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A broad view on solar and stellar activity

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Stellar activity is ubiquitous among low-mass stars in the Galaxy. On the Sun, a plethora of activity-related phenomena such as sunspots, flares, the chromosphere, and the corona can be studied in great detail. Although highly diverse in appearance, these phenomena are all thought to be intimately related to the solar magnetic field. In my presentation, I discuss fundamental aspects of solar activity and how it relates to observations on other low-mass stars. Although some relations like the dependence of the activity level on stellar rotation and age have been studied for decades, open questions remain abundant in activity research. The discovery that active low-mass stars are also common planet host stars places further importance on understanding their activity and its impact on their planets.

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Solar activity: basic phenomena and processes

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Solar activity involves many phenomena which are all driven by the complex solar magnetic fields that are generated by a dynamo mechanism. I will review the most important aspects of solar activity, including the activity cycle, sunspots and active regions, and the most dramatic form of solar activity: solar eruptive events (flares and coronal mass ejections). Finally, I will address the issue of how we can apply what we learn about solar activity in the wider context of stellar activity (and vice versa).

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Hunt for magnetic cycles in solar-type stars

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Magnetic cycles in solar-type stars detected using spectropolarimetric observations together with chromospheric activity monitoring provide important insights into magnetic field regeneration and amplification in stars other than the Sun. We investigate the variability of the large-scale magnetic field of two solar-type stars 61 Cyg A and HN Peg using spectropolarimetric observations. Zeeman Doppler imaging is used to reconstruct the large-scale magnetic field over multiple epochs to investigate how the large-scale field varies with chromospheric activity cycle. We report the first detection of polarity reversals of the large-scale field in phase with its chromospheric activity cycle for the K5V dwarf 61 Cyg A. The magnetic geometry of the G0V dwarf HN Peg however do not exhibit any polarity reversal, but exhibits a rapidly varying magnetic field with strong azimuthal component.

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Understanding Solar and Stellar Dynamos with numerical simulations

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At the beginning of the cycle sunspots appear at high latitude, whereas at the end they appear close to the equator. This is associated with an underlying strong toroidal field which migrates equatorward. Since a few years this behavior has been reproduced in global convective dynamo simulations. I will present results from our simulations of global convective dynamos. All of these simulations produce cyclic and migrating mean magnetic fields. Through detailed comparisons, we show that the migration direction can be clearly explained by an alpha-Omega dynamo wave following the Parker-Yoshimura rule. This lead to the conclusion, that the equatorward migration in this and other work is due to a positive (negative) alpha-effect in the northern (southern) hemisphere and a negative radial gradient of rotation outside the inner tangent cylinder of these models. Furthermore, I will present results of identifying various dynamo mechanism in these simulation using obtain transport coefficients: alpha effect, turbulent pumping and the turbulent magnetic diffusivity calculated with the test-field method. These coefficients show a clear temporal variation with the activity cycle indicating a non-linear dynamo mechanism.

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Stellar activity: key or nuisance?

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"Stellar activity" is a term that came originally from solar astrophysics, where astronomers refer to the quiet Sun and the active Sun depending on whether our star is in a state of sunspot minimum or maximum. More physically, we mean with activity all (mostly) non-thermal phenomena inside and outside of a star that are typically related to its magnetic field (rather than classical pulsation), e.g., the rise of flux tubes in a stellar convection zone and their appearance as spots and plages on the stellar surface, or magnetically/electrically induced particle acceleration and its braking effect on stellar rotation, or simply the interplay between a magnetic field and its surrounding plasma from the convection zone to the asterosphere. Detecting and characterizing extrasolar planets put stellar activity in yet another spotlight; the role of astrophysical noise.

In this talk, I will focus on the many aspects of stellar magnetic fields and surface inhomogeneities. I will concentrate on the available observations and some interpretations even though that fundamental progress will equally come from modern numerical magneto-hydrodynamics. I will emphasize how present magnetic activity will become once the new generation of large telescopes and high-resolution spectrographs are turned to stars with dynamic atmospheres.

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Solar chemical abundances from three-dimensional magnetoconvection models and VTT observations

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Magnetic fields in the solar photosphere are known to modify the profiles of spectral lines. I present a comparison between synthetic spectra from 3D MHD numerical simulations and observed high-quality spectra obtained at the Vacuum Tower Telescope (VTT). Differences between disc-centre spectra for quiet Sun and magnetic network regions are significantly above the noise level of the observations. By fitting the VTT observational data, the 3D MHD synthetic intensity profiles allow us to derive accurate and precise values of the solar chemical composition.

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IRIS observations and simulation of explosive events in the transition region of the Sun

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Small-scale explosive events on the Sun are thought to be related to magnetic reconnection. While Petschek reconnection has been considered as a reconnection mechanism for explosive events on the Sun for quite a long time, the fragmentation of a current sheet in the high-Lundquist-number regime caused by the plasmoid instability has recently been proposed as a possible mechanism for fast reconnection. The actual reconnection sites are too small to be resolved with images but these reconnection mechanisms, Petschek and the plasmoid instability, have very different density and velocity structures and so can be distinguished by high-resolution line profiles observations. We use high-resolution sit-and-stare spectral observations of the Si IV line, obtained by the IRIS spectrometer, to identify sites of reconnection, and follow the development of line profiles. The aim is to obtain a survey of typical line profiles produced by small-scale reconnection events on the Sun and compare them with theoretical line profiles of reconnecting current sheets to determine whether reconnection occurs via the plasmoid instabilty or the Petchek mechanism. To make direct comparison with IRIS observations, we set up a numerical experiment with a current sheet under high Lundquist number and use the simulation result to construct synthetic line spectra of the current sheet. The synthetic line spectra agree qualitatively with IRIS observations, suggesting that the plasmoid instability is a possible explanation for observed line spectra of the explosive events.

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Coronal magnetic field modeling using stereoscopy constraints

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Nonlinear force-free field (NLFFF) extrapolation has been used extensively in the past to extrapolate solar surface magnetograms to stationary coronal field models. In theoretical tests with known boundary conditions, the nonlinear boundary value problem can be solved reliably. However, if the magnetogram is measured with errors, the extrapolation often yields field lines that disagree with the shapes of simultaneously observed and stereoscopically reconstructed coronal loops. We here propose an extension to an (NLFFF) extrapolation scheme that remedies this deficiency in that it incorporates the loop information in the extrapolation procedure.

We extended the variational formulation of the (NLFFF) optimization code by an additional term that monitors and minimizes the difference of the local magnetic field direction and the orientation of 3D plasma loops. We tested the performance of the new code with a previously reported semi-analytical force-free solution.

We demonstrate that there is a range of force-free and divergence-free solutions that comply with the boundary measurements within some error bound. With our new approach we can obtain the solution out of this set the coronal fields which is well aligned with given loops.

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Modeling the Production of Cosmogenic Radionuclides due to Galactic and Solar Cosmic Rays

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Cosmogenic radionuclides such as ^{10}Be, ^{14}C and ^{36}Cl are a product of the interaction of high energetic primary particles, in particular galactic cosmic rays (GCR), with the Earths atmosphere. Because GCRs are modulated on their way through the interplanetary medium the GCR-induced production of these radionuclides is anti-correlated to the solar cycle. Furthermore, during phases of strong solar activity also solar energetic particle (SEP) events occur frequently. While the production due to GCRs can be seen as background production, in particular so-called Ground Level Enhancement (GLE) events, strong SEP events which can be detected at the Earths surface may strongly contribute to the production of ^{10}Be, ^{14}C and ^{36}Cl, a topic by now highly discussed in the literature. Using energy spectra of modern GLE events, which have occurred since 1941, we will investigate the influence of 58 out of the 71 GLEs and statistically investigate the possibility to detect such events in present ice-core and tree-ring records.

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INFLUENCE OF SOLAR DISTURBANCE'S INITIAL PARAMETERS ON THE ARRIVAL OF THE ASSOCIATED INTERPLANETARY SHOCK AT EARTH AND THE SHOCK PROPAGATION MODELS

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Violent forms of solar activity, such as solar flares, coronal mass ejections (CMEs) and so on, are believed to be major sources of strong interplanetary (IP) disturbances and corresponding non-recurrent geomagnetic storms. Fast eruptions usually drive an IP shock ahead of them when they propagate outward in the heliosphere. Predicting the arrival times of solar disturbances and their related shock waves at Earth is an important aspect of space weather forecasting. Based on a large number of solar-IP disturbance events, this study investigates the influence of initial parameters of solar disturbances on the arrivals of the corresponding IP shocks at Earth. Then, the Shock Propagation Models with different versions are developed to predict the shock's arrival times. These models are based on an analytical solution to the propagation of blast waves in a moving, steady-state, medium with variable density. The inputs include the solar disturbance's initial parameters observed near the Sun. The outputs provide whether or not the shock will hit Earth and the corresponding arrival time if it does with enough lead time as models are analytic. For the latest version (SPM3), the prediction test based on 498 events of Solar Cycle 23 reveals that its prediction success rate is 70%–71%, and the prediction error of arrival time for the Earth-encountered shocks is within 9 hr (mean-absolute). Comparisons to other similar models also demonstrate that SPM3 has the highest success rate and best prediction performance.

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Observation of the Cosmic-Ray Shadow of the Moon and Sun with IceCube

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Moon shadow analyses are standard methods to calibrate cosmic-ray detectors. We report on a four year observation of cosmic-ray Moon and Sun shadows in different detector configurations. The cosmic-ray Moon shadow was observed with high statistical significance ($> 6\sigma$) in previous analyses when the IceCube detector operated in a smaller configuration before it was completed in December 2010. This work shows the first analyses of the cosmic-ray Sun shadow in IceCube. A binned analysis in one- and two-dimensions is used to measure the Moon and Sun shadow with high statistical significance greater than 12σ. The cosmic-ray shadow of the Sun is expected to be influenced by the solar magnetic field, which has already been observed by the Tibet AS-Gamma Experiment.