PhD – Master – Bachelor topics: Prof. Strassmeier

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PhD theses topics

A search for Maunder Minimum stars (AIP – Klaus G. Strassmeier, with C. Denker)

The solar Maunder minimum in 1650-1700 was a period in which the solar dynamo had operated at a much reduced efficiency. Despite that our numerical dynamo models have some difficulties to explain such nonlinearities it can be reproduced for the Sun. In the past decade a fair number of solar-type stars were found with chromospheric emission-line fluxes smaller than even the Sun's in its regular 11-year activity minimum. These stars were interpreted to be in a Maunder-minimum like state. Just recently though, it was shown that almost all of these stars were subgiants and their absolute chromospheric fluxes underestimated. In the proposed thesis, we suggest to search the AIP RAVE survey data for real Maunder-minimum stars and calibrate absolute CaII IRT emission-line fluxes for a total of 100,000 late-type stars, a factor of 1000 more than what is available from all previous surveys together. These calibrations would be very useful for the upcoming GAIA data. We hope to deduce statistically sound relations between magnetic flux and secondary stellar parameters, like metallicity, that play a major role during some parts of stellar evolution. The main goal shall be the development of a semi-empirical method to include magnetic flux into (low-mass) stellar evolutionary codes.

Molecular Doppler imaging: Probing the Dynamos of Fully-Convective Stars (AIP – Klaus G. Strassmeier, with M. Weber)

This thesis shall apply our new molecular Doppler-Imaging code to low-mass M stars and possibly to fully convective L dwarfs. The scientific goal is to detect surface inhomogeneities due to magnetic fields and to find evidence for differential rotation and interpret these with the predictions of concurrent turbulent dynamo models. Our new DI inversion code (A&A 444, 931) makes it possible to perform the reconstruction of surface temperature maps either solely from molecular features of, e.g., TiO, CO, OH, and CN bands, but also simultaneously with an unlimited number of atomic lines. Its kernel is based on the mathematical approach of quasi-optimal Kolmogorov-Wiener filtering of the eigenvalues of the Fisher information matrix. Our central scientific objective is to find out whether, and if yes, how different, the surface topology of fully-convective M and L dwarfs appears compared to solar-like interface-type dynamo stars. The long-term goal is to pave the way to quantify the structure and dynamics effects of stellar activity at the lower end of the main sequence, and its consequent implementation into stellar evolutionary models.

Photometric Spot Modelling with APT, CoRoT, Kepler and BRITE-Constellation (AIP – Klaus G. Strassmeier, with T. Granzer)

High-precision photometry can be used to time a spot's repeated appearance on the visible stellar hemisphere, and thereby obtain stellar rotation periods ten times more precise than from spectroscopic measurements. In principle it also allows to determine differential surface rotation in case the latitude of the spot can be determined, or at least constrained to a certain range. Combined with automatic telescopes, like our APTs and the upcoming STELLA-II & RoboTel facilities, photometry is unbeatable in obtaining long-term information on the growth and decay of spots and even on decades-long activity cycles. We have also access to some data from the space missions CoRoT and *Kepler* and possibly soon also from the Austrian-Canadian nano-satellite BRITE-constellation.

The PEPSI ``deep spectrum'' project (AIP – Klaus G. Strassmeier, with M. Steffen)

The idea of a PEPSI ``deep spectrum'' is to provide the highest quality optical spectra ever obtained for any star other than the Sun. A signal-to-noise ratio of 5000:1 at a spectral resolution of 1 km/s covering the entire optical spectrum from 390 to 1050nm is the goal. The thesis shall address the properties of stellar surface convection as a function of spectral type by measuring the asymmetry of selected spectral line profiles. This kind of information is essential for our understanding of the nature of `turbulence' in stellar atmospheres, and for the validation of current hydrodynamical models of stellar convection. The accurate determination of chemical abundances and isotope ratios is a fundamental building block of our knowledge about stellar nucleosynthesis and the chemical evolution of the Galaxy. The detection of ^{6}Li in solar-metallicity stars might indicate the existence of an extrasolar planetary system, part of which has been accreted onto the star and thus contaminated its atmosphere with ^{6}Li-rich material. PEPSI is foreseen to see first light in December 2012. Data would be taken in its commissioning phase until spring 2013.

Measuring Stellar Surface Magnetic Fields (AIP – Klaus G. Strassmeier, with Drs. T. Carroll & I. Ilyin)

Magnetic fields likely play an important role in almost any astrophysical target, from the early Universe to the Sun, Earth, and its environment. While numerical 3-D MHD simulations became more and more sophisticated in the previous years, magnetic-field observations are still extremely rare (except for the Sun). We propose to carry out such measurements with the high-resolution spectropolarimeter PEPSI of the 11.8m Large Binocular Telescope (LBT). A central scientific question in this thesis is to map the distribution of magnetic flux throughout the H-R diagram and qualify its impact on stellar evolution. Are there observable signs when the surface field transfers from dynamo-generated like in our Sun to fossil like in white dwarfs? Is the angular momentum loss from magnetized winds and its associated braking of stellar rotation just a brief epoch on or near the ZAMS?

PhD theses on the topics of Extrasolar Planets, Asterospheres, and Astrobiology

Stellar magnetic activity influences the non-thermal particle environment of potentially habitable planets in three different manners: by modulation of the galactic cosmic ray environment through changing magnetized stellar winds and stellar mass ejections (CMEs),

by energetic particles accelerated by stellar flares, and by CME-magnetosphere interactions resulting in geomagnetic storms and associated particle acceleration. Biomarkers in general, e.g. like the strength of the vegetation red edge (VRE), could be severely affected by such non-thermal emission from the planet's host star. It is therefore very relevant to incorporate stellar non-thermal processes that eventually impinge on a planet. The consequence of these processes for habitability would be particularly important in the case of M dwarfs, partly due to the close proximity of any potentially habitable planets, but also due to the fact that M dwarfs tend to be more magnetically active than earlier-type stars. Solid number statistics are still missing and an observing campaign for selected targets with our APT in Arizona or RoboTel in Chile could be done. Moreover, terrestrial planets will most probably be first detected around M dwarfs, strengthening the case for a detailed assessment of their activity's impact on habitability. The topic is structured for four PhD theses over the years to come:

1. **The flare statistics and non-thermal energy budget of M dwarfs hosting planets (AIP – Klaus G. Strassmeier, with Drs. Warmuth & Granzer)**

2. **A search for CMEs in nearby solar-type stars with LOFAR (AIP – Klaus G. Strassmeier, with Drs. Warmuth & Vocks)**

3. **Observations and analysis of the Vegetation Red Edge in the Earthshine (AIP/PIK – Klaus G. Strassmeier, with Prof. S. Franckh, PIK and I. Ilyin, AIP)**

4. **Towards a spectropolarimeter for the E-ELT (AIP – Klaus G. Strassmeier, with Dr. I. Ilyin & M. Woche)**

… and many other topics suggested by the candidate personally and after a 3-month feasibility study. PhD students are regular AIP staff members with the salary of ½ that of a young staff astronomer with a PhD.

Master (Diploma) theses topics

Doppler imaging of stellar surfaces (AIP – Klaus G. Strassmeier, with T. Carrroll & M. Weber)

Doppler imaging is an inversion technique to recover a 2-D image of a rapidly rotating star from a series of high-resolution spectral line profiles. The inverse problem for stars with cool spots amounts to solving the integral equation relating the surface temperature distribution to the observed line profiles and light and color curve variations, while controlling the effects of noise in the data through a regularizing functional. Our group had developed two inversion codes, TempMap and iMAP, that we would want to apply to new, unpublished time-series of high-resolution stellar spectra. Thanks to our automated telescopes we have several targets with fully reduced spectra that are (almost) ready to be inverted into surface maps. The master student basically takes care of one star and goes through the entire process of the line-profile inversion including an interpretation of the surface map obtained. Auxiliary data, e.g. like continuum photometry, will be either taken from the literature or can be reobserved. The goal is to obtain a well-constrained Doppler image of the target in question, or even a series of images if the data allow, and to place the results in context to other stars. We have currently binary stars with giant or main-sequence components, stars with high lithium abundances, single class III giants as well as very young main-sequence stars and a few pre-main sequence targets.

The eclipse of epsilon Aurigae (AIP – Klaus G. Strassmeier, with T. Granzer & M. Weber)

Epsilon Aurigae is an eclipsing binary comprising of an F0 supergiant and a companion which is generally accepted to be a huge dark disk orbiting an unknown object, containing possibly a binary system of two small B-type stars. The orbital (eclipse) period is 27 years, and thus the eclipsing binary with the longest known orbital period. An eclipse took place in mid 2010 ±1 year. We have continuously observed it with our STELLA-I telescope and its echelle spectrograph in Tenerife as well as with our Amadeus-APT in Arizona. Epsilon Aurigae's brightness drops from +2.92 to +3.83. This dimming lasts ~700 days. The theses (may be two theses due to the wealth of data) shall wrap up all the data we have and analyze towards a publication. In particular we see pulsational variations of the radial velocity of the F supergiant that could be analyzed by means of a periodogram analysis. Particular spectral indicators shall be measured out of the echelle spectra and investigated towards modulation, e.g., a singly-ionized Scandium line was detected in emission just recently and shall be investigated. H-alpha appears as a very complex line profile and its modulation could me modelled. The APT light curve provides information on the continuum obscuration from the supergiant and could be used to detect inhomogeneities in the obscuring disk.

The most eccentric binary orbit in the sky revisited (AIP – Klaus G. Strassmeier, with M. Weber)

We have obtained STELLA spectra (and still ongoing) of the nearby M-star binary Gliese 586. Its orbit has an eccentricity of 0.97 and a period of around 900 days. It is a double-lined binary and thus we can determine minimum masses for both M dwarfs to a very high degree of precision. The thesis shall redetermine the orbital elements from our STELLA spectra and

obtain absolute stellar parameters, including also Hipparcos data (astrometry and photometery). Are these M stars any different than a single, nominal M dwarf of comparable mass? What are these stars' rotational periods and are they synchronized to the huge eccentricity?

The STELLA Open Cluster Survey (AIP – Klaus G. Strassmeier, with T. Granzer)

Several Master theses will be possible with the survey data. We have scheduled 18 open clusters with ages between 30 Myrs and 4 Gyrs which will be observed during the next years. Thirteen of them are our core targets, five more are on the ``wish list''. As of January 2011, NGC752, Melotte 111 and NGC1647 are being observed in monitoring mode. Others are pending. We employ the Wide Field STELLA Imaging Photometer (WiFSIP) on STELLA-I in Tenerife with the Sloan *r* filter for the "monitoring" mode and in Strömgren *uvbyβ* in "deep-field" mode. Possible Master topics include the membership determination/verification based on metallicities and gravities (in the absence of radial velocities), the determination of rotational periods for selected clusters, the search for L-dwarfs from combined (stacked) CCD images, the search for transits from extra-solar planets, eclipsing binaries etc.. A separate thesis is envisioned for new observations that include a narrow H-alpha filter. The goal is to determine a mass-rotation and a rotation-activity relation and, later on, a mass-rotation-activity-age relation that shall constrain models of angular-momentum transport and evolution in the early phases of stellar evolution.

Testing the high-resolution optical spectrograph for the Large Binocular Telescope (AIP – Klaus G. Strassmeier, with I. Ilyin & M. Woche)

We are nearing completion of the PEPSI (Potsdam Echelle Polarimetric and Spectroscopic Instrument) for the 2×8.4m LBT in Arizona. The instrument is assembled in the integration hall of the Schwarzschild Haus at AIP in Babelsberg and will undergo various stages of lab tests starting end of 2011, early 2012 until disassembly and delivery in summer 2012. For the period fall 2011 to spring 2013, we seek a young astronomer (e.g. a masters student) who assist in all testing aspects, i.e. FITS file preanalysis, optical stray-light mapping, stability issues, electronic noise reduction issues, and observations of the day sky for spectral-resolution determination. All of the aforementioned issues, and many others, have specialists at AIP. The student's task is to accompany all of them, some in great detail depending on the candidate, and support the task with proper documentation that can be used as the masters thesis.

Robotic telescopes in astronomy (AIP – Klaus G. Strassmeier, with T. Granzer)

The STELLA Control System (SCS) is a java based software written in-house currently runs three telescopes (STELLA-I, STELLA-II, and RoboTel), their instruments and their buildings. Combined with other software packages it also takes care of data reduction and pipelining the data to the user = astronomer. An interface within the Virtual Observatory is in progress. Within this field of "(Astronomical) Software engineering" we offer master theses in the following subtopics

- Interfacing the STELLA cloud monitor to the SCS. We run an automatic cloud images (at 8μm plus visual) in Tenerife and want to interface it to the SCS scheduler for possible target interference with moving (night) clouds.

- Currently located at AIP in the dome on top of the Scharzschild Haus, RoboTel will receive a new home in Chile at Cerro Armazones in late 2012, early 2013. It is a 80cm-diameter copy of STELLA-I and also carries a copy of the WiFSIP instrument with a 4k CCD imaging photometer. It is to be thoroughly tested and documented before delivery and equipped with a modified version of the STELLA-I/WifSIP-I user and operations GUI.
- Design and implement an interface of the SCS for a robotic-telescope network as part of the e-science initiative.

… many of above Master topics can be upgraded to a PhD thesis depending on the input of the candidate. Additionally, some can be split up into several smaller bachelor works. All of this is to be discussed about with the candidate.

Bachelor works

The serendipitous spectroscopy project

We will obtain a single spectrum of a star chosen by the student and try to find out what this spectrum is telling us. The selection of the star is made basically on its HD number without a priori knowledge – "tell me the HD number and we give you a spectrum" - under the constraint that it can be observed by STELLA (see www.aip.de/stella). The student must know in advance when the bachelor work is to be carried out and then tell us the HD number no later than a month in advance. The star shall be at or at least close to the meridian during this month so that the observation will be successful and in time for the bachelor work. The work itself then consists of a description of the spectrum and what you can determine from it. The introductory shall summarize all literature that is known about the target in question, mostly based on the www entries at Simbad CDS Strasbourg.

Stellar polarimetry – an inventory of spectropolarimetric night-time facilities in the world

The work shall identify and catalogue all existing spectropolarimeters for night-time work in astronomy. It shall collect all instrument specifications as far as they are known and have been published. The content is then added to our own web page and submitted to Wikipedia.

Period analyses for late-type stars

A given star's light curve is to be analyzed with various period-search techniques. The period(s) found shall be compared and an error analysis performed. All software exists and the application could be done on a laptop PC. A description of the data, the search technique, the windowing, the error bars, and an interpretation sums up to an approximately 30-page document. Language can be English or German. What physical mechanism may have caused the light variations? Is the period plausible or could it be an alias?

The optical spectrum of the Sun

We have obtained many spectra of the day sky (and or the Moon) as proxies for the Sun. A single such spectrum from STELLA shall be analyzed and compared with ultra-high quality catalog spectra of the Sun. Individual chemical elements and particularly interesting spectral lines are to be identified and compared in detail, e.g. neutral lithium at 670.8 nm.

The water-vapour spectrum above Tenerife

Day-time and dawn sky spectra shall be used to separate the many water-vapour absorption lines from Earths atmosphere. This will be achieved in first order by subtracting a degraded solar-catalog spectrum from the STELLA sky spectra. Which wavelengths between 390-870 nm are free of atmospheric water? Which wavelength regions are severely contaminated?

The stability of the SES

A brief analysis of stability aspects of the STELLA Echelle Spectrograph shall be carried out. What are the influences of the environment on the quality of stellar spectra taken with the STELLA facility? In particular we will compare radial velocities and/or Thorium-Argon calibration lamp wavelengths as a function of day/night, i.e. temperature and barometric pressure, but also on humidity, wind, pointing and other parameters that were monitored. All data are at hand and the analysis can be done on a laptop PC.

The exoplanet zoo

The currently existing zoo of extrasolar planets (500+ in January 2011) shall be examined towards various astrophysical selection effects. Less well-known astrophysical parameters shall be searched for in the web database and a statistics prepared. Such parameters could be, e.g., metallicity, lithium abundance, rotation period if known or the projected rotational velocity. Select planets in bins of e.g. vsini and check out which spectral types are these. Another approach is the selection of transiting systems, again with the previously mentioned parameters. Which of the catalogued transiting planets would enable an application of the Transit-Doppler-Imaging technique?

… several of above bachelor works can be upgraded to a masters thesis. This will depend somewhat on the availability of accompanying AIP staff. Many more topics could be proposed depending on suggestions by candidates.