Detailed Program

Morphology of stellar light curves
Gibor Basri

The signature of starspots in Kepler data is obvious and pervasive. There have been many papers discussing rotation period detection, dependence of amplitude on rotation, differential rotation signatures, and activity cycles. There are some subtleties of interpretation, however, that have received much less attention but are relevant to these analyses. 1) As the light curve morphology changes (including apparent activity cycles), how much of that is due to differential rotation and how much is due to spot number and evolution? 2) What can light curves really tell us, given that there are generally only one or two dips in intensity per rotation? 3) How can we properly convert differential light curves to actual spot areas (where is the unspotted continuum in Kepler data)? 4) How are starspot signatures related to faculae? I discuss progress on these questions, utilizing a large search of parameter space with spot models. I also present a new rotation-activity relation: there is a strong correlation between the ratio of time spent in single/double dip mode and the rotation period of a star. Finally I present a re-analysis of the faculae/spot question in Kepler data.

The Sun's Unusual Luminosity Variation and Possible Implications for the Vaughan – Preston Gap
Peter Foukal

The decrease of facular relative to spot area at the highest levels of recorded solar activity, has interesting consequences for variation of total solar irradiance, TSI. It may also help to understand the Vaughan – Preston gap, the solar activity signature in paleoclimate, and possibly even have consequences for life on Earth. The saturation observed in the increase of TSI with activity level in recent moderate cycles appears to turn over into an actual solar dimming below quiet sun levels around the peaks of the largest cycles 18 and 19, when faculae are used to reconstruct the bright contribution to TSI. Photometric imaging has shown that white light faculae are a more accurate proxy than the chromospheric plage emissions used in many previous reconstructions. Dimming at both extremes of a star's activity range is unique in the sample of 72 Sun - like stars studied so far in both Ca II and wide band photometry; no other star exhibits a switch from a positive to a negative correlation with increasing activity on the cycle time scale. This limitation of TSI (but not UV) variation to dimming affects the sign of solar activity signature expected in the paleoclimatic record, and may even have facilitated life on Earth. A less pronounced decrease is also observed in the area ratio of plage versus spots, at high activity levels. In late type stars exhibiting somewhat higher Ca II emission than the Sun, an increasing fraction of the magnetic flux seems to appear as large spots, which are weaker Ca II emitters than the smaller plage flux tubes. This tendency may explain the lower frequency of such stars observed in the intermediate range of Ca II emission. Progressing to much younger stars, an increasing area filling factor of total magnetic flux should gradually more than compensate for the lower Ca II brightness of spots, explaining the increased number of stars exhibiting the highest Ca II fluxes. So the Vaughan – Preston gap might simply be a consequence of a gradual shift with age of the stellar dynamo towards higher spatial frequencies. Such a shift appears to be consistent with dynamo models.

Transition from spot to faculae domination – An alternate explanation for the dearth of intermediate Kepler rotation periods
Timo Reinhold

We study the appearance of activity signatures in contemporaneous photometric and chromospheric time series to understand the underlying process that causes magnetic activity. Phase differences between the two time series are obtained by fitting both time series simultaneously using the same cycle period.
We find cycle periods in 27 of the 30 stars in our sample. The phase difference between the two time series reveals that the variability in fast rotating active stars is usually in anti-phase, while the variability of slowly rotating inactive stars is in phase. We find on average six times

larger photometric cycle amplitudes for the active stars. This demonstrates that active stars are dominated by dark spots, whereas less active stars are dominated by bright faculae. The transition from spot to faculae domination occurs at the Vaughan-Preston gap, and around a Rossby number equal to one.
As a consequence, we propose a new explanation for the previously detected dearth of Kepler rotation periods between 15–25 days. We suspect that stars change their dominant surface activity from spots to faculae around an age of 800 Myr; the dearth at intermediate rotation periods reflects the non-detection of periodicity caused by the cancellation of dark spots and bright faculae.

Magnetic Cycles of Sun-Like Stars
Benjamin Montet

Dedicated observations of hundreds of stars over the past decades have enabled the first observations of stellar activity cycles on stars similar and dissimilar to the Sun. Large photometric monitoring missions aimed towards the detection of transiting planets also enable studies of intrinsic stellar variability. While they have shorter baselines and often lower precision than dedicated surveys, their ability to monitor hundreds of thousands of stars at once provide new opportunities to place the solar variability in context of a large sample of Sun-like stars. Here, I will discuss data from the Kepler mission as a tool to understand stellar magnetic activity variations and their temporal evolution, both for individual stars and over stellar lifetimes. I will close with a look to the future, highlighting current work to better understand stars in the Kepler field and opportunities from future missions like TESS and PLATO.

Towards stellar butterfly diagrams
M. B. Nielsen

An important indicator of the solar magnetic activity cycle is the change in emergence latitudes of sunspots, leading to the well-known butterfly diagram. The corresponding phenomenon in other stars is poorly understood since starspot latitudes are generally unknown. Rotation rates from starspots are, however, comparatively easy to measure. Here we study an ensemble of 3091 Kepler stars for variations in rotation rate over the course of their magnetic activity cycles, which has been measured previously using photometric variability. We find that the spot rotation rate is generally anti-correlated with the activity cycle, similar to what is seen in the latter part of the solar activity cycle. The degree of anti-correlation is greatest for stars with rotation periods close to that of the Sun. On the other hand, both fast and very slow rotators on average show almost complete decorrelation between their measured spot rotation rate and their activity level. Furthermore, for solar-like rotators the variation in rotation rate begins to show an asymmetry between the start and end of the activity cycle, similar to what is seen from the solar butterfly diagram.

Simulation of photometric time series: from the Sun to the stars
Nadège Meunier

Simulations of photometric time series allows to properly interpret observation of stellar activity and estimate how other stars are similar or differ from the Sun, to tests possible analysis methods and to estimate the impact of activity on exoplanet detectability. In this talk I will present a model which has been tested on the Sun, extended to old main sequence solar-type stars using a grid of coherent physical parameters to describe the star properties, in particular its dynamics and activity. The model provides photometric, radial velocity, astrometric and chromospheric emission time series for various star inclinations and a large range of activity configurations. I will present the first results and comparisons between photometric time series and Kepler observations, and will address the following questions: What can we learn from such comparisons? How does the Sun help us to interpret the results? What are the limitations of such an approach?

Activity variation driven by flux emergence and transport on Sun-like stars
E. Isik

In G dwarfs, the surface distribution, coverage and lifetimes of starspots deviate from solar-like patterns as the rotation rate increases. We set up a numerical platform which includes the large-scale rotational and surface flow effects, aiming to simulate evolving surface patterns over an activity cycle for up to 8 times the solar rotation and flux emergence rates. We assume a solar projected butterfly diagram at the base of the convection zone, and follow the rotationally distorted trajectories of thin flux tubes to obtain latitudes and tilt angles. Using them as source properties, we run a surface flux transport model with solar parameters. Our models predict surface distributions of both the signed radial fields and starspots, which qualitatively agree with observations.

The Rarity of Sun-like Activity Cycles and their Dependence on the Rossby Number
Ricky Egeland

The magnetic activity of a few dozen solar-analog stars have been observed using the Ca II HK proxy for about 50 years. In this small sample, we find that smooth, regular Sun-like cycles are exceedingly rare. Returning to the larger FGK-type sample of Baliunas et al. 1995, we have combed the literature for rotation period measurements and used these to compute the Noyes et al. 1984 semi-empirical Rossby number. Analyzing the statistics of this larger sample, we find that most of the known high-quality Sun-like cycles are from K-type stars, and of the G-type stars only the Sun and the subgiant HD 81809A demonstrate Sun-like cycles. What these sets of stars have in common is a relatively large Rossby number, which we hypothesize is necessary to have a smooth, approximately mono-periodic variability like the Sun. Finally, we will review the importance and problematic derivation of the stellar Rossby number, how it may evolve in evolved stars like HD 81809A, and how recent global convective MHD simulations stand with respect to these observational results.

Stellar limb darkening and polarization: Application to stellar spots and transiting exoplanets
N.M. Kostogryz
Polarization from scattering is an important effect for investigating physical and geometrical properties of stars and stellar environments. The scattering and absorption processes in the atmospheres affect center-to-limb variations of the intensity (CLVI) and the linear polarization (CLVP) of the radiation. These variations, in turn, depend on the choice of geometry of stellar atmosphere. We modelled the CLVI and CLVP in continuum spectra, taking into account different contributions of scattering and absorption opacity for a variety of spectral type stars with plane-parallel and spherical PHOENIX atmosphere models. It was shown how the CLVI and CLVP depend on effective temperature and surface gravity of a star and how the considered geometry of stellar atmosphere affects the signal.
Center-to-limb variations of intensity and polarization can be used to detect and characterize stellar spots and interpret magnetic variability of stars and signatures of transiting exoplanets. Here we present variation of intensity and polarization in exoplanetary systems caused by transits, grazing transits and starspots and show how the considered geometry of stellar atmosphere models affect the transit curves of exoplanets.

Effect of magnetic activity on the detection of acoustic modes in solar-like stars
Savita Mathur

During the first ten months of the Kepler mission, over 2000 stars were observed for one month in short cadence mode allowing us to look for stochastically excited acoustic modes. This led to the detection of solar-like oscillations in only about 540 stars (Chaplin et al. 2011a). Chaplin et al. (2011b) explained the lack of detection in most of the other stars as a consequence of their high surface magnetic activity. However the sample of stars studied was polluted with many classical pulsators and red giants.
In this talk we re-visit the study on a cleaner sample of stars where we have removed stars with

newly detected oscillations using the latest DR25 from Kepler along with the classical pulsators and red giants that were polluting the sample. For the remaining main-sequence solar-like stars, we measured the rotation and magnetic activity proxy based on photometric data (called Sph, Mathur et al. 2014). While close to half of this sample has an Sph value larger than the one of the Sun, we find that a large fraction of stars without oscillations detected have a low magnetic activity level, which was unexpected. We also investigate on the origin of these missing detections using new spectroscopic observations of those stars (in particular in terms of metallicity). An upper limit of Sph is also inferred as a limit above which no pulsations were detected. Understanding the non detection of solar-like oscillations is key to predict the yield of solar-like pulsating stars for missions such as TESS and PLATO where the detection of solar-like oscillations will allow us to better characterize the stars, in particular the ones hosting planets.

Exoplanet Detection: Know Your Star, Know Your Planet
Joe LLama

Abstract: Since the first detection over 20 years ago, the number of exoplanets continues to grow rapidly with over 3,500 confirmed systems and an additional 4,500 candidates. The success of radial velocity surveys such as ELODIE and HARPS/HARPS-N, along with photometric surveys such as WASP and Kepler, have redefined our paradigm of planetary systems. However, despite the vast number of confirmed exoplanets, we have yet to identify an Earth analog. The detection of an Earth-sized planet orbiting within the habitable zone of a solar-type star is an extremely challenging measurement to make, requiring 0.1 m/s radial velocity precision. The next generation of radial velocity surveys such as EXPRES, ESPRESSO, and HARPS3 are all being designed to achieve this goal.
One unavoidable issue with detecting small exoplanets is contamination from host star variability, the result of magnetic activity, rotation, and convection. For photometric surveys, the timescale of an exoplanet transit is typically much shorter than the variability from starspots; however, small-scale variability from granulation and convection may still mask the signal of an Earth-sized planet. For radial velocity surveys, the situation is more complicated because the timescale of the planetary signal is determined by the orbital period, which may be much closer to the stellar rotation period or activity cycle length.
In this talk, I will review the state-of-the-art exoplanet surveys along with the next generation of 0.1 m/s precision instrumentation. I will also review the fundamental impact stellar activity has on these searches and the methods and simulations that are helping disentangle the exoplanetary signal from that of the host star.

Boosting or mitigating the activity signal in radial-velocity measurements
Xavier Dumusque

The study of stellar activity provides important diagnostics on the structure and evolution of stars and their atmospheres and on stellar magnetic fields. In addition, stellar activity is also a limitation to the detection of Earth-twins orbiting cool stars using the radial-velocity (RV) technique, and therefore finding a way to mitigate stellar activity is crucial for a successful RV follow-up of TESS candidates.
Stellar activity of quiet cool stars can be probed by looking at spectral lines presenting a chromospheric emission, like the Ca II H and K lines, H-alpha or the Ca triplet. However, spectral lines formed in the photosphere should also be affected by activity. Photospheric lines have different sensitivity to temperature, they are formed at different depth, therefore stellar activity that create spots much cooler than the photosphere and that modifies the convection as a function of depth should affect every spectral line in a different way.
By deriving the RV of each individual spectral line in HARPS high-resolution spectra, we found that the RV of some spectral lines are much more sensitive to activity than others. By looking at the radial-velocity data of Alpha Centauri B in 2010, where a clear activity signal is observed, we can either multiply by three the activity signal seen in RV, or mitigate it by a factor of 2.5, depending on the choice of lines used to measure the stellar radial velocity.

The Sun as a Model for Stellar Activity
Timothy Milbourne

To detect Earth-like exoplanets in the habitable zones of Sun-like stars, Precise Radial Velocity spectrographs require sensitivities below 10 cm/s. To realize these design goals, non-planetary variability in the measured radial velocity (RV) must be understood and its effects accounted for. On timescales of the stellar rotation period, these non-planetary RV variations are dominated by the effects of magnetic features, such as spots and faculae, which have velocity signatures exceeding 1 m/s.

In this work, we use the Sun as a model system for the effects of magnetic processes on RV measurements. We use a purpose-built solar telescope to measure the Sun as a point source, and extract solar RVs using the High Accuracy Radial velocity Planet Searcher for the Northern hemisphere (HARPS-N) spectrograph on La Palma. In parallel, we use magnetograms from the Helioseismic and Magnetic Imager onboard the Solar Dynamics Observatory and simultaneous photometry from Solar Radiation and Climate Experiment to extract information about how magnetic features interact with solar convection and change the solar rotation profile, and how these effects change the solar RVs. By combining these data sources, we estimate the relative contributions of solar magnetic variations to the solar RVs, and investigate how these contributions vary with time.

The ages of exoplanet hosts
Ruth Angus

Thanks in large part to Kepler, it is now possible to infer the occurrence rate of exoplanets as a function of their radii and orbital periods. The influence of host stars on planet occurrence rate is also being explored: host star mass and metallicity, for example, appear to influence the radii and orbital periods of the planets that form around them. The ages of young planet hosts even provide tentative observational evidence of shrinking planet radii due to cooling and photoevaporation. Searching for evidence of time-dependent trends in the exoplanet population is challenging however, in part because stellar ages are difficult to measure and in part due to inconsistent planet detection efficiency over stellar age (it is more difficult to detect planets orbiting young stars as they are typically more active). I will highlight new advances in the accuracy and precision of stellar age-dating methods applicable to Kepler exoplanet hosts, with particular emphasis on light curve-based dating methods, and present preliminary results from an exoplanet population study that searches for trends in the planet population as a function of host star age.