formation with the VLT and JWST** University of Nottingham, UK

Mücket, J.P.: **Measuring the cosmic Mach number by the Sunyaev-Zeldovich effect.** XXth IAP Colloquium, ` CMB Physics and Observations', Paris, Frankreich

Müller, V..: **Superclusters and Voids in the SLOAN DSS.** IAU Coll. 195 `Outside of Galaxy Clusters: intense life in the suburbs', Torino, Italien

Müller, V.: **Cosmology with Large Redshift Surveys: Cluster Mergers, Superclusters and Void.** Colloqium Astronomical Institut of Universidad Autonoma di Mexico, Mexiko

Rädler, K.-H.: **On the Karlsruhe dynamo experiment: 1. The last measurements, 2. The restricted role of the kinetic helicity.** Joint Meeting of COST P6 Working Group 1 and CNRS GdR Dynamos, Paris, Frankreich

Rädler, K.-H.: **Mean-field dynamo theory: early ideas and today's problems.** International Workshop on `The History of Magnetohydrodynamics', Coventry, UK

Rädler, K.-H.: **The dynamo in a turbulent screw flow.** 10th European Turbulence Conference, Trondheim, Norwegen

Rädler, K.-H.: **Mean-field dynamo theory, alpha-effect etc. – born in Thuringia.** 7. MHD-Tage, Ilmenau

Rädler, K.-H.: **Mean-field view on rotating magnetoconvection and a simple geodynamo model.** International Meeting on Dynamos of the Sun, Stars & Planets, Freiburg/Br.

Rädler, K.-H.: **The mean-field concept in stellar dynamos.** Workshop `Stellar Dynamo', Leeds, UK

Rausche, G.: **Fiber bursts as coronal magnetic field probe.** CESRA Conference, Sabhal Mor Ostaig, UK

Rendtel, J.: **Solar Observations at Izana, Tenerife.** 327. WE-Heraeus-Seminar Atmospheric Optics, Bad Honnef

Rendtel, J.: **Evolution of the Geminids observed over 60 years.** Meteoroids 2004, Univ. of Western Ontario, London, Kanada

Roth, M. M.: **Science Results from PMAS after 2 Years of Operation.** Calar Alto Colloquium, IAA Granada, Spanien

Roth, M. M.: **3D Spectroscopy.** Gemini South Observatory, La Serena, Chile

Roth, M. M.: **Promoting Integral Field Spectroscopy in Europe: first Results from the Euro3D Collaboration.** European Southern Observatory, Santiago, Chile

Roth, M. M.: **Spectroscopy of Extragalactic Planetary Nebulae as Tracers of Intermediate Age and Old Stellar Populations.** Jahrestagung der Astronomischen Gesellschaft, Prag, Tschech. Republik

Roth, M. M.: **Crowded Field 3D Spectroscopy.** Euro3D Data Analysis Workshop, CRAL Lyon, Frankreich

Rüdiger, G.: **How anti-solar rotation laws can be produced.** Hamburg

Rüdiger, G.: **MRI in magnetic TC experiments.** Catania, Italien

Rüdiger, G.: **MRI and the seed-field problem of the galactic dynamo.** Krakau, Polen

Rüdiger, G.: **MRI in protoplanetary disks & in the laboratory.** Tübingen

Rüdiger, G.: **MRI in galaxies.** Würzburg

Rüdiger, G.: **Instability of magnetized protoplanetary disks.** Heidelberg

Rüdiger, G.: **MHD Taylor Couette flow, also with Hall effect.** Nizza, Frankreich

Rüdiger, G.: **Differential rotation and the solar dynamo.** Paris, Frankreich

Rüdiger, G.: **Hall effect plus MRI for neutron stars and protoplanetary disks.** Institutscolloquium, Jena

Rüdiger, G.: **Hall effect and star formation.** Szczecin, Polen

Rüdiger, G.: **Global disk models with MRI and Hall effect.** Kopenhagen, Dänemark

Rüdiger, G.: **Das magnetische Universum.** Colloquiumsvortrag, TU Braunschweig

Rüdiger, G.: **Tachocline and dynamo theory.** Cambridge, UK

Schaffenberger, W.: **Simulating MHD flows with a Roe solver.** Colloquium, Kiepenheuer-Institut für Sonnenphysik, Freiburg

Schmeja, S.: **Star Formation from Gravoturbulent Fragmentation: Mass Accretion and Evolution of Protostars.** Dublin Institute for Advanced Studies, Dublin, Irland

Schmeja, S.: **Star Formation in Turbulent Molecular Clouds: Mass Accretion and Evolution of Protostars.** Jahrestagung der Astronomischen Gesellschaft, Prag, Tschech. Republik

Schmeja, S.: **Star Formation from Gravoturbulent Fragmentation: Mass Accretion and Evolution of Protostars.** Workshop `Low-mass stars and brown dwarfs: IMF, accretion and activity', Volterra, Italien

Scholz, R.-D.: **Open Cluster Stars for RAVE Observations in the Galactic Plane.** RAVE meeting, Edinburgh, UK

Schwope, A.: **Source detection and pipeline design for the 2XMM catalogue.** 16th XMM-SSC Consortium meeting, Santander, Spanien

Schwope, A.: **A serendipituous distant cluster survey with XMM-Newton.** X-ray survey workshop Garching

Staude, J.: **Solar magnetic fields and oscillations. Gemeinsames kern- und astrophysikal.** Colloquium des Forschungszentrum Karlsruhe sowie der Universitäten Tübingen, Heidelberg und Karlsruhe,Forschungszentrum Karlsruhe

Staude, J.: **Langperiodische Eigenoszillationen des Sonneninneren und geophysikalische Zeitskalen.** Astrophysikalisches Colloquium der Universität Göttingen. Sternwarte Göttingen

Steffen, M.: **LTE Line formation in convective stellar atmospheres.** Seminar, Observatoire de Paris/Meudon, Frankreich

Steinmetz, M.: **Galactic Archeology: The Formation History of the Galaxy Revealed.** Colloquium Institute Astrophysique de Paris, Frankreich

Steinmetz, M.: **Galactic Archeology: The Formation History of the Galaxy Revealed.** Joint Colloquium Steward Observatory/NOAO/NRAO, Tucson, USA

Steinmetz, M.: **Galactic Archeology: The Formation History of the Galaxy Revealed.** Physics Colloquium University of California at Santa Cruz, USA

Steinmetz, M.: **Unravelling the formation history of the Galaxy using stellar kinematics and abundances.** Symposium in Honour of the 60th Birthday of Wolfgang Hillebrandt, Schloß Ringberg

Steinmetz, M.: **Galactic Archeology and the Formation History of the Milky Way.** Physics Colloquium University of Basel, Schweiz

Steinmetz, M.: **Where are the first stars now?** Oort Workshop: CMB and first objects at the end of the dark ages: observational consequences of re ionization, Leiden Observatory, Niederlande

Steinmetz, M.: **Small Scale Structure and Cold Dark Matter.** DESY theory Workshop on Particle Cosmology

Steinmetz, M.: **Accretion Relicts in the Galactic Disk.** Friday Scientific Lunch Talks, NOAO Tucson, USA

Steinmetz, M.: **How I stopped worrying and learned to love baryons,** program introduction KITP blackboard lunch

Steinmetz, M.: **Cosmology with the Milky Way.** Colloquium IfA, Hawaii

Steinmetz, M.: **Cosmology with the Milky Way,** Astronomical Colloquium Caltech, USA

Steinmetz, M.: **Galactic Archeology with RAVE.** KITP, USA

Strassmeier, K. G.: **The STELLA instrumentation and building.** Sternwarte Hamburg

Strassmeier, K. G.: **Das Astrophysikalische Institut Potsdam.** Delegationsbesuch MPG-China, Potsdam

Strassmeier, K. G.: **The STELLA robotic observatory.** 3rd Potsdam Thinkshop on Robotic Astronomy, Potsdam

Strassmeier, K. G.: **Eddington goes Dome C?** 3rd Potsdam Thinkshop on Robotic Astronomy, Potsdam

Strassmeier, K. G.: **Observing stellar activity cycles.** Solar and Stellar Dynamos, Freiburg

Valori, G.: **Extrapolation of highly twisted magnetic structure from photospheric boundary data.** Platon meeting, Strasbourg, Frankreich

Valori, G.: **Extrapolation of highly twisted magnetic structure from photospheric boundary data.** Università Firenze, Italien

Verheijen, M.A.W.: **Galaxy evolution in dense environments; a concise HI perspective.** IAU Colloquium 195, Torino, Italien

Warmuth, A.: **The Outflow Termination of the X-class Flare of 18 July 2002.** RHESSI Topical Workshop, Glasgow, UK

Warmuth, A.: **Large-scale Waves and Shocks in the Solar Corona.** CESRA Workshop 2004, Isle of Skye, UK

Warmuth, A.: **The role of the outflow termination shock in solar flares.** RHESSI/ SOHO/ TRACE Workshop, Sonoma (CA), USA

Weber, M.: **Automatic data reduction & archiving for STELLA.** 3rd Potsdam thinkshop on Robotic Astronomy, Potsdam

Weber, M.: **Evolution of stellar active regions.** Cool Stars, Stellar Systems and the Sun 13, Hamburg

Wisotzki, L.: **Astronomical Surveys and the `Virtual Observatory'.** Workshop on `Statistical data mining between research and practice', Hamburg

Wisotzki, L.: **The evolution of optically faint AGN in COMBO-17 and GEMS.** Seminarvortrag, Universität Potsdam

Wisotzki, L.: **Spectroscopic evidence for quasar microlensing.** IAU Symp. 225, Impact of Gravitational Lensing on Cosmology, Lausanne, Schweiz

Wisotzki, L.: **AGN evolution with OmegaCAM.** OmegaCAM-Workshop, München

Ziegler, U.: **Adaptive Mesh Magnetohydrodynamics – the NIRVANA3 code.** Universität Tübingen

Ziegler, U.: **Adaptive Mesh Magnetohydrodynamics in Astrophysics.** AFD workshop, Heidelberg

Zinnecker, H.: **Star Formation and the IMF: The Origin of Stellar Masses.** EC-RTN meeting `The Young Local Universe', La Thuile, Italien

Zinnecker, H.: **The IMF: Basic Questions.** IMF@50 Konferenz `The Initial Mass Function 50 years later', Spineto, Italien

Zinnecker, H.: **Giant Planet Formation around Herbig stars.** Workshop `Protoplanetary Disks', Schloß Ringberg

Zinnecker, H.: **Formation of Brown Dwarves by Photo-Erosion of pre-stellar cores.** Cool Stars Workshop 13, Hamburg

Zinnecker, H.: **Detection of Terrestrial Planets with extremely large telescopes.** Bioastronomie 2004, Reykjavik, Island

Zinnecker, H.: **Formation of massive stars in OB associations.** Vlieland, Niederlande

Zinnecker, H.: **The Formation of Massive Stars by Collisional Mergers: Theoretical Constraints and Observational Predictions.** Jahrestagung der Astronomischen Gesellschaft, Prag, Tschech. Republik

Zinnecker, H.: **The 30 Doradus Starburst Cluster: Infrared Luminosity Function and Low-mass IMF in a Spatially Resolved Dense Young Stellar System.** Jahrestagung der Astronomischen Gesellschaft, Prag, Tschech. Republik

Zinnecker, H.: **The Formation of Massive Stars by Stellar Collisions.** Peking University, China

Zinnecker, H.: **The Formation of Massive Stars by Accretion.**Tsinghua University, THCA Peking, China

Zinnecker, H.: **HST direct imaging search for giant planets around white dwarfs.** Colloquium, Universität Jena

Zinnecker, H.: **The detection of terrestrial planets: Key science case for an 100m extremely large telescope (ELT).** ELT science meeting, Florenz, Italien

Zinnecker, H.: **Star Formation in the Early Universe.** 6th Sino-German Workshop on Cosmology and Galaxy Formation, Huangshan City, China

Zinnecker, H.: **Vom Sternenstaub zu Planeten.** Hakos Guest Farm, Namibia

2004 – Populärwissenschaftliche Vorträge
2004 – Educational Talks

Arlt, R.: **Sternschnuppenregen.** Wilhelm-Foerster-Sternwarte Berlin

Auraß, H.: **Urania-Führung im Observatorium.** AIP, Potsdam

Auraß, H.: **Solare Radiobeobachtungen in Potsdam - Vorgeschichte, Geschichte und Gegenwart.** Festveranstaltung zum 50. Gruendungstag des Obs. Tremsdorf am AIP

Balthasar, H.: **Sonnenphysik am Einsteinturm.** Urania Potsdam

Balthasar, H.: **Die aktive Sonne.** 3. Berliner MNU-Kongress, Berlin

Balthasar, H.: **Die aktive Sonne.** Lange Nacht der Sterne, AIP

Fröhlich, H.-E.: **Vom Urknall zum Urmenschen – die kosmischen Grundlagen unserer Existenz.** Bruno-H.-Bürgel Sternwarte, Berlin

Fröhlich, H.-E.: **Vom Urknall zum Urmenschen – die kosmischen Grundlagen unserer Existenz.** Urania-Planetarium Potsdam

Fröhlich, H.-E.: **Die dunklen Seiten des Universums.** Wilhelm-Foerster-Sternwarte Berlin

Fröhlich, H.-E.: **Wo kommen die Sterne her?** Herrmann Köhl Oberschule

Fröhlich, H.-E.: **Raum und Zeit.** Ev. Gymnasium Hermannswerder

Fröhlich, H.-E.: **Vom Urknall zum Urmenschen – die kosmischen Grundlagen unserer Existenz.** Robert-Havemann-Oberschule Berlin

Gottlöber S.: **Die Strukturen des Universums (Neue Erkenntnisse durch Supercomputer).** Urania Berlin

Jahnke, K.: **Galaxien – Quasare – Schwarze Löcher.** Barnim-Oberschule Berlin-Lichtenberg

Kelz, A.: **Astronomische Instrumente.** Lange Nacht der Sterne, AIP

Klessen, R.-S.: **Die turbulente Geburt der Sterne.** Wilhelm-Foerster-Sternwarte Berlin

Kliem, B.: **Beobachtung und Simulation eruptiver Sonnenprotuberanzen**, Lange Nacht der Sterne, AIP

Liebscher, D.-E.: **$E=mc^2$: Die Geometrie mit der Zeit.** Urania Berlin

Liebscher, D.-E.: **$E=mc^2$.** Planetarium Potsdam

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Schwope, A.: **Isolated Neutron stars with ROSAT, Chandra & XMM-Newton.** HESS & MAGIC workshop on Pulsars, HU Berlin

Sharma, S.: **The spin of baryonic structures in LCDM simulations.** The Formation of Disk Galaxies, Ascona, Schweiz

Siebert, A.: **Data Processing & Quality status.** RAVE meeting, Siding Spring Observatories, Australien

Siebert, A.: **Pre-GAIA spectroscopic surveys.** ESF exploratory meeting : modelling the Galaxy, Oxford, UK

Staude, J.: **Solar Physics at Potsdam. Sunspot Oscillations.** Colloquium: Institute of Physics, Marie Curie-Sklodowska University, Lublin, Polen

Staude, J.: **Diagnostics of unresolved magnetic field meso-structuring.** Colloquium Astron. Inst. of the Slovak Acad. of Sciences, Tatranska Lomnica, Slowakei

Steffen, M.: **Integral Field Spectrospcopy of Faint Haloes around Planetary Nebulae.** Calar Alto Colloquium, MPIA Heidelberg

Steffen, M.: **3D Simulation of Stellar Convection and Radiative Transfer.** Institut d'Astrophysique de Paris, Frankreich

Steffen, M.: **Stellar Physics: Research Topics at the Astrophysical Institute Potsdam.** Helmholtz Summer School, AIP, Potsdam

Steinmetz, M.: **Cosmology with the Milky Way.** Colloquium Oxford, UK

Steinmetz, M.: **Galactic Structure: Perspectives and Outlook.** Annual meeting Société Française d'Astronomie et d'Astrophysique, Strasbourg, Frankreich

Steinmetz, M.: **The Properties of Galactic Disks in a LCDM Universe.** The Formation of Disk Galaxies, Ascona, Schweiz

Steinmetz, M.: **Cosmology with the Milky Way.** Colloquium Albert Einstein Institut, Golm

Steinmetz, M.: **Galaxienentstehung und die Entstehung der Galaxis.** Physik. Colloquium, Univ. Würzburg

Steinmetz, M.: **Galaxy Formation and the Formation of the Galaxy.** Joint SISSA/ICTP colloquium, Triest, Italien

Steinmetz, M.: **The Formation of the Milky Way.** Seminar Univ. Ljubljana, Slovenien

Steinmetz, M.: **RAVE as a test case for GAIA.** GAIA-RVS workshop, Cambridge, UK

Steinmetz, M.: **The German Astronomical Community GRID.** D-GRID Vorprojekt kickoff meeting, Frankfurt

Steinmetz, M.: **The German Astrophysical Virtual Observatory.** DESY Workshop `Astroteilchenphysik in Deutschland', Zeuthen

Steinmetz, M.: **Kosmologische Evidenz für Dunkle Materie.** DESY Workshop ´Astroteilchenphysik in Deutschland', Zeuthen

Steinmetz, M.: **AstroGrid-D: A Community Project of the German e-Science Program.** LOFAR Workshop, Jülich

Steinmetz, M.: **Unraveling the Formation History of the Galaxy with RAVE.** Kick-off meeting des DFG-SPP 1177, Kloster Irsee

Steinmetz, M.: **Galaxy Formation and the Formation of the Galaxy.** Colloquium McDonald Observatory, Univ. of Texas, Austin, USA

Steinmetz, M.: **Substructure in the Milky Way.** MKI colloquium, MIT, Cambridge, USA

Steinmetz, M.: **Disk Formation.** Nearly Normal Galaxies in a LCDM Universe, Santa Cruz, USA

Storm, J.: **How good are RR Lyrae and Cepheids really as distance indicators?** Stellar pulsation and Evolution, Monte Porzio Catone, Italy

Strassmeier, K.G.: **A robotic photometric telescope for the Antarctic.** Science at Dome C, MPIA Heidelberg

Strassmeier, K.G.: **Doppler Tomographie von Sternoberflächen.** Colloquium, Univ. Ulm

Strassmeier, K.G.: **STELLA and COROT.** Eight COROT week, Toulouse, Frankreich

Strassmeier, K.G.: **Doppler imaging of rapidly-rotating M stars.** Close Binaries in the 21st Century, Syros, Griechenland

Strassmeier, K.G.: **Twenty Years of Doppler Imaging.** Colloquium Lowell Observatory, Flagstaff, Arizona, USA

Strassmeier, K.G.: **The AIP technology division and its projects.** Lowell Observatory, Flagstaff, Arizona, USA

Strassmeier, K.G.: **Laudatio Alexander G. Kosovichev.** WEMPE-Preis 2005, AIP

Strassmeier, K.G.: **Astrophysik, Robotik und Ingenieurwissenschaften.** Fa. Roschiwal+Partner, AIP

Strassmeier, K.G.: **Robotic Astronomy. From APTs to STELLA.** Colloquium IEEC Barcelona, Spanien

Strassmeier, K.G.: **Magnetic-field research at the AIP.** 8th MHD days, Potsdam

Valori, G.: **Extrapolation of coronal magnetic fields from photospheric measurements.** 8th MHD days, Potsdam

Vocks, Ch.: **Solar wind electron halo and strahl formation by resonant interaction with whistler waves.** Solar Wind 11 / SOHO 16, Whistler, Kanada

Vocks, Ch.: **Electron halo and strahl formation by resonant interaction with whistler waves.** DPG-Jahrestagung, Berlin

Vocks, Ch.: **Monitoring of Solar Activity with LOFAR.** DLR Weltraumwetter-Workshop, Neustrelitz

Vocks, Ch.: **Solar radio astronomy with the Low Frequency Array (LOFAR).** TU Braunschweig

Warmuth, A.: **A study of the relation between metric type II radio bursts and large-scale coronal waves.** 6th International Workshop on Planetary and Solar Radio Emissions, Graz, Österreich

Warmuth, A.: **New evidence for particle acceleration at reconnection outflow termination shocks in solar flares.** 3rd RHESSI/NESSI Topical Wokshop, Glasgow, UK

Warmuth, A.: **Using radio and HXR data to study coronal shocks (both stationary and propagating ones).** Group seminar, Institute of Astronomy & Astrophysics, Univ. Glasgow, Glasgow, UK

Weilbacher, P.: **The MUSE Data Reduction Software Pipeline.** Integral Field Spectroscopy, Durham, UK

Weilbacher, P.: **News from the Dentists Chair: VIMOS observations of AM 1353-272.** Science Perspectives for 3D Spectroscopy, Garching

Wisotzki, L.: **Connecting quasar and galaxy evolution – new constraints from COMBO-17 and GEMS.** Sternwarte Hamburg

Wisotzki, L.: **Microlensing in SDSS J1004+4112?** ANGLES Science Workshop, Analipsi, Kreta

Wisotzki, L.: **Quasar Absorption Lines and the Intergalactic Medium.** 5th Serbian conference on Spectral Line Shapes in Astronomy, Vrsac, Serbien

Wisotzki, L.: **Evolution of QSO host colours.** QSO Hosts: Evolution and Environment, Leiden, Niederlande

Wisotzki, L.: **Quasare und die Entwicklung von Galaxien.** Institutsbesuch, Göttingen

Wisotzki, L.: **Gravitational Lensing and Integral Field Spectroscopy.** Science Perspectives for 3D Spectroscopy, Garching

Worseck, G.: **The First Stars.** Astrophysikalisches Doktorandenseminar, Universität Potsdam

Zinnecker, H.: **History of Potsdam astronomy.** Star Meeting, Christchurch, Neuseeland

Zinnecker, H.: **The history of binary star research and the discovery of the interstellar medium.** Canterbury Astronomical Society, Christchurch, Neuseeland

Zinnecker, H.: **Multiplicity and origin of massive stars.** Workshop, CSIRO/Epping, Australien

Zinnecker, H.: **Planet search around white dwarfs.** ETH Zürich, Schweiz

Zinnecker, H.: **Massive star formation in clusters.** IAU-Symp. 227, Acireale/Catania, Italien

Zinnecker, H.: **Young clusters in the infrared.** Art and Science in Europe, MPG, Berlin

Zinnecker, H.: **Multiplicity of massive stars.** ESO Workshop Multiple Stars across the HRD, ESO Garching

Zinnecker, H.: **Science with extremely large telescopes.** Univ. of Canterbury Science Club, Christchurch, Neuseeland

Zinnecker, H.: **Search for giant planets around white dwarfs.** Honolulu, Hawaii, USA

Zinnecker, H.: **Search for giant planets around white dwarfs.** Univ. St. Andrews, UK

Zinnecker, H.: **The binary population in the Orion nebula cluster.** MODEST-6, Northwestern Univ. Evanston/Chicago, USA

Zinnecker, H.: **The runaway OB field star population.** Clemson Univ., Clemson, S.C., USA

Zinnecker, H.: **Search for giant extrasolar planets around white dwarfs: direct imaging with NICMOS/HST and NACO/VLT.** IAUC 200, Villefranche sur Mer, Frankreich

Zinnecker, H.: **Binary statistics and star formation.** Colloquium "Frontiers of Infrared-Astronomy", MPIA, Heidelberg

2005 – Populärwissenschaftliche Vorträge
2005 – Educational Talks

Arlt, R.: **Magnetfelder in Sternen.** Vortragsreihe, Wilhelm-Foerster-Sternwarte Berlin

Arlt, R.: **250 Jahre Naturtheorie von Immanuel Kant.** Langer Donnerstag am AIP

Auraß, H.: **Radiobeobachtung der Sonne am AIP.** Jahrmarkt der Wissenschaften, Potsdam

Böhm. A.: **Kalte Dunkle Materie – Ein heisses Thema.** Astronomie-Stiftung Trebur, Trebur

Fröhlich, H.-E.: **Die astronomischen Grundlagen unserer Existenz.** Langer Donnerstag am AIP

Fröhlich, H.-E.: **Astronomie des Unsichtbaren – Wo kommen die Sterne her?** Barnim-Oberschule, Berlin

Fröhlich, H.-E.: **Raum und Zeit.** Zuarbeit zur Ausstellung `Ein Turm für Albert Einstein' im Haus der Brandenburgisch-Preußischen Geschichte

Fröhlich, H.-E.: **Von Karl Schwarzschild zu den schwarzen Löchern.** Langer Donnerstag am AIP

Fröhlich, H.-E.: **Vom Urknall zum Urmenschen – die kosmischen Grundlagen unserer Existenz.** Tag der Wissenschaft, Wittenberge

Fröhlich, H.-E.: **Astronomie nach Einstein.** Lange Nacht der Sterne, AIP

Fröhlich, H.-E.: **Vom Urknall zum Urmenschen.** Vortrag vor Schülern, Eisenhüttenstadt

Fröhlich, H.-E.: **Astronomie nach Einstein.** Wilhelm-Foerster-Sternwarte, Berlin

Granzer, T.: **Robotische Teleskope.** Langer Donnerstag am AIP

Jappsen, A.-K.: **Turbulenz im Kreisssaal – Sternentstehung in Theorie und Beobachtung.** Wissenschaftssommer 2005, Potsdam

Jappsen, A.-K.: **Nach den Sternen greifen – Von der Schule ans AIP.** Zukunftstag, AIP

Kelz, A.: **Ein 3D Blick in den Himmel.** Lange Nacht der Sterne, AIP

Kelz, A.: **Von kleinen grünen Sternen und galaktischen Zusammenstößen.** Wissenschaftssommer, Potsdam

Klessen, R.: **Die turbulente Geburt der Sterne.** Astronomiestiftung Trebur, Trebur

Kliem, B.: **Albert Einstein and the Einstein Tower Observatory in Potsdam.** Gymnasium Michendorf & Partnerschule Seattle, AIP

Kliem, B.: **Die Sonne.** Wahlpflichtkurs Astronomie Gymnasium Michendorf, AIP, Potsdam

Krumpe, M.: **Offroad den Mars erkunden.** Planetarium Potsdam

Krumpe, M.: **Offroad den Mars erkunden.** Tag der offenen Tür, AIP

Krumpe, M.: **Spektroskopie: Die Kunst aus dem Licht der Sterne zu lesen.** Tag der offenen Tür, AIP

Küker, M.: **Sternentstehung.** Jahrmarkt der Wissenschaften, Potsdam

Lamer, G.: **Die Jagd nach entfernten Galaxienhaufen.** Langer Donnerstag am AIP

Liebscher, D.-E.: **Geometrie mit der Zeit und der schnellste Weg zu $E=mc^2$.** Heraeus-Weiterbildung, Potsdam

Liebscher, D.-E.:**Geometrie mit der Zeit und der schnellste Weg zu $E=mc^2$.** Heraeus-Weiterbildung, Bad Honnef

Wissenschaftliche Veröffentlichungen
Scientific Publications

Liebscher, D.-E.: **Der kürzeste Weg zu $E=mc^2$.** Helmholtz-Gymnasium Potsdam

Liebscher, D.-E.: **Geometrie mit der Zeit.** Thüringische Landesschule Schulpforta

Liebscher, D.-E.: **Wie schwer ist das Vakuum?** Thüringische Landesschule Schulpforta

Liebscher, D.-E.: **Chemie mit Urknall.** Planetarium Potsdam

Liebscher, D.-E.: **Einstein und das gespiegelte Licht.** Planetarium Potsdam

Liebscher, D.-E.: **Einstein und die Energie auf der Waage.** Albert-Einstein-Gymnasium Buchholz i.d.Nordheide

Liebscher, D.-E.: **Einstein und der Versuch, auf der Lichtwelle zu surfen.** Albert-Einstein-Gymnasium Buchholz i.d.Nordheide

Liebscher, D.-E.: **Mit dem Kompasswagen durch gekrümmte Räume.** Wilhelm-Foerster-Sternwarte Berlin

Liebscher, D.-E.: **Einstein und die Energie des Photons.** Planetarium Potsdam

Liebscher, D.-E.: **Geradeaus durch gekrümmte Räume.** Thüringische Landesschule Schulpforta

Liebscher, D.-E.: **Einstein und die Energie auf der Waage.** Sommerlager der Vereinigung der Sternfreunde, Klingenthal/Vogtland

Liebscher, D.-E.: **Relativitätstheorie zum Mitmachen.** Sonntagsvorlesung Wissenschaftssommer 2005, Potsdam

Liebscher, D.-E.: **Gekrümmte Räume oder: Wie schnell sind die Galaxien hinter dem Horizont.** Sommerlager der Vereinigung der Sternfreunde, Klingenthal/Vogtland

Liebscher, D.-E.: **Einstein und der Versuch, auf der Lichtwelle zu surfen.** Sommerlager der Vereinigung der Sternfreunde, Klingenthal/Vogtland

Müller, V.: **Die Entwicklung des Universums. Einsteins Erbe in der Kosmologie.** AIP-Nacht, Potsdam

Müller, V.: **Die Entwicklung des Universums.** Herweg-Oberschule Hermsdorf

Müller, V.: **Weltmodelle und Strukturbildung.** Einsteins Erbe in der Kosmologie. Leibniz-Symposium, Kunst- und Ausstellungshalle Bonn

Müller, V.: **Albert Einstein: Physiker und Weltbürger.** Besuch Schmidt-Unternehmensberatung, Potsdam Einstein-Park

Müller, V.: **Entwicklung der Universums.** Tag der Naturwissenschaften, Gymnasium Wittenberg

Rausche, G.:**Jupiter und Saturn.** Planetarium Halle/Saale (3 mal)

Rausche, G.: **Riesen und Zwerge unter den Sternen.** Planetarium Halle/Saale (3 mal)

Rendtel, J.: **Astronomische Jahresvorschau 2005.** Urania-Planetarium Potsdam

Rendtel, J.: **Sonne und Sterne – Aus der Forschung.** Kulturverein, Dorfkrug Marquardt

Rendtel, J.: **Optik der Atmosphäre. Zwischen Himmel und Erde.** Urania-Planetarium Potsdam

Rendtel, J.: **Deep Impact – das Loch im Kometen oder mehr?** Zwischen Himmel und Erde, Urania-Planetarium Potsdam

Rendtel, J.: **Astronomische Jahresvorschau 2006.** Vortragsreihe, Urania-Planetarium Potsdam

Rendtel, J.: **Sonnenphysik am Einsteinturm.** Hörsaal GFZ, Potsdam

Rendtel, J.: **Astrofotografie – wie bekommt man den Himmel auf das Bild.** Zwischen Himmel und Erde, Urania-Planetarium Potsdam

Rendtel, J.: **Aktueller Sternhimmel.** Urania-Planetarium Potsdam

Rendtel, J.: **Der Sternhimmel über Potsdam.** Urania-Planetarium Potsdam

Rendtel, J.: **Optische Erscheinungen in der Atmosphäre.** W.-Foerster-Sternw. Berlin

Rendtel, J.: **Die Sonne – ein unruhiger Stern.** Zwischen Himmel und Erde, Urania-Planetarium Potsdam

Rendtel, J.: **Aktueller Sternenhimmel.** Urania-Planetarium Potsdam

Rendtel, J.: **Führung mit Vortrag `Sonnenforschung am Einsteinturm' (32x)** Guided tour with lecture "Solar physics at the Einsteinturm" (8x)

Roth, M.: **The Universe in Colours.** IAC Winterschool Public Lecture, La Laguna, Tenerife, Spanien

Rüdiger, G.: **Das magnetische Universum.** Bruno-H.-Bürgel Sternwarte Berlin

Rüdiger, G.: **Gustav Spörer in Anklam als Begründer der modernen Astrophysik.** Anklam

Rüdiger, G.: **The magnetic Universe.** Wilhelm-Foerster-Sternwarte Berlin

Rüdiger, G.: **Das magnetische Universum.** Dresden

Rüdiger, G.: **Das magnetische Universum.** Urania-Planetarium Potsdam

Rüdiger, G.: **Das magnetische Universum.** Bruno-H.-Bürgel Sternwarte, Berlin

Schmeja, S.: **Schmetterlinge im All – Planetarische und symbiotische Nebel.** Wilhelm-Foerster-Sternwarte Berlin

Schmeja, S.: **Wie aus Gas und Staub Sterne werden.** Langer Donnerstag am AIP

Scholz, R.-D.: **Versteckte Zwergsterne in unserer Umgebung.** Lange Nacht der Sterne, AIP

Schwope, A.: **Weisst Du, wieviel Sternlein stehen? Zur Problematik des Lichtsmog aus Sicht eines Astrophysikers.** Lichtforum Semperlux, Berlin

Schwope, A.: **Wie groß ist das Universum?** Besuch einer Schulklasse, AIP

Schwope, A.: **Mit dem Zollstock durch das Universum – Wie groß ist der Kosmos?** VBIW, Eisenhüttenstadt

Schwope, A.: **Unser Sonnensystem.** Unterrichtsbesuch mit Vortrag, Ev. Schule Spandau

Staude, J.: **GREGOR, ein neues Hightech-Sonnenteleskop auf Teneriffa.** Sternennacht am Donnerstag. Mit URANIA und AIP ins Universum, URANIA-Planetarium Potsdam

Staude, J.: **Sonnenforschung am Einsteinturm des AIP.** Wissenschaftssommer 2005/Einsteinjahr, Museum der Brandenb.-Preuss. Geschichte

Staude, J.: **Geschichte des Potsdamer Telegrafenberges und des Großen Refraktors.** Wissenschaftssommer/Einsteinjahr 2005, Wissenschaftspark A. Einstein, Potsdam

Staude, J.: **Einsteinturm und Großer Refraktor: Zur Geschichte der Astrophysik auf dem Telegrafenberg.** Lange Nacht der Sterne, AIP

Steinmetz, M.: **ART und Kosmologie.** WE-Heraeus Lehrerfortbildung, Potsdam

Steinmetz, M.: **Das Fernrohr – eine kosmische Zeitmaschine.** Lehrerfortbildung, Planetarium Herzberg

Steinmetz, M.: **Das Fernrohr – eine kosmische Zeitmaschine.** Wilhelm-Foerster-Sternwarte Berlin

Steinmetz, M.: **Die dunkle Seite des Universums.** Wissenschaftssommer 2005, Potsdam

Steinmetz, M.: **Das Fernrohr, eine kosmische Zeitmaschine.** Tag der Wissenschaften, Wittenberge

Steinmetz, M.: **Das Fernrohr: Eine Kosmische Zeitmaschine.** Lange Nachtder Wissenschaften, AIP

Strassmeier, K.G.: **Die Unendlichkeit zum Greifen nah.** Urania Berlin

Strassmeier, K.G.: **Das LBT sieht erstes kosmisches Licht.** Bruno-H.-Bürgel Sternwarte, Berlin

Storm, J.: **The Large Binocular Telescope.** Bruno-H.-Bürgel Sternwarte, Berlin

Storm, J.: **Mit zwei Augen sieht man besser: Das Large Binocular Telescope.** Jahrmarkt der Wissenschaften, Potsdam

Warmuth, A.: **Sonnenstürme und Weltraumwetter.** Jahrmarkt der Wissenschaften, Potsdam

Wisotzki, L.: **Galaxien, Quasare, Schwarze Loecher.** Besuch der Oberschule Rathenow am AIP

Wisotzki, L.: **Mit Hubble ins Universum.** Potsdamer Wissenschaftssommer, Potsdam

Wisotzki, L.: **How astronomers explore the sky.** Internationale Schülergruppe, Planetarium Berlin am Insulaner

Wisotzki, L.: **Die Welt der Galaxien.** Lange Nacht der Sterne, AIP

Wisotzki, L.: **Mit Hubble ins Universum.** Lange Nacht der Sterne, AIP

Wisotzki, L.: **Wie Astronomen den Himmel erkunden.** Marie-Curie-Tag, Marie-Curie-Gymnasium Ludwigsfelde

Wisotzki, L.: **Galaxien, Quasare, Schwarze Loecher.** Planetarium Berlin am Insulaner

Zinnecker, H.: **Die Großteleskope der Astronomen: auf der Suche nach der zweiten Erde.** Astronomie Stiftung Trebur, Trebur

2005 – Bücher
2005 – Books

Corbelli, B., Palla, F., Zinnecker, H.: **The Initial Mass Function 50 years later.** Astrophysics and Space Science Library Vol. 327, Springer, Dordrecht, 2005

Dzhalilov, N. S., Staude, J.: **Global oscillations of the Sun.** ELM, Baku - Moskva 2005 (in Russian), ISBN 5-8066-1720-3

Liebscher, D.-E.: **Cosmology,** Springer Berlin Heidelberg New York 2005, ISBN 3-540-23261-3

Liebscher, D.-E.: **The Geometry of Time**, Wiley-VCH Weinheim 2005, ISBN 3-527-40567-4

Müller, V.: **Abell's Universe.** Trigg,G., Lerner, R.: Encyclopedia of Physics, Wiley-VCH, 2005

Rendtel, J.: **Sonnenstürme - Das Wetter im Weltraum, Finsternisse - Wenn die Gestirne verschwinden, Kollisionskurs - Banger Blick ins All. Entfesselte Elemente - Der Mensch und die Kräfte der Natur.** Wissen Media Verlag Gütersloh, München, 2005, ISBN 3-577-16206-6

Warmuth, A., Mann, G.: **The application of radio diagnostics to the study of the solar drivers of space weather 2005,** Springer Lecture Notes in Physics, Vol. 656, 49-70

Weigert, A., Wendker, H.-J., Wisotzki, L.: **Astronomie und Astrophysik - ein Grundkurs.** Wiley-VCH, 2005

Ziegler, U.: On the efficiency of AMR in NIRVANA3. Plewa, T., Linde, T., Weirs, V.G.:**Adaptive Mesh Refinement - Theory and Applications.** LNCSE/Springer, 2005

Diplomarbeiten

Jacob, Ralf: **Das Expansionsverfahren Planetarischer Nebel: Theorie und Beobachtung.** Universität Potsdam (D. Schönberner, M. Steffen)

Krämer, Felix: **Entwurf und Implementierung eines API zur Steuerung der Off-Axis-Einheiten des Large Binocular Telescopes (LBT).** HTW Dresden (J. Storm)

Krumpe, Mirko: **Röntgendurchmusterung des Marano-Feldes.** Universität Potsdam (A. Schwope)

Önel, Hakan: **Transport energiereicher Elektronen im Flareplasma der Sonnenkorona** TU Berlin (G. Mann)

Schulze, Michael: **Suche nach Galaxienhaufen in XMM-Newton-Beobachtungen.** TU Berlin (A. Schwope)

Vogel, Justus: **Kartierung des Akkretionsstromes wechselwirkender Doppelsterne im Orts- und Geschwindigkeitsraum.** TU Berlin (A. Schwope)

Godolt, Mareike: **Röntgenspektren von Galaxienhaufen.** TU Berlin (A. Schwope)

Schramm, Malte: **Quasar host galaxies at high redshifts.** Universität Potsdam (L. Wisotzki)

Dissertationen

Carroll, Thorsten A.: **Zur Linienentstehung und Diagnostik in kleinskaligen Magnetfelder der solaren Photosphäre. Ein Modell des stochastischen Transports polarisierter Strahlung.** Universität Potsdam (J. Staude)

Faltenbacher, Andreas: **Entwicklung von Galaxienhaufen.** Universität Potsdam (S. Gottlöber)

Török, Tibor: **Instabilität magnetischer Flussröhren in solaren Eruptionen.** Universität Potsdam (B. Kliem, J. Staude)

Washüttl, Albert: **The long-term surface activity of the RSCVn binary EL Eridani.** Universität Potsdam (K. P. Strassmeier)

Weber, Michael: **Differential rotation from time series Doppler imaging.** Universität Potsdam (K. P. Strassmeier)

Andersen, Morten: **The infrared luminosity function and low-mass IWP of the R136 starburst cluster.** Universität Potsdam (H. Zinnecker)

Benda-Beckmann, Sander: **Großräumige Strukturen im Universum.** Universität Potsdam (V. Müller)

Cemeljic, Miljenko: **Resistive magnetohydrodynamics jets from protostllar accretion disk.** Universität Potsdam (Ch. Fendt)

Christensen, Lise: **Spectroscopy of faint galaxies.** Universität Potsdam (M. M. Roth, L. Wisotzki)

Dziourkevitch, Natalia: **MRI-driven turbulence in galaxies.** Universität Potsdam (D. Elstner, G. Rüdiger)

Sharma, Sanjib: **Models of Disk Galaxies based on the Angular Momentum Distribution in Dark Matter Halos.** University of Arizona (M. Steinmetz)

Habilitationen

Klessen, Ralf: **Relation between Interstellar Turbulence and Star Formation.** Universität Potsdam

Institutsdaten und Geschichte

Das Astrophysikalische Institut Potsdam (AIP) im Überblick

Das Astrophysikalische Institut Potsdam ist errichtet als Stiftung privaten Rechts und Mitglied der Leibniz-Gemeinschaft. Das AIP wird vom Land Brandenburg und vom Bund institutionell gefördert.

Kuratorium
Das Kuratorium entscheidet über die allgemeinen Forschungsziele und die wichtigen forschungspolitischen und finanziellen Angelegenheiten der Stiftung. Es überwacht die Rechtmäßigkeit, Zweckmäßigkeit und Wirtschaftlichkeit der Geschäftsführung des Stiftungsvorstandes.

Das Kuratorium besteht am Ende des Berichtszeitraums aus folgenden Mitgliedern:
Konstanze Pistor, Vorsitzende
Ministerium für Wissenschaft, Forschung und Kultur des Landes Brandenburg

MinR Dr. Rainer Koepke, stellvertretender Vorsitzender
Bundesministerium für Bildung und Forschung

Prof. Dr. Hans-Walter Rix
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Vorsitzender des wissenschaftlichen Beirats

Prof. Dr. Frieder W. Scheller
Prorektor der Universität Potsdam

Vorstand
Prof. Dr. Matthias Steinmetz,
Wissenschaftlicher Vorstand (Sprecher)

Peter A. Stolz, Administrativer Vorstand

Wissenschaftlicher Beirat
Der Wissenschaftliche Beirat berät das Kuratorium und den Vorstand in allen wissenschaftlich-technischen Fragen von Gewicht. Er erarbeitet Vorschläge und Empfehlungen zu den vom Institut zu bearbeitenden Forschungsfeldern und zu dessen Arbeitsplanung. Er bewertet periodisch Forschungsleistungen und Arbeitspläne.

Prof. Dr. Hans-Walter Rix, Heidelberg, Vorsitzender
Prof. Dr. Andrea Dupree, Cambridge (USA)
Prof. Dr. Günther Hasinger, Garching
Prof. Dr. Dieter Reimers, Hamburg
Prof. Dr. Robert Rosner, Chicago (USA)
Prof. Dr. Erwin Sedlmayr, Berlin
Prof. Dr. Harold Yorke, Pasadena (USA)

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Gleichstellungsbeauftragte
Christiane Rein

Personal und Finanzierung (Stichtag: 31.12.2005)

Grundfinanzierung:	50 % Land Brandenburg
	50 % Bund
Grundfinanzierung:	7,3 Mio Eur
Drittmittel:	2,3 Mio Eur
Mitarbeiter Stellenplan:	78,5
Mitarbeiter Annex:	8
Mitarbeiter Drittmittel:	55
Gesamt:	141,5

Johann-Wempe-Stiftung
Zur Förderung der wissenschaftlichen Forschung auf dem Gebiet der Astrophysik, sowie damit im Zusammenhang stehender Aufgaben, insbesondere solche der Aus-, Fort- und Weiterbildung und Zugänglichmachung der Ergebnisse der durchgeführten Forschungsarbeiten für die Allgemeinheit, insbesondere zur Finanzierung des Johann - Wempe - Preises ist die Johann - Wempe - Stiftung eingerichtet worden.

Preisträger 2004: Isabelle Baraffe und Gilles Chabrier (Lyon)
Preisträger 2005: Alexander Kosovichev (Stanford)

Das Astrophysikalische Institut Potsdam (AIP) im Überblick

Organigramm

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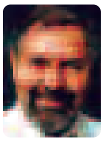
Zeittafel zur Geschichte der Astronomie in Berlin und Potsdam

1700	Einführung des sog. 'Verbesserten Kalenders' in den protestantischen Staaten Deutschlands	Introduction of the so-called 'Improved Calendar' in the Protestant states of Germany
1700-05-10	Erlass des Kalenderpatents für die zu gründende Berliner Sternwarte	Enactment of the calendar patent for the Berlin Observatory
1700-05-18	Berufung Gottfried Kirchs zum Direktor der Sternwarte	Appointment of G. Kirch as director of the observatory
1700-07-11	Gründung der Brandenburgischen Societät	Foundation of the Brandenburg Society
1711	Erstes Sternwartengebäude in Berlin	First observatory in Berlin
1832/35	Neue Berliner Sternwarte, Architekt Karl Friedrich Schinkel	New observatory, architect K.F. Schinkel
1846	Entdeckung des Planeten Neptun durch Johann Gottfried Galle	Discovery of the planet Neptune by J.G. Galle
1874	Gründung des Astronomischen Rechen-Instituts	Foundation of the "Astronomisches Rechen-Institut"
1874	Gründung des Astrophysikalischen Observatoriums Potsdam (AOP)	Foundation of the Astrophysical Observatory Potsdam (AOP)
1881	Erster Michelson-Versuch in Potsdam	First Michelson experiment in Potsdam
1886	Entdeckung der Kanalstrahlen durch Eugen Goldstein	Discovery of canal rays by E. Goldstein
1888	Nachweis der Polhöhenschwankung durch Karl Friedrich Küstner	Discovery of the variation of the Earth's pole altitude by K.F. Küstner
1888	Erste fotografische Radialgeschwindigkeitsmessung durch Heinrich Carl Vogel	First photographic determination of a radial velocity by H.C. Vogel
1896	Versuche zum Nachweis der Radiostrahlung der Sonne durch Johannes Wilsing und Julius Scheiner am AOP	Experiments to find radio emission from the Sun by J. Wilsing and J. Scheiner
1899	Fertigstellung des Potsdamer Großen Refraktors	Completion of the Large Refractor at Potsdam
1904	Entdeckung der interstellaren Materie durch J. Hartmann	Discovery of the interstellar matter by J. Hartmann
1909	Berufung von Karl Schwarzschild zum Direktor des AOP	Appointment of K. Schwarzschild as director of the AOP
1911/13	Bau der Sternwarte in Babelsberg	Building of the observatory in Babelsberg
1913	Einführung der lichtelektrischen Photometrie durch Paul Guthnick in Babelsberg	First use of photoelectric photometry by P. Guthnick in Babelsberg
1915	Fertigstellung des Babelsberger Großen Refraktors	Completion of the Large Refractor in Babelsberg
1921/24	Bau des Einstein-Turmes auf dem Telegrafenberg	Construction of the Einstein Tower on the Telegrafenberg
1924	Fertigstellung des 120cm-Spiegels in Babelsberg	Completion of the 120cm telescope in Babelsberg
1931	Angliederung der Sonneberger Sternwarte an die Sternwarte Babelsberg	Affiliation of the Sonneberg Observatory to the Babelsberg Observatory
1947-01-01	Übernahme von AOP und Sternwarte Babelsberg durch die Deutsche Akademie der Wissenschaften	Takeover of AOP and Babelsberg Observatory by the German Academy of Sciences
1954	Beginn der Radiobeobachtungen in Tremsdorf	Starting of radio observations in Tremsdorf
1960	Fertigstellung des 2m-Spiegels in Tautenburg	Completion of the 2m telescope in Tautenburg
1969	Gründung des Zentralinstituts für Astrophysik	Foundation of the Central Institute of Astrophysics
1992-01-01	Beginn der Tätigkeit des Astrophysikalischen Instituts Potsdam (AIP)	Beginning of the work of the Astrophysical Institute Potsdam (AIP)
2002	Beginn der Arbeit des Potsdamer Multiapertur-Spektrophotometers	First light for the Potsdam Multi-Aperture Spectrophotometer
2005	Einweihung des LBT	LBT Inauguration

Zur Geschichte der Astronomie in Potsdam
The History of Astronomy in Potsdam




K. Fritze, D.-E. Liebscher

Die Geschichte der Potsdamer Astronomie begann in Berlin: Auf Anregung von Gottfried Wilhelm Leibniz gründete Kurfürst Friedrich III. am 11. Juli 1700 dort die Brandenburgische Societät (später Preußische Akademie der Wissenschaften). Zuvor war einer noch zu gründenden Sternwarte das Kalendermonopol erteilt und am 18. Mai 1700 Gottfried Kirch zu deren Direktor berufen worden. Die Sternwarte sollte mit den Gebühren für den von ihr berechneten und vertriebenen Grundkalender die Akademie finanzieren helfen. Der Grundkalender wurde noch bis 1991 an der inzwischen nach Babelsberg übersiedelten Sternwarte berechnet.

Im Jahre 1711 wurde in der Berliner Dorotheenstraße ein erstes Sternwartengebäude errichtet, dem mit Unterstützung durch Alexander von Humboldt 1835 ein Neubau durch Karl Friedrich Schinkel in der Nähe des Halleschen Tores folgte.

1755 hatte Leonhard Euler der Sternwarte ein großes wissenschaftliches Programm gegeben, von dem Johann Elert Bode die Verbesserung der Sternkarten mit besonderem Erfolg betrieb. Die aus diesem Programm später entstandenen Karten ermöglichten die Auffindung des Planeten Neptun im Jahre 1846 durch Johann Gottfried Galle. Ebenso bedeutend waren die Entdeckung der Kanalstrahlen durch Eugen Goldstein 1886 im Labor der Sternwarte und der Nachweis der Polhöhenschwankung der Erde durch Karl Friedrich Küstner 1888.

Die beiden letztgenannten Leistungen fallen in die Zeit des Direktorats von Wilhelm Julius Foerster, der zugleich einen entscheidenden Anteil an der Errichtung der Observatorien in Potsdam hatte: an der Gründung des Astrophysikalischen Observatoriums auf dem Telegrafenberg im Jahre 1874 und an der Übersiedlung der Berliner Sternwarte nach Babelsberg, die 1913 vollendet wurde.

The history of astronomy in Potsdam began in Berlin: initiated by Gottfried W. Leibniz, on July 11, 1700 the 'Brandenburgische Societät' – the later Prussian Academy of Sciences – was founded by the elector Friedrich III. in Berlin. Two months earlier, the regional calendar monopoly provided the funding for an observatory. By May 18, the first director, Gottfried Kirch, had been appointed. The profits from the reference calendar, calculated and sold by the observatory, should have provided the funding for the academy. The reference calendar was calculated until 1991.

In 1711, the first observatory was built in Dorotheenstraße in Berlin, followed by a new building that was supported by Alexander v. Humboldt and designed by Karl Friedrich Schinkel near the Hallesches Tor in Berlin.

In 1755, Leonhard Euler had proposed a new scientific programme for the observatory, and it was Johann Elert Bode, who engaged in particular in the improvement of maps and catalogues of stars. The maps produced in this project enabled Johann Gottfried Galle to find and identify the planet Neptune in 1846 near the position calculated by Leverrier. The discoveries of canal rays by Eugen Goldstein in 1886 in the physical laboratory of the observatory and of the variation in the altitude of the Earth's pole by Karl Friedrich Küstner in 1888 were similarly important.

The last two scientific events took place when Wilhelm Julius Foerster was director of the observatory, which was meanwhile attached to the University of Berlin. He prepared the basis for the astronomical observatories in Potsdam: in 1874 the foundation of the Astrophysical Observatory Potsdam on the Telegrafenberg and in 1913 the move of the Berlin Observatory to Babelsberg.

Die von Schinkel erbaute Berliner Sternwarte.

Das Hauptgebäude des Astrophysikalischen Observatoriums, heute Potsdamer Institut für Klimafolgenforschung.

Der Einstein-Turm

Das Hauptgebäude der Sternwarte Potsdam-Babelsberg

Die Gründung des Astrophysikalischen Observatoriums Potsdam

Die Mitte des 19. Jahrhunderts von Gustav Kirchhoff und Robert Bunsen entwickelte Spektralanalyse eröffnete die Möglichkeit, aus dem Licht der Himmelskörper Aussagen über ihre chemische Zusammensetzung und ihren physikalischen Zustand zu gewinnen. Nach Anregung von Wilhelm Foerster und Hermann v. Helmholtz wurde am 1.7.1874 das Astrophysikalische Observatorium Potsdam (AOP) gegründet. Es nutzte zunächst den Turm des Potsdamer Militärwaisenhauses, von dem aus Gustav Spörer Sonnenbeobachtungen durchführte. Im Herbst 1879 wurde das Hauptgebäude auf dem Telegrafenberg südlich von Potsdam bezogen. Auf diesem Berg hatte von 1832 bis 1848 eine Station der optischen Telegrafenlinie gestanden, auf der militärische Nachrichten zwischen Berlin und Koblenz übertragen wurden.

Im Jahre 1882 wurde Hermann Carl Vogel zum Direktor des Observatoriums ernannt. Vogel gelang es als erstem, Radialgeschwindigkeiten von Sternen fotografisch zu messen, und er entdeckte so die spektroskopischen Doppelsterne. Im Jahre 1899 wurde auf dem Telegrafenberg der Große Refraktor fertiggestellt, dessen Kuppelbau von 24 m Durchmesser noch heute den Telegrafenberg beherrscht. Zwei Entdeckungen an diesem Instrument ragen heraus: die der ruhenden Kalzium-Linien im Spektrum des spektroskopischen Doppelsterns δ Orionis 1904 durch Johannes Hartmann – Nachweis des interstellaren Mediums – und die stellarer Kalziumemissionen – Hinweise auf Oberflächenaktivität! – durch Gustav Eberhard und Hans Ludendorff um 1900.

1908 wurde Karl Schwarzschild zum Direktor berufen. Er hat hier grundlegende Beiträge zur Astrophysik und zu der gerade

The foundation of the Astrophysical Observatory Potsdam

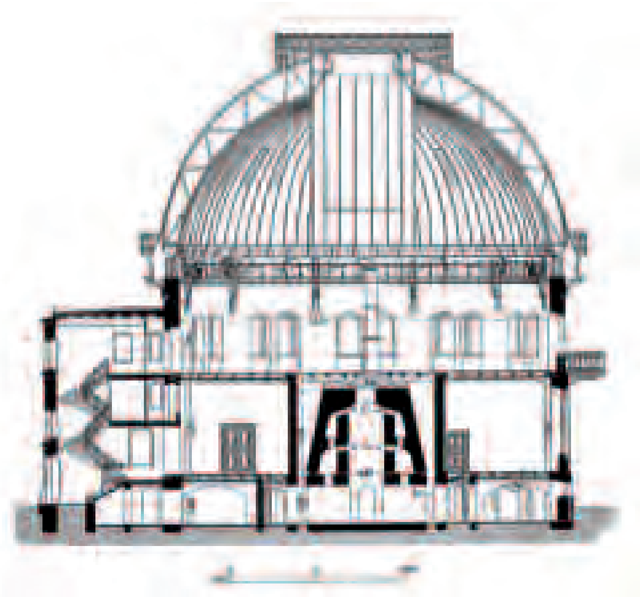
In the middle of the 19th century, spectral analysis was developed by Gustav Kirchhoff and Robert Bunsen. It provided the possibility of obtaining information on the physical parameters and chemical abundances of stars, by the spectral analysis of their light. Initiated by Wilhelm Foerster and Hermann v. Helmholtz, the Astrophysical Observatory Potsdam was founded on July 1, 1874. It used at first the tower of the military orphanage, where Gustav Spörer observed the sun. In autumn 1879, the new main building on the Telegrafenberg south of Potsdam was ready for occupation. The hill got its name from a station of an optical telegraph line that transmitted military information between Koblenz and Berlin.

In 1882, Carl Hermann Vogel was appointed as director of the observatory. He was the first to successfully determine radial velocities of stars photographically and as a result he discovered spectroscopic binaries. In 1899, the Large Refractor was ready on the Telegrafenberg. Its building and dome have ruled the hill until the present day. Two important discoveries should be mentioned: that of the interstellar calcium lines in the spectrum of the spectroscopic binary δ Orionis by Johannes Hartmann in 1904 and that of the stellar calcium emission lines – a hint of stellar surface activity – by Gustav Eberhard and Hans Ludendorff about 1900.

In 1908, one of the most famous astrophysicists of this century, Karl Schwarzschild, became director of the observatory. In only a few years of work – by 1916 he had died after an illness – he had made fundamental contributions in astrophysics and to General Relativity theory (GR). Schwarzschild found the first solution of Einstein's equations before they were published in their final form. This solution, the 'Schwarzentstehenden Allgemeinen Relativitätstheorie geleistet. Die von ihm gefundene erste exakte Lösung der Einsteinschen Gleichungen regelt die Bewegung um die Sonne wie um die Schwarzen Löcher.

Mit der Entwicklung der Relativitätstheorie ist das AIP in vieler Hinsicht verbunden. Im April 1881 führte Albert A. Michelson im Keller des Hauptgebäudes des AOP zum ersten Male den berühmten Interferometerversuch durch, der zeigte, dass sich die Lichtgeschwindigkeit nicht mehr additiv mit der Bahngeschwindigkeit der Erde zusammensetzen lässt, und der das Auffinden der Relativitätstheorie durch Einstein 1905 einleitete. 1913 wiesen Guthnick und Zurhellen in der Sternwarte Babelsberg nach, dass sich die Lichtgeschwindigkeit auch nicht zur Bewegung der Sterne addiert, die das Licht aussenden.

Um die von der Allgemeinen Relativitätstheorie vorhergesagte Rotverschiebung von Spektrallinien im Schwerefeld der Sonne nachzuweisen, konzipierte Erwin Finlay-Freundlich ein Sonnenteleskop. Es fand seine Verwirklichung in Gestalt des Einstein-Turms, mit dem der Architekt Erich Mendelsohn ein einzigartiges expressionistisches Wissenschaftsbauwerk schuf. Zwar konnte die Gravitationsrotverschiebung zunächst nicht von anderen Effekten getrennt werden, jedoch nahmen andere wichtige Entwicklungen der Sonnen- und Plasmaphysik hier ihren Anfang. Walter Grotrians Arbeiten zur Sonnenkorona haben dem Einstein-Turm Weltgeltung verschafft.



Schnitt durch das Gebäude des Großen Refraktors auf dem Telegrafenberg

schild solution', describes the motion in a spherically symmetric field around the sun and also around black holes.

There exist further close links between the AOP and Einstein's Relativity theory. In 1881 Albert A. Michelson performed his experiments in an attempt to demonstrate the movement of the Earth through the hypothetical ether in the cellar of the main building of the AOP. His negative results were fundamentally reconciled only through Einstein's Special Relativity theory of 1905. Guthnick and Zurhellen also demonstrated in 1913 that the motion of the stars must not be added to the velocity of light.

To prove the redshift of spectral lines in the gravitational field of the sun – an effect proposed by Einstein's GR – was the aim of a solar tower telescope, which was built between 1921 and 1924 at the instigation of Erwin Finlay-Freundlich. Though at that time it was not yet possible to measure the gravitational redshift, important developments in solar and plasma physics were started here and the architect, Erich Mendelsohn, created with this peculiarly expressionistic tower a unique scientific building.

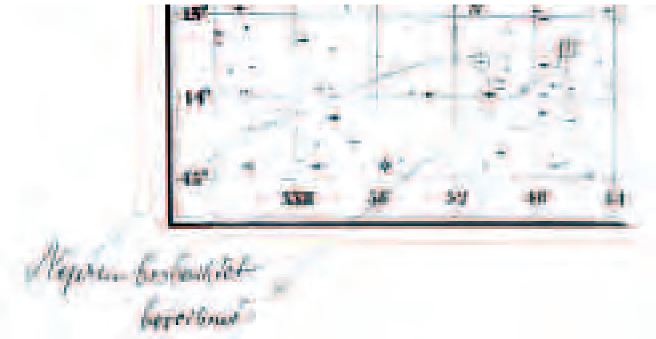
Besides the work of Schwarzschild, in the following decades important observational programmes such as the "Potsdamer Photometrische Durchmusterung" and the outstanding investigations of Walter Grotrian on the solar corona found recognition all over the world.

The move of the Berlin Observatory to Babelsberg

The location of the observatory, outside the city of 1834, was enclosed by the town at the end of the 19th century. It was Wilhelm Foerster who proposed in the 1890s to build a new observatory outside Berlin. Karl Hermann Struve, after his appointment as director in 1904, accepted the task of moving the observatory to Babelsberg.

After test observations by Paul Guthnick in the summer of 1906, a new site was found on a hill in the eastern part of the Royal Park of Babelsberg. The ground was placed at the observatory's disposal by the crown free of charge. The costs of the new buildings and the new instruments amounted to 1.5 million Goldmark and could be covered by selling the property of the Berlin Observatory. The old observatory built by Schinkel was later pulled down. In June 1911, the construction of a new observatory began in Babelsberg and on August 2, 1913 the move from Berlin to Babelsberg was complete.

The first new instruments were delivered in the spring of 1914. The 65 cm refractor – the first big astronomical instrument manufactured by the famous enterprise of Carl Zeiss Jena – was mounted in 1915, whereas the completion of the 120 cm mirror telescope was delayed until 1924 as a result



Teil der Sternkarte mit der Position, an der Neptun gefunden wurde.

Die Übersiedlung der Berliner Sternwarte nach Babelsberg

Die 1834 außerhalb der Stadt errichtete Berliner Sternwarte war Ende des 19. Jahrhunderts bereits völlig von der Stadt umgeben. Schon Mitte der neunziger Jahre hatte Wilhelm Förster den Neubau einer Sternwarte nun wieder außerhalb Berlins vorgeschlagen. Karl Hermann Struve nahm nach seiner Berufung zum Direktor im Jahre 1904 die Übersiedlung der Sternwarte nach Babelsberg in Angriff.

Das Gelände, das ursprünglich zum Schloßpark Babelsberg gehörte, wurde kostenlos zur Verfügung gestellt. Die Kosten für den Bau der Gebäude (1,1 Mill. Goldmark) und für die instrumentelle Ausrüstung (450 000 Goldmark) konnten durch den Verkauf des Grundstücks der alten Schinkelschen Sternwarte in Berlin, die später abgerissen wurde, gedeckt werden. Unter der Leitung von Baurat Eggert wurde im Juni 1911 mit dem Bau begonnen, und bereits Anfang August 1913 konnte die Übersiedlung abgeschlossen werden.

1915 wurde die Aufstellung des 65cm-Refraktors – das erste astronomische Großinstrument der Firma Carl Zeiss Jena – vollendet. Die Fertigstellung des 120cm-Spiegelteleskops zog sich infolge des Weltkriegs noch bis 1924 hin. Struve starb 1920 und konnte die Vollendung seines Lebenswerks nicht mehr erleben. Sein Nachfolger wurde Paul Guthnick, der 1913 mit der lichtelektrischen Fotometrie die erste objektive Methode zur Helligkeitsbestimmung von Sternen in die Astronomie eingeführt hatte. Mit der Fertigstellung des 120cm-Spiegelteleskops – seinerzeit das zweitgrößte Fernrohr der Welt – war die Sternwarte Babelsberg das bestausgerüstete Observatorium Europas.

Die Weiterentwicklung der lichtelektrischen Fotometrie, insbesondere im Zusammenhang mit der Untersuchung des Lichtwechsels schwach veränderlicher Sterne, und die spektroskopischen Arbeiten am 120cm-Spiegel machten die Babelsberger Sternwarte weltweit bekannt.

of the First World War. Struve died in 1920 in an accident, and his successor was Paul Guthnick, who in 1913 introduced photoelectric photometry into astronomy as the first objective method of measuring the brightness of stars. When the 120 cm telescope – at this time it was the second largest in the world – was finished, the Babelsberg Observatory was the best-equipped observatory in Europe.

The development of the photoelectric method for investigating weakly variable stars and spectroscopic investigations with the 120 cm telescope made the observatory well-known beyond Europe, too.

At the beginning of 1931, the Sonneberg Observatory founded by Cuno Hoffmeister was attached to the Babelsberg Observatory. For more than 60 years, a photographic sky survey was carried out, which represents the second largest archive of astronomical photographic plates in the world, and which provides at present a resource for scientific work.

The development after the Second World War

With the beginning of fascism, the fortunes of astronomy in Potsdam as well as in Babelsberg started to decline. The banishment of Jewish co-workers played an essential role in this process. The beginning of the Second World War practically marked the cessation of astronomical research.

Sternwarte Babelsberg, Luftbild 1930

Anfang 1931 war die von Cuno Hoffmeister in Sonneberg gegründete Sternwarte als Außenstelle an die Sternwarte Babelsberg angegliedert worden. Die fotografische Himmelsüberwachung im Rahmen des Sonneberger Felderplans ließ in über 60 Jahren die zweitgrößte astronomische Plattensammlung der Welt entstehen, die heute noch Basis für wissenschaftliche Arbeit ist.

Die Entwicklung nach dem 2. Weltkrieg

Die Machtergreifung durch den Faschismus, insbesondere die Vertreibung jüdischer Mitarbeiter, führten zu einem Niedergang der Astronomie in Potsdam und Babelsberg. Der Ausbruch des 2. Weltkriegs setzte dann der astronomischen Forschung faktisch ein Ende.

Anfang 1947 übernahm die Deutsche Akademie der Wissenschaften zu Berlin das Astrophysikalische Observatorium Potsdam und die Sternwarten Babelsberg und Sonneberg. Im Jahre 1969 fasste die Akademie der Wissenschaften der DDR das Astrophysikalische Observatorium Potsdam, die Sternwarte Babelsberg, die Sternwarte Sonneberg und das Karl-

Quadrant von Langlois, von P. de Maupertuis in Lappland benutzt, um die Abplattung der Erde zu bestimmen.

In January 1947 the German Academy of Sciences took the Astrophysical Observatory Potsdam and the Babelsberg and Sonneberg Observatory under its administration. In 1969, the four East German astronomical institutes, Astrophysical Observatory Potsdam, Babelsberg Observatory, the Thuringian Sonneberg Observatory, and Karl-Schwarzschild Observatory Tautenburg (founded in 1960 with the 2m telescope, which in its Schmidt variant is still the largest astronomical wide-field camera in the world), were combined to form the Central Institute of Astrophysics of the Academy of Sciences of the GDR. The Solar Observatory Einstein Tower and Observatory for Solar Radio Astronomy (founded in 1954 to continue the tradition of the experiments of Johannes Wilsing and Julius Scheiner in 1896 and of Herbert Daene in 1947) that was attached first to another institute, were affiliated later.

Already at this time, two directions of research were defined that guide – with new resources – the AIP even now. Under the heading of magnetically determined processes, cosmic magnetic fields, cosmic dynamos, phenomena of turbulence, magnetic and eruptive processes on the Sun, explosive energy dissipation processes in plasmas, variable stars and stellar activity were considered. Under the heading of gravitationally determined processes, the early phases of cosmic evolution, the origin of structures in the Universe, large-scale structures up to those of superclusters and to active galaxies were investigated. In this context, particularly successful methods of image processing were developed. In addition, investigations in astrometry at the Schmidt telescope of Tautenburg were performed.

In 1992, the Astrophysical Institute Potsdam was founded at the place of the ZIAP that was closed at the end of 1991. The first two scientific directors, Karl-Heinz Rädler (till his retirement in 2000) and Günther Hasinger (since 2001 with the MPI for Extraterrestrial Physics in Garching) continued the work in both directions with new weight. The first big programmes were the X-ray satellite ABRIXAS, the construction of a multiaperture spectrograph (PMAS) and the contribution to the Large Binocular Telescope (LBT), which is constructed now on Mount Graham (AZ). In 1999, the theory of dynamo action driven by turbulence was experimentally tested in Karlsruhe and Riga.

The institute is open for visitors. The public may experience not only a glimpse in the history of astronomy, but get some insight into our recent scientific work, challenges, and prospects. We organize Open Days and Evenings, and contribute to other events in Potsdam, Brandenburg and Berlin.

Schwarzschild-Observatorium Tautenburg (gegründet 1960 um das 2m-Universal-Spiegelteleskop, das in seiner Schmidt-Variante noch immer die größte astronomische Weitwinkelkamera der Welt ist) in einem Zentralinstitut für Astrophysik (ZIAP) zusammen. Das Sonnenobservatorium Einstein-Turm und das Observatorium für Solare Radioastronomie Tremsdorf (OSRA, gegründet 1954 in der Tradition der Experimente von Johannes Wilsing und Julius Scheiner 1896 und Herbert Daene 1947), die zunächst einem anderen Institutsverbund angegliedert wurden, kamen später ebenfalls hinzu.

Schon damals wurden die zwei Bereiche der Forschung gebildet, die mit neuer Ausstattung auch heute das AIP bestimmen: Unter dem Titel der magnetisch determinierten Prozesse wurden kosmische Magnetfelder und Dynamos, Turbulenzphänomene, magnetische und eruptive Erscheinungen auf der Sonne, explosive Energieumsetzungen in Plasmen und Sternaktivität untersucht. Unter dem Titel der gravisch determinierten Vorgänge richtete sich die Forschung auf die Frühphase der kosmischen Entwicklung und die Strukturbildung im Universum, auf großräumige Strukturen, Galaxienhaufen und Superhaufen und auf aktive Galaxien. In diesem Zusammenhang wurden insbesondere erfolgreiche Methoden der digitalen Bildverarbeitung entwickelt. Darüber hinaus wurden Untersuchungen zur Astrometrie mit dem Schmidt-Teleskop ausgeführt.

Die ersten beiden wissenschaftlichen Direktoren des 1992 an Stelle des ZIAP gegründeten Astrophysikalischen Instituts Potsdam, K.-H. Rädler (seit 2000 im Ruhestand) und G. Hasinger (seit 2001 am MPI Extraterrestrische Physik Garching) setzten die Arbeit in beiden Grundrichtungen mit neuen Betonungen fort. Die ersten großen Programme waren die Betreuung des Röntgensatelliten ABRIXAS, die Herstellung eines Multiaperturspektrografen (PMAS) und die Beteiligung an dem Large Binocular Telescope (LBT), das zur Zeit auf dem Mount Graham (AZ) errichtet wird. 1999 wurde die Theorie der turbulenzgetriebenen Dynamos durch Experimente in Karlsruhe und Riga zum ersten Male bestätigt.

Das Institut ist offen für Besucher. Die Öffentlichkeit kann hier nicht nur angesichts unserer historischen Geräte unsere in die Entwicklung der Astronomie eingebettete Geschichte erleben, sondern gerade auch einen Einblick in unsere aktuelle Forschung und in unsere Probleme und Projekte erhalten. Wir veranstalten Tage der offenen Tür und Beobachtungsabende und beteiligen uns an größeren Veranstaltungen in Potsdam, im Land Brandenburg und in Berlin.

Weltweit erstes Sternphotometer mit Photozelle (P. Guthnick)

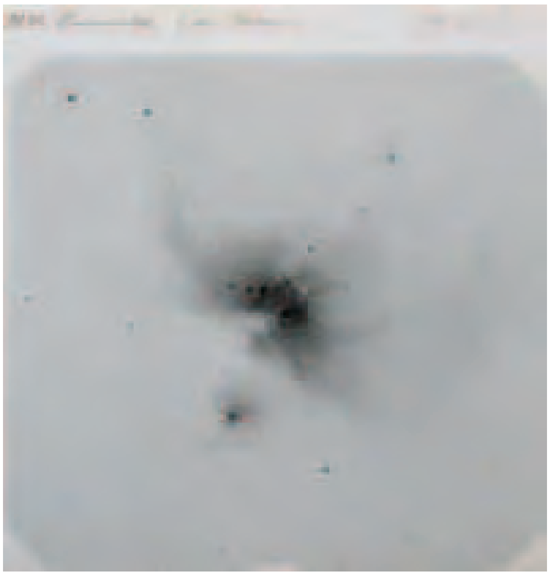
Der Große Refraktor
auf dem Potsdamer Telegrafenberg

2005 markiert die wichtigste Etappe der Restaurierung des Großen Refraktors, der 1899 in Dienst gestellt wurde und damals der größte Refraktor der Welt war.

1899 sollte der Große Refraktor dem 1874 gegründeten Astrophysikalischen Observatorium eine erhebliche Verbesserung seiner Beobachtungsbasis liefern. In einer 24m-Kuppel montiert, wurde er damals in einer großen Zeremonie von Wilhelm II. eingeweiht. Das Teleskop verbindet zwei Refraktoren mit 80 cm bzw. 50 cm Öffnung. Die bedeutendsten Entdeckungen mit diesem Teleskop waren die der interstellaren Calcium-Linien durch J. Hartmann und die stellarer Calcium-Linien in Emission durch G. Eberhard und H. Ludendorff. Nach der Inbetriebnahme des 2m-Spiegels in Tautenburg wurde der Große Refraktor außer Dienst gestellt, was mangels ausreichender Wartung zu seinem Verfall führte. 1986-1990 wurde die Außenhaut restauriert. 2003 konnte dank der großzügigen Unterstützung der Pietschker-Neeser-Stiftung und der Deutschen Stiftung Denkmalsschutz und der Werbung des Fördervereins Großer Refraktor um weitere private Spenden die Restaurierung des Instruments beginnen. Nach nunmehr über zwei Jahren kam der Doppelrefraktor, restauriert von der Firma 4H-Jena-Engineering in Jena, am 17.6.2005 nach Potsdam zurück. Er ist nun ausgerüstet mit einer modernen Computersteuerung und wird wieder einsatzfähig sein. Für aktuelle wissenschaftliche Untersuchungen weniger geeignet, soll er für Besucher eine Attraktion werden.

The year 2005 marks the most important phase of the restoration of the Great Refractor, which was inaugurated in 1899 and which was at that time the largest refractor in existence.

The Great Refractor was intended to yield an essential improvement in the observational facilities of the Potsdam Astrophysical Observatory, founded in 1874. Mounted in a 24m dome, it was inaugurated by the emperor Wilhelm II himself. The telescope combines two refractors of 80 and 50 cm aperture. The most important discoveries were those of the interstellar Calcium lines by J. Hartmann and the stellar Calcium emission lines by G. Eberhard and H. Ludendorff. After the opening of the 2m mirror in Tautenburg, the Great Refractor was put out of commision. Due to the lack of adequate maintenance, it declined. From 1986 to 1990, the outer hull was restored. In 2003, the restoration could start, thanks to the generous support of the Pietschker-Neeser foundation and the Deutsche Stiftung Denkmalschutz, and the effort of the *Förderverein Großer Refraktor Potsdam e.V* to win further private donors. After two years of restoration work in the factory 4H-Jena-Engineering in Jena, the refractor returned to Potsdam on July 17th, 2005. It is now equipped with a modern computer control and ready for work again. Although it cannot be used for up to date science work, it will become an attraction for visitors of all ages.



Aufnahme des Orion-Nebels mit dem 80 cm-Spiegel von Hartmann (vgl. Beitrag von Petra Böhm)

Das Astrophysikalische Observatorium Potsdam am Anfang des vorigen Jahrhunderts

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