Solar Astrophysics

Leibniz-Institut für Sonnenphysik, Freiburg, Germany

Dozenten:

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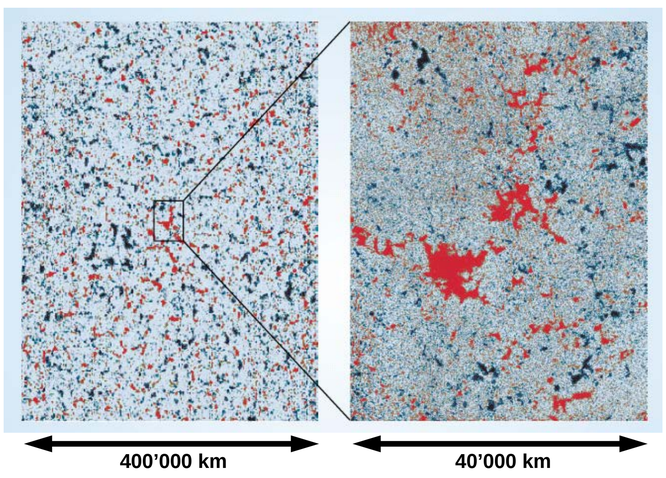
Solar Atmosphere and Magnetism

Magnetic fields on the Sun appear in various sizes and shapes. While stronger, oriented fields can be detected via the Zeeman effect, very weak fields with different polarities below the resolution limit lead to a cancellation of the circularly polarized Zeeman signatures.

We have initiated a synoptic program to investigate both turbulent, mixed-polarity magnetic fields and nearly horizontal, directed fields and their variation with the solar cycle. Through spectropolarimetric observations we monitor linear and circular polarization at the solar limb with the sensitivity of 10 parts in a million. We continue monitoring these fields through the current solar cycle in order to understand their role in the solar magnetic dynamo.



Magnetic fields in the quiet Sun are of mixed polarity which is preserved at different scales and extends beyond the current spatial resolution limit. The Hanle effect in molecular lines allows us to investigate these fields and assess their role in the global solar magnetism.

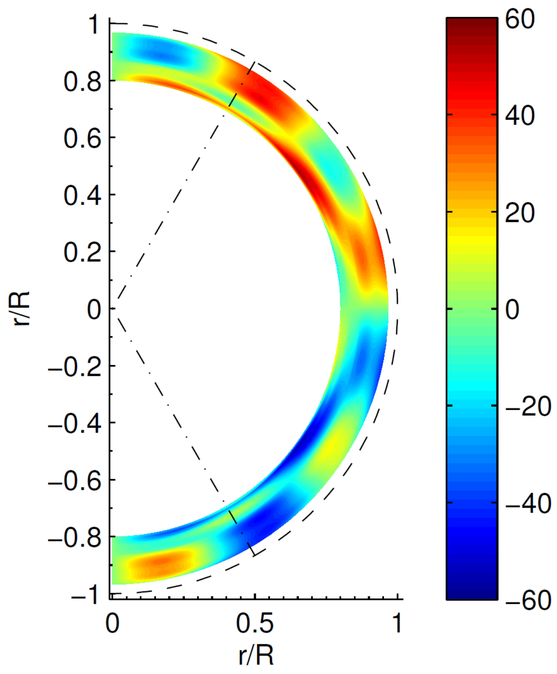
(Kleint L., Berdyugina S.V., Shapiro A.I., Bianda M., 2010, A&A, 524, A37
Berdyugina, S.V., Stenflo J.O., Gandorfer A., 2002, A&A, 388, 1062)

Helio- & Asteroseismology

Helio- and Asteroseismology are the only tools that allow measuring the internal structure of the Sun and the stars and the processes involved in the Sun's magnetic activity.

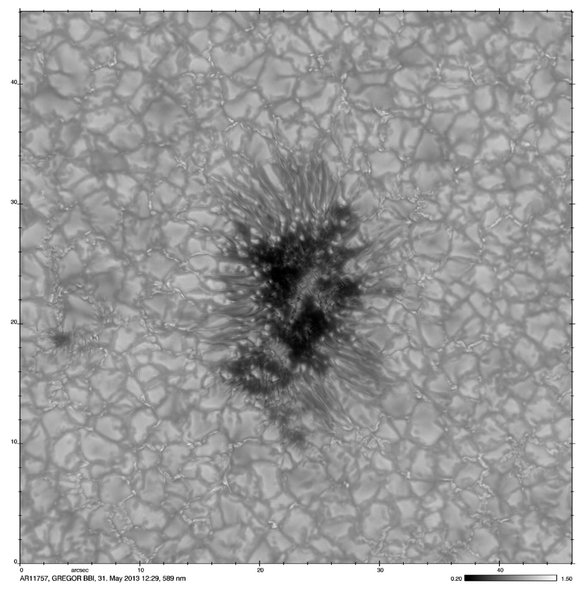
This activity impacts the near-Earth space environment and the Earth's climate. It is caused by a magnetic field which varies over an 11-year cycle, the origin of which remained so far an unsolved puzzle for astrophysics. It is assumed that self-excited dynamos generate a complex, large-scale magnetic field in shear zones in the solar interior.

To understand the working of the solar dynamo we investigate the interior dynamics.



Cross-section through the Sun's meridional flow in the (r, θ)-plane between 0.82 and 0.97 solar radii. The dashed line marks the solar surface. Dashed-dotted lines mark the latitudes θ = ±60°. Positive (negative) values correspond to northward (southward) directed flows (Schad, Timmer, Roth, 2013, Astrophys. J. Letters, 778, 38).

Small-Scale Structures on the Sun



Small sunspot and solar granulation observed with the 1.5 m solar telescope GREGOR at the Observatorio del Teide, Tenerife. The image shows an area of 32000 x 32000 km² on the Sun. The smallest details have dimensions of less than 100 km.

R. Schlichenmaier, R. Rezaei, N. Bello González, and T. A. Waldmann, 2010, Astronomy & Astrophysics 512, L1

The solar surface shows a variety of structures of very different size. Sunspots may have dimensions of up to 50,000 km, while the smallest objects within or around such spots are as small as 100 km, or less.

The KIS operates the GREGOR solar telescope; with an aperture of 1.5 meters it is the largest solar telescope in Europe with an angular resolution of 0.1 arcsec (70 km on the Sun). The filtergram shown here has been taken at a wavelength of 589 nm. The feature in the center is a small sunspot. The granulation pattern that is seen outside the spot exists everywhere on the Sun and is caused by convective motion below the surface. The bright points and elongated features that partially fill the dark lanes between the granules are locations of magnetic flux tubes with field strength of up to 1500 Gauss.

We study the formation, structure and evolution of the smallest features on the Sun.

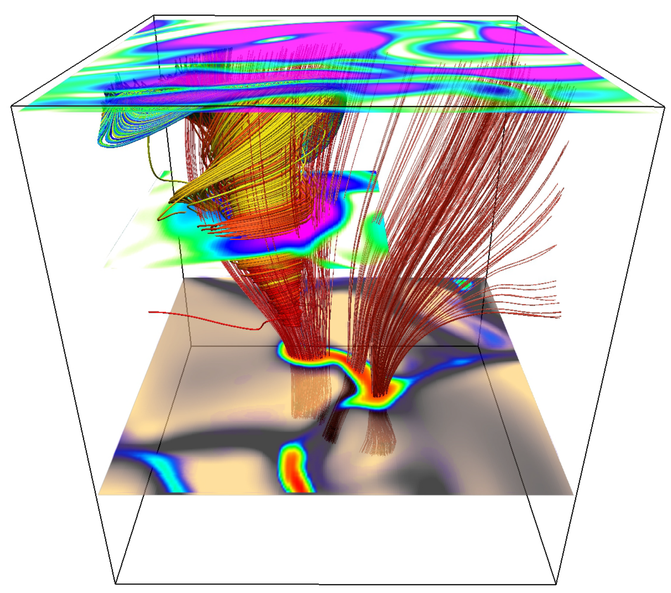
Convection and Magnetic Field 3D Simulations

We carry out extensive numerical simulations of various magneto-hydrodynamic processes in the solar atmosphere.

Our goal are highly realistic simulations that allow a direct comparison with corresponding images of the observations and be used for their interpretation of the physical processes on the Sun

The necessary computer programs for the simulations and their analysis are continuously developed and newly created at the Leibniz-Institut.

(Steiner, O. and Rezaei, R., 2012, ASP Conf. Ser. 456, 3
Wedemeyer-Böhm, S., Scullion, E., Steiner, O., Rouppe van der Voort, L., de la Cruz Rodriguez, J., Fedun, F., and Erdélyi, R., 2012, Nature 486, 505)



Three-dimensional rendering of the numerical simulation of a `magnetic tornado' in the solar atmosphere. The magnetic field concentration (red) in the photosphere (brown bottom surface) co-rotates with the plasma in the dark intergranular downdraft and leads to swirling motion in the chromosphere (top surface).

The Largest Solar Telescope – DKIST

US American research institute are currently commissioning the Daniel K. Inouye Solar Telescope (DKIST) under the direction of the National Solar Observatory (NSO) at the Haleakala summit on Maui, Hawaii. This world largest solar telescope has a free aperture of 4 meters and is designed for diffraction-limited observations in the optical and infrared spectral ranges and for coronal observations.

Equipped with adaptive optics and with modern focal plane instruments, it will be possible for the first time to sense solar physical processes near or at their dissipative scales and to directly test theoretical models, e.g., of the magneto-convection in sunspots or small magnetic elements.

Composite image of the Daniel K. Inouye Solar Telescope, the world's most powerful solar telescope at Haleakala (3000 m) on Maui. *Image credit: NSO/NSF/AURA.*

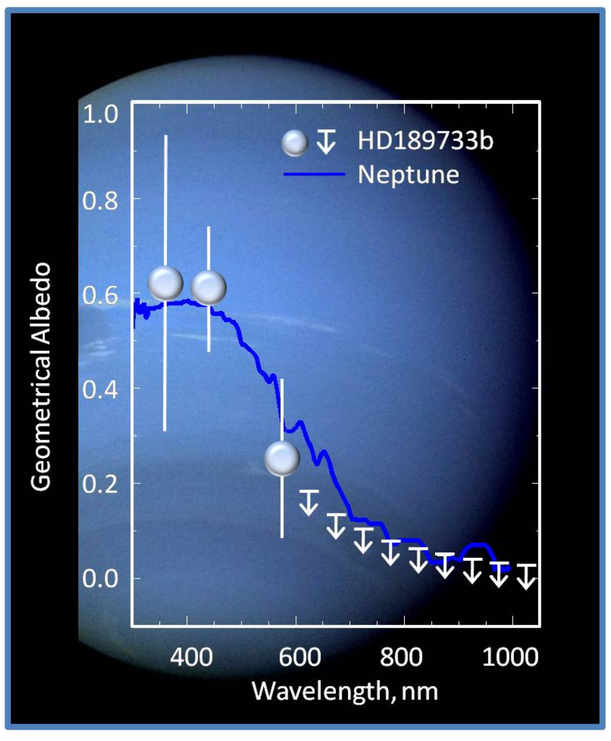
KIS has been involved in the drawing up of the scientific requirements and contributes a tunable 2D spectrograph for visible wavelengths. The design and development phase of the Visible Tunable Filter VTF started in 2012. The development of large-format Etalons with an aperture of 250 mm is a significant development effort.

Planetary Atmospheres

Studying exoplanetary atmospheres and their composition is the sole key to determining whether they can be habitable. We are developing novel methods and applications for exploring exoplanetary atmospheres and their potential habitability using our expertise in polarimetric techniques previously employed for solar and stellar atmospheres.

In particular, we were first to detect reflected light from an exoplanet (HD189733b), measure its geometrical albedo, and conclude on its blue appearance similar to Neptune.

The first measurement of the geometrical albedo of an exoplanet reveals its blue color similar to Neptune.



(Berdyugina, S.V., Berdyugin A.V., Fluri D.M., Piirola V., 2011, ApJL, 728, L6-L10)

Lectures in Astrophysics

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Bachelor of Physics

Einführung in die Astronomie und Astrophysik

Master of Physics / Master of Applied Physics

Stellar Structure and Evolution

Astrophysical Magento-Hydrodynamics

Stellar Pulsations

Helio- and Asteroseismology

Physics of Stellar Atmospheres

Stellar Magnetic Activity

Star Formation

Planet Formation, Evolution, Atmospheres, Habitability

Astrobiology

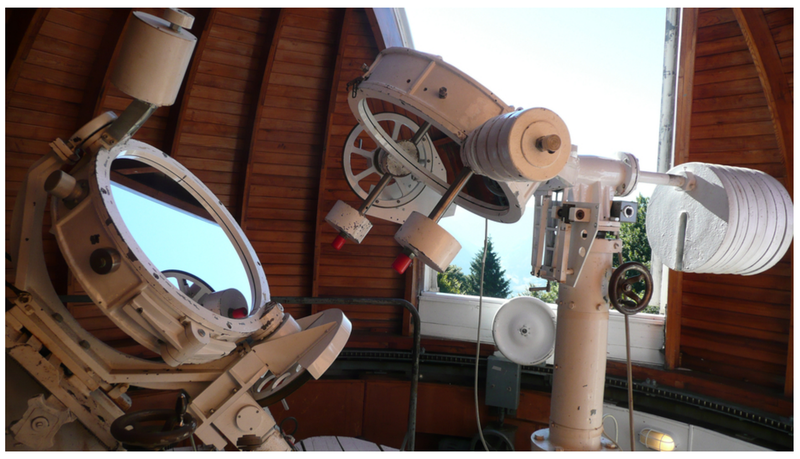
Solar Physics

Modern Astronomical Instrumentation

High-resolution Astrophysics

Observational Astrophysics

Lab Course on the Schauinsland Observatory



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