PhD and Master topics: Prof. Strassmeier

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PhD thesis topics

Chemical abundances from the VATT-PEPSI-TESS survey of the North Ecliptic Pole (AIP – Klaus G. Strassmeier, with Dr. M. Weber a.o.)

The basic idea of the survey is to characterize potential planet-host candidates for the upcoming NASA/TESS mission by providing precise spectroscopic parameters for stars in the satellite‘s continuous viewing zone, which is around the two ecliptic poles. The North survey field comprises of approximately 800 square degrees with 311 main-sequence stars brighter than V=8.5mag and cooler than F0. Two *R*=200,000 spectra will be obtained for each of these stars at different epochs and shall deliver the following parameters: Two radial velocities good to 2-3 m/s, precise global stellar parameters like effective temperature, gravity, metallicity, micro- and macroturbulence, vsini, and radii in combination with GAIA data, high-precision abundances of all important chemical elements including the α-elements (Mg, Si but also Ca, Ti) as well as CNO. Isotope ratios like ^{6}Li/^{7}Li and ^{12}C/^{13}C if applicable, average and specific line bisectors as a function of excitation as a measure for convective blueshift, and magnetic-activity signatures like absolute Ca II IRT, Hα and Hβ line-core fluxes. The PhD is focused towards the determination and analysis of chemical abundances, but not necessarily. The survey observations with the VATT (Vatican Advanced Technology Telescope, 1.8m diameter, with a 450m fiber link to PEPSI) formally start on May 27th, 2018 and last for 3 years, 50 nights per year.

Probing the dynamos of M dwarfs and fully-convective stars (AIP – Klaus G. Strassmeier, with Drs. Thorsten Carroll and Dr. Rainer Arlt)

This thesis shall expand our iMAP code to molecular Doppler-Imaging and apply it to low-mass M stars and possibly to fully convective L dwarfs and Brown Dwarfs. The scientific goal is to detect surface inhomogeneities due to magnetic fields (or density clouds in case of cold Brown Dwarfs) and to find evidence for differential rotation and interpret these with the predictions of concurrent turbulent dynamo models. The iMAP inversion shall consider the reconstruction of surface temperature maps either solely from molecular features of, e.g., TiO, CO, OH, and CN bands, and possibly also simultaneously with an unlimited number of atomic lines. The 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.

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

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 thousand at a spectral resolution of 1.3 km/s covering the entire optical spectrum from 384 to 912nm is what we can get with PEPSI at the LBT. One such spectrum was published recently for the planet-host Kepler-444 (see https://pepsi.aip.de). The thesis includes new observations and shall address some stellar properties in great detail, e.g., chemical abundances of all sorts of elements, stellar surface velocity fields like granulation and supergranulation or, in general, turbulent convection signs. This kind of information is essential for our understanding of the nature of `turbulence' in stellar atmospheres, and for the validation of current 3D hydro-dynamical 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. This is in particular exciting if the star hosts a planetary system. Are the refractory elements overabundant with respect to the volatile elements?

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). Inh this PhD, we will carry out such measurements with the high-resolution full-Stokes-vector spectropolarimeter PEPSI of the 11.8m Large Binocular Telescope (LBT). A central scientific question in this thesis is to survey the magnetic fields of stars in open clusters and, possibly, map the distribution of magnetic flux for a representative target and qualify its impact on stellar evolution. Are there observable signs when the surface field transfers from dynamo-generated morphology like in our Sun to fossil fields 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? This PhD topic is very flexible depending on what targets one would choose for PEPSI observations. Some observations already exist.

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

This topic is structured for three 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 Dr. A. Warmuth)**

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

3. **Observations and analysis of the Vegetation Red Edge in Earthshine Observations during Total Lunar Eclipse (AIP – Klaus G. Strassmeier, with Drs. I. Ilyin and M. Mallonn)**

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 STELLA and – in the near future- BMK10k in Chile could be done.

Master thesis topics – partly PhD upgradable …

… and many other topics suggested by a student and after a 3-month feasibility study (=pre Master work). Note, PhD students are regular AIP staff members with the salary of ½ that of a young staff astronomer with a PhD. Master students may be hired as HiWi's but not necessarily.

Doppler Imaging of Stellar Surfaces (AIP – Klaus G. Strassmeier, with Drs. T. Carroll & 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 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.

Light-Curve Inversion of Rotating *Kepler* Stars (AIP – Klaus G. Strassmeier, with Drs. Thorsten Carroll & Jörg Weingrill)

High-precision photometry can be used to time a starspots repeated appearance on the visible stellar hemisphere, and thereby obtain stellar rotation periods ten times more precise than from spectroscopic measurements. It also allows determining differential surface rotation in case the latitude of the spot can be obtained, or at least constrained to a certain range. The rotation of the star can also be used to infer the surface brightness distribution and thereby obtain a spot map of the (unresolved) stellar surface. The inversion module of our code iMAP shall be applied to existing *Kepler* or K2 light curves. Combined with automatic telescopes, like our APTs and the STELLA-WiFSIP facility, photometry is unbeatable in obtaining long-term information on the growth and decay of spots and even on decades-long activity cycles.

The STELLA Open Cluster Survey (AIP – Klaus G. Strassmeier & with Drs. Sydney Barnes & J. Weingrill)

Several Master theses will be possible with the survey data. We are observing 10 open clusters with ages between 30 Myrs and 1.7 Gyrs. So far, four clusters were analysed and published. We employ AIP's Wide Field STELLA Imaging Photometer (WiFSIP) on the STELLA-I telescope 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, or the search for transits from extra-solar planets, a.o.. A separate thesis is envisioned for new observations that include a narrow H-alpha filter and/or radial velocity observations with multi-object spectrographs at larger telescopes. 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.

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

The STELLA Control System (SCS) is a java based software written in-house and 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 IR cloud imager (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 is used as a test bed for new software. It is an 80cm-diameter copy of STELLA-I and also carries a copy of the WiFSIP instrument with a 4k CCD imaging photometer. It could be shipped to Tenerife and/or Chile for a new science case if it had been thoroughly tested and documented and equipped with a modified version of the STELLA-I/WiFSIP-I operation's 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. This is to be discussed with the candidate.