The many Scales of the Universe: Galaxies, their Suns, and their Planets

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Abstracts

Karl-Schwarzschild Lecture

Cosmic magnetic fields

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Magnetic fields are omnipresent in the Universe. We know of records by the Chinese or the Greeks in which magnetic effects were discussed. Certainly the navigation of ships in the middle ages depended on the use of the compass. The first experiments with magnets were described by Gilbert in 1600. Johannes Keppler speculated on the magnetic effect that was forcing the movement of the planets. This suggestion was negated by Isaac Newton who developed the gravitational theory. Finally the electromagnetic theory was developed by James Clerk Maxwell that described the action of electric current and magnetic field. Practical devices as the dynamo or electric motor came from this theory.

Peter Zeeman made measurement of magnetic field at a distance by observing the splitting of line emission in a magnetic field. Very soon after the Zeeman Effect was postulated the first measurements of magnetic fields were made by Hale in the Sun in 1908. The discovery of cosmic radio waves by Karl Jansky in 1932 added another method of measuring magnetic fields the cosmic radio waves were due to a non-thermal emission process the action of relativistic particles in magnetic fields. Since this synchrotron emission is polarized the study of the polarization of the cosmic radio waves allows the determination of magnetic fields.

I have become involved in studies of polarization of Galactic radio waves during my PhD studies in Cambridge 1960-1963. The first radio detections of magnetic field in a cosmic object, the Crab nebula, were made in 1957. In the summer of 1962 the first unambiguous detection of the polarization of Galactic radio waves and hence of magnetic fields in the Milky Way were added. The whole year 1962 may be termed a magnetic year. Polarization was detected in radio galaxies, and in supernova remnants. In 1968 pulsars were discovered and showed unusual polarization properties. The elusive radio Zeeman Effect was finally detected in 1968 using the HI line emission in selected Galactic regions. The studies of magnetic fields have started in 1962 and go on to the present day. The 100m radio telescope in Effelsberg played a significant role in this research field.

Ludwig-Biermann Award Talk

The Physics Driving the Molecular Cloud Lifecycle during Galaxy Formation and Evolution

J. M. Diederik Kruijssen

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The cloud-scale physics of star formation and feedback represent the main uncertainty in galaxy formation and evolution studies. In recent years, it has become clear that the 'star formation relation' between the gas mass (surface density) and the star formation rate (surface density) depends strongly on the spatial scale. We have shown that this multi-scale nature of the star formation relation is a direct probe of the cloud-scale physics of star formation and feedback. By quantifying the details of this scale dependence, we can directly measure fundamental quantities such as molecular cloud lifetimes, star formation efficiencies, feedback timescales, feedback outflow velocities, feedback coupling efficiencies, and coherence length scales. While these quantities were previously only accessible in the Local Group, it is now possible to measure them across a representative part of the galaxy population, from the nearby Universe out to high redshift ($z > 2$). I will present the first results of the systematic application of this method, showing that the molecular cloud lifecycle exhibits a strong dependence on the galactic environment. Understanding this environmental dependence provides a promising avenue for constraining the physics of star formation and feedback during galaxy formation and evolution.

PhD Prize Talk

Large eddy simulations of compressible magnetohydrodynamic turbulence

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Compressible magnetohydrodynamic (MHD) turbulence is thought to play an important role in many astrophysical processes. In absence of detailed three-dimensional observations, simulations can partially fill the observational gap in order to help to understand these processes. Unfortunately direct simulations with realistic parameters are often not feasible. Consequently, large eddy simulations (LES) have emerged as a viable alternative. In LES the overall complexity is reduced by simulating only large and intermediate scales directly. The smallest scales, usually referred to as subgrid-scales (SGS), are introduced to the simulation by means of an SGS model.

In this talk, I will present a new nonlinear MHD SGS model that explicitly takes compressibility effects into account. The model includes closures for all SGS terms in MHD: the turbulent Reynolds and Maxwell stresses, and the turbulent electromotive force (EMF). The model is systematically validated both in *a priori* and *a posteriori* tests, and compared to traditional models such as eddy-viscosity and scale-similarity type models.

In the *a priori* tests, we use high-resolution reference data of stationary, homogeneous, isotropic MHD turbulence ranging from the subsonic (Ms = 0.2) the supersonic (Ms = 20) regime. We compare exact SGS quantities against predictions by the closures. We find that the new nonlinear model outperforms the traditional ones in all tests conducted including the representation of the energy flux along the turbulent cascade.

In the *a posteriori* tests, we perform LES of decaying, supersonic MHD turbulence with all models and evaluate their performance in comparison to simulations without a model (and at higher resolution). We find that the models need to be calculated on a scale larger than the grid scale, e.g. by an explicit filter, to have an influence on the dynamics at all. Furthermore, we show that only the proposed nonlinear closure improves higher-order statistics such as distributions of vorticity and current density, or structure functions.

Instrumentation Prize Talk

"Es gibt nicht Gutes, ausser man tut es" - Reflections on progress in astronomical Instrumentation

A. Poglitsch[1]

[1] *Max-Planck-Institut für extraterrestrische Physik, Garching*

Progress in observational astronomy is critically depending on progress in instrumentation and observing techniques. I will share some thoughts (and questions) on how the community could create/maintain conditions which facilitate such developments.

Review

The HETDEX Dark Energy Experiment

K. Gebhardt

University of Texas, Austin, United States

No abstract available.

Highlight

Accretion outbursts from high-mass young stellar objects

B. Stecklum[1], A. Caratti o Garatti[2], R. Garcia Lopez[2], J. Eislöffel[1],T. P. Ray[2], A. Sanna[3], R. Cesaroni[4], C. M. Walmsley†[2,4], R. D. Oudmaijer[5], W. J. de Wit[6], L. Moscadelli[4], J. Greiner[7], A. Krabbe[8], C. Fischer[8], R. Klein[9] and J. M. Ibañez[10]

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The question whether high-mass stars form like their low-mass siblings has been debated for quite some time. Two pathways are considered to produce such stars - disk-mediated accretion and (proto-)stellar mergers. During recent years evidence for circumstellar disks around high-mass young stellar objects (HMYSOs) mounted. Since disk instabilities of low-/intermediate-mass YSOs cause episodic accretion outbursts, similar events are expected for HMYSOs too. In 2015 we discovered the first burst of this kind from S255IR-NIRS3, a $\sim 20 M_\odot$ HMYSO, which was signaled by flaring of its Class II 6.7 GHz masers. Incidentally, another burst of a HMYSO was detected by submm/mm observations at about the same time. We will summarize the observational findings of these discoveries and their implications for our understanding of massive star formation, the physics and evolution of circumstellar disks as well as the connection between accretion and ejection of matter.

Highlight

SOFIA in the Era of JWST and ALMA

Harold W. Yorke

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The Stratospheric Observatory For Infrared Astronomy (SOFIA) combines a Hubble-sized telescope with a modified 747SP aircraft. At an altitude of up to 45,000 feet, SOFIA can observe astrophysical phenomena above over 99% of the atmosphere's water vapor. This feature allows access to frequency ranges in the Terahertz regime and mid-infrared wavelengths inaccessible from the ground. The fact that SOFIA generally returns to its home base after every flight allows upgrades and repairs to its instrumentation not possible for space missions. As SOFIA has evolved from a development project into a fully functional observatory, important advances have been made in several areas of topical astrophysical and solar system research: star formation, stellar evolution, astrochemistry, the structure and evolution of the interstellar medium in our Galaxy and external galaxies, astrophysical processes near supermassive black holes, planetary atmospheres, and moons and small bodies in the solar system science. In this talk, rather than giving a general overview of what SOFIA has accomplished in these fields, I will focus on the role and importance of SOFIA in providing unique contributions for understanding these phenomena. Particular emphasis will be placed on current and future capabilities in high resolution spectroscopy in the wavelength range 28 – 320 micron (0.95 – 10.7 THz), thus bridging the gap between JWST and ALMA.

Review

Solar magnetoconvection observed with GREGOR

Rolf Schlichenmaier

Kiepenheuer Institut für Sonnenphysik, Freiburg

The Sun provides a unique laboratory to study cosmic magnetic fields. With an aperture of 1.5 m, the new solar telescope GREGOR operating in Tenerife is the largest of its kind in Europe. It provides an unprecedented combination of spatial and spectral resolution, and polarimetric sensitivity to investigate the small-scale magnetic fields on the Sun in the photosphere and chromosphere. The nature of the solar atmosphere is governed by energy transport in form of convection and radiation and their coupling with magnetic fields. GREGOR enhances our understanding of the various mechanisms of magneto-convective energy transport which determine a wealth of structures in sunspots, in active regions, and in the surrounding granulation. We will report on a range of topics, including magnetic reconnection in a flare, sunspot magnetic fields in the photosphere and chromosphere, material flows in active regions, and weak magnetism of the very quiet Sun. Imaging data provide details of the solar photosphere at a scale of 60 km on the Sun (0.08 arcsec angular resolution). GREGOR has resolved details smaller than 100 km in sunspot light bridges, which has advanced our understanding of magneto-convection. The excellent magnetic sensitivity in the IR enables the measurement of field strengths down to a few Gauss, unraveling for the first time that even the most quiet areas on the Sun are largely covered with magnetic field.

Highlight

Classical pulsators as population tracers: a journey to the far side of the Milky Way

I. Dékány[1], G. Hajdu[1,2], E. K. Grebel[1], S. Eyheramendy[2], F. Elorrieta[2], M. Hanke[1], A. Jordán[2], M. Catelan[2]

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Half of our Milky Way galaxy is located in a narrow stripe of the sky along the Galactic Equator, disguised by interstellar dust, which has been hindering efforts to map the far side of the Galaxy with stellar tracers, until now. Deep, time-resolved photometric surveys now enable us to probe these regions using distant pulsating stars.

We have been leveraging near-infrared time-series photometry from the VISTA Variables in the Vía Láctea (VVV) Survey to conduct a deep census of Southern Galactic Cepheids and RR Lyrae stars, accurate standard candles and well-understood population tracers. These valuable beacons enable us to probe the youngest and the oldest stellar populations in the bulge and at the far side of the Galactic disk, toward high-extinction regions which are out of the reach of all other ongoing and future surveys. By complementing the photometry of these objects with kinematical and elemental abundance measurements, we will be in the position to probe the structural and chemo-dynamical properties of the Milky Way over its complete extension, and infer global properties of the Galaxy such as general symmetry, spiral arm configuration, bulk kinematics, and metallicity distribution.

In my talk, I will present the current status of this collaborative project, and discuss our efforts to tackle the challenges of infrared light-curve classification and distance analysis with a space-varying extinction curve. I will summarize new results based on the deep census of RR Lyrae stars and both classical and type II Cepheids in the 4th Galactic quadrant and toward the inner bulge. I will highlight new insights into the spatial and metallicity distribution of the primordial Galactic bulge and disk populations, the mapping of the space-varying extinction curve toward the inner Galaxy, and probing into distant regions of the thin disk. Finally, I will outline future prospects with the upcoming VVV Extended Survey and the important role of synergies with the OGLE, GLIMPSE, and Gaia surveys.

Highlight

A MUSE view on Galactic globular clusters

S. Kamann[1]

[1]*Liverpool John Moores University, Astrophysics Research Institute, United Kingdom*

The study of the dynamics of Galactic globular clusters has always been limited by the relatively low number of stars accessible to velocity measurements. Yet we might just be witnessing the disappearance of this limitation. The combination of precise proper motion measurements and integral-field spectroscopy promises to provide a three-dimensional view of the central dynamics. Meanwhile the outer regions of the clusters can nowadays be thoroughly studied with multi-object spectrographs. These data will give us important insights into some of the open questions in globular cluster research. Do intermediate-mass black holes exist in their centres? Do different populations have different kinematics? How do binary stars influence the cluster evolution?

In my talk, I want to give an overview of our current view of the dynamics of globular clusters and introduce our campaign to learn more about them using the MUSE integral field spectrograph. It allows us to obtain samples of several thousands of stars per cluster and study the cluster kinematics in great detail. Our survey currently includes 25 clusters and I will present the results we obtained on their central dispersion and rotation fields. In addition, for many of the clusters multi-epoch data are already available, opening up the possibility to study binary stars.

Review

A Panchromatic Comparative View of Exoplanet Atmospheres

D. K. Sing[1], & the Hubble PanCET collaboration

[1] *University of Exeter, United Kingdom*

Hubble has played the definitive role in the characterisation of exoplanets and from the first planets available, we have learned that their atmospheres are incredibly diverse. With HST and JWST, a new era of atmospheric studies is opening up, where wide scale comparative planetology is now possible which can provide insight into the underlying physical process through comparative studies. Hubble's full spectroscopic capabilities are now being used to produce the first large-scale, simultaneous UVOIR comparative study of exoplanets with 20 planets ranging from super-Earth to Neptune and Jupiter sized planets. With full UV to infrared wavelength coverage, an entire planet's atmosphere can be probed simultaneously and with sufficient numbers of planets, it will be possible to statistically compare their features with physical parameters. The panchromatic treasury program aims at build a lasting HST legacy, providing the UV and blue-optical exoplanet spectra which will be unavailable to JWST, providing key insights into clouds and mass loss. I will present the latest findings from the ongoing Hubble Treasury program, revisit longstanding and controversial issues with new data, and discuss how JWST will transform the field of exoplanet characterisation.

Highlight

CCAT-prime: A fast Sub-millimeter Telescope for Large-area Surveys

Frank Bertoldi[1]

[1] *Argelander-Institut für Astronomie, Universität Bonn*

CCAT-prime is a 6-meter aperture sub-millimeter telescope being constructed on a 5600 meter high and dry site near ALMA by 2021. Its novel optical design delivers a high-throughput and wide-field of view that enables rapid spectral line and multi-wavelength continuum surveys to (i) map local star-forming regions and galaxies in [CI] and mid-J CO, (ii) study the cosmic evolution of dusty star-forming galaxies and resolve the fainter objects responsible for most of the FIR background, (iii) trace the first population of star-forming galaxies through intensity mapping of their [CII] emission, and (iv) put new constraints on cosmology from galaxy cluster Sunyaev-Zel'dovich effect observations. Our German-U.S.-Canadian collaboration welcomes input for the survey designs and on synergies with upcoming missions at other wavelengths, such as eROSITA and Euclid.

Highlight

The hot interstellar medium

M. Sasaki[1]

[1] *Dr. Karl Remeis-Sternwarte, Erlangen Centre for Astroparticle Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg*

The interstellar medium is heated and ionized by radiation, by stellar winds, and finally, by supernova explosions of massive stars. These processes are often correlated in space and time, generating superbubbles filled with hot thin plasma with sizes of typically $100 - 1000$ pc. Supernova remnants and superbubbles can be studied best in soft X-ray line and continuum emission, since the plasma in their interiors is very hot ($10^6 - 10^7$ K), while there are also a few cases in which the emission from non-thermal particles dominates that of the thermal gas. I will present recent results of our studies of the hot interstellar medium in the Milky Way and nearby galaxies. I will discuss the physics of the hot plasma, the evolution and energetics of supernova remnants and superbubbles, and their impact on star formation.

Review

Magnetic stars and their elusive planets

S.V.Jeffers[1]

[1] *Georg-August-Universität Göttingen, Institut für Astrophysik*

Exoplanet research is currently driven by the detection of smaller planets, with emphasis on rocky planets in the habitable zones of their host stars. In this review I will describe how we are pushing the planet detection limits by understanding the planetary host star, and by developing the next generation of planet hunting instrumentation. At the high precision required to detect such planets, it is necessary to also understand the host star as commonly observed stellar features can both mask the presence of a planet or indeed lead to a false detection. The next generation of planet hunting instruments will also push this further by building on what we have learnt over the last 22 years since the first exoplanet was confirmed.

Highlight

Probing the Ionised ISM with LOFAR Pulsar Observations

J.P.W. Verbiest[1,2]

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The free electrons in the ionised component of the interstellar medium interact with radio waves in many, frequency-dependent, ways. The advent of highly sensitive low-frequency radio telescopes like LOFAR (the LOw-Frequency ARray), in Germany operated by the German LOng-Wavelength (GLOW) consortium, allow unprecedentedly precise measurements of this plethora of effects, probing the ionised gas in the ISM across a wide range of scales: from the smallest density variations causing diffractive scintillation to the large-scale clouds probed by dispersion in decade-long pulsar-timing campaigns.

In this talk, we provide an overview of the capabilities of LOFAR to study the ionised ISM and discuss in some detail the various pitfalls that plague this new window on the ISM. We also briefly highlight the relevance of these studies for so-called pulsar-timing array projects aiming to detect gravitational waves from a cosmological population of supermassive black-hole binaries.

Highlight

First Science Results of the GRAVITY interferometer

O. Pfuhl[1], F. Eisenhauer[1], G. Perrin[2], K. Perraut[3], C. Straubmeier[4], W.Brandner[5], A. Amorim[6], and the GRAVITY collaboration

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GRAVITY is a recently deployed instrument, which coherently combines the light of the European Southern Observatory (ESO) Very Large Telescope Interferometer. The instrument exploits the tremendous 130 m resolving power and 200 m^2 collective area of the VLTI. GRAVITY uses a novel design of fiber-fed integrated optics beam combination, high resolution spectroscopy, phase- tracking, laser metrology and dual-beam operation. GRAVITY opens the techniques of phase-referenced imaging and narrow-angle astrometry to optical interferometry.
We present some key science results, which have been obtained during the first year of operation. This includes milli-arcsec scale imaging of the Galactic Center supermassive black hole and its fast orbiting star S2; few μas differential spectro-astrometry of the high mass X-ray binary BP Cru and the active galactic nucleus of PDS 456; high accuracy visibility observations and imaging of the resolved stars ξ Tel and 24 Cap.
GRAVITY has shifted the limits of optical interferometry in terms of sensitivity and accuracy by orders of magnitude. During the commissioning we demonstrated real-time phase stabilisation on stars as faint as $m_K \approx 10$ mag, phase-referenced interferometry of objects as faint as $m_K \approx 18$ mag, visibility accuracies better than 0.25% and a spectro-astrometric precision of better than ten micro-arcseconds (μas). The experimental dual-beam astrometry mode shows residuals as low as 50 μas when following objects over several months. The demonstrated performance represents a game-changer in optical interferometry, which leads to exciting new science prospects.

Public Talk

Wundervolles mysteriöses Universum - eine (Zeit-)Reise

M. Kramer

Max-Planck-Institut für Radioastronomie, Bonn

Das Universum ist 13,8 Milliarden Jahr alt. Egal mit welchen Teleskopen wir es beobachten, es ist wunderschön und faszinierend. Obwohl wir gerade in den letzten 100 Jahren viel von dessen Eigenschaften und Entwicklung gelernt haben, bleibt das Universum weiterhin mysteriös und birgt noch viele Geheimnisse. Warum sieht es so aus, wie wir es beobachten, und warum gerade jetzt? Was sind Dunkle Materie und Dunkle Energie? Gibt es Leben außerhalb der Erdeu und ist es intelligent? Hatte Einstein mit seiner allgemeinen Relativitätstheorie recht, oder gibt es Bausteine im Weltbild der Fundamentalphysik, die wir noch nicht verstehen oder gar kennen? Mit mehr Verständnis kommen auch mehr Fragen, die aber um so faszinierender sind. Trotz – oder gerade wegen – immer neueren und besseren Instrumenten entdecken wir neue Phänomene und Details. Der Vortrag versucht(!), die großen unbeantworteten Fragen der Astrophysik zu beschreiben und in Verbindung zu setzen.

Review

Cosmic reionization and 21cm observations

B. Ciardi[1]

[1] *Max-Planck-Institut für Astrophysik, Garching*

The reionization of the intergalactic medium represents a major phase transition undergone by our Universe. In this talk I will discuss our theoretical understanding of the process, together with current observational constraints and the progress expected with measurements of the 21cm line from high redshift neutral hydrogen with instruments like LOFAR and SKA.

Highlight

The systematic search for gravitational wave sources using synoptic surveys

T. Kupfer[1] on behalf of the PTF/ZTF collaboration

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Ultracompact binaries (UCB) are a rare class of binary systems with periods below 60 min (detached or semidetached), consisting of a neutron star (NS)/white dwarf (WD) primary and a He-star/WD/NS secondary. The study of ultracompact binaries and their subsequent mergers are important to our understanding of such diverse areas as supernova Ia progenitors, production of r-process elements, binary evolution and they are predicted to be the strong gravitational wave sources in the eLISA and LIGO-Virgo band.

The Zwicky Transient Facility is the next generation of optical synoptic surveys utilizing the entire focal plane of 47 deg^2 of the 1.2m telescope on Mount Palomar. The field-of-view allows us to cover the entire visible sky in one night revisiting fields on timescales of a few hours and providing hundreds of visits per field each year. Part of the survey will be a public 3-4 night cadence all sky survey as well as a nightly sweep of the Galactic Plane. Science operations is expected to start by the end of 2017.

In this talk I will give an overview of the survey design and our effort to identify the optical counterpart to NS mergers triggered by LIGO. I am lead investigator of an approved high-cadence survey covering the full inner Plane visible from the northern hemisphere as part of ZTF. We will obtain 2-3 hr continuous lightcurves of each field with a cadence of 40 sec starting winter 2017 to identify the Galactic population of ultracompact binaries. I will give an overview of the survey as well as discuss the expected numbers of ultracompact eLISA sources from this survey.

Highlight

IllustrisTNG: the new frontier to understand the co-evolution of dark-matter and galaxies with cosmological simulations of structure formation

A. Pillepich[1] and the IllustrisTNG team[2]

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[2] *www.tng-project.org*

I will describe the numerical efforts to simulate galaxies with the code AREPO across an unprecedented range of halo masses, environments, evolutionary stages and cosmic times. In particular, I will focus on the IllustrisTNG project (www.tng-project.org), a collaboration among Heidelberg, Munich, New York and Boston. There we are aiming to simulate a series of three gravity+magnetohydrodynamics cosmological volumes (50, 100, 300 Mpc a side, respectively) capable of both resolving the inner structures of galaxies as small as the classical dwarfs of the Milky Way, as well as of sampling the large scale structure of the Universe with thousands among groups and clusters of galaxies. I will briefly review what is explicitly and empirically solved in gravity+magnetohydrodynamics simulations for galaxy formation in a cosmological context and what is required and what it means to "successfully" reproduce populations of galaxies which resemble the real ones. I will therefore show preliminary results from the IllustrisTNG simulations, by focusing on the assembly of the most massive structures in the Universe, the build up and characterisation of the faint stellar envelopes around galaxies, the connections of the latter to their host DM haloes, and our theoretical expectations for the distribution of dark matter (DM) and stars on large scales and within galaxies.

Review

Realistic MHD simulations of the solar atmosphere

M. Rempel[1]

[1] *High Altitude Observatory, National Center for Atmospheric Research, United States*

Realistic simulations of the solar photosphere date back almost three decades. While the physical ingredients in terms of compressible MHD, a realistic equation of state and 3D radiative transfer have remained mostly unchanged, tremendous progress since then can be mostly attributed to an about millionfold increase of computing power in combination with improvements in code efficiency and robustness. Today about a handful of mostly independent codes are in use in the solar physics community and high resolution simulations have contributed significantly to almost all aspects of photospheric magnetoconvection. In this talk I will give a brief overview of recent developments and focus in particular on: (1) Small-scale dynamo simulations that provide an explanation of quiet sun magnetism, (2) Magneto-convective sunspot models that give a consistent picture of sunspot fine structure from umbral dots to penumbral filaments and light bridges, and (3) Models of flux emergence on scales of active regions that demonstrate the amplification of emerging flux to pores and sunspots including structures such as complex light bridges and penumbrae.

Highlight

Modeller's view to solar and stellar dynamos: perspectives and challenges

M. J. Käpylä[1]

[1] *Max-Planck-Institut für Sonnensystemforschung, Göttingen*

Thanks to the steadily increasing computational resources, global convection simulations of stars of various types are becoming abundant. Even though these models still are - and will to some extent always be - only toy models of the real objects, they provide us very useful information, if properly exploited. The challenge is to be able to meaningfully analyse the massive data and develop tools with which one is able to establish which physical effect is responsible for a certain phenomenon emerging in the models - also those arising from turbulent effects, posing the greatest challenges.

Highlights of recent modelling efforts include the emergence of solar-like dynamo solutions without a tachoclinic shear layer, dynamo solutions with multiple cycles of different lengths and spatial distributions, models that spontaneously generate irregular behavior and grand-minima type epochs, and the established transition from axisymmetric to non-axisymmetric modes as the rotation rate is increased. In this talk, these novel findings are reviewed, and their implications for observations are discussed.

Highlight

Tracking Jupiter with a Trapezoid: Geometrical Methods in Ancient Babylonian Astronomy

M. Ossendrijver[1,2]

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On four Babylonian clay tablets written between 350 and 50 BCE, the distance travelled by Jupiter along the ecliptic is computed as the area of a figure in time-velocity space (2016, Science 351, 482–484). This figure, which has the form of a trapezoid, describes Jupiter's changing velocity for an interval of 60 days, while its area yields the total distance covered during that time. On these tablets the moment when Jupiter has covered half the total distance is also computed geometrically by partitioning the trapezoid into two smaller ones of equal area. These findings challenge the widely accepted view that Babylonian astronomers only used arithmetical methods, unlike their ancient Greek colleagues. However, the geometrical approach to motion attested in the Babylonian tablets is unknown from ancient Greek astronomy and was previously thought to have been invented by European scholars in the 14th century AD.

Poster General

After 64 years dedicated to astrometric instrumentation, a Gaia successor is in sight

Erik Høg

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The astrometric foundation of astrophysics has been enormously improved by two ESA satellites that determined the positions, distances and motions of stars. I was fortunate to be at the right place and right time so that I could contribute towards various developments after beginning work as a student in 1953 at a new Danish meridian circle. These include the designs of: a new method of astrometry by photon counting for the Hamburg meridian circle in 1960; a new design for the Hipparcos mission in 1975; the Tycho experiment for the Hipparcos satellite in 1981; direct-imaging on CCDs for the Gaia mission in 1992; and most recently, a Gaia successor in 2013 that should be launched in about twenty years. In April 2017 ESA approved our proposal (Hobbs et al. 2016, arXiv 1609.07325) to study a Gaia successor with infrared detecting capabilities. That proposal was one of three selected out of 26 submitted in response to ESA's call for new "Science Ideas" to be investigated for feasibility and technological developments.

Poster General

FIFI-LS Observations of Galactic PDRs

R. Klein[1], S. Colditz[2], D. Fadda[1], C. Fischer[2], N. Geis[3], R. Hönle[4], C. Iserlohe[4], A. Krabbe[4], L. Looney[5], A. Poglitsch[3], W. Raab[6], F. Rebell[4], W. Vacca[1]

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Photo-dissociation regions or photon-dominated regions (PDRs) are the interfaces between ionized HII-regions and adjacent molecular clouds usually found in massive star-forming regions. As the places where molecular clouds are destroyed by the UV radiation of the forming massive stars, they are the regions where the effects of star formation on the interstellar medium and the energetics and physical properties of the feedback can be best studied.

FIFI-LS, SOFIA's far-infrared (FIR) spectrometer, is well suited to observe galactic PDRs and study them in great detail. The bulk of the energy from PDRs is emitted in the wavelength range of *FIFI-LS*, which ranges from 50 to 200 μm. In this wavelength range, there are many strong atomic and ionic fine-structure lines, which can serve as diagnostic tools to trace these species and to determine densities and temperatures of the ionized and neutral medium in PDRs. *FIFI-LS's* ability to map large bright regions quickly and in two transitions simultaneously allows researchers to analyse the varying conditions in star-forming regions comprehensively.

We will show first results of *FIFI-LS* observations of M42 and M17. M42 with the Orion Bar, a well-known PDR seen edge-on was one of the very first objects observed with *FIFI-LS*. Subsequently, we have observed M42 in a growing number of transitions. We also have observed the PDR in M17 in several transitions. The PDRs are clearly identified by the complementary spatial extent of the ionized and neutral species. From the ratios of the [OI] (63 and 146μm) and [OIII] (52 and 88μm) line pairs, the [CII] (158μm) line and combinations thereof, physical conditions in the different phases and the transition regions can be derived. We are presenting preliminary results. Rigorous modeling of the observed PDRs will follow.

Poster General

Infrared Observations with SOFIA

R. Klein[1] and the SOFIA team

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The infrared is a crucial wavelength range to study any astrophysical object with a temperature between a few 100K and a few Kelvin. At these temperature, which are typical for the cold and warm interstellar medium (ISM), the spectral energy distribution (SED) peaks in the infrared. For example, the absolute maximum of an SED of a star-forming galaxy is located in the infrared as the bulk of the star light is absorbed by the ISM and reemitted in the infrared. Fine-structure lines from atoms and ions are prominent cooling lines of the ISM and can be used as diagnostic tool for various phases of the ISM. Another example for targets in the right temperature range are planetary atmospheres or surfaces of minor bodies.

SOFIA, the Stratospheric Observatory for Infrared Astronomy, is the only facility providing community access to the this curial part of the spectrum currently and for the foreseeable future. Infrared observations are possible from 5μm up to 240μm with suite of five instruments. The instrument offer imaging and spectroscopy over the whole wavelength range.

This poster presents a short summary of the capabilities and instruments of SOFIA together examples of how they have been employed. The science highlights range from extra-galactic star formation, the galatic center and galactic star formation over to planetary science.

Poster General

Digging deeper: The first catalogue of X-ray detections from stacked XMM-Newton observations

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From all publicly available observations of Europe's X-ray space telescopes XMM-Newton since 1999, the XMM-Newton Survey Science Centre Consortium has been generating catalogues of individual detections and published the most recent incarnation 3XMM-DR7 June 1st. The AIP contributes and maintains the source-detection software used to process them. About a third of the XMM-Newton sky was observed more than once. In order to achieve ultimate sensitivity in these sky regions, we have now developed a new standardized approach to source detection on images of multiple pointings, making use of maximum likelihood fitting like the 3XMM catalogues and introducing a new algorithm to model the background emission. The full procedure is open to all users as a new task of the XMM-Newton Science Analysis System software. Currently, we are compiling the first catalogue of stacked detections. It is based on about 2000 observations with reasonably low background level which overlap by 20 % or more in area and are grouped in more than 400 stacks. We are detecting at least 5 % more sources than in the individual pointings. Our new catalogue provides enhanced parameters of the abundant faint objects and gives information about long-term variability for the first time directly from source detection.

Contributed Talk

Splinter Activity

Dynamo mechanism for magnetic activity and cycles of stars

J. Warnecke[1]

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The magnetic field in the Sun undergoes a cyclic modulation with a reversal typically every 11 years due to a dynamo operating under the surface. Observations of other stars have revealed magnetic activity being present at a large variety. I will start by presenting some theoretical background about what determine the cycle period in dynamos. Furthermore, I will present result from simulation of rapidly rotating solar-type stars, where the interplay between convection and rotation self-consistently drives a large-scale magnetic field. With the help of the test-field method, we are able to measure the turbulent transport coefficients in these simulations and therefore get insights about the dynamo mechanism operating in these simulations. It will allow us to derive a scaling of the cycle period with the relevant effects of the dynamo. Furthermore, I will discuss how magnetic helicity is a key quantity connecting the stellar convection zone with the stellar surface and the stellar coronae. Magnetic helicity is produced in the convection zone of stars via a dynamo in the present of convection and rotation. At the surface, it plays an important role in the formation process of active regions. In the corona, it is believed to be essential for the release of energy leading to the eruption of plasma via coronal mass ejection and it might play an important role in the heating process of the coronal plasma. Using numerical simulations of stellar convection zones and the solar corona allow us to investigate this process. I will present some preliminary results linking the magnetic helicity below the surface to the heating process in the corona. This connection is crucial for understanding the rotation-activity relation of stars.

Contributed Talk

Splinter Activity

Axi- to non-axisymmetric dynamo transition in stellar models with varying rotation rate

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Rotation is one key parameter that influences stellar magnetic activity and there is growing evidence that it also plays a role in the transition from solar-like axisymmetric dynamo modes to non-axisymmetric modes on more rapidly rotating stars. In order to study this transition, we perform a set of simulations, using semi-global magneto-convection models in which rotation is systematically varied.

To estimate the dynamo efficiency at increasing rotation, we compare the magnetic energy to the kinetic energy and we found that the ratio magnetic-to-kinetic energy increases with rotation. We decompose the magnetic field in spherical harmonics and calculate the energy contained in the large-scale field and in the small-scale fluctuations. We found that at high rotation, the first non-axisymmetric mode is excited, leading to several evidence for an azimuthal dynamo wave.

Contributed Talk

Splinter Activity

Search for physical mechanisms underlying solar and stellar activity variations

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Following half a century of detailed monitoring of solar and stellar activity, we do not have predictive physical models for the wide variety of their manifestations. We review attempts to model magnetic activity variations in the Sun and other G- and K-type stars, in particular on how stellar dynamos could change with the rotation rate and on the surface distribution of magnetic regions. We show how effects of differential rotation and the emergence patterns of starspots can substantially drive the modulation of radiative flux in rotational and cycle time scales. We discuss possible mechanisms responsible for the nonlinear saturation of solar and stellar activity cycles. Finally, we give an account of the unsolved problems in the field, followed by an outlook on further modelling attempts.

Contributed Talk

Splinter Activity

Strong surface magnetic field on a brown dwarf

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Radio surveys by Berger (2002, 2006) and McLean et al. (2012) revealed a large number of brown dwarfs with radio emission. The origin of the radio emission is most likely the electron acceleration in the global magnetosphere of the dwarf. Depending on the acceleration mechanism, gyrosynchrotron or electron-cyclotron maser instability, the strength of the global magnetic field can be as large as ~ 10 G or ~ 1 kG (Berger et al. 2008 or Hallinan et al. 2008, respectively). Although this is a rather rough and assumption-dependent estimate, until recently there were no other means for studying the substellar magnetism.

We present the first detection of a strong magnetic field of a brown dwarf, which is independent of the radio estimates (Kuzmychov et al. 2017; Berdyugina et al. 2017). We introduce our spectropolarimetric technique, which makes use of the Zeeman and the Paschen-Back effects in atomic and molecular lines (Berdyugina et al. 2003; Kuzmychov & Berdyugina 2013; Berdyugina et al. 2017). We discuss a possible magnetic field topology for the M8.5 dwarf LSR J1835, which we can reconstruct with the help of our technique and the radio observations found in the literature.

This study demonstrates that the magnetism of brown dwarfs can be successfully studied with the help of spectropolarimetry. It also paves the path for probing the magnetospheres of hot Jupiters with the effective temperatures of L- and T-type dwarfs.

This work is based on the full-Stokes data obtained with the Low-Resolution Imaging Spectropolarimeter (LRISp) at the Keck observatory on August 22nd and 23rd, 2012.

Contributed Talk

Splinter Activity

Spectral variability of photospheric radiation due to small-scale magnetic features

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Stellar spectral variability on timescales of a day and longer arise from magnetic surface features such as dark spots and bright faculae. As such, facular contrasts are an important parameter in modelling stellar variability and exoplanet transits. Current 1D models of faculae do not capture the geometric properties and fail to reproduce observed solar facular contrasts. The ultimate goal of this work will be to model the contrasts of faculae using 3D magneto-convection simulations for different spectral types and thus improve the modelling of solar and stellar photospheric variability. This is done by using a radiative transfer algorithm (ATLAS9) on 3D simulated atmospheric snapshots (calculated with MURaM). We derive facular contrasts as a function of limb angle and activity level and discuss their wavelength dependence.

Contributed Talk

Splinter Activity

Effect of Metallicity on Stellar Brightness Variability

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Spaceborne measurements of the Sun have shown that its brightness varies on several time-scales, where variations on time-scales greater than a day are associated with the surface magnetic field. Independently, observations of Sun-like stars indicate a broader pattern of photometric variability for stars. Comparing stellar brightness variability of Sun-like stars with the same magnetic activity as the Sun showed that the solar variability on the magnetic activity cycle time-scale appeared to be anomalously low. One recently proposed explanation is based on the fact that solar brightness variability is caused by a delicate balance between dark and bright magnetic features. This balance is sensitive to the combination of stellar fundamental parameters, i.e. effective temperature, metallicity and surface gravity. So that stars with slightly different fundamental parameters can show significantly higher brightness variations. To check this hypothesis it is essential to study the effect of fundamental stellar parameters on stellar brightness variability. Using 1D models the effect of metallicity and effective temperature on stellar spectra and thus on brightness variations on the magnetic activity cycle time-scale is investigated. For that the contrast of bright and dark magnetic features is taking into account by exploiting the SATIRE model of solar brightness variability.

Contributed Talk

Splinter Activity

Connecting chromospheric emission to photospheric magnetic field

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Solar full-disc photographs in Ca II K line have been taken since 1892 at various observatories around the globe. Such images are considered as good tracers of the photospheric magnetic field due to the good spatial correspondence between the brightness excess in Ca II K images and strong magnetic fields found in magnetograms. Numerous studies found a power law relationship between the Ca II K brightness and the photospheric line-of-sight magnetic field strength. Still, there is no general agreement between the parameters derived in these studies, and even the existence of such a relationship has been debated. However, all previous studies were limited to rather few images, low quality observations, or isolated regions on the solar disc.

We reassess the relation between the photospheric line-of-sight magnetic field strength and the Ca II K excess brightness using high-quality full-disc and almost co-temporal SDO/HMI magnetograms and Rome/PSPT Ca II K observations covering half a solar cycle. We also test the derived relationship by employing it for a reconstruction of unsigned magnetograms from the Ca II K observations.

Contributed Talk

Splinter Activity

Measurements of Total Solar Irradiance on FengYun3 Satellites, from 2008 to 2017

Hongrui Wang[1], Wolfgang Finsterle[1]

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Impact of solar variability on the Earths climate change has been a controversial topic for about two centuries. The inherent solar driving mechanism cant be understood completely without accurate data sets of solar irradiance (SI). Total solar irradiance (TSI) has been measured by FengYun3 (FY-3) Satellites since FY-3A was launched in May 2008 as the first satellite of the series. The TSI instruments on FY-3A and FY-3B operated in a scanning mode and the Sun is only measured when the sunlight is in FOV of the instrument. FY-3C satellite was launched in September 2013 as the third satellite and it has carried a TSI instrument with a pointing system.

Year 2013 has witnessed several historical events in space measurements of TSI. Configuration for TSI space instruments has changed 4 times from July to December in 2013. FY-3C TSI data from Oct. 2013 to Dec. 2013 is important for composite of TSI data series, since it seems the most accurate data set without too much detector degradation. In my previous work (Hongrui Wang and etc. Initial In-flight Results: The Total Solar Irradiance Monitor on the FY-3C Satellite, an Instrument with a Pointing System. Solar Physics, 2017, 292:9), correction of detector degradation was not performed yet. The correction method of detector degradation for Level 1 product of FY-3C TSI data will be presented here.

In the coming years, several missions of SI measurements have been planned on FY-3 satellites. One TSI space mission will fly on the FY-3E satellite and Physikalisch-Meteorologisches Observatorium Davos will contribute one radiometer package for the TSI radiometer on the FY-3E satellite. Measurements of TSI on the FY-3 satellites will be presented here, including instrument overview, current progresses of data corrections and composite of multi TSI data series.

Contributed Talk

Splinter Activity

Solar Irradiance Reconstruction over Holocene: A Consistent Multi-proxy Reconstruction

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Knowledge of solar variability on different time scales is important for many research applications, from solar and stellar physics to palaeoclimatology. Direct observations of the solar irradiance and the sunspot number provide information on solar activity on time scales of decades and centuries, respectively. On longer time scales, however, one has to rely on indirect proxies, such as abundances of the cosmogenic isotopes, e.g. ^{10}Be and ^{14}C, in terrestrial archives. These isotopes are produced in the terrestrial atmosphere by cosmic rays, whose flux is modulated by solar activity. Therefore isotope data retrieved from various natural archives around the globe show a high degree of similarity. Nevertheless, significant short-term deviations can be observed due to other factors, e.g., the different geochemical paths in the atmosphere or local climatic conditions. We will present most recent solar total and spectral irradiance reconstruction over the Holocene based on a new consistent analysis of a composite multi-isotope proxy series covering the last 9000 years. The solar irradiance reconstruction reveals the global and robust pattern of solar variability in the past.

Contributed Talk

Splinter Activity

GPS: A novel method to obtain stellar rotational periods

Eliana M. Amazo-Gómez[1,2], Alexander Shapiro[1], Natalie Krivova[1], Sami K. Solanki[1,3], Timo Reinhold[1], Mahmoudreza Oshagh[2], Ansgar Reiners[2]

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High-quality photometric data acquired from planet searching missions as Kepler and COROT allow better insights into the variability and activity of stars. Analysing periodic patters in stellar light curves we can, within certain confidence, link the observed variability to transits of magnetic features over the stellar surface. This in turn, allows us to calculate stellar rotational periods from the analysis of the gradient of the power spectra (GPS) of stellar light curves. We simulate transits of magnetic features and calculate the GPS of the generated stellar brightness variations for the Sun-like stars. We show that the power spectra of brightness variations of stars with magnetic activity similar to that of the Sun and lower do not contain a prominent rotational harmonic. Nevertheless, the rotational periods of these stars can be reliably determined from the profile of the GPS. We apply this method to 1176 Sun-like stars to calculate their rotational periods and compare our results to the earlier works. The method gives results consistent with others but allows determining periods of less variable stars.

Contributed Talk

Splinter Activity

Evidence for photometric activity cycles in 3203 Kepler stars

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In recent years it has been claimed that the length of stellar activity cycles is determined by the stellar rotation rate. It is observed that the cycle period increases with rotation period along two distinct sequences, the so-called Active and Inactive sequences. In this picture the Sun occupies a solitary position in between the two sequences. Whether the Sun might undergo a transitional evolutionary stage is currently under debate. We present measurements of cyclic variations of the stellar light curve amplitude and the rotation period using four years of Kepler data. Periodic changes of the light curve amplitude or the stellar rotation period are associated with an underlying activity cycle. Using the McQuillan et al. 2014 sample we compute the rotation period and the variability amplitude for each individual Kepler quarter and search for periodic variations of both time series. To test for periodicity in each time series we consider Lomb-Scargle periodograms and use a selection based on a False Alarm Probability. We detect amplitude periodicities in 3203 stars with cycle periods between 0.5 and 6 years, covering rotation periods between 1 and 40 days. Our measurements reveal that the cycle period shows a weak dependence on rotation rate, slightly increasing for longer rotation periods. We further show that the shape of the variability deviates from a pure sine curve, consistent with observations of the solar cycle. Our measurements do not support the existence of distinct sequences in the rotation period - cycle period plane, although there is some evidence for the inactive sequence for rotation periods between 5 and 25 days. Unfortunately, the total observing time is too short to draw sound conclusions on activity cycles with similar length as the solar cycle.

Contributed Talk

Splinter Activity

X-ray emission and activity in late-type stars

S. Czesla[1]

[1] *Hamburer Sternwarte*

Although the photospheres of late-type stars – and in fact all main-sequence stars – are too cool to produce any significant X-ray emission, virtually all late-type stars within reach of current instrumentation are found to be X-ray sources. This is thought to be a consequence of ubiquitous magnetic activity. Produced in the stellar interior, magnetic fields reach beyond the photosphere, where they heat the chromospheres and coronae. Our understanding of activity remains incomplete, and many questions are being intensively researched, e.g.: How does activity and X-ray emission evolve during the course of the stellar lifetime; How common is cyclic behavior?; and what are the details of the heating mechanism? Studying activity is vital to better understand late-type stars and its impact on planets in the solar system and beyond.

Contributed Talk

Splinter Activity

The XUV Sun in Time

N.-E. Nemec[1,2], J. Fontenla[3], M. Güdel[2], T. Lüftinger[2], C. Johnstone[2]

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The evolution of the X-ray and extreme ultraviolet radiation (XUV) is important to understand the evolution of planetary atmospheres. The XUV output of solar-like stars varies with time, with a decay seen in all wavelength regimes. We put forward a new way of modeling the flux in the 36-92 nm wavelength regime. Due to interstellar extinction is it not possible to measure fluxes in this regime for stars other than our Sun. We use solar spectral features that are co-added according to filling factors derived from the S-index. This index is obtained from the strength of Ca II H&K lines min two prominent chromospheric lines. These lines are primarily formed in the chromosphere and trace, like H-alpha, plage. This feature can be seen as bright patches in the chromosphere and are correlated with the spots in the photosphere. We find that our integrated fluxes in the EUV are consistent with literature. We are able to study the effect of the variation in the S-index on the XUV spectra for our sample stars. Our approach has the advantage, that is in general possible to get the EUV spectra for any cool star with known S-index.

Contributed Talk

Splinter Activity

Scaling MHD models of solar active regions to more active stars

H. Peter[1]

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On the Sun we can observe magnetic activity to a detail that is not accessible for other stars. Thus models of active region coronae of a high degree of sophistication can be put to the test in the solar case. However, when considering the Sun alone we are always limited to the (low) magnetic activity found with our star. Therefore, extending these models to a range of stellar activity is a key step. This contribution will describe the basic ingredients required for an appropriate (solar) model, in particular which processes have to included, as well as the limitations for a self-consistent treatment. The main goal is to describe what information 3D MHD models for solar active regions can provide, and how these models might be scaled up to serve as a description of the corona of a more active star. Some preliminary results for how the heat input into a corona scales with the surface magnetic flux based on 3D MHD experiments will be presented.

Poster

Splinter Activity

Deep focusing in time-distance helioseismology

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Deep focusing in time-distance helioseismology aims to obtain high sensitivity to perturbations at a desired target point in the solar interior. We study the deep-focusing time-distance technique for travel-time and amplitude measurements using a toy model that considers acoustic waves propagating in a 3D homogeneous background medium. Three-dimensional spatial sensitivity kernels for sound-speed are derived under the first-order Born approximation. Averaged travel-time and amplitude measurements are compared. We find that selecting the pairs of points according to the ray theory leads to a maximum sensitivity shell surrounding the target location and zero at the target location for travel-time measurements which is inefficient. However, averaging amplitude measurements results in maximal sensitivity at the target point.

Considering the noise due to the stochastic excitation of solar oscillations, we compare the signal-to-noise ratio for both travel time and amplitude for different types of sound-speed perturbation. As expected from the shape of the kernels, the amplitude measurements have higher signal-to-noise ratios than the travel-time measurements for localized sound-speed perturbations. This preliminary study is promising for using amplitude measurements as a complement to travel time in time-distance helioseismology.

Poster

Splinter Activity

Solar near-surface flows from ring-diagram helioseismology

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There are many reasons to want to measure flows in the solar near-surface layers: to study convection, flows around active regions, differential rotation and meridional circulation, and even waves of vorticity (Rossby waves). Here we use a method of local helioseismology known as ring-diagram analysis applied to SDO/HMI observations to infer horizontal flows and their dependence on depth. We present a comparison of ring-diagram and granulation-tracking results, showing that the flows measured by the two methods are in good agreement both qualitatively and quantitatively.

Poster

Splinter Activity

Chromospheric Activity Indicators in Visible Light and Near Infrared

P. Schöfer[1], A. Reiners[1] and the IAG CARMENES team[1]

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Chromospheric activity imposes a challenge on high-precision radial velocity measurements and has therefore to be considered carefully by exoplanet hunters who are using the radial velocity method. CARMENES is searching for Earth-like planets around M dwarfs using two Échelle spectrographs which simultaneously cover wavelength ranges from 520 Å to 960 Å and 960 Å to 17100 Å. Using a spectral subtraction technique, we measure equivalent widths of several spectral lines that are sensitive to chromospheric activity in both the visible and the near infrared range.

The sample size of $\sim$ 300 M dwarfs and more than 7000 observations in total enables us to study correlations between the strengths of the different spectral lines for individual stars and across the M dwarf range, which we present on this poster.

Poster

Splinter Activity

A Possible Improvement on Helioseismic Holography

Dan Yang[1]

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Helioseismic holography is a powerful technique to probe the solar interior and its application of detecting active regions on the far-side of the Sun plays an important role in the space weather prediction. The basic principle of helioseismic holography is that the wavefield can be estimated by the back-propagation (in time) of the acoustic waves observed at the surface into any depth in the Sun. Porter-Bojarski holography, which is a well-established method used in acoustics to recover sources and scatterers in 3D, is also an estimation of the wavefield, and hence has the potential to be applied to helioseismology. Through a comparison of the two imaging techniques in a solar-like stratified background medium, I find that PB holography better resolves acoustic sources than helioseismic holography. In order to implement PB holography in the Sun, however, a method for determining the normal derivative of the wavefield needs to be developed.

Contributed Talk

Splinter AGN

Reverberation Mapping of the Most High Luminosity Quasars

S. Kaspi

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Over the past three decades reverberation mapping (RM) was applied to about 100 AGNs. Their broad line region (BLR) sizes were measured and yielded a mass measurement of the black holes in their center. However, very few attempts were carried out toward high-luminosity quasars, at luminosities higher than 10^{46} erg/sec in the optical. Most of these attempts failed since RM of such quasars is difficult due to a number of reasons, mostly due to the long time needed to monitor these objects. During the past two decades we carried out two RM campaign on two samples of high-luminosity quasars, one at the Hobby-Eberly Telescope in the USA and one at the Las Campanas Observatory in Chile. This contribution will present the results of these two RM campaigns in which we measured the BLR size of ~ 10 of the objects. The BLR size, mass, and luminosity relations will be presented over eight orders of magnitude in luminosity, pushing the luminosity limit to its highest point so far.

Contributed Talk

Splinter AGN

Variability timescales of QSOs from the Tautenburg long-term monitoring program

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The Tautenburg QSO long-term monitoring program provides optical B band lightcurves for about 300 QSOs in two Schmidt fields over more than five decades (observer frame). This is the longest time span available so far for a statistical investigation of the variability of a flux-limited ($B \leq 20$) QSO sample. We derived characteristic variability timescales from two different approaches, structure function analysis and damped random walk model. For both methods extensive simulations were performed for evaluating the results. We found longer mean timescales than derived previously from the multi-epoch data in the Sloan Digital Sky Survey Stripe 82, which cover about one decade. A small fraction of the QSO sample shows long-term trends over the whole time interval covered by our observations.

Contributed Talk

Splinter AGN

Optical Photometric Monitoring of Active Galactic Nuclei at Wise Observatory

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We have started an automatized photometric monitoring of active galactic nuclei using the 46 cm telescope of the Wise observatory in Israel. The telescope is specially equipped with narrowband filters to perform high-fidelity photometric reverberation mapping of the accretion disk and of the broad line region in V $<$ 17 mag sources and up to $z \sim 0.1$. Here, we describe the capability and accuracy of the experiment, and present the first science verification data obtained for the Seyfert 1 galaxy Mrk279. With sub-day sampling over more than two months, and typical flux measurement uncertainties of 1%, we are able to robustly measure inter-band time-delays of up to ~ 2 days across the optical range.

Contributed Talk

Splinter AGN

Line profile variations in the changing look AGN HE 1136-2304

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In the center of active galactic nuclei (AGN) reside supermassive black holes surrounded by broad emission line regions (BLR).

The AGN HE 1136-2304 was classified as a Seyfert 1.95 galaxy by the Hamburg ESO Survey in 1993. In June 2014, the XMM-Newton slew survey found an increase in the X-ray flux by a factor of more than ten compared with the flux it had in the ROSAT all-sky survey in 1990.

An ensuing optical spectrum, taken in July 2014 with the SALT telescope, shows greatly increased broad line emission which qualified HE 1136-2304 as a Seyfert 1.5 AGN. To investigate in the BLR of this changing look AGN a optical variability campaign was carried out in the years 2014/2015. HE 1136-2304 shows a common BLR where the distance from the Hβ-emitting region to the ionizing source is about 10 light days.

Contributed Talk

Splinter AGN

IC4329A: a red Seyfert-1 nucleus in an edge-on host galaxy

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At Universitäststernwarte Bochum near Cerro Armazones in Chile, we performed photometric reverberation mapping of the Seyfert-1 galaxy IC4329A at $z = 0.016$. Hα variations lag the B and R band continuum variations by about 15 days and the J band dust emission variations lag by about 30 days – consistent with the orientation dependent AGN unified model where the BLR lies inside the dust torus. Combining the Flux Variation Gradient method with multi-aperture photometry, we disentangled the SED of the AGN and the host galaxy. The AGN continuum is strongly reddened, presumably by dust in the host galaxy which appears to be edge-on on the images. Thus one may expect a reduced AGN continuum luminosity. Nevertheless, IC4329A perfectly lies on the relation between BLR size and 5100Å AGN luminosity for unreddened AGN.

Contributed Talk

Splinter AGN

On the Origin of Optical Time Delays in AGN

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There is increasing evidence for finite time lags, of order a day, between the emission in different bands across the UV-to-optical wavelength range in AGN. Such delays are often attributed to the presence of irradiated accretion disks in those sources, with far-reaching implications for accretion-disk physics, black-hole growth rates, and quasar structure. In this talk additional physical mechanisms that lead to finite continuum time-delays will be explored, with a particular emphasis on the contribution of the BLR to the signal. It will be shown, by means of state-of-the-art models for the BLR, that the contribution of irradiated accretion disks to the time-delay signal, if present, is secondary in some of the sources. We discuss new results for Mrk 279 and emphasize emerging problems with the interpretation of the time-delays in the framework of naive models for the BLR and for irradiated accretion disks.

Contributed Talk

Splinter AGN

The role of AGN in cosmic reionization

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Claims of a previously undetected population of faint AGN at high redshift have sparked new interest in scenarios in which AGN contribute significantly to the reionization of hydrogen. We model such scenarios and test them against post-reionization observational constraints on the temperature of the intergalactic medium (IGM) and the opacity of the hydrogen and HeII Lyman-alpha forests. While such an AGN population could provide an explanation for observed spatial fluctuations in the hydrogen Lyman-alpha forest opacity at $z > 5.5$, it is disfavoured by IGM temperature measurements and observations of the HeII Lyman-alpha forest.

Contributed Talk

Splinter AGN

The non-thermal astrophysics of relativistic AGN jets

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Non-thermal processes are both driving and shaping the appearance of relativistic AGN jets. I will report on recent progress to probe into the physics of these jets by means of high-energy observations. Particular attention will be given to the large-scale jet characteristics in M87 where complex X-ray emission features have been emerging, and to physical scenarios capable of explaining the origin of the extended X-ray emission in the kiloparsec-scale jets of AGN. The relevance of these results for future studies in the context of SKA and CTA will be discussed.

Contributed Talk

Splinter AGN

Testing the connection between major mergers and the triggering of high-accretion black holes

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With the feedback of Active Galatic Nuclei (AGN) possibly playing a role in the truncation of star formation and therefore severely affecting the evolution of a galaxy, it is of utmost interest to understand the processes involved in the growth of black holes. For decades, it was a widely accepted scenario that the occurrence of AGNs are a result of a merger of gas-rich galaxies.

However, over the last years the relevance of major interactions for the growth of black holes has been extensively tested, leading to a model in which the merging of two gas-rich galaxies is playing a sub-dominant part for the occurrence of an AGN. This circumstance holds in particular true for the majority of the black holes ($M_* < 10^{11.7} M_\odot$) since z $\sim$ 1, but also black holes with the highest masses at z = 2 and z = 0.2.

In our current work we want to test whether this conclusion is also valid for black holes with highest accretion rates ($L/L_{Edd} > 0.3$). As large amounts of gas and its transfer to the central region is needed, it may very well be that for this particular population of black holes major mergers are still the best or maybe only suitable mechanism. To examine this question we analyze the merger fractions of 21 QSO host galaxies at z = 2 (peak of black hole growth), observed by HST and 19 at z = 0.2 observed with VLT/FORS2 and compare them to the fractions of two matched samples of inactive galaxies. As all other parameters between the QSO samples and the respective selections of inactive galaxies are comparable, a significant increase of the merger fractions in regard to the QSOs means that major merging is in those particular cases a trigger for the growth of black holes.

Contributed Talk

Splinter AGN

Galaxy overdensities around 3C radio galaxies and quasars at $1 < z < 2.5$ revealed by *Spitzer* 3.6 / 4.5 μm and Pan-STARRS

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Luminous radio sources are thought to reside in galaxy clusters or proto-clusters. To confirm this idea , it is necessary to identify possible companion galaxies around RGs at the same redshift. Taking the advantage of the impressive and complete sample of 64 high-redshift 3C sources at $1 < z < 2.5$ which has been mapped by the *Spitzer Space Telescope*. The IRAC 3.6 μm and 4.5 μm 5-σ detection limit of 4 μJy (22.4 AB mag) allows us to search for the brightest candidate cluster member galaxies associated with the 3C sources. To remove the contamination of foreground stars and galaxies along the lines of sight toward the 3C sources we apply color cuts: removed sources satisfy either the IRAC1/2 cut $[3.6]-[4.5] < -0.3$ or the Pan-STARRS/IRAC cut $i - [4.5] < 0.5$ if detected by Pan-STARRS. For both selection methods, about half of the 3C radio sources show significant overdensities ($> 3\,\sigma$) within $30''$ ($\sim$250 kpc) projected distance from the radio source compared to the surrounding galaxy densities measured in the $50''$–$120''$ annulus. The Pan-STARRS/IRAC cut reveals higher average overdensities than the IRAC1/2 cut. To infer the nature of the cluster members, we rerun the analysis using a stronger IRAC1/2 cut $[3.6] - [4.5] < -0.1$ which removes $1 < z < 1.4$ passive ellipticals but not star-forming galaxies. For the strong cut, the overdensities, on average, completely disappear at $1 < z < 1.4$. We therefore suggest that the 4.5 μm detected cluster member galaxies are mainly passive ellipticals.

Contributed Talk

Splinter AGN

FR-type radio sources in COSMOS: relation to size, accretion modes and large-scale environment

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The radio sources associated with AGN can exhibit a variety of radio structures, from simple to more complex, and often they extend beyond the size of their host galaxy, giving rise to a complex classification scheme. The question which still remains open is whether this plethora of radio structures can be attributed to the physical properties of the host or to the environment. Here we present an analysis on the radio structure of radio AGN from the VLA-COSMOS Large Project at 3-GHz (JVLA-COSMOS) in relation to: 1) their linear project size, 2) the Eddington ratios of the black hole, and 3) the environment their hosts lie within. We classify these as FRI (jet-like) and FRII (lobe-like) based on the FR-type classification scheme, and compare them to a sample of jet-less radio AGN in JVLA-COSMOS. We measure their linear projected size using a semi-automatic machine learning technique. Their Eddington ratios are calculated from X-ray data available for COSMOS. As environmental probes we take the X-ray groups (hundreds kpc) and the density fields (∼Mpc-scale) in COSMOS. We find that FRII radio sources are on average larger than FRIs, which agrees with literature. But contrary to past studies, we find no dichotomy in FR objects in JVLA-COSMOS given their Eddington ratios, as on average they exhibit similar values. Furthermore our results show that the large-scale environment does not explain the observed dichotomy in lobe- and jet-like FR-type objects as both types are found on similar environments, but it does affect the shape of the radio structure intro-

Contributed Talk

Splinter AGN

The Extremely Luminous Quasars Survey (ELQS) in SDSS

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Studies of the most luminous quasars at high redshift directly probe the evolution of the most massive black holes in the early universe and their connection to galaxy formation. The Sloan Digital Sky Survey (SDSS) and the Baryon Oscillation Spectroscopic Survey (BOSS) have so far provided the largest sample of Type I quasars and the most widely adopted measurements of the Type I quasar luminosity function (QLF) at $z>3.0$. However, a careful re-examination of the SDSS/BOSS quasar sample revealed that their quasar selection is in fact missing a significant fraction of $z>3.0$ quasars at the brightest end. In order to avoid the limitations of purely optical quasar selections we have designed a new spectroscopic survey based on near-infrared photometry. The Extremely Luminous Quasar Survey (ELQS) uses a near-infrared color selection complimented with modern machine learning methods to reach unprecedented completeness for bright $z>3.0$ quasars over the $12000\,\mathrm{deg}^2$ of the SDSS footprint. I will present the novel quasar candidate selection along with the latest results of the survey. With the ELQS we will not only provide a more complete measurement of the known bright-end QLF, but it also allows us to extend the bright-end QLF by more than a magnitude at $2.8<z<4.5$.

Contributed Talk

Splinter AGN

OJ287 – Deciphering the Rosetta stone of blazars

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OJ287 is the best candidate Active Galactic Nucelus (AGN) for hosting a supermassive binary black hole (SMBBH) at very close separation. Periodicities in the historical optical light-cuve (1890-now) have been modeled successfully within an SMBBH scenario (e.g., Valtonen et al. 2016). At a redshift of z=0.306 and with a mass of more than $10^{10}M_{\odot}$, OJ287 is one of the few AGN which promises to allow observations on event horizon scales. OJ287 has thus been observed with the Event Horizon Telescope (EHT) project in April this year.

Contributed Talk

Splinter AGN

Accretion disks in space-times of compact objects with mass quadrupole

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Compact massive objects like neutron stars always rotate. This leads to a deformation of the massive compact object which results in axially symmetric mass multipoles. The gravitational field of such a compact object gives a space-time different from known Black Hole space-times like the Kerr space-times. We describe thick and thin accretion disks in such axially symmetric space-times and discuss the modifications compared to accretion disks around Black Holes.

Contributed Talk

Splinter CCAT

CCAT-prime project overview

Frank Bertoldi[1] on behalf of the CCAT-p collabroation

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CCAT-prime (CCAT-p) will be a 6-meter diameter telescope located at 5600 meters elevation on Cerro Chajnantor in the high Atacama Desert of northern Chile. Situated at a high, dry site and with a surface accuracy of better than 10 μm, CCAT-p will observe the sky at submillimeter to millimeter wavelengths. A novel "crossed-Dragone" optical design will deliver a high-throughput, wide-field-of-view telescope capable of illuminating more than 100,000 detectors enabling rapid mapping of large areas of the sky. The high site offers superb observing conditions, yielding routine access to the 350 μm window and improved performance at longer wavelengths.

A partnership of Cornell University, a consortium of German institutions led by the Universities of Cologne and Bonn, and a consortium of eight Canadian academic institutions are working together to create CCAT-p. Researchers at additional institutes in the U.S., Canada, Germany and Chile are involved in science planning and instrument development.

Deployment of the CCAT-p telescope and instrumentation on Cerro Chajnantor will also provide operational experience at high altitude, reducing risk for the future construction of a 25-meter class telescope at the same site.

Contributed Talk

Splinter CCAT

CCAT-p first light instrumentation

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We present an overview of the planned first light instrumentation of the new CCAT-p 6m off-axis submm telescope on Cerro Chajnantor, Chile at 5600 m altitude, which is presently being built and is scheduled for first light towards end of 2019. The instrumentation planned covers the prime science areas envisaged for CCAT-p. One instrument is a large format, multi-wavelength direct-detection camera, which focuses on the cosmological aspects of the CCAT science. The second first light instrument is a large format heterodyne high-spectral-resolution camera aimed at the study of the physical conditions of the star forming interstellar medium in the Milky Way and nearby galaxies.

Contributed Talk

Splinter CCAT

CCAT-p: The Galactic ECology (GEco) Project

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The star formation rate is governed by the flow of gas from galactic scales down to individual star-forming cores. Once stars are formed, they provide feedback in form of winds, UV radiation and eventually supernova explosions, which self-regulate star formation.

Of particular observational importance are the far-infrared fine structure lines ([C I], [C II], [O I] and [N II]) as well as mid- and high-excitation CO lines, since they are agents of cooling in molecular cloud formation or star formation feedback, and therefore important tracers of these processes. The Galactic disk, but also in particular the Galactic Center and the Large and Small Magellanic Clouds, are important laboratories in this respect, since they allow to study, at high resolution, star formation in normal disk molecular clouds, a galaxy core and in both normal and low metallicity environments, all of which are ingredients of star formation in the early and contemporary universe.

In the local universe, some of the key spectral lines ([C I] and mid-J CO lines) can be observed from the ground. Even [N II] and high-J CO lines are accessible to ground-based observatories on mountain sites with better transmission than the Chajnantor plateau (ALMA site). The main objectives of the CCAT-p Galactic Ecology (GEco) programme are the study of the formation, growth, evolution and dispersal of molecular clouds. For this, we will use large format heterodyne arrays to survey [C I] 1-0 and mid-J CO lines over areas that are large enough to have a statistically significant sample for clouds in the Galactic plane and the Magellanic Clouds. These observations

Contributed Talk

Splinter CCAT

High-redshift galaxy surveys with CCAT-p

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Characterising the far-infrared emission of high-redshift galaxies is essential to estimate their dust-enshrouded star-formation activity otherwise only measured using not-well-understood rest-frame UV corrections. To date, far-infrared measurements are mostly based on *Herschel* or ALMA observations. However, while *Herschel* could map large areas of the sky, this 3.5 meter telescope was significantly limited by confusion (inability to separate emission from multiple galaxies within a single resolution element), providing far-infrared measurements only for the most luminous and thus not representative high-redshift galaxies.
On the other hand, ALMA can perform ultra-deep far-infrared observations but its relatively narrow field-of-view does not provide us with the statistic needed to study the evolution over cosmic time of galaxy populations.
I will demonstrate how CCAT-p, with its wide-field-of-view and 6 meter aperture, will fill this gap, providing deeper (at $z > 1$) and wider extragalactic surveys than those from the *Herschel Space Observatory.* The planned CCAT-p Galaxy Evolution (GEvo) survey will improve our understanding of the faint galaxy population that is responsible for the bulk of the cosmic far-infrared background. This wide-area survey will also allow for the detection of exotic, highly luminous galaxies.

Contributed Talk

Splinter CCAT

Tomography of Cosmic Reionization Through [CII] Intensity Mapping at Redshifts 5–9 with CCAT-p

D. A. Riechers[1], on behalf of the CCAT-p consortium

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The epoch of cosmic reionization (EoR) describes the time period during which the transition from the cosmic dark ages when the universe is largely neutral to a universe in which intergalactic hydrogen is largely ionized takes place. This transition is thought to be dominantly driven by ionizing photons that emerge from the first star-forming galaxies early in cosmic history, within the first billion years after the Big Bang – corresponding to redshifts beyond 5.7. Due to the faintness of most of these young galaxies, and the absorption of their ultraviolet emission by the increasingly neutral intergalactic medium at these early epochs, systematic studies of the EoR based on individual sources of reionization remain challenging even in the era of the James Webb Space Telescope. We here describe a new promising method to probe the EoR using the upcoming CCAT-p telescope. Instead of targeting individual galaxies, this method maps the clustering signal from the faint, but highly numerous reionization sources in aggregate through the intensity mapping technique. CCAT-p will target the [CII] line at rest-frame 158 micron, typically the brightest cooling line of the interstellar medium in star-forming galaxies, which in contrast to more traditional tracers is not absorbed by neutral hydrogen in the intergalactic medium. Through this experiment, CCAT-p will shed light on the end of the cosmic dark ages, probing one of the last largely unexplored eras in the history of the universe.

Contributed Talk

Splinter CCAT

Cluster cosmology with CCAT-p

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A main focus of CCAT-p cosmological research will be to carry out a wide-area, multi-band survey of galaxy clusters in the Sunyaev-Zel'dovich (SZ) effects. CCAT-p will be the first survey telescope to clearly detect the three main types of SZ effects in a large sample of clusters. Already with its first-light survey of 1000 deg^2 CCAT-p will detect over 2000 galaxy clusters from their thermal SZ signal. A significant fraction of these will have good signal-to-noise for a measurement of their line-of-sight peculiar motion from the kinetic SZ effect and also the average temperature from the relativistic SZ effect. These data will provide unique and high-precision tests for the standard cosmological model. The power spectrum of the kinetic SZ effect will be a probe for the epoch of reionization and can be combined with intensity mapping results. An important application for the high-frequency observing capability of CCAT-p will be to measure the FIR emission associated with galaxy clusters, which will be important for the precise characterization of the individual cluster properties as well as the thermal SZ power spectrum and bispectrum.

Contributed Talk

Splinter CCAT

Observations of the relativistic SZ effect: From *Planck* to CCAT-p

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The Sunyaev-Zel'dovich (SZ) effect is a spectral distortion of the cosmic microwave background (CMB) due to inverse Compton scattering of CMB photons by free electrons in the hot plasma found in clusters of galaxies. Its signal is proportional to the line of sight integral of the thermal gas pressure and not dimmed with redshift. The SZ effect has been used extensively in the last two decades to detect and characterise galaxy clusters and has become an important tool for cosmology.
Due to the high temperatures of several keV found in the ICM, relativistic effects are expected to distort the SZ spectrum allowing to measure the temperature of the scattering gas. We attempt to measure these relativistic distortions by performing a stacking analysis of a large sample of galaxy clusters with data from the Planck mission. With its nine frequency channels, Planck allows to probe the entire spectrum of the SZ, making it ideally suited for this study. Of particular interest are high frequencies from 353 up to 857 GHz where the relativistic corrections are strongest but that are difficult to access with ground-based observatories.The main challenge in utilizing these frequencies is to separate the SZ signal from much brighter galactic foregrounds as well as far infrared emission from the clusters themselves.
We conclude by providing an outlook for the upcoming CCAT-p telescope, which will improve upon Planck with lower noise and better spatial resolution.

Poster

Splinter CCAT

Simulation of Galactic disk PDRs line emission

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In star-forming regions the fractal structure of the interstellar medium suggests that much of the physical and chemical conditions can be described by using a clumpy approach representing a large fraction of the ISM in the Milky Way by photon-dominated regions (PDRs). We make predictions for the large-scale distribution of the CO 4-3 and CO 7-6 lines and the two [CI] fine structure lines that can be obscured with CCAT-prime. We model the structure of the ISM as a superposition of spherical clumps with different sizes using an extension of the KOSMA-τ 3D-Code. We build a 3D PDR-model of the Galactic disk with mass-, density-, velocity- and FUV-distributions as input parameters and perform radiative transfer computations for the IR continuum and various molecular, atomic and ionic emission lines. We fit the model parameters by comparing the simulated position-velocity map of CO 1-0, integrated line profiles of [CII] and CO lines from CO 1-0 to CO 8-7, as well as dust continuum emission in FIR. Comparison of CCAT-prime observations of the [CI] lines with the model predictions will allow to verify the underlying assumptions on the PDR physics and chemistry.

Poster

Splinter CCAT

Predictions for the redshift 5-8 [CII] intensity distribution

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The ionic [C II] fine structure line at 158 μm is one of the brightest lines in the spectrum of star-forming galaxies. It is an excellent target for unresolved spectral line intensity mapping observations at redshifts 5 to 8, where the far-IR line can be observed through mm atmospheric windows with ground based telescopes such as CCAT-p, providing an integral, unbiased tomographic view of the star formation activity and source distribution throughout the epoch of reionization. Numerous authors have been investigating the feasibility of such observations. I review the different approaches to predict the expected signal, based on simulations, semi-analytical models, and observationally derived scaling relations.

Poster

Splinter CCAT

Mapping the ISM in nearby galaxies with CCAT-p: the case of M51

M. Ziebart[1], C. Buchbender[1], M. Röllig[1], R. Simon[1], J. Stutzki[1]

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Large scale spectral line mapping of a nearby galaxies in radio, sub-mm and far-infrared emission lines with a spatial and spectral resolution that allows separating the major structural features such as the spiral arms and the interarms-regions, as well as Giant Molecular Cloud complexes, is a powerful tool to study the star formation activity, including the cloud formation, and thus the galaxy evolution. One of the scientific goals for which the CCAT-p telescope has been designed is the study of the star forming interstellar medium in the Milky Way and in nearby galaxies. In this poster we discuss, as an example, the feasibility of sub-mm observations as a complementary data to the spectroscopic resolved full map of the M51 grand designed nearby spiral galaxy in the [CII] 158 μm line observed with upGREAT on SOFIA (we note that M51 is not necessarily the best target for the southern CCAT-p telescope; nevertheless we use it here as an example because of the available complementary data). We estimate the observing time for full maps of M51 in the emissions lines of [CI] 370 μm, [CI] 609 μm, CO J=4-3 650 μm and CO J=7-6 372 μm observed with the future 64 pixel CHAI receiver on the CCAT-p telescope. The 6 m diameter of the CCAT-p dish gives an angular resolution comparable to the SOFIA [CII] 158 μm observations and the mm-wave low-J CO mapping with e.g. the IRAM 30m telescope.

Contributed Talk

Splinter Computation

Magneticum: The largest cosmological hydrodynamical simulations

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The Magneticum simulations allows to study halos across a whide range of mass and environments, from massive galaxy cluster down to normal galaxies. It includes a detailed treatment of the chemo-energetic feedback from the stellar component and its evolution as well as feedback from the evolution of super massive black holes. The largest of the simulations follows a recod number of 2×4536^3 particles and was performed using the complete Phase II of SuperMUC at LRZ. I will report on optimization strategies which allowed us to perform such simulation on 172032 tasks utilizing 155 TB of main memory for a single run. I will also describe the progress and need for developments towards next generation of HPC hardware.

Contributed Talk

Splinter Computation

Towards Fast High-Order Magnetohydrodynamics in the AREPO Code

T. Guillet[1,2], R. Pakmor[2], V. Springel[1,2]

[1] *Zentrum für Astronomie der Universität Heidelberg*
[2] *Heidelberg Institute for Theoretical Studies*

I present our latest developments on MHD schemes for the cosmological hydrodynamical simulation code AREPO. The code implements finite volume solvers for hydrodynamics and MHD, and can operate on two major types of grids: either a fully dynamic quasi-Lagrangian unstructured Voronoi mesh, or an octree-based adaptive mesh refinement (AMR) grid. The moving mesh solver is based on a second-order unsplit Godunov scheme. For AMR grids, we implemented a higher-order discontinuous Garlerkin (DG) hydrodynamics solver, which we have extended to MHD based on locally divergence-free basis functions. I discuss some challenges to achieve a robust and efficient implementation of high-order methods for MHD that can be applied to astrophysical problems. I also highlight some key aspects of DG schemes for computational efficiency on modern CPU architectures.

Contributed Talk

Splinter Computation

Forming (more) realistic galaxy clusters in simulations

Ewald Puchwein[1], Nicholas Henden[1], Debora Sijacki[1], Sijing Shen[2]

[1] *Institute of Astronomy & Kavli Institute for Cosmology, University of Cambridge*
[2] *Institute of Theoretical Astrophysics, University of Oslo*

We present a new suite of high-resolution galaxy cluster simulations performed with the moving-mesh cosmological hydrodynamical simulation code AREPO. Galaxy formation and feedback are modelled with the "Illustris" galaxy formation model, which previous studies found to be highly successful in obtaining realistic galaxy populations. A number of modifications of this model will be discussed which result in much better agreement with observations on the scale of galaxy groups and clusters. Based on this model we predict the most important galaxy cluster scaling relations and discuss various challenges that the current generation of simulations still faces.

Contributed Talk

Splinter Computation

Constraining Feedback Prescriptions with Lyα Absorption

D. Sorini[1], J. Oñorbe[1], J. F. Hennawi[1,2], Z. Lukić[3]

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[3] *Lawrence Berkeley National Laboratory, USA*

Understanding the physics of the intergalactic and circumgalactic media (IGM and CGM) is fundamental to study galaxy formation in a cosmological context. Galactic winds, supernovae and AGN feedback alter the physical state of the CGM, although the details of these processes are still poorly understood. Lyman-α (Lyα) absorption represents a powerful tool to probe the physics of both CGM and IGM. For the first time, we compare the predictions of the state-of-the-art Nyx and Illustris hydrodynamic cosmological simulations with observations of Lyα absorption around foreground galaxies at different transverse separations from background quasars (between $\sim 25\,$kpc and $\sim 17\,$Mpc). For the first time, we show that the exquisitely precise BOSS measurements of the mean Lyα absorption in the range of transverse distance from galaxies (1, 17) Mpc are capable of discriminating between the predictions of the simulations considered. As such, they can set tight constraints on the physics implemented in cosmological simulations. Furthermore, Nyx and Illustris predict a different Lyα absorption for transverse distances $< 1\,$Mpc but larger than the virial radius, which we argue are due to the different feedback prescriptions in the two simulations, although they are consistent with the error bars of the observations in this regime. We thus call for future observations to increase the precision of measurements out to $\sim 1\,$Mpc in the CGM, as that would allow setting tighter constraints on simulations. Nyx and Illustris underpredict the mean Lyα absorption within the virial radius. Through the implementation of a a novel semi-analytic technique to alter the temperature of the CGM in post-processing, we discuss how this discrepancy could be mitigated in order to improve feedback prescriptions in future simulations. To summarize, the main conclusion of our work is that, considering the constraining power given by current and near-future observations, the comparison

Contributed Talk

Splinter Computation

Line and continuum radiative transfer simulations: From magnetic fields to polarization

R. Brauer[1], S. Wolf[1], and S. Reissl[2]

[1] *University of Kiel, Institute of Theoretical Physics and Astrophysics*
[2] *University of Heidelberg, Institute of Theoretical Astrophysics*

The impact of magnetic fields on the formation of stars and planets is a matter of ongoing discussions. Measuring the structure and strength of magnetic fields in star-forming regions is therefore of crucial importance. Using radiative transfer simulations that consider the influence of magnetic fields, we provide predictions for observations and insights about internal physical properties from molecular clouds to circumstellar disks.

We present the 3D radiative transfer code POLARIS (Reissl et al. 2017, Brauer et al. 2017) that is able to simulate the emission of aligned non-spherical dust grains and the Zeeman splitting of spectral lines. Furthermore, we give a detailed overview of its abilities and potential applications. As an example, we show three already performed studies that take advantage of the key capabilities of POLARIS. In the first one, we investigate polarization holes in submm observations of Bok-Globules. The second study focuses on the uncertainty of the analysis method, which is usually used to estimate the magnetic field strength in the line-of-sight direction from Zeeman split spectral lines. Finally, we investigate which constraints for magnetic fields in circumstellar disks can be obtained from Zeeman observations of the 113 GHz CN lines.

Contributed Talk

Splinter Computation

Simulations of merging cool-core clusters

W. Schmidt[1], C. Byrohl[2], and J. C. Niemeyer[2]

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[2]*Institut für Astrophysik, Georg-August-Universität Göttingen*

Major mergers are considered to be a significant source of turbulence in clusters. We present simulations of a major merger event with the Nyx code developed in collaboration with the Computational Cosmology Center at Lawrence Berkeley National Laboratory. To follow the evolution of the merger, we applied nested-grid initial conditions, adaptive mesh refinement, radiative cooling of primordial gas, and a homogeneous ultraviolet background. The turbulent velocity dispersion in the intracluster medium (ICM) and warm-hot intergalactic medium (WHIM) is computed with a new in-situ method based on adaptive temporal filtering. An important open question concerns the impact of magnetic fields on fluid properties of the ICM and WHIM. By calculating the microscopic viscosity on the basis of various theoretical assumptions and estimating the Kolmogorov length from the turbulent dissipation rate computed with a subgrid-scale model, we are able to demonstrate that most of the WHIM can sustain a fully turbulent state only if the magnetic suppression of viscosity is considerable. Accepting this as premise, it turns out that ratios of turbulent and thermal quantities change only little in the course of the merger. This confirms the tight correlations between the mean thermal and non-thermal energy content for large samples of clusters in earlier studies, which can be interpreted as second self-similarity on top of the self-similarity for different halo masses.

Contributed Talk

Splinter Computation

Non-equilibrium energy balance in the solar chromosphere

A. L. S. Bhasari[1], M. van Noort[1]

[1]*Max Planck Institute for Solar System Research*

The enormous increase in computing resources in recent years has made it feasible to approximate the solar photosphere in great detail using numerical magneto-hydrodynamic (MHD) simulations. Extending these simulations to the solar chromosphere, that lies above, has been challenging, due to the dominant role played by radiative losses there. These losses are driven by a small number of strongly scattering spectral lines, so that the approximation of local thermodynamic equilibrium cannot be used. In addition, the dynamic time scale of the atmosphere is similar or below that of the dominant collisional processes, so that even statistical equilibrium cannot be assumed. We present a time-implicit numerical method that simultaneously solves the atomic population evolution and radiative transfer equations, together with the MHD quantities. The method is implemented as a module for the MHD code MURaM, which was used to simulate some preliminary results for a one-dimensional, pure hydrogen atmosphere.

Contributed Talk

Splinter Computation

A Smooth Particle Hydrodynamics Code to Model Collisions Between Solid, Self-Gravitating Objects

C.M. Schäfer[1], T.I. Maindl[2], C. Burger[2], O.J. Wandel[1]

[1] *Department of Computational Physics, University of Tübingen*
[2] *Department of Astrophysics, University of Vienna*

We will present the latest improvements and applications of the Tübingen-Vienna Smooth Particle Hydrodynamics (SPH) code. Modern graphics processing units (GPUs) lead to a major increase in the performance of the computation of astrophysical simulations. Owing to the different nature of GPU architecture compared to traditional central processing units (CPUs) such as x86 architecture, existing numerical codes cannot be easily migrated to run on GPU. Here, we present the implementation of the numerical method SPH using CUDA^{TM}. We have implemented the SPH equations to model fluids and elasto-plastic solid bodies and added a fragmentation model for brittle materials. Our material models allow for treatment of granular media and porosity. Self-gravity may be optionally included in the simulations and is treated by the use of a Barnes-Hut tree. We will present some recent applications of the code: collisions between Ceres-sized objects, modelling of sampling processes on Phobos' surface and impacts into asteroids related to the AIDA mission. The code is freely available upon request.

Contributed Talk

Splinter Computation

Simulating the Jupiter's interior dynamics

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[2] *IPGP, Paris*
[3] *CEMPS, University Exeter*
[4] *Institut für Physik, Universtität Rostock*

With Juno orbiting Jupiter, new insights on the planets magnetic field and interior structure have started to arrive. We conduct numerical simulations of the internal dynamo process to help interpreting the measurements. The simulations were performed with the MHD code MagIC freely available at GitHub. MagIC uses pseudospectral methods to solve for convection and magnetic field generation in a rotating spherical shell, using the anelastic approximation. We explore various parameter combinations as well as different internal density and electrical conductivity profiles using the Max-Planck super computer in Garching. Key to a Jupiter-like dynamo process is a combination of a steep density stratification and an electrical conductivity profile that captures the transition from the weakly conducting outer molecular hydrogen envelope to inner metallic hydrogen layer. In addition, the vigor of the convective driving (Rayleigh number) needs to be adjusted. Weak driving yields too simplistic field geometries while strong driving promotes multipolar rather than dipole dominated magnetic fields. The surface magnetic fields only closely resemble known magnetic field models when the convective driving is intermediate. The convective flow is dominated by a realistic prograde equatorial jet but lacks multiple mid to high latitude jets which, according to our simulations, seem incompatible with a Jupiter like magnetic field. Dynamo action is a combination of two processes: A primary process generates the large scale dipole dominated field in the deeper metallic region. At the transition to the weakly conducting outer layer, the equatorial jet drives a secondary dynamo that produces strong low-latitude magnetic features reminiscent of the recent Juno observations.

Contributed Talk

Splinter Education

Structure-forming phenomena in the universe and simple applications at school

L. Bzduskova[1], S. Hohmann[1]

[1] *University of Siegen, Department of Physics, Observatory*

In the universe and on earth, patterns and structures are formed. These self-running phenomena are not to be understand easily, because there are very complex processes going on. But for teachers, it is possible to put some experiments together, which can explain this complexity of the structure-forming phenomena. This contribution presents three experiments treating structure-forming phenomena: Kelvin-Helmholtz Instability, Rayleigh-Taylor Instability and Rayleigh-Bénard Convection. To reach a better understanding for the students. This contribution shows pre-experiments leading to a better understanding of the main experiments. The presented phenomena should only treat a small section of the possible structures found in the animated and unanimated nature. The self-organization of structures can wake the interest of the students in astronomy, astrophysics or physics in general, because observing these structures can be very fascinating.

Contributed Talk

Splinter Education

Stable Atmospheres inside and outside the Solar System

S. Hohmann[1]

[1] *University of Siegen, Didactics of Physics, Observatory*

The search for life on other planets is one of the most fascinating aspects in astrophysics, especially for learners of all ages. Recently, thousands of exoplanets - with an increasing number of terrestrial ones - have been discovered. This is leading to the question, if some of them are fit for life.
Usually, the habitable zone of a star is synonymous with the area, in which liquid water may be found. This aspect has a very "earth-bound" point of view - there is no proof, that life without water is impossible. But a long-time stable atmosphere is one (of the many) essential keys for the evolution of life. This talk shows an estimation which allows to have a look at planets with different atmospheres surrounding stars with diverse luminosities and therefore diverse radiation pressures. If the radiation pressure predominates the gravity of a planet, the atmosphere cannot be stable for a long time. With the earth's atmosphere as a scale, one can assume, whether an atmosphere can exist long enough for the evolution of life or not.
This argument gives a lower limit for the necessary distance between star and planet fit for life. Most of the discovered exoplanets are quite close to their stars, caused by the methods of detection, so this estimation can be applied on a big part of them.

Contributed Talk

Splinter Education

The Michelson-Morley Experiment in a proper representation

H. Melcher[1]
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In the literature, including Wikipedia, the Michelson-Morley experiment is interpreted with the Lorentz contraction. Einstein had repeatedly described this misinterpretation as artificial and unnatural. The contradiction between the experimental "zero result" and the mechanical (inadequate) velocity equation had a serious effect on the "negative" result (or experiment). Since 1905, however, the unity of mechanics and electrodynamics, and thus a uniform law for the addition of mechanical and electrodynamic velocities, has been known by Einstein's special theory of relativity. It is shown below that the application of the relativistic velocity addition is readily in accordance with the experimental "zero result", i.e., without imagination of an ether and without incomprehensible body deformations. The incorrect interpretation by the Lorentz contraction is to be replaced by the correct speed addition.

Contributed Talk

Splinter Education

The need for astronomical contexts in inclusive Physics classes

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[2] *Lehrstuhl für Erziehungshilfe und sozial-emotionale Entwicklungsförderung, Universität zu Köln*

In response to the increasing heterogeneity of learning groups in German schools, didactical research in Physics has begun to place a greater emphasis on the question of how to create a meaningful context for learning in inclusive settings. This is now crucial because students who require special pedagogical support must be provided with motivating learning situations as well as emotional access to ensure learning success. One approach to addressing learners increasing diversity of interests could be to offer individual contexts for each student; however, programs with this level of individual attention are impractical for organizational reasons. On the other hand, the wide range of students interests could also be accommodated by selecting a context that has the potential to be interesting for all the students (what Feuser (1989) referred to as a 'Gemeinsamer Gegenstand' [common subject]). This then serves as a common thread to tie together the curriculum and has the added benefit of releasing positive emotions in the learners. In this presentation, we examine why curricula that employ astronomical contexts are particularly successful for groups of inclusive learners. Our analysis is based on the 'Modell dualer Unterrichtsplanung' [dual lesson planning model] (Ferreira Gonzalez et al., 2016) and the IPN and ROSE studies of students learning interests.

Contributed Talk

Splinter Education

‘With light through our solar system and beyond’ an astronomical learning conception for inclusive teaching of Physics

A. Küpper[1], A. Schulz[1], T. Hennemann[2]

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Based on findings of the IPN and ROSE learning studies, we have developed a conceptual framework for teaching Optics in grades 5 or 6 (subjects: light sources, process of sight, straight propagation of light, shadows of one or two light sources, phases of the Moon, eclipses, absorption, reflection and scattering of light) under the title ‘With light through our solar system and beyond’. Applying the principle of Design Based Research, we drafted a teaching concept (‘design’) based on an astronomical context that included phases of learning in small collaborative groups of learners as well as single learners in differentiated exercises and application tasks. This conception has been tested in an initial pilot phase, which we present here and offer up for discussion.
In addition to the frame context chosen, we also present a toolbox of experimental materials including a system of supporting guide to help with issues that we expect students may encounter in live classroom settings. Furthermore, we discuss what kinds of changes to the program we deemed to be appropriate after our evaluation of the pilot phase.

Contributed Talk

Splinter Education

White dwarfs as school topic

M. Quast[1], A. Schulz[1,2]

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[2] *Institut für Physik und ihre Didaktik, Universität Köln*

White dwarfs are the remnants at the end of a low-mass star's live. They serve as important observational verifications for theories of stellar evolution and standard candles for modern cosmology. However, understanding their inner structure requires both classical and quantum physics. We investigate Chandrasekhar's model for complete electron degeneration and show that white dwarfs provide a tremendous opportunity to implement topics like quantum statistics and fluid dynamics into high school education. Furthermore we discuss pedagogical and didactic implications for teachers and students.

Contributed Talk

Climate Change: Discoveries in Physics Lessons

Hans-Otto Carmesin[1,2,3]

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[3] *University Bremen, 28334 Bremen*

Topics that are relevant for the future are especially interesting for high school students. Climate change is such a topic.

This topic has been treated in several physics courses ranging from class 7 to 11 as well as in an astronomy club with students from class 5 to 12 and in various youth groups. So climate change is treated at various levels here.

At the basic level the students play a climate game. Here they can build power stations using coal or renewable energy. The power stations using coal exhaust greenhouse gas and thus heat the atmosphere according to the Stefan-Boltzmann law. If the earth is overheated then everybody looses the game while otherwise the player having most money wins. So the students discover a dilemma between economic and ecologic interests. Within the game they develop and test strategies to overcome the dilemma. After the game they reflect their experiences. This takes 90 min altogether.

In the above game the students de-escalate the dilemma, but they do not resolve it. For the latter purpose an advanced game is provided. Here the players experience how technological progress can resolve the dilemma.

At an advanced level the students analyze the results of the game. They model climate change in the framework of climate models while they model the economic behaviour using Nash equilibria of the mathematical game theory. Moreover they combine both models and discover the emerging time schedule for technological change.

At an advanced science level the students explore radiation physics using experiments or an infrared camera. Thereby they discover the Stefan-Boltzmann law and the solar constant both underlying the game.

I report on the concept as well as on experiences in the classroom.

Contributed Talk

Quantum Gravity: Discoveries about the early Universe including big bang, big bounce and a critical discussion of these

Hans-Otto Carmesin[1,2,3]

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High school students can discover the expansion of the universe from observations. Next they can model this expansion. For this purpose they can derive the Friedmann-Lemaitre equations FLE in the framework of Newtonian Cosmology and perform computer experiments on that basis. Thus they can model gravity. As a result they discover the big bang singularity with a diverging density.

The students can overcome the singularity by applying quantum physics QP at the school level and derive an extension of the FLE. Thus they can model gravity combined with QP, altogether it is called quantum gravity QG. With it they can perform computer experiments and discover the overcoming of the singularity. Finally they can critically discuss consequences like big bang and big bounce.

This topic has been treated in an astronomy club with students ranging from class 5 to 12. So the topic is treated at various levels here. At the basic level the students perform experiments about the density as well as the above computer experiments. At an advanced level the students derive the above equations.

I report on the concept as well as on experiences in the classroom.

Contributed Talk

Splinter Education

The Pitfalls of Determining Time and Location

S. Kraus[1], P. Raack[1]

[1] *University of Siegen – Physics Education Group*

One major task of astronomical observatories during the height of the classical astronomy was to provide the local time as well as to assist in land surveying by providing precisely measured reference sites. In addition to classical astronomical methods, sufficiently robust and mobile chronometers permitted an independent checking of the longitude differences by the end of the 18th century.

For this purpose, numerous chronometers – by sea– and land-transport – were repeatedly exchanged between the chief observatories and reference points and compared with the respective stationary pendulum clocks. The implementation of such comparative measurements involved several practical difficulties and also one fundamental problem. Since the time of Friedrich Wilhelm Bessel (1784–1846), transit observations revealed that time differences within a few tenths of a second between different observers could not be prevented in principle. The need to take account of these time lags and to correct them through personal equation was already common at that time and appropriate procedures were established. However, these procedures couldn't be directly applied for the purpose of comparing longitudes.

This article describes the historical and technical circumstances and the need for taking into account physiological effects. Based on a historical example, it will be shown that the processes of determining time and location are necessarily intertwined. Learners should be given an understanding of these fundamental issues – together with the historical context – in the course of their schooling. Especially due to the fact that precise location and timing information are readily but seemingly unconditionally available nowadays.

Contributed Talk

Splinter Education

A research project for students from schools based on variable stars

M. Geffert

Argelander-Institut für Astronomie der Universität Bonn

Young people from schools are interested in getting a little bit of an insight in the life of a scientist. For these students, we have established a lab course based on the determination of light curves of variable stars. Using scans of photographic plates from the Bonner “Sammlung Historischer Himmelsaufnahmen” the students learn, how to reduce optical observations. Results of their work were published in the “BAV-Rundbriefe”. As a byproduct we detected a few new variable stars. In addition, by lessons and work sheets the pupils learn about the importance of variable stars for the determination of distances in astronomy.
An overview of the project and the experience with the “young scientists” is given.

Contributed Talk

Splinter Education

Training of Teachers

Planung und Durchführung einer astrophysikalischen Projektwoche für die Oberstufe

C. Rogge[1], P. Huke[1], J. Dürbye[1]

[1] *Georg-August-Universität Göttingen, Institut für Astrophysik*

Im Zuge des internationalen Science Camps besuchen Schülerinnen und Schüler der Oberstufe das Institut für Astrophysik und erarbeiten ein astrophysikalisches Projekt. Das Camp wird vom XLab, dem Experimentierlabor für junge Leute e.V. organisiert. Innerhalb einer Woche konstruieren die Schülerinnen und Schüler einzelne Elemente des Projektes und fügen diese in effektiver Gruppenarbeit zusammen.
Bei der Durchführung geht es darum die Notwendigkeit der Kommunikation innerhalb der eigenen, aber auch in Interaktion mit den anderen Gruppen zu erkennen. Die Elemente des Projektes sind ein Teleskop, ein Spektrograph, Verbindungen der Instrumente über Fasern und die Datenauswertung. Die Schülerinnen und Schüler experimentieren während der Erarbeitung der Elemente mit den einzelnen Bauteilen und verstehen deren physikalische Hintergründe. Durch die Arbeit an dem Projekt soll die Fähigkeit effektiver Gruppenarbeit gefördert werden.
Für eine erfolgreiche Durchführung eines komplexen Projektes ist eine strukturierte Zeitplanung und das Wissen um jeden Arbeitsschritt an den Komponenten entscheidend. In diesem Beitrag geht es um die Planung und Durchführung der Projektwoche und wie dies sich im Management abbildet.

Contributed Talk

Splinter eROSITA

Galaxy Clusters from the Magneticum Simulations

K. Dolag[1]

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Recent, cosmological hydrodynamical simulations can cover very large dynamical ranges in the resolved structures, while following a large variety of physical processes (e.g. star-formation, chemical enrichment, AGN feedback) which are important for the formation of galaxies and galaxy clusters. I will present the results from the "Magneticum" set of cosmological simulations with special emphasis on galaxy clusters. I will present results connecting the shape of the underlying dark matter halo, the ICM and the stellar component to the formation history of the halos.

Contributed Talk

Splinter eROSITA

Forecasting Impact of DES Weak Lensing Mass Calibration on eROSITA Cluster Cosmology Constraints

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In this work we forecast the cosmological constraints obtained from the number counts of eROSITA selected galaxy clusters, with special focus on the improvement of such constraints coming from the weak lensing calibration of the cluster mass with Dark Energy Survey (DES) imaging data. To perform this forecast, we construct a galaxy cluster mock catalogue taking into account (1) the theoretically determined abundance of halos as a function of mass and redshift, (2) the observed scaling relation involving halo mass, redshift and the observable X-Ray properties, and (3) the eROSITA response. We also simulate the DES weak lensing signal of these objects, adopting realistic noise from ongoing DES analyses. Then, we simultaneously fit the abundance of eROSITA clusters and the weak lensing signal with a Bayesian hierarchical model to jointly constrain the X-Ray scaling relation parameters and the cosmological parameters. We show that the addition of the DES weak lensing data significantly improves the constraints on both the X-Ray scaling relation parameters and the cosmological parameters.

Contributed Talk

Splinter eROSITA

The multi-component matched filter cluster confirmation tool (MCMF)

M. Klein[1], J. Mohr[2]

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[2]*Faculty of Physics, Ludwig-Maximilians-Universitaet (LMU-Munich)*

Surveys identifying galaxy clusters via measurements of properties of the intra cluster medium, either via X-ray or the Sunyaev-Zel'dovich effect (SZE) have shown to be successful to constrain cosmological parameters. Up to now those results were based on only a few hundred of clusters. This will change soon with upcoming surveys such as eROSITA , that will detect up to hundred thousand clusters. This brings up one downside of those surveys, the lack of redshift information for the majority of the identified clusters.

The multi-component matched filter cluster confirmation tool (MCMF) was therefore developed to provide these information for large numbers of clusters. The tool currently uses photometric data from the Dark Energy Survey (DES) to obtain cluster redshifts up to $z \simeq 1$ with high precision. Further it allows additional cluster confirmation and cleaning of contaminated cluster samples by estimating the probability of a source of being a chance superposition with a given optical counter part.

Results of MCMF to follow up the ROSAT based 2RXS catalogue and the SZE based catalogue from the South Pole Telescope (SPT) will be shown during this presentation.

Contributed Talk

Splinter eROSITA

eROSITA on SRG: an overview

P. Predehl, A. Merloni[1]

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The next generation of wide-area, sensitive X-ray surveys designed to map the hot and energetic Universe will be heralded by eROSITA (extended ROentgen Survey with an Imaging Telescope Array), the core instrument on the Russian-German Spektrum-Roentgen-Gamma (SRG) mission, scheduled for launch in 2018. eROSITA will perform a deep survey of the entire X-ray sky, and will be about 30 times more sensitive than ROSAT in the soft energy band (0.5-2 keV), while in the hard band (2-8 keV) it will provide the first ever true imaging survey of the full sky. In this talk, we will give an overview of the scientific goals of the mission, and an update on the status of the program.

Contributed Talk

Splinter eROSITA

Understanding AGN evolution with large X-ray surveys: prospects for eROSITA

A. Merloni[1]

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In the past 50 years, astronomers have used X-ray surveys to tackle fundamental questions for structure formation such as: How did supermassive black holes form and grow in the nuclei of galaxies? Why are their physical properties today so tightly linked to those of their hosts? What was the impact on the surrounding structures of the copious energy release, either in radiative or mechanical form, associated to the growth of such black holes in active galactic nuclei (AGN)? State of the art observations with Chandra and XMM-Newton have been used to give at least partial answers to some of these questions. However, there are major limitations with existing X-ray surveys: many crucial aspects of the study of the connection between AGN and host galaxies cannot be explored because of the limited volume of the Universe explored. eROSITA is expected to yield a sample of around 3 million active galactic nuclei, which is bound to revolutionize our view of the evolution of supermassive black holes and their impact on the process of structure formation in the Universe. Here I will briefly highlight some of the most promising outcomes of such program, including a discussion of key multi-wavelength synergies with current and future wide-area survey projects.

Contributed Talk

Splinter eROSITA

Sunyaev-Zel'dovich Effect Galaxy Cluster Cosmology and Implications for eROSITA

Joseph Mohr[1,2,3]

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[2] *Excellence Cluster Universe* [3] *Max Planck Institute for Extraterrestrial Physics*

During the past decade the first successful Sunyaev-Zel'dovich effect (SZE) surveys for galaxy clusters have been carried out, delivering hundreds to thousands of new systems extending to the highest redshifts to which galaxy clusters have so far been detected. The cosmological analyses of these samples have delivered constraints competitive with the best other cosmological probes, but have also delivered lessons on the importance of cluster mass calibration, the importance of including selection effects and even the crucial role played by massive neutrinos in the cosmological interpretation of cluster samples. These samples have driven the development of new and improved analysis techniques that can now be applied to the eROSITA cluster sample. Moreover, the combination of SZE and X-ray constraints on large cluster samples opens the possibility of altogether new science.

Contributed Talk

Splinter eROSITA

Weak-lensing mass calibration of the Sunyaev-Zel'dovich effect using APEX-SZ galaxy clusters

A. Nagarajan[1], F. Pacaud[1] and APEX-SZ collaboration

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The use of galaxy clusters as precision cosmological probes relies on accurate determination of their masses. However, inferring the relationship between cluster mass and observables from direct observations is difficult and requires adequate control of the systematic effects caused by sample selection. In this talk, I present results on the mass (M_{500}) calibration of the integrated Comptonization ($Y_{\rm SZ}$) using weak-lensing estimates for an X-ray luminosity ($L_{\rm X}$) selected sample. To mitigate the sample selection biases, a novel Bayesian approach was used to fit the $L_{\rm X} - M_{500}$ and $Y_{\rm SZ} - M_{500}$ relations jointly. A special focus was also placed on the role played by the intrinsic covariance of cluster observables and the correlation of the intrinsic covariance of X-ray luminosity and integrated Comptonization at fixed mass. Our constraints on the correlation favour a positive value at 1σ. Ignoring this correlation tends to bias the $Y_{\rm SZ} - M_{500}$ relation, even though the Comptonization played no role in the sample selection. I discuss the impact of such systematic biases in scaling relations on some near-future cluster-based cosmological experiments and report that the systematic effect could dominate the cosmological error budget.

Contributed Talk

Splinter eROSITA

Galaxy clusters as cosmological probes: from observations to parameter constraints

F. Pacaud[1]

[1] *Argelander-Institut für Astronomie, Universität Bonn, Auf dem Hügel 71, 53121 Bonn*

Using galaxy clusters to study the large-scale structure of the Universe counts among the main science drivers of the eROSITA all sky survey. It is notably expected to provide accurate and essential information on the behaviour of the Dark Energy as well as any other component that affects the build-up of cosmic structures - such as relic neutrinos. In this contribution, I will describe which cosmological information can be extracted from the study of galaxy clusters and how this can be achieved with X-ray selected cluster samples. Based on some examples based on past and on-going X-ray surveys, I will highlight some of the challenges that the eROSITA cosmological program will need to solve and possible ways forward.

Contributed Talk

Splinter eROSITA

The X-ra cluster survey with eROSITA: constraints on dark-energy

A. Pillepich[1], T. Reiprich[2], C. Porciani[2]

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[2] *Argelander-Institut für Astronomie, Auf dem Hügel 71, D-53121 Bonn, Germany*

We forecast the potential of the X-ray galaxy-cluster telescope eROSITA to constrain Dark-Energy models. We focus on spatially-flat cosmological scenarios with either constant or time-dependent Dark-Energy equation of state parameters. The results are given by the combination of the abundance and spatial clustering of a synthetic photon-count limited sample of clusters of galaxies up to $z \sim 2$. We quantify our findings according to different scenarios for the availability of 1) X-ray follow-up observations, 2) photometric and spectroscopic redshifts, and 3) accurate knowledge of the observable – mass relation down to the scale of groups of galaxies. With 10^5 clusters from an average all-sky exposure of 1.6 ks (with at least 50 photons each), eROSITA will give marginalized, one-dimensional, 1σ errors of $\Delta\sigma_8 = 0.008$ ($\sim$1%), $\Delta\Omega_m = 0.006$ (2.2%), $\Delta w_0 = 0.07$ (7%), and $\Delta w_a = 0.27$ (optimistic scenario), in combination with and largely improving upon Planck data from the temperature anisotropies of the Cosmic Microwave Background.

Contributed Talk

Splinter eROSITA

Synthetic simulations of the extragalactic sky seen by *eROSITA*: pre-launch selection functions and cosmological forecasts

M. E. Ramos-Ceja[1], N. Clerc[2], F. Hofmann[3], J. Ridl[3], G. Lamer[4], F. Pacaud[1], H. Brunner[3], T. H. Reiprich[1], F. Käfer[3]

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[2] *IRAP, Université de Toulouse, CNRS, UPS, CNES, Toulouse, Frankreich*
[3] *Max-Planck-Institut für Extraterrestrische Physik, Garching, Deutschland*
[4] *Leibniz-Institut für Astrophysik Potsdam, Potsdam, Deutschland*

Galaxy cluster and AGN selection functions are essential in the science exploitation of the future extragalactic eROSITA survey. In this talk we present our strategy to perform extensive and dedicated “synthetic simulations” of eROSITA event lists and images. These simulations are specifically designed to reach a trade-off between tractability and realism. We show the results obtained when employing the current state-of-the-art eROSITA source detection algorithm. We derive a meaningful cluster selection function based on cluster fluxes and sizes. Such a selection function represents a step ahead of the simple count limit assumed so far in cosmological forecasts. Using this eROSITA cluster selection function, we confirm that eROSITA will be able to detect of $\sim 10^5$ clusters in the whole sky.

Contributed Talk

Splinter eROSITA

Results from current X-ray selected galaxy cluster samples and way forward to eROSITA cosmology

T.H. Reiprich[1]

[1] *Argelander-Institut für Astronomie, Universität Bonn, Auf dem Hügel 71, 53121 Bonn*

The latest results from detailed X-ray follow-up observations of large X-ray selected galaxy cluster samples are presented. A reanalysis of the ROSAT All-Sky Survey with a source detection method optimized for very extended sources is discussed. A new test to study the cosmological isotropy of the cluster population is introduced. An outlook on expected cosmological constraints from eROSITA, in particular on neutrino masses, is given.

Contributed Talk

Splinter eROSITA

Calibrating the masses of high-redshift galaxy clusters with deep weak lensing data

T. Schrabback[1]

[1] *Argelander-Institut für Astronomie, Universität Bonn, Auf dem Hügel 71, 53121, Bonn, Germany*

Cosmological constraints from galaxy cluster surveys, such as the one *eROSITA* will conduct, are currently limited by the accuracy and precision of the cluster mass calibration. In particular, constraints on dark energy properties and modified gravity theories require an accurate calibration over a wide redshift range. Ongoing ground-based weak lensing surveys employing wide-field imagers have the potential to provide the required calibration at low and intermediate redshifts. However, at higher redshifts deeper images with superb resolution are required in order to resolve the small and faint distant background galaxies.

In this talk I will first summarise and present results from our HST campaign to calibrate the masses of distant SPT clusters. First results have been presented in Schrabback et al. (2016; arXiv:1611.03866), and we are currently working on the analysis of an expanded sample at $z \sim 0.9$, as well as our latest Cycle 24 programme targeting 9 high SZ-significance clusters at $z > 1.2$. In addition, I will present results from a pilot study, which demonstrates that very deep good-seeing VLT/HAWK K_s images yield a weak lensing performance that matches single-orbit depth HST/ACS mosaics, thereby providing a viable alternative for the calibration of mass-observable scaling relations for high-mass clusters at redshifts $0.7 \lesssim z \lesssim 1.1$.

Contributed Talk

Splinter E-Science

Reproducibility in an Era of Data Driven Science

Polsterer, Kai

Heidelberger Institut für Theoretische Studien

Reproducibility of scientific research results is of tremendous importance, to enable other researchers to validate, to check and to build on published results. In data-driven research this requirement is more than publishing research results as a plain paper. We have to start sharing and publishing code as well as referencing the software packages that had been utilized. Data-sets used to train and/or derive models have to be published alongside with the code. The provenance of the data is as important as providing uncertainties. The use of proper scores to evaluate the performances and the publication of reference data-sets have to become standard in astronomy. When using deep learning schemes the derived weights, biases and hyper-parameters have to be published, too. This talk will focus on some of these important aspects.

Contributed Talk

Splinter E-Science

5 years of Daiquiri - Lessons learned and further developments

J. Klar[1], G. Matijevic[1], A. Galkin[1], K. Riebe[1], H. Enke[1]

[1]*Leibniz Institute for Astrophysics Potsdam (AIP)*

The publication of astronomical research data from observational surveys, as well as from computer simulations, remains a challenge to collaborations and data centers. These datasets, reaching hundreds of terabytes in volume, need to be selected and filtered before download, limiting the amount of transfered data to reasonable quantities. In recent years, queries written in SQL, or it's VO dialect ADQL, submitted through dedicated web services, became the preferred method for this process. This, however, results in a significant effort for the development and maintenance of these applications, in particular when hosting several different archives.

Already in 2012 we addressed this problem with the creation of the Daiquiri framework. Daiquiri enables us to create different highly customizable web applications for data publication, while only maintaining one common code base. At AIP, we employ Daiquiri to host the CosmoSim database, the APPLAUSE archive, the data releases of the RAVE survey, and our mirror of the Gaia archive. Daiquiri is open-source software and available on GitHub.

While Daiquiri is a great tool to keep our portfolio of data publications maintainable, several problems became evident in the past. Some of our choices regarding the used technology were not optimal and lead to a insufficient extensibility of the code. Also, more tools and libraries where recently developed and are now available to us. Therefore, we started a refactoring process towards a second version of Daiquiri written in Python. In Fall of 2017 we will publish this new `django-daiquiri` package.

In my talk, I will give an overview on our experiences with Daiquiri and discuss the different issues, which lead to the current rewrite. In addition, I will show a first web site created with `django-daiquiri` and how it can be applied by other institutions.

Contributed Talk

Splinter E-Science

A web portal for hydrodynamical, cosmological simulations

K. Dolag[1]

[1] *University Observatory Munich, Scheinerstrasse 1, 81679 Muenchen*

I will describes a new data centre hosting a web portal for accessing and sharing the output of large, cosmological, hydro-dynamical simulations with a broad scientific community hosted at LRZ. It also allows users to receive related scientific data products by directly processing the raw simulation data on a remote computing cluster. The data centre has a multi-layer structure: a web portal, a job control layer, a computing cluster and a HPC storage system. The outer layer enables users to choose an object from the simulations. Objects can be selected by visually inspecting 2D maps of the simulation data, by performing highly compounded and elaborated queries or graphically by plotting arbitrary combinations of properties. The user can run analysis tools on a chosen object. These services allow users to run analysis tools on the raw simulation data. The job control layer is responsible for handling and performing the analysis jobs, which are executed on a computing cluster. The innermost layer is formed by a HPC storage system which hosts the large, raw simulation data.

Contributed Talk

Splinter E-Science

Publishing Solar System Data using EPN-TAP and DaCHS

M. Demleitner[1]

[1] *Zentrum für Astronomie, Universität Heidelberg*

In the last couple of years, a new data model and protocol for publishing solar system data has been developed: EPN-TAP. By cleverly re-using VO technologies, the designers of the standard could concentrate on what metadata should be represented, not worrying about the technicalities of serialising data, transporting queries, or even query syntax. As an added benefit, standard VO tools can be used to discover and operate EPN-TAP services, as can a value-added web-based interface at `http://vespa.obspm.fr`. In this talk, we briefly describe the principles of EPN-TAP and how one would publish solar system data using GAVO's DaCHS publication package (see also `http://soft.g-vo.org/dachs`).

Contributed Talk

Splinter E-Science

Licensing of Open Source Projects

Streicher, Ole

Leibniz-Institut für Astrophysik Potsdam

Careful maintenance of the licenses for open source projects plays an important role for the distribution and long-term evolution of the software. This not only embraces the license selection for the own source code, but also license management for source code taken from elsewhere, and required third-party software. Wrong decisions here may significantly hinder the distribution of the package and create problems even after years of use.

In this talk, I will give an overview on the licenses used for astronomy packages in Debian, their advantages and disadvantages. I will both discuss the licensing problems experienced during the packaging, and the efforts to solve them.

Contributed Talk

Splinter E-Science

Fedora Astronomy - Integration of astronomical software into a Linux distribution

C. Dersch[1]

[1] *Philipps-Universitaet Marburg, Fachbereich Physik, D-35032 Marburg, Germany*

Fedora Astronomy is an effort to improve the astronomical software ecosystem. Many fundamental software packages in astronomy are free software and required for the astronomers daily work. An example is the Astropy package with its many affiliated packages for more special applications, but also the AstrOmatic software like SExtractor and applications to access the Virtual Observatory. Fedora Astronomy is organized as a *Special Interest Group* (SIG) which takes care of the integration of astronomical software into the Fedora Linux distribution. The advantage of this way of software distribution is a well integration into the operating system and between the different packages. Another task of the Fedora Astronomy SIG is the deployment of a ready to use Linux environment for the purposes of both amateur and professional astronomers, the Fedora Astronomy Lab. Finally the Fedora Astronomy SIG discusses issues, for example changes in depending applications or licensing, with upstream developers and takes care of the cooperation with other distribution projects like Debian Astronomy.

The talk will cover the organization of the Fedora Astronomy SIG as well as the current state of Fedora Astronomy and its position in the astronomical software ecosystem. Furthermore possible improvements in scientific software distribution and schemes for cooperation between the different Linux distributions will be discussed.

Contributed Talk

Splinter E-Science

Probabilistic photometric redshift derivation from multi-band imaging data

D'Isanto, Antonio

Heidelberger Institut für Theoretische Studien

The need to analyze the available large synoptic multi-band surveys drives the development of new data-analysis methods. Photometric redshift estimation is one field of application where such new methods improved the results, substantially. Up to now, the vast majority of applied redshift estimation methods utilize photometric features. We propose a method to derive probabilistic photometric redshift directly from multi-band imaging data, rendering pre-classification of objects and feature extraction obsolete. A modified version of a deep convolutional network is combined with a mixture density network. The estimates are expressed as Gaussian mixture models representing the probability density functions (PDFs) in the redshift space. In addition to the traditional scores, the continuous ranked probability score (CRPS) and the probability integral transform (PIT) are applied as performance criteria. We adopt a feature based random forest and a plain mixture density network to compare performances on experiments with data from SDSS(DR9). It is shown that the proposed method is able to predict redshift PDFs independently from the type of source, e.g. galaxies, quasars or stars. Thereby the prediction performance is better than both presented reference methods and is comparable to results from the literature. The presented method is extremely general and allows the solving of any kind of probabilistic regression problems based on imaging data, e.g. estimating metallicity or star formation rate of galaxies. This kind of methodology is tremendously important for the next generation of surveys.

Poster

Splinter E-Science

A study of photometric errors on two different photographic plate scans

M. Spasović[1], C. Dersch[1], A. Schrimpf[1], P. Kroll[2]

[1]*History of Astronomy and Observational Astronomy, Physics Department, Philipps Universität Marburg*
[2]*Sonneberg Observatory, Germany*

A considerable number of photographic plate archives exist world wide and digitization is in progress or already has been finished. Not only different type of scanners were used but also spatial resolution and dynamic range often were limited due to process duration and storage space. The open question is the effect of these limitations on the results. 61 high resolution photographic plates of the Gamma Cyg field from the Bruce astrograph at Landessternwarte Heidelberg–Königstuhl (aperture 40 cm, focal length 200 cm) had been digitized both in Heidelberg and Sonneberg. Both scanners were set to 16 bit dynamic range. The Heidelberg scanner was operated at 2540 dpi resolution, resulting in a scale of 1 arcsec/pixel, while the Sonneberg scanner was operated at 1200 dpi, yielding a scale of 2.1 arsec/pixel.

In the presented study the standard deviation of non–variable star light curves were examined in dependence of brightness and plate coordinates in both series. No evident differences could be found. A comparison of both scan series will be presented.

Poster

Splinter E-Science

The Bochum Galactic Disk Survey

M. Hackstein[1], C. Fein[1], M. Haas[1], R. Chini[1]

[1] *Astronomisches Institut, Ruhr–Universität Bochum, Universitätsstraße 150, 44801 Bochum, Germany*

The Bochum Galactic Disk Survey (GDS) is an on-going project dedicated to monitor the variability of the intermediately bright stellar population in a 6° wide stripe along the Galactic plane.
Started in 2010 it currently comprises light curves for $\sim 2 \times 10^7$ stars in Sloan r and i as well as average brightnesses in $UBVz$. Of those we currently find 110.456 stars to be variable in brightness.
The project aims at detecting any kind of stellar variability and providing high-quality light curves for their further analysis.
In particular, we focus on the variability during the star formation process as well as the stellar multiplicity as a function of mass as witnessed by eclipsing binaries, and the determination of Galactic Cepheid distances.

Contributed Talk

Splinter Euclid

The Euclid Dark Universe Mission, an introduction

Knud Jahnke[1] and the Euclid Consortium

[1] *Max-Planck-Institut für Astronomie*

ESA's Euclid Dark Universe Mission will launch in 2021 for a 6.5 year survey of the extragalactic sky. Its data are primarily meant as input for our understanding of Dark Matter and Dark Energy, but its high spatial resolution visible band imaging, deep multiband near-infrared imaging and spectroscopy, associated ground based, and simulation data will have legacy value from planets to galaxy evolution, from primeval universe science to solar system bodies. We will give an introduction to the Euclid mission, its technology, data, and timeline, and the options for still getting involved.

Contributed Talk

Splinter Euclid

The EUCLID NISP instrument status

F. Grupp[1], R. Bender[1]

[1] *Max Planck Institut für extraterrestrische Physik*

We will present the technical status of EUCLID NISP and the challenges we are acing together with the answers to these challenges.

Contributed Talk

Splinter Euclid

How to forecast a Euclid sky: simulating the Euclid telescope

G. Seidel[1]

[1] *Max-Planck-Institut für Astronomie, Heidelberg*

In anticipation of Euclid survey data, cosmological and instrument simulations are essential to develop an analysis pipeline adapted to the survey, integrate it across multiple science data centres, and validate end-to-end performance. Very recently, in June 2017, a major milestone in this effort was achieved with the completion of the Euclid Flagship cosmological simulation and galaxy catalogue. Instrument simulations were and are used to access the impact of specific survey conditions and instrumental effects on the science performance. More visible outside of the instrument teams, simulation challenges of increasing level of detail and data volume are set up, providing homogeneous output for given input source catalogues, instrument parameters, and environment conditions, across the Euclid VIS and NISP, and external, currently KiDS and DES, instruments. The data produced in these challenges are used to validate and verify the simulation software itself, in addition to supporting development of the analysis pipeline, including shear and redshift estimation. I will provide a brief overview of this effort, focusing on the instrument simulations.

Contributed Talk

Splinter Euclid

Galaxy clustering measurements with Euclid: an overview

Ariel G. Sánchez[1]

[1] *Max-Planck-Institut für extraterrestrische Physik, Postfach 1312, Giessenbachstr., 85741 Garching, Germany*

Thanks to the information of baryon acoustic oscillations (BAO) and redshift-space distortions (RSD), galaxy clustering measurements can both constrain the expansion history of the Universe and the growth-rate of cosmic structures, offering one of the most powerful cosmological probes. Due to its large volume and high number density, Euclid will provide BAO and RSD measurements with unprecedented precision, allowing us to put the LCDM model to its most stringent test yet. However, the small statistical uncertainties that can be expected from Euclid demand a careful analysis of all potential systematic errors, as these could dominate the final results. I will provide an overview of the expected galaxy clustering measurements from Euclid, with an emphasis on the strategies to mitigate and control all potential sources of systematic errors.

Contributed Talk

Splinter Euclid

Weak lensing science with Euclid: An overview

T. Schrabback[1]

[1] *Argelander-Institut für Astronomie, Universität Bonn, Auf dem Hügel 71, 53121, Bonn, Germany*

Weak gravitational lensing is one of the two primary techniques for the extraction of cosmological information from the *Euclid* data. I will provide a brief introduction into the field and illustrate some of the measurements that will be enabled by *Euclid*.

Contributed Talk

Splinter Euclid

Legacy Science with the Euclid Dataset

Joseph Mohr[1,2,3]

[1] *Faculty of Physics, Ludwig-Maximilians-Universitaet (LMU-Munich)*
[2] *Excellence Cluster Universe* [3] *Max Planck Institute for Extraterrestrial Physics*

The high angular resolution optical imaging from the Euclid VIS instrument, the deep near-infrared imaging in bands YJH together with the grism spectroscopy from the Euclid NISP instrument, and the associated ground based multiband optical imaging over 15000 deg^2 comprise a unique and phenomenally rich dataset for studies of the Universe. In addition to the core cosmic shear and galaxy clustering cosmological experiments, there is a broad range of other science— termed Legacy Science— that will be made possible by the Euclid mission. These broad scientific interests are represented in a large number of science working groups to which you are welcome to contribute. I'll present some highlights of the planning for Euclid Legacy Science with focus on some aspects that are particularly relevant for our community here in Germany.

Contributed Talk

Splinter Euclid

Cosmology with Galaxy Cluster with Euclid

J. Weller[1]

[1] *Ludwig-Maximilians-Universitt Mnchen*

I will discuss the potential of the Euclid Satellite to constrain cosmological parameters with the counts and distribution of galaxy clusters. I will elaborate on the importance on getting a good calibration of the uncertainties in the mass-observable relation. I will also briefly show the current efforts to define a cluster finder for the Euclid Satellite program.

Contributed Talk

Splinter Euclid

The Euclid Theory Working Group

L. Amendola[1]

[1] *ITP, University of Heidelberg*

I will present the activity of the Euclid Theory Working Group and highlight some of its recent work.

Contributed Talk

Splinter Euclid

Preparing Dark Energy Survey imaging for Euclid: Overview & Activities of Organizational Unit External Data (OU-EXT) Germany

Holger Israel[1], Joseph Mohr[1,3], Thomas Vassallo[1], Michael Wetzstein[2], Mohammad Mirkazemi[3,1], Maximilian Fabricius[2]

[1] *Fakultät für Physik, Ludwig-Maximilians-Universität München*
[2] *Max-Planck-Institut für Extraterrestrische Physik. Garching bei München*
[3] *Computational Center for Particle and Astrophysics, Excellence Cluster Universe, Garching bei München*

I will give an overview on the activities and goals of the Euclid Organizational Unit on External Data (OU-EXT) in Germany. The focus of our work is in ensuring that the Dark Energy Survey (DES) imaging data processed and calibrated within Euclid meet the data quality requirements on external data. These external data are needed for robust calibration of the Euclid VIS point response function and for the measurement of unbiased photometric redshifts of the Euclid VIS shear sample. The DES data are going to play a particularly crucial role for the early data releases of Euclid.

Contributed Talk

Splinter Euclid

OU-MER Status

Martin Kümmel

Faculty of Physics, Ludwig-Maximilians-Universitaet (LMU-Munich)

The Euclid satellite is an ESA mission scheduled for launch in 2020. It will observe an area of 15 000 deg^2 with two instruments, the Visible Imaging Channel (VIS) and the Near IR Spectrometer and imaging Photometer (NISP). Ground based imaging data in griz from surveys such as the Dark Energy Survey complement the Euclid data to enable photo-z determination. The mission investigates the distance-redshift relationship and the evolution of cosmic structures by measuring shapes and redshifts of galaxies and clusters of galaxies out to $z \sim 2$

The responsibility of the Organizational Unit (OU) MER is to generate multiwavelength catalogs from the Euclid data with in total $\sim 10^9$ objects which are stored in the archive and passed on to other OU's for photo-z and weak lensing analysis. I will discuss the concepts and strategies to generate the Euclid catalogues that meet the tight requirements on photometric accuracy.

The entire cataloging processing function saw first light during the currently ongoing Euclid Science Challenge 3 (SC#3). In SC#3 the various data processing functions (for VIS, NIR and external data) are run on simulated data in the Science Data Centers (SDC) in Garching and elsewhere in order to test and validate the data products against the requirements, and I will report preliminary results for the MER processing function.

Contributed Talk

Splinter Euclid

The German Euclid Science Data Center & Scientific Challenge 3

Maximilian Fabricius[1], Javier Gracia Carpio[1], Holger Israel[2], Joe Mohr[2,3], Antonello Piemonte[1], Frederic Raison[1], Thomas Vassallo[2], Michael Wetzstein[1]

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[2] *Fakultät für Physik, Ludwig-Maximilians-Universität München*
[3] *Computational Center for Particle and Astrophysics, Excellence Cluster Universe, Garching bei München*

The Euclid science data centers (SDC) provide the infrastructure for the processing of data not only from the space probe itself but also for the processing and homogenization of external datasets such as the Dark Energy Survey (DES) and the Kilo-Degree Survey. Further, they are responsible for the integration of the pipeline algorithms that are provided by the organizational units (OU) into the Euclid system and to interface them with the central orchestration and data archive. Specifically at SDC-DE, we integrate the processing pipeline for the data from the Dark Energy Survey, assist the implementation of the MER processing function that joins the photometric datasets from all instruments, are leading the definition of the strategy, selection and adaption of tools for common testing and validation, and are implementing a central monitoring and control system for the ground segment. Crucial for the computation of photometric redshifts, the DES dataset will be fully reprocessed within Euclid, following the requirements and standards for the Euclid data products. Currently we participate the ongoing Scientific Challenge 3 (SC3) which tests the processing functions, central processing orchestration, and the archive system across all SDCs using simulated data. The DES and MER processing functions participate such a project wide challenge for the first time. We will give an overview over the ongoing activities around the integration and development of pipelines, the testing and the hardware, specifically in the context of the SC3.

Contributed Talk

Splinter Euclid

Weak-lensing shear measurement with machine learning

M. Tewes[1]

[1] *Argelander-Institut für Astronomie, Universität Bonn, Auf dem Hügel 71, 53121, Bonn, Germany*

To minimize the statistical uncertainty of the cosmological inference, Euclid will measure weak gravitational lensing using images of $\sim 10^9$ source galaxies. The benefit from this large galaxy population can only be exploited if systematic errors of the shear measurement stay within unprecedented requirements. At the same time, the shear estimation on each source galaxy has to remain CPU-efficient, so that the measurement process remains applicable both to the data and to large simulations for calibration and testing purposes. I will present a supervised machine-learning approach to address this task. Using image simulations, we train artificial neural networks to predict shear estimates for each source galaxy. The networks empirically learn to correct for the PSF, noise bias, pixelization, morphology, and further bias sources on a galaxy-by-galaxy basis, reducing the dependence on prior knowledge of the source galaxy properties.

Contributed Talk

Splinter Euclid

How Accurate are Gravitational Lensing Simulations?

Stefan Hilbert[1,2], Alexandre Barreira[3]

[1] *Exzellenzcluster Universe, Boltzmannstr. 2, 85748 Garching, Germany*
[2] *Ludwig-Maximilians-Universität, Universitäts-Sternwarte, Scheinerstr. 1, 81679 München, Germany*
[3] *Max-Planck-Institut für Astrophysik, Karl-Schwarzschild-Str. 1, 85748 Garching, Germany*

The full science exploitation of Euclid requires very accurate predictions for key observables such as the gravitational lensing shear correlation functions. I present results from our project on the accuracy of numerical simulations of gravitational lensing, including a comparison study of various simulation codes in current use.

Contributed Talk

Splinter Euclid

Responses: a novel approach to the covariance of the matter power spectrum

F. Schmidt[1], A. Barreira[1]

[1] *Max Planck Institute for Astrophysics*

The covariance of the matter power spectrum is an essential ingredient in the inference of cosmological information from large-scale structure data. However, due to the nonlinear nature of large-scale structure, this covariance includes a significant non-Gaussian contribution, which is challenging to predict either numerically or analytically. I will describe a recently developed novel approach which combines perturbation theory with small-volume simulations to deal with this challenge. The core underlying idea is that the impact of large-scale density fluctuations, which dominate the non-Gaussian part of the covariance, can be captured by the local response of the small-scale power spectrum to such large-scale modes. This response in turn can be calibrated accurately with relatively small cosmological simulations.

Contributed Talk

Splinter Euclid

Reconstructing cosmological initial conditions using Bayesian statistics

F. Elsner[1], F. Schmidt[1], M. Nguyen[1], J. Jasche[2], G. Lavaux[3]

[1] *Max Planck Institute for Astrophysics*
[2] *Excellence Cluster Universe, Technische Universität München*
[3] *Institut d'Astrophysique de Paris*

To take full advantage of the constraining power of future experimental probes of large scale structure like *Euclid*, we have to develop and deploy improved statistical methods. Here, I will review a Bayesian framework introduced to infer the initial conditions that gave rise to the large scale structure that we observe today. I discuss recent advances in our theoretical understanding that allow to establish a principled connection between the underlying dark matter field and observable (biased) tracers thereof, like galaxies. After demonstrating how this model can be integrated into our statistical framework to faithfully reconstruct initial conditions on large scales that are exact up to the three point function statistics, I conclude my presentation providing a worked example analyzing simulated data.

Contributed Talk

Splinter Euclid

The Magneticum Simulations

K. Dolag[1]

[1] *University Observatory Munich, Scheinerstrasse 1, 81679 Muenchen*

Upcoming astronomical surveys and instruments like Planck, SPT, PanStars, DES, Euclid, LOFAR, eRosita and many more will need a theoretical counterpart in form of simulations which follow the formation of cosmological structures in so far unaccomplished detail, taking into account enough physical processes to allow a self consistent comparison to observations at multiple wavelength and throughout the entire epoch of structure formation. I will report the results from a recent simulation campaign (Magneticum, www.magneticum.org), where we followed the formation of cosmological structures in so far unaccomplished detail, performing a large set of cosmological, hydrodynamical simulations covering up to Gpc^3 volumes, taking into account enough physical processes (star-formation, chemical enrichment, AGN feedback) to allow a self consistent comparison to observations at multiple wavelength.

Contributed Talk

Splinter Exoplanets

SPP1992: Exploring the Diversity of Extrasolar Planets

H. Rauer[1]

[1] *A. Center for Astronomy and Astrophysics, TU Berlin, and Institute for Planetary Research,DLR*

One of the most exciting recent discoveries in astronomy is the existence of a huge variety of extrasolar planets orbiting other stars. Exoplanets can be very different to those found in our Solar System, and range from the so-called "Hot Jupiter" and "mini-Neptune" gas planets to large rocky planets ("super-"Earths).

In 2016 the Deutsche Forschungsgemeinschaft(DFG)accepted a proposal for a Priority Program (SPP 1992) which aims to explore such diversity and understand its origins.

The SPP will make substantial contributions to answering the following fundamental questions: What does the diversity of exoplanets tell us about their formation processes and the evolution of planets and planetary systems? What can we learn about the astrophysical conditions necessary to harbour life and are these conditions common in our Milky Way?

During 2017 the SPP is being implemented and will start with its kick-off meeting in early 2018. The talk will give an overview about the planned activities in the first funding period.

Contributed Talk

Splinter Exoplanets

Blue Planets around Red Stars – DFG Research Unit about the CARMENES Search for Exoplanets

A. Reiners[1]

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In a German-Spanish collaboration, we are carrying out a survey for exoplanets in 300 M dwarfs with CARMENES, the new optical- and near-infrared spectrograph at Calar Alto Observatory. The survey started Jan 01, 2016 and collected more than 8000 spectra until today. The talk will give an overview about the CARMENES project and the DFG Research Unit FOR 2544 that has been installed in 2017 for science exploitation of the CARMENES survey.

Contributed Talk

Splinter Exoplanets

First results from CARMENES visual-channel radial-velocity measurements

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We report new precise optical radial velocity (RV) measurements obtained with CARMENES for seven known M-dwarf planet hosts. These stars had been observed before with ultra-precise optical spectrographs such as HIRES and HARPS and were either reported to have one short period planetary companion (GJ 15 A, GJ 176, GJ 436, GJ 536 and GJ 1148) or are multiple planetary systems (GJ 581 and GJ 876). We aim at extending the baseline of observations for these stars and to quantify the performance of the CARMENES visual-channel in comparison with HARPS and HIRES. Our Doppler analysis of the combined HIRES, HARPS and CARMENES data uses by far the

Contributed Talk

Splinter Exoplanets

An Earth-sized planet transiting an M-dwarf in a 4.3-hour orbit

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We report the discovery from $K2$ of a transiting terrestrial planet in an ultra-short-period orbit around an M3-dwarf. The planet completes each orbit in just 4.3 hours, the second-shortest orbital period of any known planet, only 4 minutes longer than that of KOI 1843.03, which also orbits an M-dwarf. Using a combination of imaging, RV measurements, and light curve modelling, we show that no plausible eclipsing binary scenario can explain the $K2$ light curve, and thus confirm the planetary nature of the system. The short-period orbit of the planet, whose radius we determine to be 0.89 ± 0.09 $R_\oplus$, allows us to place constraints on its composition - we find it must be composed of at least 45 % iron. We also discuss the possible implications of the surprising fact that the two shortest-period planets known both orbit M-dwarfs.

Contributed Talk

Splinter Exoplanets

The optical slope in exoplanet spectra and a host star variability survey

Matthias Mallonn

Leibniz-Institut für Astrophysik Potsdam (AIP)

Ground-based extrasolar planet transmission spectroscopy is mostly done with 8meter-class telescopes, also by our group. In this talk, I will present how we extend these measurements by small-class telescope observations to obtain the planetary optical spectral slope. My explanation uses the illustrative example of our recent finding of magnesium silicates in the atmosphere of HAT-P-32b. The optical spectral slope of this planet is put into the context of the literature values of other hot Jupiters, revealing the text-book optical slope of HD189733b as an oddball. An optical slope in a planetary transmission spectrum can also be mimicked by spots on the host star. In the second part of the talk, I will briefly present our large survey VAMOS (VAriability MOnitoring of host Stars) to characterize star spots of the host stars. One of our first results was to reveal a particularly interesting target as one of the most active host stars known.

Contributed Talk

Splinter Exoplanets

Detecting the variation of measured spin-orbit angles of exoplanet due to the stellar activity

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The occultation of stellar active regions by the transiting exoplanet can generate anomalies in the high-precision photometric transit light-curves, and lead to an inaccurate estimate of the planetary parameters. Since the physics and geometry behind the transit light-curve and the Rossiter-McLaughlin (RM) effect are the same, the RM observations are expected to be affected by the occultation of a stellar active region in a similar way. Recently, Oshagh et al. 2016 demonstrated, by using simulations, that the inaccurate estimation on the spin-orbit angle owing to stellar activity can be significant (up to 40 degrees). In this talk I will present the preliminary result obtained from our simultaneous high-precision RM measurements (performed by HARPS) and photometric transit light-curve (through TRAPPIST telescope) during several consecutive transits of several transiting planets which they transit very active stars. Our results reveal, for the first time, the detection of variation in the measured value of spin-orbit angle due to variation in the stellar spots configuration between different transits.

Contributed Talk

Splinter Exoplanets

Matter Under Planetary Interior Conditions

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The new DFG Research Unit FOR 2440 *Matter Under Planetary Interior Conditions* aims at improving the understanding of the composition and structure of planetary interiors through an interdisciplinary approach, involving experiments, theory and modeling activities. The joint research program is performed at the BGI at U Bayreuth, DESY Hamburg, the DLR Institute for Planetary Research Berlin, the European XFEL GmbH Schenefeld, TU Berlin, and the U Rostock.

We study the physical properties of rock-forming minerals and complex molecular mixtures, which are relevant for super-Earths and Neptune-sized planets. Experimentally, structural properties and phase stabilities will be investigated using novel methods of high pressure and plasma physics enabling to access the pressure–temperature regime relevant for deep planetary interiors. Simultaneously, *ab initio* simulations will be performed in order to predict the thermophysical properties of these materials for a wide range of pressure and temperature. These simulations will be benchmarked by experiments, but will also be important for the preparation and evaluation of the proposed experiments. The acquired data will be used to constrain new models for the interior and the evolution of super-Earths and Neptune-like planets and for the evaluation of a proposed new observable, the tidal Love number $k_{2,f}$ as a measure for central mass concentration.

The modeling results including the tidal Love number shall be applied to evaluate observational data from running and future space missions such as GAIA, TESS, CHEOPS und PLATO 2.0.

Contributed Talk

Splinter Exoplanets

Debris Disks in Planetary Systems

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Debris disks are belts of comets, asteroids, and their dust around main-sequence stars. This circumstellar material represents a natural component of planetary systems – just as planets themselves. The incidence rate of debris disks, about one-fifth for solar-type stars, is roughly comparable to the frequency of exoplanet detections with current techniques. Debris disks serve as tracers of directly invisible small bodies and carry signatures of as yet undiscovered planets. They also reflect the accretion history and composition of planetesimals and bear imprints of the dynamical evolution of the entire systems, including planetary migration and scattering. Warm debris dust observed in some of the systems may indicate the ongoing terrestrial planet formation, as well as violent dynamical instabilities leading to orbital re-arrangement of planets. Thus debris disks have a vast potential as a source of information on planetary systems, complementary to the direct studies on exoplanets and their host stars.

In 2015, the German Research Foundation (DFG) established the Research Unit FOR 2285 "Debris disks in Planetary Systems". The Research Unit, running till at least 2019, is the first large-scale coordinated program in the German research landscape to focus on debris disks. The program is a joint effort of the University of Jena, Technical University of Braunschweig, University of Kiel, and the Hamburg Observatory. We employ state-of-the-art theoretical and laboratory methods to deeply analyze a wealth of observational data available and to prepare future observations of debris disks. We also carry out and interpret our own observations with facilities such as ALMA and SOFIA. This talk will briefly characterize the Research Unit and present some of the recent highlights from our ongoing research. It will also discuss the placement of the Research Unit among the other coordinated programs on exoplanets in Germany.

Contributed Talk

Splinter Exoplanets

Evolution of Planetary Systems on the Giant Branch

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With the growing number of exoplanets detected around evolved stars, it becomes evident that close-in planets (a $\lesssim$ 0.5 AU) are very rare around giant stars, while they are abundant around main-sequence stars.
One proposed explanation for this is that the stellar post-main-sequence evolution may alter planetary systems and cause engulfment of close-in planets (e.g. Villaver et al. 2014).
We study the effect of stellar evolution on the orbital architecture by simulating the combined effects of tidally induced orbital decay and mass loss induced orbital expansion on the semi-major axes of a number of planets detected around evolved stars belonging to the sample of the Lick radial velocity survey of giant stars (Reffert et al. 2015).
Starting out with the observed stellar, planetary, and orbital parameters, we use evolutionary tracks to reconstruct the past stellar evolution. We implement mass loss, tidal forces, and the change of eccentricity and evaluate their effect on the semi-major axis. Finally, we determine the initial orbital separations at zero stellar age by running our simulation backwards in time.
To illustrate the capabilities of our method, we present detailed simulation results for three stars from our sample: η Cet hosting a system of two planets in a 2:1 resonance, 91 Aqr whose planet might just barely have avoided engulfment, and the peculiar case of ι Dra and its very eccentric planet.

Contributed Talk

Splinter Exoplanets

A search for bow shocks around hot gaseous planets

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During the last years of exoplanet studies many planets with large radii, high masses and close orbits (the so-called hot Jupiters) were shown to have hydrogen rich atmopheres. It is generally assumed that hot Jupiters experience significant mass-loss through planetary winds, which transport neutral hydrogen into the expanded thermosphere. In the interaction region (bow shock) cold planetary material mixes with hot ionized gas from the stellar wind and a considerable excitation of neutral hydrogen occurs. This interaction region is located 5-10 Jupiter radii ahead of the planet so that it will manifest as an absorption signal before the beginning of the planetary transit.
To investigate the bow shocks we use optical transit spectra. The planetary atmosphere and the bow shock will manifest themselves as excess absorption in certain spectral lines. By analysing the time-dependence of the line depth we attempt to find planetary absorption features. Because we expect the atmophere to be composed primarly of hydrogen we focus on the Balmer series. Unfortunately, these lines are also affected by the stellar activity level. To exclude stellar activity patterns we also analyse the behaviour of strong chromospheric emission lines, e.g. Ca H and K as well as the Ca IRT triplet. Additionally we apply a telluric correction to our data.
So far we were unable to confirm any pre-transit absorption features. This allows us to deduce an upper limit of the strength of the planetary hydrogen absorption of about 5 milliangstroms. This finding is in contrast to Cauley et al. (2017), who suggest that a pre-transit signal of about 10 milliangstroms might be present in spectra of HD 189733b.
With the exception of HD 189733, significant pre-transit absorption signals in general have not been found. This implies that even strong stellar UV irradiation of a quiescent F or A star is not capable to excite enough hydrogen. For

Contributed Talk

Splinter Exoplanets

ALMA Observations of Planetary Systems

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Debris discs were first detected 3 decades ago when it was noticed that IRAS observations of a number of stars showed an infra-red excess above the stellar photosphere. These observations were quickly followed-up by a resolved image of the dust around beta Pictoris, clearly demonstrating it to be an edge on disc. But few other discs were resolved until much more recently. By looking for signatures in these resolved images they can tell us about the dynamical history of the planetary system and where planets might orbit today. ALMA has revolutionised such observations by giving us both high resolution and high sensitivity at long wavelengths. I will demonstrate its benefits by focusing on observations of three systems, all of which are also known to host planets: HR 8799, HD 95086 and epsilon Eridani. The ALMA images of all of these discs clearly resolve the inner edges and, in some cases, show other interesting features in the disc, allowing us to determine whether the known planets are responsible for the shape of the disc or whether other planets may be hiding in the system.

Contributed Talk

Splinter Exoplanets

Constraints on the structure of hot exozodiacal dust belts and their observability in the MIR

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Hot exozodiacal dust emission was detected around several main sequence stars at distances of less than 1 au using NIR and MIR interferometry. Studies of exozodis offer a way to better understand the inner regions of extrasolar planetary systems, and the possible presence of small grains in exozodiacal clouds is a potential problem for the detection of terrestrial planets in the habitable zone of these systems.

We modelled the observed excess of nine of these systems and found that grains have to be sufficiently absorbing to be consistent with the observed excess, while dielectric grains with pure silicate compositions fail to reproduce the observations. The dust should be located within $\sim 0.01 - 1$ au from the star depending on its luminosity. Furthermore, we found a significant trend for the disc radius to increase with the stellar luminosity. The dust grains are determined to be below $0.2 - 0.5\,\mu$m, but above $0.02 - 0.15\,\mu$m in radius. The dust masses amount to $(0.2 - 3.5) \times 10^{-9}\,\mathrm{M}_\oplus$. The near-infrared excess is probably dominated by thermal reemission.

In addition, we assessed the feasibility of observation and characterization of exozodis with the upcoming MIR instrument MATISSE at the Very Large Telescope Interferometer (VLTI). We find that MATISSE is potentially able to detect dust emission in five of the nine systems and will allow one to constrain the dust location in three of these systems, in particular to determine whether the dust piles up at the sublimation radius or is located at radii up to 1 au.

Poster

Splinter Exoplanets

Using ThNe calibration lamps for the radial velocity method

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The search for planets in the habitable zone around M dwarfs, like with CARMENES, requires a spectrograph that operates in the red part of the visible spectrum and offers a long-term precision of $1\,ms^{-1}$ in radial velocity measurements. ThAr hollow cathode lamps (HCLs) are the traditional choice for wavelength calibration but the red part of the spectrum is polluted with numerous strong and saturated lines of the filling gas Ar. The use of Ne is more promising. A critical issue for all HCLs is the current at which the lamp is operated. A low value of the operating current has the advantage that the lifetime of the lamp is longer whereas the number of useful lines is lower. This is important since the required calibration precision can only be achieved when combining a large number of spectral lines. We will report on measurements of a ThNe HCL taken at different operating currents. They were obtained with the Echelle spectrograph at the Thuringian State Observatory in Tautenburg.

Poster

Splinter Exoplanets

Photodynamical Modelling: An Update on Kepler-9

J. Freudenthal[1], C. von Essen[2], S. Dreizler[1] and the KOINet

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A photodynamical model describes all transit lightcurves of a planetary system simultaneously under consideration of the system's dynamics. Calculating the lightcurves from the output of a numerical integration over the time span of observations leads to a better understanding and characterization of the system. Such a model is most suitable for systems that show variations in the transit time (TTVs). These variations as well as variations in transit depth and duration are directly modeled and explained by the gravitational interaction of all system's objects. Our model is coupled with a Markov chain Monte Carlo algorithm, that helps to explore the parameter space.
We present the application of our model to the Kepler-9 system including new ground-based observations of transit lightcurves from the years 2014 - 2017 obtained by the KOINet, a multi-site network of telescopes around the globe organized to follow-up KOIs with large TTVs.

Poster

Splinter Exoplanets

Wavelet based filter methods for the detection and characterization of transiting planets in light curves of space based telescopes

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Stellar variability is one of the main constraining factors for the detection of shallow transits of small planets in high resolution stellar light curves. The Rheinisches Institut fr Umweltforschung (RIU-PF) has developed the software EXOTRANS to detect transits of exoplanets in stellar light curves since the CoRoT space mission (2006-2013). During the following years EXOTRANS was improved with different wavelet based filter methods (VARLET and PHALET) to separate stellar variation, orbital disturbances and instrumental effects from light curves. PHALET was also integrated into our Advanced BLS algorithm to remove detected transits from the light curve to improve the search for additional transits in systems with multiple planets. EXOTRANS removes detections of false positives including most binaries, many diluting background binaries and technical disturbances from the candidate list. Future missions like TESS and PLATO will need automatic detection pipelines like EXOTRANS to process the large number of light curves and to select the best candidates for follow-up observation. In future RIU-PF will further improve VARLET and PHALET for a better characterization of transiting exoplanets as part of the SPP 1992 Exploring the diversity of extrasolar planets Currently EXOTRANS is used to detect transit candidates in light curves of the Kepler successor K2 as part of the KESPRINT collaboration. Many new candidates were detected in K2 light curves and successfully confirmed by ground-based follow-up. Interesting new results of the KESPRINT collaboration are presented.

Poster

Splinter Exoplanets

Detectability of Moons Around Extrasolar Planets

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Moons in our solar system serve as tracers of planet formation and evolution. The densities and water contents of the Galilean moons, for example, put observational constraints on the properties of the circum-Jovian accretion disk, in which they formed 4.5 billion years ago; the Uranian satellites store information about the proposed bombardment process that caused the tilt of Uranus' spin axis; and most important for us, the Moon was formed through a giant impact of a Mars-sized object into the proto-Earth, which set the initial conditions for our contemporary astrophysical environment and, hence, for the terrestrial climate and life as we observe it today.

High-accuracy space-based stellar photometry, e.g. from the Kepler space telescope, has now opened the possibility of finding extrasolar moons. We present an overview of the methods that have been proposed to find exomoons, from photometry to spectroscopy and direct imaging. We summarize the current state of exomoon searches and we show new simulations of light curves as they will be obtained with PLATO, set to launch in 2026. In particular, we predict that the transits of large exomoons could be detectable in the wings of the phase-folded planetary transit light curves, an effect known as the orbital sampling effect. Such a historic detection would (i.) offer new constraints on planet formation and migration; (ii.) trigger an innovation push for moon formation theories; (iii.) provide unprecedented tools to measure planetary obliquities; (iv.) offer new means to constrain planetary masses; (v.) deliver novel insights into the wider context of the solar system planets and moons.

Poster

Splinter Exoplanets

The ROME/REA Microlensing Key Project – a window to planets beyond the snowline

M. Hundertmark[1] and the RoboNet team

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Gravitational microlensing provides us with a threefold complementary view on exoplanets: i) microlensing planets are typically found in orbits of ∼1-10 AU (i.e. beyond the snowline) around their host stars, ii) the majority of the stellar hosts are K or M dwarfs which are iii) located at distances of several kiloparsecs. Stellar microlensing events are very rare occurrences (about one in a million bulge stars is microlensed at any given time), but modern surveys that regularly monitor a few 100 million of stars, discover about two thousand stellar microlensing events per year. A handful of these exhibit the tell-tale signature of a planet beyond the snowline.

The ROME/REA Key Project is the largest science project running at the Las Cumbres Observatory (LCO) with the express aim of deriving the mass function of cold exoplanets via microlensing. Very little is yet known about those planets, yet they play a central role in models of planet formation and evolution.

We employ a novel approach that uses LCO's 1-m robotic telescopes at different longitudes on three continents to monitor a few times per day certain areas of the sky with a known high microlensing event rate. Additional LCO telescopes are relied upon to provide hourly observations of the most promising targets. Observations are scheduled automatically and carried out in three bands. The photometry for about three million stars observed by this survey will be released publicly at the end of the project and will be used as a training set for the upcoming WFIRST space mission.

We present a summary of the first observing season and ongoing software development. For further information, please visit *https://robonet.lco.global/*

Poster

Splinter Exoplanets

The Design of the High Resolution Spectrograph CARMENES - From the Optical to the Near-IR

A. Kaminski[1]

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The CARMENES instrument is installed at the 3.5 meter telescope at the Calar Alto Observatory in Spain and is in operation since January 2016. Its design is tailored to the search for extrasolar planets around M dwarfs. CARMENES consists of two independent but simultaneously fiber-fed high-resolution Echelle spectrographs. Together both channels cover the wavelength range from 520 to 1710 nm. Thereby CARMENES is the first instrument on sky that is dedicated to and optimized for precise radial velocity measurements at the level of a few meters per second across the visual and the near-IR wavelength range.

Except for the camera and detector systems, the two channels are identical in their design. Both spectrographs are being operated in vacuum. The visual channel is operated at room temperature, whereas the near-infrared instrument is cooled down to around 140 K.

A synopsis of the instrument's design will be given, including the substantial elements along the entire light path. In addition, the Carmenes survey aiming at detecting exoplanets around M-dwarfs, as well as further possible applications of the instrument are shortly outlined.

Poster

Splinter Exoplanets

Orbital parameter estimation of extrasolar multi-planet systems by Transit Time Variation

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Transit Time Variation (TTV) is the earlier or later occurrence of a planetary transit across the stellar disk relative to the time of a reference transit. TTV is dominantly caused by third body orbit perturbations by attracting forces acting on the transiting planet by at least one another planet inside or outside of the orbit of the known transiting planet. Gravitational interactions perturb the velocity of the transiting planet in its orbit which manifests in a periodical perturbation of the revolution period. Measurements of the transit times and the identification of differences from a mean transit period may prove the existence of further planets. The TTV is therefore a tool to confirm planetary candidates in multi-planet systems. Even non-transiting planets can be detected by the analysis of the TTV of a transiting planet. Their orbital elements can be estimated if the TTV is sufficiently resolved. The shape of the TTV curve, the sequence of the individual transit time differences as a function of observing time, depends on the orbital elements of the planet(s) in the system and may show very complex structures. Upcoming spaced-based surveys will observe various stars for which the usual planetary mass determination by ground-based radial velocity observation is not always possible. TTV is an alternative method for orbit determination which uses only the information from the light curve.

Poster

Splinter Exoplanets

Hydrodynamics and Thermodynamics of super-Earth Planets' First Atmospheres

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In the core accretion paradigm of planet formation, gas giants form a massive atmosphere in a run-away gas accretion phase once their progenitors exceed a threshold mass: the critical core mass. On the one hand, the majority of observed exo-planets, being smaller and rock/ice-dominated, never crossed this line. On the other hand, these exo-planets have accreted substantial amounts of gas from the circumstellar disk during their embedded formation epoch.

We investigate the hydrodynamical and thermodynamical properties of proto-planetary atmospheres by direct numerical modeling of their formation epoch. Our studies cover one-dimensional (1D) spherically symmetric, two-dimensional (2D) axially symmetric, and three-dimensional (3D) hydrodynamical simulations with and without radiation transport. We check the feasibility of different numerical grid geometries (Cartesian vs. spherical), perform convergence studies, and scan the physical parameter space with respect to planet mass and optical depth of the surrounding.

In terms of hydrodynamic evolution, no clear boundary demarcates bound atmospheric gas from disk material in a 3D scenario in contrast to 1D and 2D computations. The atmospheres denote open systems where gas enters and leaves the Bondi sphere in both directions. In terms of thermodynamics, we compare the gravitational contraction of the forming atmospheres with its radiative cooling and advection of thermal energy, as well as the interplay of these processes. The coaction of radiative cooling of atmospheric gas and advection of atmospheric-disk gas prevents the proto-planets to undergo run-away gas accretion. Hence, this scenario provides a natural explanation for the preponderance of super-Earth like planets.

Poster

Splinter Exoplanets

PhD Students Meeting

Measuring the radial velocity of Alpha Centauri

M. Lisogorskyi, H.R.A. Jones

University of Hertfordshire

Alpha Centauri is a primary target for planet search as it is the closest star system and its B component is a solar-type star. The HARPS spectrograph has provided over 22500 high resolution spectra over the last 10 years, but the data is hampered by stellar noise. This work is aimed at more in-depth study of the data set to reduce the impact of activity and enable robust inferences to be made about any exoplanets in orbit.

Poster

Splinter Exoplanets

Indicators for planets in debris disc systems

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We statistically analysed a sample of 71 spatially resolved debris discs in order to find indicators for existing planets in these systems. This sample is the largest of resolved debris discs investigated so far and contains nine systems with known planets. We combined targets resolved in thermal emission with a collection of discs resolved in scattered light. For each disc in the sample, the dust fractional luminosity is known from the spectral energy distribution, while the disc radius is constrained directly by the resolved image.

We searched for possible trends between the disc parameters (fractional luminosity and disc radius) and other properties of the systems (such as stellar luminosity and age of the systems). We have also considered the subsample of systems known to harbour planets to see whether they follow the same trends as the systems without previously discovered planets. For instance, we checked whether debris discs in systems with known planets are dustier or have a different size than those without planets. The primary goal here has been to find the systems that are likely to host as yet undiscovered planets and thus to identify the most promising targets for future planet searches.

We confirmed several trends reported previously. These are consistent with theoretical predictions, indicating that the collisional evolution models used can describe the observational results in a reliable way. Several other potential trends seen in this study can probably be attibuted to observational limitations or biases. As a result, we find it difficult to identify direct indicators for planets in systems with debris discs.

Poster

Splinter Exoplanets

Looking for Planets around A type stars - did we miss 166 of them in the Kepler field?

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Up to now very little is known about close-in planets of stars that are more massive than the Sun. Detecting such planets is important because they challenge our current understanding of planet formation and migration.

Recently, Balona (2014) identified 166 possible short-period planets around A-stars in the Kepler-survey. The stars show peculiar variations in their light-curves which can neither be caused by the rotation nor by pulsation of the stars. Using the formulae described in Faigler & Mazeh (2011), we conclude that the variations have the same order of magnitude as that of the ellipsoidal, beaming and reflection effects on a Jupiter sized planet.

We have therefore obtained about 160 spectra of a small subsample of those "Balona Stars" with the two echelle spectrographs at the Tautenburg and Ondřejov 2m telescopes. In our poster we will show first results of our analysis and provide upper limits for the masses of those possible planets.

Poster

Splinter Exoplanets

Masses and radii of the CARMENES target stars

A. Schweitzer[1], V. Bejar[2], J. Caballero[3], C. Cifuentes[4] C. del Burgo[5], D. Montes[4], V. Passegger[6], E. Solano[3], A. Reiners[6], I. Ribas[7] and the CARMENES consortium

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The mass of an individual, isoloated star can typically only be determined within large error bars. However, in order to also estimate the mass of a potential planetary companion it is crucial to have a small error bar for the mass of the host star.

For the CARMENES survey we implement different spectroscopic methods of determening the masses of its targets. Since the CARMENES targets are all nearby M dwarfs, they have or soon will have accurate trigonometric parallaxes. This allows us to determine luminosities, radii and finally masses. Depending on which spectroscopic parameters (T_{eff}, $\log(g)$) are used, which way of estimating B.C. is employed and which further (empirical) relations need to be applied, we get different accuracies for our results. They are further compared to empirical mass–luminosity relations or (if possible) to independent measurements.

Poster

Splinter Exoplanets

Towards Consistent Stellar Parameters for Giant Stars

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Lloyd (2011), Sousa et al. (2015) and Takeda & Tajitsu (2015) have recently shown that the mean sample masses of evolved stars targeted by Doppler searches for planets are significantly higher than masses derived by various other statistical methods. We use a Bayesian inference method to determine stellar parameters from evolutionary tracks for 1013 giant stars of the Kepler field that have available photometry and Gaia parallaxes and compare them to available asteroseismic masses and radii. Our method is also capable to distinguish between red giant branch and horizontal branch stars as it provides a probability for each case. For 86.3% of the investigated stars our determined evolutionary stage coincides with that from asteroseismology. For red giant branch stars, evolutionary track masses are systematically smaller than asteroseismic masses. The average fractional difference is $\langle \frac{M_{\rm trk.} - M_{\rm ast.}}{M_{\rm ast.}} \rangle_{\rm RGB} = -13.3 \pm 1.1\,\%$, while for horizontal branch stars we find systematically higher masses using evolutionary tracks, as the average fractional difference is $\langle \frac{M_{\rm trk.} - M_{\rm ast.}}{M_{\rm ast.}} \rangle_{\rm HB} = 19 \pm 1.2\,\%$. However, our current results are limited by the large statistical and systematic errors of the first Gaia data release. Using a sub-sample of stars with smaller observational errors decreases the average fractional difference of the red giant branch stars to $\langle \frac{M_{\rm trk.} - M_{\rm ast.}}{M_{\rm ast.}} \rangle_{\rm RGB} = -4.4 \pm 2.4\,\%$, while the average fractional difference of the horizontal branch stars is $\langle \frac{M_{\rm trk.} - M_{\rm ast.}}{M_{\rm ast.}} \rangle_{\rm HB} = 11.9 \pm 3.6\,\%$.

Contributed Talk

Splinter HiRes

Magnetic vortex flow at a supergranular vertex

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Photospheric vortex flows are thought to play a key role in the evolution of magnetic fields. Recent studies show that such swirling motions are ubiquitous in the solar surface convection and occur on a large range of temporal and spatial scales. Yet, their interplay with magnetic fields is poorly characterized. In this contributed talk we study the relation between a persistent photospheric vortex flow and the evolution of a network (NE) magnetic element at a supergranular vertex. We use long-duration sequences of continuum intensity images acquired with *Hinode* and the local correlation tracking method to derive the horizontal photospheric flows. Supergranular cells are detected as large-scale divergence structures in the flow maps. At their vertices, and co-aligned with NE elements, isolated regions are found where the velocity fields converge on a central point. One of them is observed as a vortex flow during the whole 24 hr time series. It is made of three consecutive vortices that appear nearly at the same location. At their core a NE element is also detected. Its evolution is strongly correlated to that of the vortices. The magnetic feature is concentrated and evacuated whenever is caught by the vortices and weakened and fragmented after the whirls disappear.

Contributed Talk

Splinter HiRes

Doppler Spectroscopy of the Solar Corona: Detection of Cool Prominence Material Embedded in a Hot Fe XIV Plasma Environment within a Fast Moving CME-Front

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Multi-wavelength eclipse observations of the coronal forbidden lines, namely Fe IX, X, XI, XIII and XIV, have shown how minor ions offer unique plasma diagnostics in the inner corona, starting from the solar surface out to several solar radii. These are currently untenable from any other platform or instruments. One of the advantages of these spectral lines is the radial extent of their emission that surpasses that of the ultraviolet. It is this radial coverage and the excitation properties of these lines, dominated by resonance very close to the Sun, which provides a unique tool for exploring the most critical region of the corona, namely the acceleration region of the solar wind. This is where the changes in the plasma properties and magnetic fields are the most pronounced. Coronal mass ejections (CMEs) are the largest and most dynamic explosions detected in the million degree hot Solar corona, with speeds reaching up to 3000 $km.s^{-1}$ at Earth's orbit. Triggered by the eruption of prominences, in most cases, one of the outstanding questions pertaining to the dynamic CME-prominence system is the fate of the cool ejected filaments. We present spectroscopic observations acquired during the 20. March 2015 total solar eclipse, which captured a plethora of red-shifted plasmoids from Fe XIV emission at approx. 2 x $10^6 K$. Approximately 10% of these plasmoids enshrouded the neutral and singly ionized plasma below 2 x $10^5 K$, also observed in prominences anchored at the Sun at that time. This discovery was enabled by the novel design of a dual-channel spectrometer and the exceptionally clear sky conditions on the island of Svalbard during totality. The Doppler red-shifts corresponded to speeds ranging from under 100 to over 1500

Contributed Talk

Splinter HiRes

Multi-wavelength observations of an arch filament system

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In this study, we present multi-wavelength observations of an arch filament system (AFS) using high-resolution data of the Dunn Solar Telescope (DST) covering different regions in photosphere and chromosphere. The AFS was observed close to active region NOAA 11658 on 2013 January 20 with the camera system Rapid Oscillations in the Solar Atmosphere (ROSA) and the Interferometric BIdimensional Spectrometer (IBIS) providing imaging and spectropolarimetric data, respectively. Examining the temporal evolution of the fibril system shows that a clumpy and an elongated part separated and a third structure formed at the same location. All three structures of the AFS are likely rooted in bright regions, as observed in the Fraunhofer G-band $\lambda 4308$ Å and the near-infrared (NIR) chromospheric absorption line Ca II $\lambda 8542$ Å, which are typically associated with footpoints of magnetic flux loops. In particular, we calculate horizontal and line-of-sight velocities of the plasma. The results show up- and down-streaming flows within the system. Especially, down-streaming flows in the lower part of the AFS increased to supersonic flow speeds towards the end of observations. The comparison of spectropolarimetric data obtained in the NIR Ca II line with satellite data of the Helioseismic and Magnetic Imager (HMI) demonstrates that the filamentary structures form Ω-loops by connecting positive polarities in the upper half with the dominating negative polarity in the lower half of the field-of-view (FOV). The clumpy structure resides at lower heights than the other elongated fibril structures and connects the positive polarity in the middle of the FOV with a strong negative polarity in the upper part of the region. Evolution and height dependence of different morphological structures in an AFS provided insight into the complex interaction between cool chromospheric plasma and magnetic fields.

Contributed Talk

Splinter HiRes

Small-scale Flux Cancellations Observed with Sunrise II/IMaX

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Magnetic flux cancellation is a dynamic process during which converging opposite polarity elements undergo mutual flux loss, followed by partial or complete disappearance of either or both of the elements from the photosphere. We investigated flux cancellations in a young active region observed with the IMaX magnetograph during the second flight of the balloon-borne observatory Sunrise. We identified eleven events, of which six take place between new emerging flux and pre-existing one, and five happen between previously disconnected features which converge toward each other and cancel out. All these cancellation events have an apparent lifetime less than ten minutes. The disappearing elements are of sub-arcsec spatial scale and reach a peak flux of about 10^{17} Mx. All the events except one exhibit linear polarization signal along the polarity inversion line (PIL) for at least some time during the event. Rise in line core intensity along the PIL is observed as cancellation proceeds between emerging flux and pre-existing one. Also, the Doppler velocity of the disappearing patch gradually switches from blueshift during the emerging phase to redshift towards the end. The Doppler velocity of the cancellations occurring between previously disconnected features is consistently redshifted. Based on these results, we will discuss possible physical scenarios that led to the observed cancellation events.

Contributed Talk

Splinter HiRes

Small scale chromospheric fibrils observed by SUNRISE 2

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The special observing conditions of the Sunrise observatory allow us observations with unprecedented temporal stability and spatial resolution in the UV. During the second scientific flight, a time series of narrow-band intensity images were recorded using the Sunrise Filter Imager (SuFI) in the Ca II H line for approximately one hour at a cadence of 7 seconds. Using this unique data set we used an automatic fibril tracking algorithm to identify and characterise the morphological properties of 598 slender Ca II H fibrils. In addition, the fibril tracking algorithm delivered an average backbone of every fibril allowing us the study of width and intensity oscillations at several positions along the fibril. A wavelet analysis was then applied to these oscillations to compute their periods, phase relations and the phase speeds. We find that a majority of the fibrils exhibit a clear anti-correlation between the width and intensity oscillations which can be interpreted as a sausage mode.

Contributed Talk

Splinter HiRes

High-resolution imaging and near-infrared spectroscopy of penumbral decay

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Combining high-resolution spectropolarimetric and imaging data is key to understanding the decay process of sunspots as it allows to examine the velocity and magnetic fields of sunspots and their surroundings. Active region NOAA 12597 emerged on 2016 September 22 in the southern hemisphere of the solar disk. The region was observed two days later on 2016 September 24 with the GREGOR solar telescope. High-resolution imaging, spectroscopic, and spectropolarimetric data in various spectral lines revealed the physical properties of the photosphere and chromosphere. These data were complemented by synoptic line-of-sight magnetograms and continuum images obtained with the Helioseismic and Magnetic Imager (HMI) onboard the Solar Dynamics Observatory (SDO). The leading sunspot was at its maximum growth and slowly started to disintegrate at the time of GREGOR observations. We discuss the photospheric and chromospheric flow fields along with the magnetic fields during the decay of a large penumbral sector. The penumbral filaments of the leading spot facing the site of ongoing flux emergence started to decay first. However, they do not simply vanish but intermingle with nearby granules and even temporarily form darkened areas resembling umbral cores. The interaction between newly emerging and already established flux systems likely

Contributed Talk

Splinter HiRes

Probing the photospheric magnetic field with new spectral line pairs

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The magnetic line ratio (MLR) method has been extensively used in the measurement of photospheric magnetic field strength. It was devised for the neutral iron line pair at 5247.1 Å and 5250.2 Å (5250 Å pair). Other line pairs as well-suited as this pair have not been reported in the literature. We have identified two new line pairs that are very well adapted to be used for MLR measurements. The first pair is in the visible, Fe I 6820 Å - 6842 Å, and the other is in the infrared (IR), Fe I 15534 Å - 15542 Å. We use a three dimensional magnetohydrodynamic (MHD) simulation representing the quiet Sun atmosphere to synthesize the Stokes profiles. Then, we apply the MLR technique to the Stokes V profiles to recover the fields in the MHD cube both, at original resolution and after degrading with a point spread function. In both these cases, we have made the first attempt to empirically represent the field strengths returned by the MLR method in terms of the field strengths in the MHD cube. The lines in the new pairs reproduce the magnetic fields in the MHD cube rather well, better than the original 5250 Å pair. Due to their higher Zeeman sensitivity, the lines in the new pairs are ideal for the measurement of weak fields. The new IR pair, due to its large Stokes V signal samples more fields in the MHD cube than the old IR pair at 1.56 μm, even in the presence of noise, and hence likely also on the real Sun, making them favourable also for the inversions.

Contributed Talk

Splinter HiRes

Brightness of solar magnetic elements as a function of magnetic flux at high spatial resolution

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We investigate the relationship between the photospheric magnetic field of small-scale magnetic elements in the internetwork region of the quiet Sun at disk center, and the brightness in the UV spectral ranges at 214 nm, 300 nm, 313 nm, 388 nm, and 397 nm, and in the visible at 525.02 nm (line core of the Fe I spectral line) and 525.40 (continuum), by analysing spectropolarimetric and imaging time series acquired simultaneously by the Imaging Magnetograph eXperiment (IMaX), and the Sunrise Filter Imager (SuFI), on-board the balloon-borne observatory Sunrise during its first science flight in June 2009, with high spatial and temporal resolution.

We find a tight dependence between the line of sight component of the magnetic field B_{LOS}, and the emission from the lower chromosphere (sampled by Ca II H-line at 397 nm), revealing the role of these elements in chromospheric heating. We also find a dependence between the contrast in the UV and B_{LOS}, that is best described by a logarithmic function. This, along with the high contrast reached at these wavelengths, reveals the contribution of small-scale elements in the QS to the irradiance changes for wavelengths below 388 nm, which was never studied before at such high resolution. We also show by plotting the continuum contrast at 525.40 nm against B_{LOS}, that strong magnetic field elements in the internetwork were resolved by IMaX, resulting in constant contrasts for large magnetic fields in our I-B scatterplot, unlike the turnover obtained in previous observational studies. This turnover is due to the intermixing of the bright magnetic features with the dark intergranular lanes surrounding them.

Contributed Talk

Splinter HiRes

Spectropolarimetric inversions using spectral lines formed in non-local thermodynamic equilibrium

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Strong spectral lines which provide diagnostics of higher layers of the solar atmosphere are usually formed in so called non-local thermodynamic equilibrium (NLTE). This makes calculation of the emergent Stokes spectrum computationally demanding, which is especially important in the context of so called spectropolarimetric inversions. In this contribution we present our take on this problem. We present a semi-analytical method for computing response functions of NLTE lines to atmospheric parameters which significantly speeds-up the inversion procedure. We then comment of diagnostic capabilities of Na D1 and D2 spectral lines and discuss the eventual inversions using the spectral window around this line pair.

Contributed Talk

Splinter HiRes

Image restoration of solar slit spectra

Michiel van Noort

Max-Planck Institute for Solar System Research

Image restoration has become an indispensable post-facto tool for removing residual image distortions and degradation in solar image data, necessary to reach the diffraction limit of current solar telescopes, even if the data are corrected in real time by state-of-the-art adaptive optics systems. These methods do not work very well on spectrograph data, due to the lack of image information in such data in the direction perpendicular to the slit. With the latest generation of fast, low-noise detectors, this problem can now be addressed by using images recorded strictly simultaneously with the spectral data, and using the PSF of each exposure, obtained during the image restoration of these data, to map the spectral data back to their undegraded state. The restored spectra have a spatial resolution that is close to the diffraction limit of the telescope.

Contributed Talk

Splinter HiRes

The potential of many-line inversions of photospheric spectropolarimetric data in the visible and near UV

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Our knowledge of the lower solar atmosphere is mainly obtained from spectropolarimetric observations, which are often carried out in the red or infrared spectral range and almost always cover only a single or a few spectral lines. In preparation for the development of a slit spectropolarimeter for the third science flight of the balloon-borne observatory Sunrise we investigate the feasibility of spectropolarimetry in the short-wavelength range, 3000 Å – 4300 Å, where the line density but also the photon noise are considerably higher than in the red. For an ensemble of state-of-the-art magneto-hydrodynamical atmospheres we synthesize exemplarily spectral regions around 3140 Å (containing 352 lines), around 4080 Å (265 lines), and, for comparison reasons, around 6302 Å (80 lines). The spectral coverage is chosen such that at a spectral resolving power of 150000 the spectra can be recorded by a 2K detector. The synthetic Stokes profiles are degraded with a typical photon noise and afterwards inverted. The atmospheric parameters of the inversion are compared with the original MHD quantities. We find that from many-line inversions significantly more information can be obtained than from the traditional approach at identical wavelengths. A comparison of the three considered wavelength regions shows that the many-line approach at 4080 Å provides equally good results than at 6302 Å, the determination of the line-of-sight (LOS) velocity is even more precise by a factor of two. Compared with the red, the many-line approach at 3140 Å provides indeed larger uncertainties for the magnetic field strength, but similarly good temperatures, and LOS velocities that are more precise by roughly a factor of two. We conclude from our results that many-line spectropolarimetry at short wavelengths offers high potential in solar physics.

Contributed Talk

Splinter HiRes

The new understanding of penumbral formation

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Fully-fledged penumbrae are a well characterised phenomenon from an observational point of view. Also, MHD simulations reproduce the observed characteristics and provide us with insights on the physical mechanisms possibly running behind the observed processes. Yet, how this penumbral magneto-convection sets in is still an open question. Due to the fact that penumbra formation is a relatively fast process (of the order of hours), it has eluded its observation with sufficient spatial resolution by both, space- and ground-based solar observatories. Only recently, some authors have witnessed the onset of both orphan and sunspot penumbrae in detail. We are one of those. In July 2009, we observed the early stages of the NOAA 11024 leading sunspot while developing its penumbra. The spectro-polarimetric dataset lead us to new observational findings. In this contribution, we put into context our and other authors? results to draw the overall picture of sunspot formation. Most important, the comparison on the properties of different types of penumbrae lead us to the conclusion that the formation of penumbrae is not just one mechanism. The sole cause necessary for penumbral magneto-convection is a stably inclined magnetic field. Observations show that inclined fields can be caused by flux emergence, to form orphan penumbrae, or by field lines dragged down from upper photospheric layers, to form sunspot penumbra. This conclusion, together with the recent finding by Jurcak et al. on a canonical value of the vertical component of the magnetic field blocking the action of penumbral magneto-convection in umbral areas, is a crucial step forward to our understanding on the coupling of solar plasmas and magnetic fields in penumbral atmospheres. We shall present all these new insights on penumbra magneto-convection.

Contributed Talk

Splinter HiRes

Dynamic fine-structure in magnetic processes in the solar photosphere

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We present multi wavelength observations of an active region observed with the upgraded Broad Band Imager (BBI) at the GREGOR telescope. The BBI was recently equipped with two sCMOS cameras capable of taking 50 frames per second at 2560 x 2160 pixels. With the help of a filter wheel holding up to 4 broad band interference filters, a cadence of 8 seconds per wavelength position can be reached. A second imaging channel is equipped with a Lyot filter tuned to the H-Alpha line to take cospatial and cotemporal images of chromospheric layers. On May 25th 2017 we could take a sequence consisting of 100 images per wavelength position of a dissolving pore in active region NOAA 12659. During this sequence, which lasted about an hour, a light bridge located inside and partly surrounding the pore underwent a rapid evolution.

Contributed Talk

Splinter HiRes

The Jurčák criterion: Magnetic property of boundaries in pores, proto-spots, and umbrae

Markus Schmassmann, Philip Lindner, Michael Pircher, Nazaret Bello González, Morten Franz, & Rolf Schlichenmaier

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The various ways of energy transport in radiatively driven magneto-convection determine the structure of sunspots. At first glance, sunspots are composed of a dark umbra and a brighter penumbra. The transition between umbral and penumbral has only recently been discovered to depend on an invariant magnetic property: a value of 1860 G for the vertical magnetic field component. This Jurčák criterion states that region with values smaller than that value are prone to form a penumbra, and that fully-fledged stable sunspots have their umbral-penumbral boundary at that value. We use HMI@SDO and GRIS@GREGOR spectro-polarimetric data to further investigate the boundaries of pores, proto-spots, and umbrae in order to elaborate on the consequences of the Jurčák criterion for the stability of these magnetic manifestations.

Contributed Talk

Splinter HiRes

Fast dual-beam spectropolarimetry - first results on scattering polarization measurements with FSP II at the DST

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Calculations, based on 3D MHD solar atmosphere simulations, of the photospheric Sr I 4607 Å spectral line, known for its strong scattering polarization signals of up to 1%, predict a unique spatial distribution of linear polarization, induced by scattering of the locally fluctuating radiation field, even when observed at disc center. Thus far, however, insufficient polarimetric sensitivity, spatial resolution and/or low cadence have prevented this pattern in the linear polarization from being detected in observations. We present preliminary results of observations with the Fast Solar Polarimeter (FSP) in the Sr I 4607 Å line at disc center, carried out with the Dunn Solar Telescope (DST) at Sacramento Peak, New Mexico. With a high-cadence, dual-beam spectropolarimeter (FSP II) attached to a modified commercial CMOS camera, noise levels as low as $5 \cdot 10^{-4}$ per pixel are achieved after 2 minutes of temporal binning.

Contributed Talk

Splinter HiRes

VTF: visible tunable filter for DKIST

Nazaret Bello González & the VTF team

Kiepenheuer-Institut für Sonnenphysik, Freiburg

The VTF is an instrument based on large-format Fabry-Prots for imaging spectro-polarimetry. It will take narrow-band images of the Sun at very high spatial and temporal resolution, allowing for rapid imaging spectrometry, Stokes imaging polarimetry, and accurate surface photometry. At first light, the VTF will be available in a configuration with one hi-res etalon. In the talk, we will give a brief update on the overall instrument development and the etalon manufacture. We will discuss key science cases that will/can be addressed with the single-etalon VTF and give an outlook on the full science capabilities of an upgraded two-etalon VTF.

Contributed Talk

Splinter HiRes

Autonomous data reduction for the space-borne spectropolarimeter PHI

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ESA's next mission for solar science, the Solar Orbiter, will carry the Polarimetric and Helioseismic Imager (PHI). The spacecraft will orbit the Sun in highly elliptical orbits, gradually leaving the ecliptic plane. This unique orbit design makes PHI the first solar spectropolarimeter to be subjected to such dynamic environment, under highly restricted operational conditions.

Leaving Earth orbit Solar Orbiter provides as little as 50 Gbits/orbit temeletry for PHI, while the desired high resolution spectropolarimetric data with the necessary accuracy is 2 Gbits/dataset. Due to this restriction PHI implements on-board data analysis as a sophisticated data compression strategy, inverting the radiative transfer equation before downloading the data.

The pre-calibration of the raw science images is consequently done onboard too. The data necessary for the pre-calibration is partly obtained from ground calibration campaigns, and partly measured in flight, enforced by the large environmental changes and instrument ageing (e.g. the dark and flat field).

Due to the lack of dedicated calibration equipment on-board we have designed and tested methods that estimate the calibration data from images taken of the Sun. The most significant challenge in their implementation is the low communication rate with the satellite. This imposes full autonomy in collecting the calibration data, processing it, then applying it to the science data. For all the steps we analysed potential faults, designed detection

Contributed Talk

Splinter HiRes

High-resolution Fast Imager (HiFI) Image Quality and Image Restoration

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The High-resolution Fast Imager (HiFI) is one of the facility instruments of the GREGOR telescope at Observatorio del Teide, Izaña, Tenerife, Spain. High-cadence (about 50 Hz), large-format (2560 × 2160 pixels) detectors facilitate exploring the dynamic Sun with a spatial resolution close to the telescope's diffraction limit. Standard interference filters cover three interesting regions in the blue part of the spectrum, i.e., the strong chromospheric absorption line Ca II H (λ396.80 nm), the Fraunhofer G-band (λ430.70 nm), and the blue continuum (λ450.55 nm). A programmable timing unit precisely synchronizes the two scientific CMOS imagers and serves as the interface between control computer and cameras. We present preliminary HiFI results and demonstrate its science capabilities. High-cadence imaging and frame selection ('lucky imaging') in combination with real-time correction by an adaptive optics (AO) system are essential for image restoration to obtain nearly diffraction-limited solar images. Thus, assessing image quality in time-series data is very important. The 'Median Filter Gradient Similarity' (MFGS) image quality metrics is applied to AO-corrected image sequences of a pore and a small sunspot. Modifications of the MFGS algorithm uncover field- and structure-dependence of this image quality metrics. We demonstrate that fast cadence and millisecond exposure times are still insufficient to reach the coherence time of daytime seeing. This poses challenges for large-format and high-cadence detectors, which are proposed for the next generation of 4-meter aperture solar telescopes.

Poster

Splinter HiRes

Model Based Calibrations of Microlensed Hyperspectral Imager

Anantha Chanumolu[1], Michiel van Noort[1]

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A prototype of Microlensed Hyperspectral imager (MiHi) was installed and tested at the Swedish Solar telescope, La Palma. MiHi can simultaneously record spatial and spectral information onto a 2D detector without compro-minising on either resolutions. In order to reformat the data and flat field the frames from the instrument, a model based calibration technique is being developed. The two step calibration technique uses the physical model of the instrument to map the spatial and spectral elements from object plane onto the detector. The first step is the developement of a physcial model based on the optical principles of the instrument. Telluric lines' positions in the flat frame from the the instrument are used to match the physical model to the actual instrument by optimizing selected open parameters in the model. The second step involves modelling the psf of the instrument. Using earlier discussed physcial model of the instrument and initial guess of psf, the expected image from the instrument can be simulated. This simulation is matched to the actual data by optimizing the psf of the instrument. Such an optimized model is then ready to do a predictive calibration of the data. In this poster we will present the development and performance of model based calibration technique of MiHi.

Poster

Splinter HiRes

PAMIS: A Partially Multiplexed High Resolution Imaging Spectrometer

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A multi-channel partially multiplexed spectrometer (PAMIS) has been developed for the investigation of sparse spectra as they are typical for emission and absorption processes in the Sun and it's corona.
The analysed object is imaged onto a slit mirror (a mirror where a slit-like portion has been removed by laser ablation) the image being monitored by a separate camera. Light transmitted through this slit is then analysed by the PAMIS spectrometer. The spectrometer separates the incoming light into different broad spectral regions with the use of multi-layer dichroic mirrors in combination with colour cut-off and band filters. The output from each of these channels is then analysed by a an echelle gratings (one for each channel) operated in higher - typically 40th to 60th - order thus obtaining a resolution between 15000 and 20000 for slit sizes of 50 micron. Each spectral line appears several times in the spectrum in different order, the separation of the lines being a function of wavelength. Due to the well defined positions of each of these higher order lines a unique assignment is possible for as many as 200 lines in each channel. Data taken by a 2-channel and a 3-channel PAMIS will be shown which have been collected during the 2015, 2016 and possibly the 2017 total Solar eclipses. Data reduction techniques will be discussed.

Poster

Splinter HiRes

New results on supergranulation

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Supergranulation appears on the solar surface as a cellular pattern of horizontally diverging flows. Its characterization remains an important subject of solar physics since its discovery over fifty years ago. The depth of supergranules and their subsurface behavior are open questions and answering them could eliminate some scenarios of formation of the structure.

In particular, different hypotheses of convective origin place involve different vertical extents and driving scales for supergranulation. We aim to constrain the depth and subsurface velocity of supergranular flows for an average supergranule.

We design axisymmetric models of mass-conserving supergranular flows in spherical-polar coordinates and study their ability to reproduce photospheric observations from the Helioseismic Magnetic Imager (HMI) for an average supergranule. We obtain the radial flow from Doppler observations and the horizontal flow from local correlation tracking applied to intensity images.

Flow perturbations lead to changes in the wave propagation inside the Sun which are reflected in the value of travel-times. We simulate a flow perturbation to a solar-like reference model using the Montjoie finite element solver.

Models that are not separable in r (radius) and θ (heliocentric angle from the center of the supergranule) cannot reproduce the observations. For a separable model that fits the horizontal component, the radial χ_r^2 is 52.

We show one example of flow perturbation to a solar-like reference model using a non-separable flow model that fits photospheric observations. The simulated cross-correlations for the reference model match observations. This is a first step to constrain flow models using time-distance helioseismology.

Poster

Splinter HiRes

Umbral sunspot spectra observed with LARS compared to cool stars

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Compared to the Quiet Sun, sunspot umbrae yield a much more complex spectrum consisting of atomic and especially molecular lines. By the lack of magneto-convection the temperature in the umbra is decreased by up to 2000 K. To gain information about the umbra observed with the Laser Absolute Reference Spectrograph (LARS) at the Vacuum Tower Telescope (VTT) on Tenerife, we compare the high-resolution umbral spectrum with additional cool star spectra recorded with the High Accuracy Radial velocity Planet Searcher (HARPS). For the spectral region around 538 nm we find a high correlation between the umbral spectrum and late K and early M dwarf stars. By applying a weak field approximation to the strong magnetically sensitive Fe I lines in the spectral range, we estimate the magnetic field strength in the dark umbra to around 3000 G. In conclusion, we were able to indirectly estimate the temperature and chemical composition in the sunspot umbra based on star spectra. Future multi-instrumental studies of the high-accuracy instruments LARS and HARPS will allow a deeper insight into molecular investigations.

Poster

Splinter HiRes

Scattering theory of Paschen-Back effect: application to Li i 6708 Å doublet

Sowmya K.[1], Nagendra K. N.[2], Sampoorna M.[2], Stenflo J. O.[3,4]

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The diagnostically important Li i D lines in the Second Solar Spectrum result from the transitions between the fine structure states and are separated by 0.15 Å. Since the Li atom possesses a finite nuclear spin, it undergoes hyperfine structure splitting, and hence is governed by the quantum interference processes that take place among the magnetic substates belonging to different fine and hyperfine structure states. This interference gets modified in the presence of a magnetic field, and leaves its signatures in polarization which can serve as tools to study the vector magnetic field in the solar atmosphere. With this motivation, we develop the polarized redistribution matrix including Paschen–Back effect, based on the Kramers–Heisenberg scattering matrix approach, and apply it to model the polarization profiles of the Li lines observed in the Sun. We make use of the last scattering approximation which is based on the concept that the polarization of the emergent radiation is generated in the last scattering event, before the radiation escapes from the atmosphere. We present a comparison of the quiet Sun observations of the linear polarization profiles of Li D lines with the theoretical profiles computed using our simple modeling approach.

Poster

Splinter HiRes

Comparison between time-distance and ring-diagram helioseismology measurements of subsurface convective flows

Kaori Nagashima[1], Thomas L. Duvall Jr. [1], Aaron C. Birch[1], Laurent Gizon[1,2]

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Helioseismology enables us to probe the solar interior using the acoustic oscillation signals observed on the solar surface. Here we focus on two methods: time-distance and ring-diagram analysis. In time-distance analysis, the travel times of the acoustic waves are measured from the surface oscillation signals and used to infer the flows in the subsurface region where the acoustic waves propagate. On the other hand, in ring-diagram analysis, shifts of the acoustic-wave eigenfrequencies in each targeted area are measured and used to infer the flows under the area.

We aim to find the cause of the orders-of-magnitude discrepancy between the two measurements of the deep convective flow energy: the deep-focusing time-distance analysis (Hanasoge et al. 2012) and the ring-diagram analysis (Greer et al. 2015) measurements. For that, we directly compare the two methods with each other using the identical observational datasets from the Helioseismic and Magnetic Imager (HMI) on board Solar Dynamics Observatory. We also compare them with the HMI ring-diagram pipeline products (Bogart et al. 2011).

We confirm that the intermediate products from both (HMI pipeline and Greer's) ring-diagram analyses as well as the deep-focusing time-distance analysis give the similar-order-of-magnitude estimates of the subsurface flow. This indicates that the huge discrepancy between the final estimates of the deep convective flow given by the time-distance (Hanasoge et al. 2012) and ring-diagram (Greer et al. 2015) analyses likely result from the later stages of the

Poster

Splinter HiRes

Multiple scattering of acoustic waves

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Convective motions near the solar surface may interact with the acoustic waves propagating in the solar medium, which is not taken into account by current helioseismic studies. However, this can affect the interpretation of the observations, since it triggers heterogeneities in the medium, thus turbulent scattering of the waves. Moreover, the timescale of variation of granulation is comparable to the period of the waves, meaning that the medium may not be assumed stationary anymore. In order to study this acoustic scattering, I look at the average and variance of scattered waves over realisations of a random medium. As a preliminary diagnosis, I use finite differences to model the propagation of acoustic waves in a 1D medium with random sound speed. The results show that multiple scattering occurs for low correlation times ($\tau < 1$ min) or strong perturbations ($\delta c > 0.1 c_0$). For granulation ($\tau \simeq 400$ s, $\delta c < 0.1 c_0$), it turns out that the stationary-medium approximation is valid.

Poster

Splinter HiRes

Dissipation of Alfvén waves through ion-neutral interactions

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We investigate the ability of ion-neutral interactions to dissipate Alfvén waves in the solar chromosphere. An acoustic driver is used to generate perturbations in a self-similar magnetohydrostatic flux tube model. As these waves travel into the center of the magnetic field concentration, significant energy is dissipated, a factor of 20 higher than the dissipation of static currents. This heating is caused by the damping of magnetic waves, as seen by a decrease in Poynting flux when ambipolar diffusion is included. The dependence of this energy dissipation with resolution, driver amplitude and frequency is studied.

Poster

Splinter HiRes

Supergranular Waves Revisited

J. Schou[1], A. Barekat[1]

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Supergranulation, a pattern of roughly 30 Mm sized convective cells on the Sun, was initially discovered by Hart et al. in the 1950s, but they are still poorly understood. In 2002 Gizon, Duvall and Schou, using a time-distance helioseismic method, reported that the supergranulation shows a wave-like behavior. This was subsequently confirmed using direct Doppler shift observations by Schou (2003). Here we extend the latter analysis using data from the Helioseismic and Magnetic Imager and are able to study various properties in more detail, including their temporal evolution.

Poster

Splinter HiRes

Dynamics of vortex flows in the lower solar atmosphere

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Vortices are believed to be of fundamental importance in the photosphere as well as in the rest of the solar atmosphere. Vortex studies have become even more important in view of their role in coronal heating via both AC and DC mechanisms. In AC mechanisms, vortices excite a wide variety of MHD waves and in DC mechanisms, they produce twisting in neighbouring magnetic field lines that may lead to reconnection events. In the present work, we demonstrate the evolution of small scale vortices in near-surface regions and chromosphere. We have used the MURaM code to solve the MHD equations which includes radiative energy transfer and an equation of state that incorporates partial ionization. Performing eigen-analysis of the velocity gradient tensor, we find subset of regions with high vorticity which gives us locations of vortical features with high swirling strength. It is found that these vortices are associated with strong downflows in the chromosphere which is consistent with their occurrence in inter-granular lanes in previous photospheric MHD simulations in the literature. These vortices are also the sites of local heating in the solar chromosphere. These swirling structures extend from the photosphere to the solar chromosphere and maybe further to corona. Vortex sites are also the locations of locally bright points which is a result of the associated density depression in those subregions. We also found that at each time instance, though the velocity streamlines are showing swirling structures, the associated test particle pathlines are more consistent with wave-like motion.

Contributed Talk

Splinter HotStars

Modeling hot star atmospheres: Challenges, applications, and the next generation

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Stellar atmosphere models are a key tool in order to understands stars. Not only do they yield synthetic spectra which can be compared to observations in order to obtain the stellar parameters, their stratification results are also used in a wide range of studies and simulations. For massive stars, winds are inherent and their proper accounting in atmosphere models is imperative. Unified model atmospheres that connect the quasi-hydrostatic and the supersonic wind regime in a consistent way are therefore essential. However, this requires complex calculations, including the radiative transfer in an expanding atmosphere and the solution of the statistical equations in a non-LTE situation for large model atoms having hundreds of levels. On top of these two major problems there are several further challenges, so that only very few codes exist worldwide which can accurately simulate an expanding stellar atmosphere and provide synthetic spectra that sufficiently reproduce observations.

One of them is the Potsdam Wolf-Rayet (PoWR) model atmosphere code. Originally developed to understand Wolf-Rayet (WR) stars, it has since been significantly extended and is nowadays applicable for any hot star. Using PoWR as an example, this talk will give a brief summary about the major tasks of modern unified atmosphere models and provide an examaple for a recent application of a next-generation model to the donor star of the high-mass X-ray binary Vela X-1.

Contributed Talk

Splinter HotStars

Massive binary stars with relativistic companions: Studying donor winds with the HST

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High-mass X-ray binaries (HMXBs) are essential massive star laboratories. These objects represent an advanced stage in the evolution of massive binary systems, after the initially more massive star has already collapsed in a supernova explosion, but its remnant, a neutron star or a black hole, remains gravitationally bound to the system. The stellar wind from the OB-type donor is partially accreted onto its compact companion, powering its high X-ray luminosity. Recently, the number of known Galactic HMXBs was more than doubled by the unexpected discovery of a new type of objects: the supergiant fast X-ray transients with OB supergiant donor stars. It was suggested that the physics of these objects is governed by their donor's stellar winds. To correctly model the populations of relativistic binaries in galaxies we shall understand the reasons for the existence of different types of HMXBs with OB donors. But, up to now, only a few donor stars were analyzed by means of sophisticated stellar atmosphere models. Therefore, using the HST we performed a UV spectroscopic survey of donor stars, covering both the newly discovered as well as the classical HMXB systems. The UV spectra were complemented by optical and simultaneously obtained X-ray data. The analysis was performed using PoWR non-LTE stellar atmospheres. In this talk, I will present first results of this survey, including an up-to-date overview of our knowledge about OB supergiant donors with relativistic companions.

Contributed Talk

Splinter HotStars

Mass transfer evolution in high mass X-ray binaries

M. Quast, N. Langer

Argelander-Instut für Astronomie, Bonn

High mass X-ray binaries (HMXB) consist of a massive star surrounded by a compact object. Mass accretion via Roche-lobe overflow (RLOF) or wind capture makes these systems the brightest X-ray sources in the sky. Furthermore HMXB are progenitors of gravitational wave signals by merging stellar black holes. Unfortunately formation, evolution and fate of these systems is only partly understood, due to uncertainties in evolution of massive stars, mass transfer, common envelope description and so on. We investigate the evolution of HMXB using a one-dimensional stellar evolution code and discuss, how the inner structure of the massive component influences the mass transfer rate and subsequently the long term orbital evolution. We find the hydrogen gradient as an important factor determining the behaviour of a RLOF-system and show that systems with large hydrogen gradients can undergo long term stable mass transfer, even in the case of high mass ratios.

Contributed Talk

Splinter HotStars

An in-depth look into the earliest O-type Galactic binary, HD 93129A

D. Gruner[1]

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Massive stars are the key drivers of the cosmic chemical evolution, their properties and evolution are therefore of great interest. In the Carina Nebula, we find the extremely early-type star system HD 93129A, which acted as the prototype for its own spectral class O2 If* while it was still considered as a single star. The later revelation as a multiple system overthrows the entire classification of this system. Applying newly obtained high-resolution spectra covering the UV, optical, and NIR, I performed the first spectral analysis of this system that accounts for the binary character consistently across the entire spectral range. The spectral analysis made use of the Potsdam Wolf-Rayet (PoWR) model atmospheres. PoWR is a state-of-the-art code for expanding stellar atmospheres. In my talk I will present the results of this analysis, the synthetically disentangled spectra, and address the consequences and implications of the newly derived stellar parameters, e.g. for the system's stellar feedback and its evolutionary status.

Contributed Talk

Splinter HotStars

Magnetic stars as a laboratory for constraining the weak-wind problem in massive stars

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Late-type massive stars are often reported to exhibit mass-loss rates that are smaller than predicted by more than an order of magnitude, a discrepancy referred to as the weak-wind problem. However, deriving the true mass-loss rates of weak-wind stars can be extremely difficult due to the lack of wind signatures in their spectra.

Global magnetic fields in massive stars bind the stellar wind up to the Alfven radius, greatly enhancing the circumstellar densities, and enabling the measurement of the intrinsic mass-loss rates of magnetic stars. HD 54879 (O9.7 V) is one of a dozen O-stars for which an organized magnetic field has been detected ($B \approx 2kG$). We acquired HST and XMM-Newton X-ray data for HD 54879. In addition, 35 optical spectra were secured to study its spectral variability. We performed a multiwavelength (X-ray to optical) spectral analysis using the Potsdam Wolf-Rayet (PoWR) model atmosphere code and the xspec software. The analysis enabled us to assess the intrinsic mass-loss rate of the star. In my talk, I will illustrate why the analysis of magnetic stars is essential for constraining the weak-wind problem of massive stars.

Contributed Talk

Splinter HotStars

The giant-dwarf connection

D. Hoyer

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The Asymptotic Giant Branch (AGB) phase is one of the most complex and yet not fully understood phase in stellar evolution. Spectral analyses of hydrogen-deficient AGB descendants yield constraints on nuclear processes in that phase – a pre-requisite to understand AGB stellar evolution.

The DO-type white dwarf RE 0503−289 was discovered in the ROSAT all-sky EUV survey two decades ago. Analyses of extreme and far-ultraviolet spectra of RE 0503−289 allowed to identify many metal lines up to the trans-iron elements. Thus, RE 0503−289 may be a rosetta stone to understand AGB nucleosynthesis and the post-AGB stellar evolution. To investigate its uniqueness, we selected three stars close to RE 0503−289 in the $\log T_{\mathrm{eff}} - \log g$ plane. These are the PG 1159-type star PG 1707+427 and the two DO-type white dwarfs PG 0109+111 and WD 0111+002. We present a NLTE spectral analysis and discuss their evolution.

Contributed Talk

Splinter HotStars

Spectral Analysis of the hybrid PG 1159-type Central Stars of the Planetary Nebulae Abell 43 and NGC 7094

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About a quarter of all asymptotic giant branch (AGB) stars lose their hydrogen rich envelope due to a reignition of the helium-burning shell in a final thermal pulse (FTP). Hybrid PG 1159 stars with a still detectable amount of hydrogen in the photosphere form if the FTP occurs at the tip of the AGB. We calculated non-local thermodynamic equilibrium model atmospheres using the Tübingen Model Atmosphere Package and compared them to recently obtained ultraviolet and optical spectra of the central stars of Abell 43 and NGC 7094. To prove the presumption that the previously detected iron deficiency could result from the conversion of iron into heavier elements via the s-process on the AGB, the opacities of the trans-iron elements zinc, gallium, germanium, krypton, zirconium, molybdenum, xenon, and barium, that became available recently, were included in the model calculations. Several computed lines could be used to determine upper abundance limits for six of them. We compared these to the predictions from stellar evolution models and to the determined values for other hot post-AGB stars to conclude on their evolution and to establish constraints for nucleosynthesis and mixing processes on the AGB.

Contributed Talk

Splinter HotStars

The Born-again Planetary Nebulae Abell 30 and Abell 78

H. Todt[1] et al.

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The born-again scenario was suggested in the 1980s to explain the formation of hydrogen-deficient central stars of planetary nebulae.

The planetary nebulae Abell 30 and Abell 78 are such born-again nebulae, which are believed to have undergone a very late thermal pulse, resulting in the ejection of hydrogen-poor material.

We present the results of kinematic analyses of the expanding nebulae of these objects together with multi-wavelength spectral analyses of the nebulae and their central stars, aiming to probe the born-again scenario. We discuss whether this evolutionary channel can also explain the formation of other hydrogen-deficient central stars.

Contributed Talk

Splinter HotStars

The catalog of hot subdwarf stars

S. Geier[1], et al.

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In preparation for the upcoming all-sky data releases of the Gaia mission we compiled a catalog of known hot subdwarf stars and candidates drawn from the literature and yet unpublished databases. The catalog contains 5613 unique sources and provides multi-band photometry from the ultraviolet to the far infrared, ground based proper motions, classifications based on spectroscopy and colors, published atmospheric parameters, radial velocities and light curve variability information. Using several different techniques we removed outliers and misclassified objects. By matching this catalog with astrometric and photometric data from the Gaia mission, we will develop selection criteria to construct a homogeneous, magnitude-limited all-sky catalog of hot subdwarf stars based on Gaia data.

Contributed Talk

Splinter HotStars

The population of ultracompact hot subdwarf binaries

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Ultracompact hot subdwarf (sdO/B) binaries are short period binaries with orbital periods so short that the subdwarf will fill its Roche Lobe before the turning into a white dwarf. The study of these systems are important for our understanding of topics such as supernova Ia progenitors or binary evolution. Some of them might be detectable as Galactic gravitational wave sources with eLISA. However, the number of known systems is still limited with one confirmed system a few years ago. In this talk I will report on the discovery of three new systems with orbital periods of 44.5 min, 76.3 min and 87.5 min and discuss implications for stellar evolution.
The Zwicky Transient Facility (ZTF) is a next-generation optical synoptic survey with a 47 sqd. survey camera that builds on the experience and infrastructure of the Palomar Transient Factory and starts science operations in winter 2017. I am lead investigator of an approved high-cadence survey in the Galactic Plane ($|b| < 7\,\mathrm{deg}$) covering the full inner Plane visible from the northern hemisphere (Galactic longitude $10 < l < 230$) as part of ZTF. I will give an overview of the survey as well as discuss the expected numbers of ultracompact hot subwarf binaries from this survey

Contributed Talk

Splinter HotStars

News from the EREBOS project

V. Schaffenroth[1], B. Barlow[2], S. Geier[1], M. Vuckovic[3] and the EREBOS collaboration

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Common envelope ejection triggered by a close companion is regarded as most probable formation channel for hot subdwarf stars (sdO/Bs), which are stripped cores of red giant stars, as the fraction of close binaries with periods of 1.5 h to about 1 day is with 50% much higher than in standard stellar evolution. Of special interest are hereby eclipsing post-common envelope systems with hot subdwarf stars and cool low-mass companions (HW Vir systems), as they are perfect systems to study the influence of cool, low-mass companions on stellar evolution. They are easily discovered by their characteristic lightcurves with the eclipses and the prominent reflection effect. By systematically investigating the lightcurves provided by the OGLE survey we discovered 90 new HW Vir systems additionally to the only 17 systems that were published before. We were awarded with a ESO Large Program for a spectroscopic follow-up of 23 of this systems. The main goal is to find the mass distribution of the companions to better understand which kind of companions are able to survive a common envelope phase and eject the envelope. Here we will give the current status of the project and the first results.

Contributed Talk

Splinter HotStars

The stellar pulsation timing method to detect substellar companions

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Subdwarf B stars (sdBs) are stripped He-burning cores of red giants with a thin hydrogen atmosphere. The canonical model to explain the existence of sdB stars is binary evolution. Formation scenarios for single sdBs are more controversially discussed and can be hard to reconcile with observational properties. Besides the merger of two helium white dwarfs or other merger processes for apparently single sdB stars, an alternative formation channel involves planetary systems. During the RGB the star would develop a common envelope with a giant planet that leads to the loss of the envelope.

To empirically test this scenatio, we have monitored the rapid pulsations of a number of sdBs, which allows to detect sub-stellar companions. Periodic variations in the expected arrival times of the pulsation maxima provide evidence for companions. This timing method is particularly sensitive to planets at large distances and complementary to other exoplanet detection methods which are not efficient for stars with small radii and high gravities. Thus, the timing method opens up a new parameter range in terms of the host stars and helps to understand the formation process of single sdBs.

In consideration of future photometric space missions like TESS and PLATO it is essential to enhance the diversity of potential exoplanet host stars that can be probed. We report on the development of an automated pipeline to validate this method and to apply it to a variety of both ground- and space-based observations.

Contributed Talk

Splinter HotStars

The O–C diagram of V391 Peg revisited: planet or not?

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V391 Peg is a hybrid pulsating subdwarf B star that shows both pressure and gravity modes. By studying the arrival times of the p-mode maxima and minima through the O–C method, Silvotti et al. 2007 inferred the presence of a planet with an orbital period of 3.2 years and a minimum mass of 3.2 Jupiter masses. The 2007 results were based on photometric data spanning from 1999 to 2006.

Silvotti et al. have recently submitted a detailed updated O–C analysis using a data set that covers the period between 1999 and 2012. Comprising 1066 hours of photometric time series, this data set is about 2.5 times larger in terms of number of data points than in the previously published analysis.

The analysis of the new data revisits the O–C diagrams that can be constructed for the two rapid main pulsation frequencies at mean values of f_1=2860.938272(06) μHz and f_2=2824.096225(10) μHz. Up to the end of 2008, the new O–C diagram of the main pulsation frequency f_1 is compatible with (and improves) the previous 2-component solution representing the long-term variation of the pulsation period (parabolic component) and the giant planet (sine wave component). Since 2009, the overall O–C trend of f_1 changes in a surprising way. And while the O–C diagram of the secondary pulsation frequency f_2 continues to show 2 components (parabola and sine-wave) like in the previous analysis, the sinusoidal component now shows a different period and amplitude.

We discuss various solutions and their implications for the giant planet scenario. At the same time, $\dot{P}$ measurements are improved. A rotational splitting of f_2 is suggested by the new data, leading to the measurement of the stellar rotation period. The main g-mode pulsation periods of the star are constrained.

Contributed Talk

Splinter HotStars

Spectral analysis of four very similar hot hydrogen-rich subdwarf O stars.

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Post-Extreme Horizontal Branch stars (post-EHB) are helium-shell burning objects evolving away from the EHB and contracting directly towards the white dwarf regime. While the stars forming the EHB have been extensively studied in the past, their hotter and more evolved progeny are not so well characterized. We performed a comprehensive spectroscopic analysis of four such bright sdO stars, namely Feige 34, Feige 67, AGK+81°266, and LS II+18°9, among which the first three are used as standard stars for flux calibration. By fitting high quality optical spectra with a grid of Non-LTE TLUSTY/SYNSPEC model atmospheres, we found the stars to have very similar atmospheric parameters. with $T_{\rm eff}$ ~61 000 K and log g ~6.0. This places them right on the theoretical post-EHB evolutionary tracks. In addition to having similar atmospheric parameters, the four stars also have almost identical FUSE and IUE spectra. We used the UV data to derive abundances of metallic elements and found the stars to be significantly enriched in iron and nickel. Fits of the photometric data were performed to derive spectroscopic distances that are in good agreement with the Hipparcos values available for our three brightest targets.

Poster

Splinter HotStars

Stellar Laboratories: High-precision Atomic Physics with STIS

Conny Glaser

Institut fr Astronomie und Astrophysik, Universitt Tbingen

Stellar atmospheres are prime laboratories to determine atomic properties of highly ionized species. Since reliable opacities are crucial ingredients of many astrophysical simulations and a detailed comparison of iron-group oscillator strengths is still outstanding, we used the Space Telescope Imaging Spectrograph to measure high-resolution spectra of three hot subdwarf stars that exhibit extremely high iron-group abundances. These allow us to identify even very weak spectral lines. The predicted relative strengths of the identified lines are compared with the observations to judge the quality of Kuruczs line data and to determine correction factors for abundance determinations of the respective elements.

Poster

Splinter HotStars

The enigma of the missing flux in the hot, helium-rich white dwarf RE 0503-289

M. Knörzer

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Recent spectral analyses of RE 0503-289 show a strong difference between model flux and observations in the extreme ultraviolet wavelength range (220Å $\leq \lambda \leq$ 400Å). Only models with a significantly lower effective temperature than previously determined from optical and ultraviolet observations can reproduce the observed flux. In our attempt to investigate this discrepancy, we include 17 not yet considered elements with atomic number $29 \leq Z \leq 55$ with up to 10000× solar abundances in our model atmospheres. We present preliminary results of our analysis.

Poster

Splinter HotStars

The formation of the observed Wolf-Rayet stars in the Magellanic Clouds is not dominated by mass transfer in binaries

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Classical Wolf-Rayet (WR) stars are evolved, hydrogen-poor stars characterized by powerful, radiation-driven stellar winds. Massive stars reach the WR phase after having shed much material via either stellar winds or mass-transfer in binary systems. Current evolutionary models predict that the majority of WR stars at the low metallicity environments of the Magellanic Cloud form via mass-transfer in binaries.

Using the PoWR code, we performed a non-LTE spectral analysis of the complete population of Wolf-Rayet binaries in the Small and Large Magellanic Clouds (SMC and LMC), testing mass-luminosity relations against orbital masses, and constraining evolutionary channels for each system using the BPASS and BONNSAI tools. A comparison with evolutionary tracks reveals that, while mass-transfer in binaries may have played a role in their detailed evolution, it does not dominate the formation of WR stars in the Magellanic clouds.

Contributed talk

Splinter Non-Thermal

The High Time Resolution Universe Survey For Pulsars

M. Cruces[1], on behalf of HTRU Collaboration

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Pulsars are neutron stars, detected mainly through the pulses of electromagnetic radiation emitted from their poles, which is modulated by the stable rotation of the object. Since their discovery in 1967 they have become fundamental tools for understanding stellar evolution, to test theories of gravity, to map the electron content of our galaxy and to understand the behavior of matter at extreme conditions, to name a few. Further discoveries allow us to advance in these areas.

Although more than 2500 pulsars have been found so far, most of them are normal isolated pulsars. Of the more rare objects, only fewer than 20 are double neutron stars systems and just one is a double pulsar system. Moreover, no neutron star-black hole system has been detected to date. With the aim of finding the most intriguing pulsars and the potential pulsar-black-hole binaries, in early 2008 the High Time Resolution Universe (HTRU) collaboration began, an all sky blind survey for pulsars. In the southern hemisphere the survey was conducted with the 64-m Parkes radio telescope, while in the northern hemisphere the observations were carried out with the 100-m radio telescope Effelsberg. The data have a high time- and frequency-resolution that allows an unprecedented volume of the galaxy to be searched. This has led to the discovery of hundreds of new pulsars, among them tens of millisecond pulsars, a Fermi-millisecond pulsar, the first radio-loud magnetar, two pulsar-planet systems and the most relativistic pulsar to date. Additionally, among its findings, the HTRU establish the existence of a cosmological population of Fast Radio Bursts (millisecond duration burst whose origin remains unknown).

Contributed Talk

Splinter Non-Thermal

Magnetic Fields in Galaxy Clusters and beyond

K. Dolag[1]

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In galaxy clusters, non-thermal components such as magnetic field, turbulence and high energy particles keep a record of the processes acting since early times till now. These components play key roles by controlling transport processes inside the cluster atmosphere and therefore have to be understood in detail. However including them in cosmological simulations is extremely challenging as the structures in and around clusters are quite complex and span a very large dynamic range in scales. I will report the status of what can be achieved in numerical simulations of the formation of galaxies and galaxy clusters in cosmological context and our predictions for the magnetic field structure based on models of magnetic seeding directly coupled to the star-formation process. This allows to model the transport of heat coupled directly to the magnetic fields in galaxy clusters as well as the modeling of cosmic ray electrons powering the diffuse radio emission within galaxy clusters.

Contributed Talk

Splinter Non-Thermal

Merging galaxy clusters in radio surveys

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The intra-cluster medium accounts for most of the baryon mass in galaxy clusters. However, its dynamical processes, magnetic fields properties, and cosmic ray content are still poorly constrained. Diffuse synchrotron emission in galaxy clusters provides a probe for all of these three components.

Radio relics are synchrotron emission sites found in downstream regions of galaxy cluster merger shocks. While they are often confirmed through targeted X-ray and radio observations their signature is also present in large surveys. Several models for the origin of radio relics have been proposed.

Through Bayesian statistics one can infer the posterior likelihood of competing models given the data and prior information. Approximate Bayesian Computation (ABC) is an approach to estimate the posterior likelihood if the complexity of the data is high.

We use ABC to investigate diffusive shock acceleration models with and without pre-existing relativistic electrons based on the NVSS survey and cosmological simulations. I present what we can infer from our current data pool and which surveys we need to strengthen the model inference capabilities of our ABC approach.

Contributed Talk

Splinter Non-Thermal

Semi-simultaneous detections of single pulses in the radio regime with Effelsberg and Lofar

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The transient radio sky has revealed a host of astronomical phenomena, among the most recent discoveries are the Fast Radio Bursts (FRBs). These millisecond, ∼Janksky bright single pulses are seen with dispersion measures (DMs) several times larger then those caused by the electron density in our own Milky Way and therefore thought to be of extra-galactic origin. The non-repetitive behaviour of all but one FRB and the majority being single-dish detections make it hard to pinpoint their exact location on the sky and deduce which sources produce them.

In an effort to get a handle on the progenitor of the only repeating FRB to date: FRB 121102, simultaneous observations were performed using Lofar and the Effelsberg Radio Telescope. The large difference in their operational central frequency allowed for the determination of the most constraining broadband spectral index limit for the source and lead to the development of an observing system potentially capable of localising non-repeating FRBs up to an arcsecond resolution. Both the performed observations and the obtained spectral index limit will be presented here as well as a future outlook on when the developed system will be used to search archival data and detect FRBs in real-time.

Contributed Talk

Splinter Plasma

The Structure of the Heliosphere and Astrospheres: Measurements and Simulations

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In recent years significant progress has been made regarding the large-scale structures of the Heliosphere and of Astrospheres and, via this, about the interstellar media surrounding these stellar wind cavities. This progress is, on the one hand, driven by heliospheric spacecraft measurements particularly in the transition region to the local interstellar medium, and, on the other hand, by intensified campaigns regarding remote observations of other stars. In the talk the latest results will be discussed along with those of comprehensive simulations of the interactions of stellar winds with their interstellar environments. The accordingly refined or modified corresponding paradigms will be presented.

Contributed Talk

Splinter Plasma

Temperature evolution of solar atmosphere for a nonlocal heat flux

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The heat fux is an important mechanism for energy transport in the weakly collisional plasma of the solar corona. Most of the investigations regarding the thermal dynamics of the upper part of solar atmosphere are based on a collisional formulation for heat flux. However, the contribution from free electrons to the heat transport it is better described when considering a non-local heat flux model. To investigate the degree of dependency of the coronal plasma thermal evolution on the heat flux model, we have performed 3D MHD simulations of an active region considering classical (collisional) heat flux and nonlocal models. We have obtained in average similar plasma dynamics for both simulations with main differences appearing in the upper chromosphere/transition region/lower corona. The nonlocal model leads to coronal temperatures two times higher than the classical heat flux along loops which presented more intense currents dissipation. Therefore, our results indicates that the heat flux model considerably affects how the plasma answer to heating mechanisms.

Contributed Talk

Splinter Plasma

Global coronal magnetic field modeling using stereoscopic constrains

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The extrapolation of solar surface vector magnetograms into the corona under the model assumption that the coronal plasma is in a force-free state has now become a standard technique to reconstruct the coronal magnetic field. Even though the method has its shortcomings, the lack of direct magnetic field measurements in the corona makes it a unique tool to estimate the topology of the coronal field, its energy and helicity. Comparisons of the field models with stereoscopically reconstructed loops have revealed occasional discrepancies in the local field directions of 20 degrees and more. For the purpose to reconcile the field model with the loop reconstructions, we extended the NLFFF optimization code by the inclusion of stereoscopic loop reconstruction constrains. The extended method (called S-NLFFF) contains an additional term that minimizes the angle between the local magnetic field direction and the orientation of the 3D coronal loops reconstructed by stereoscopy. This approach results in force-free field models which agree with both types of observations and are therefore much more reliable.

Contributed Talk

Splinter Plasma

Origins of ^{3}He-Rich Solar Energetic Particles

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Particle acceleration in solar or stellar flares remains an outstanding problem in astrophysics. Solar flare energetic particles are characterized by a peculiar chemical composition with the rare elements like ^{3}He or ultra-heavy ions enhanced by factors up to ten thousand above their thermal abundances. Such huge fractionation is unknown in any other site in the Universe. The solar sources of these events have been commonly associated with coronal jets, believed to be a signature of magnetic reconnection involving field lines open to interplanetary space. With the improved resolution of extreme ultraviolet imaging observations, the ^{3}He-rich sources have been systematically analyzed in the last decade. Alongside with a modeling effort, which now focuses on various ion species, significant progress has been achieved in the understanding of the phenomena. Observational predictions of various models of ion acceleration in solar flares are discussed.

Contributed Talk

Splinter Plasma

Saturn's radiation belts: a comprehensive view after the end of the Cassini mission

E. Roussos[1], P. Kollmann[2], N. Krupp[1], C. Paranicas[2] and Cassini's MIMI team

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The Cassini MIMI instrument suite and its energetic particle detector LEMMS have been exploring Saturn's radiation belts since July 2004, completing more that 220 crossings through them until the end of the mission, which occurs on September 15 of 2017. Besides constructing detailed radiation belt maps, this extensive survey allowed us also to capture the system's dynamics and its characteristic time scales of variability, revealing also the source processes associated with the production, acceleration and loss of MeV electrons and ions. Furthermore, we found that measurements in the radiation belts can be diagnostic for the global state of Saturn's magnetosphere and for geophysical aspects of the planet's moon and ring system. In this review talk, only few days after the plunge of Cassini into Saturn's atmosphere, we summarise the major findings resulting from MIMI/LEMMS observations in the planet's radiation belts, focusing on the MeV particle populations. We show that the structure and dynamical evolution of the electron and ion components of the radiation belts is weakly coupled and how the study of each component provides different insights into the magnetosphere, the planet, its moons and rings. We will also present some of the early, exciting findings from Cassini's Proximal Orbits, focusing particularly on the origin of energetic particles inside the D-ring and what the final measurements of the MIMI instrument revealed deep in Saturn's atmosphere and before the loss of signal from the spacecraft.

Contributed Talk

Splinter Plasma

Wave particle interaction in Jupiter's magnetosphere: Comparison with JUNO observations of Jupiter's aurora

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The understanding of Jupiters aurora currently experiences a quantum leap due to the insitu particle and fields and the remote sensing measurements by the JUNO spacecraft. To help understand the associated magnetospheric acceleration processes, we investigate wave particle interactions, i.e., Landau and cyclotron damping, in Jupiter's magnetosphere for electrons, sulfur, oxygen and hydrogen ions. Therefore we calculate kinetic length and temporal scales, which we cross-compare for various regions within Jupiter's magnetosphere. Based on these scales, we investigate the roles of possible wave particle mechanisms in each region, e.g., Jupiter's plasma sheet, the auroral acceleration region and the polar ionosphere. We thereby consider that the magnetospheric regions are coupled through convective transport, and Alfven and other wave modes. We particularly focus on the role of stochastic acceleration by kinetic Alfvn waves in contributing to Jupiter's aurora.

Poster

Splinter Plasma

Electromagnetic star-planet-interaction at TRAPPIST-1

C. Fischer[1], J. Saur[1]

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We investigate the TRAPPIST-1 system with its seven close-in terrestrial planets for possible electromagnetic star-planet-interactions. Our results show that the innermost planets, especially TRAPPIST-1b and c, are subject to sub-Alfvénic interaction. Both planets are therefore expected to generate Alfvén wings, that can couple to the star. Our model describes the stellar wind in a semi-analytic approach as a thermal wind, according to the Parker-model. Therefore we can estimate the Alfvén Mach number at each planet for different sets of parameters. That allows for conclusions about the type of electromagnetic interaction.

Contributed Talk

Splinter Populations

The Gaia Mission - Overview, First Results, and future prospects

Stefan Jordan[1]

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The astrometric satellite Gaia was launched in December 2019. After a comprehensive commissioning phase Gaia began its nominal scientific measurements in mid 2014. Gaias main goal is the determination of precise astrometric data for more than one billion stars in our Milky Way with extremely high precision.

Gaia Data Release 1 was published in September 2016. It contains positions and magnitudes for about 1.1 billion stars. For two million stars proper motions and parallaxes could also be determined. More than 160 scientific papers based on this catalogue were published until July 2017. Gaia Data Release 2 will be available in April 2018 and will probably contain more than one billion stars with positions, proper motions and parallaxes, many having a precision of better than 0.1 milliarcsecond.

Contributed Talk

Splinter Populations

Stellar populations in the bulge – from no-resolution to high-resolution

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The Galactic bulge is one of the oldest, yet very metal-rich populations in the Milky Way, suggesting that it experienced early, rapid chemical enrichment. With large *high-resolution* spectroscopic bulge surveys, we are only gradually uncovering metal-poor stars ([Fe/H] < -2 dex) that are predicted in galactic models, according to which the first stars formed in the bulge. The chemical abundances of those candidates vastly overlap with those of halo stars. However, chemically peculiar stars (such as a CEMP-s star and a hitherto inexplicable NEMP star with anomalous abundance patterns) are of particular interest in terms of the nucleosynthetic origin of the elements in the early Galaxy. Further clues to the evolution of the versatile populations in the bulge can be gleaned from photometric surveys. Here, narrow-to-intermediate band *Strömgren* photometry provides a powerful tool to separate stars by their metallicity, age, and evolutionary status. In the second part of this talk, I will thus introduce our comprehensive HST program to disentangle the age-metallicity relation of the bulge using an unprecedented combination of nine Strömgren and broad-band filters.

Contributed Talk

Splinter Populations

Uncovering metal-poor stars in the Galactic bulge with the Pristine survey

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[4] *Dept. of Physics and Astronomy, University of Victoria, Canada*

The oldest and most metal-poor stars are crucial for our understanding of the early universe, because they likely carry the imprint of the first supernovae. Studying these stars in detail helps our understanding of (early) star formation, supernovae and the early period of galaxy formation. It is predicted by several N-body and hydrodynamical simulations that the fraction of stars that are metal-poor and old is highest towards the centers of galaxies. Therefore, it appears that the Galactic bulge is an interesting location to search for the oldest and most metal-poor stars in our Galaxy, even though in general it is a relatively metal-rich environment.

The Pristine survey is a metal-poor targeted survey, which uses the narrow-band Ca H&K filter on CFHT MegaCam to find candidate metal-poor stars in the Galactic halo. Metal-poor stars are expected to have weak Ca H&K features, which makes it possible to select metal-poor candidates among stars of the same colour using dereddened (broadband) photometry. The most metal-poor candidates are then followed up with spectroscopy. This method has been shown to work excellently for the main Pristine survey, focussing on the Galactic halo.

Here, we present the first results of a pilot survey testing the capabilities of Pristine in the Galactic bulge. Compared to the halo, the bulge is a much more crowded region and has significantly higher extinction. The first results are promising, and we hope to significantly extend the sample of bulge metal-poor stars with Pristine.

Contributed Talk

Splinter Populations

4MOST - *The* facility to spectrally explore Stellar Populations in and around the Milky Way

R.S. de Jong[1], and the 4MOST Consortium

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4MOST is a major new wide-field, high-multiplex spectroscopic survey facility under development for the VISTA telescope of ESO. 4MOST has a broad range of science goals ranging from Galactic archeology and stellar physics to the high-energy sky, galaxy evolution, and cosmology. Starting in 2022, 4MOST will deploy 2436 fibres in a 4.1 square degree field-of-view using a positioner based on the tilting spine principle. The fibres will feed one high-resolution (R$\sim$20,000) and two medium-resolution (R$\sim$6500) spectrographs with fixed 3-channel designs with identical 6k x 6k CCD detectors. After a brief introduction of the instrument and its operation concept, I will present the four Galactic Archeology Surveys and the Magellanic Clouds Survey that are being prepared by the 4MOST Consortium. These surveys are expected to deliver about 10–15 million spectra at R$\sim$6500 and 3–4 million at R$\sim$20,000 of a large variety of stellar targets (e.g., local White Dwarfs, extended Solar neighbourhood stars, Disk and Bulge FGK dwarfs and giants, halo Giants, extremely metal-poor stars, Magellanic Clouds Giants and variable stars). Some of the key scientific goals are: Near-field cosmology tests, Chemo-dynamical characterisation of the major Milky Way stellar components to derive its assembly history, the Formation of the Galactic Halo and Milky Way satellites, and Discovery and characterisation of the earliest Milky Way stellar populations.

Contributed Talk

Splinter Populations

MUSE – The Discovery Machine

T.-O. Husser[1], S. Kamann[1,2], S. Dreizler[1], and students

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Within the MUSE collaboration we are doing a large survey on Galactic globular clusters using GTO time. While having well-defined science goals like cluster dynamics, binaries, and multiple populations, this “blind” survey yielded plenty of new projects and interesting targets. We work on, for instance, Ca triplet spectroscopy, mass-dependent dynamics, photometric variables, blue straggler stars, ISM/extinction, and more. Furthermore we found exotic objects like companions of black holes and neutron stars, plenty of cataclysmic binaries, and other emission line objects. In this talk I want to summarize the work that we have done within the globular cluster project and give an outlook to future plans.

Contributed Talk

Splinter Populations

Search for emission line objects in Galactic globular clusters

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Over a million stellar spectra have been obtained as part of the ongoing GTO program "A spectroscopic census of Galactic globular clusters" with the integral field spectrograph MUSE at ESO-VLT. Since most stellar spectra contain absorption features only, emission lines point to stars that are peculiar and differ from a normal main-sequence or red giant star. With an automated approach, we detect known cataclysmic variables, RR Lyrae variables, a black hole companion, a low-mass X-ray binary and other variable stars only by the presence of emission lines in their spectra. This approach leads to the detection of two new cataclysmic variables, several unidentified curious spectra, and an emission nebula.

Contributed Talk

Splinter Populations

Spectroscopic insights on the extreme horizontal branch population of ω Centauri

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The formation mechanism of extreme horizontal branch (EHB) stars in massive globular clusters is still highly debated and many different theories have been proposed to explain their existence. The important fraction of helium-enriched EHB stars is especially challenging to explain by canonical evolution. In order to better characterize that population in ω Centauri, we combined our own ω Cen EHB stars' spectra with previously published data to gather a significant sample representative of the EHB population of that cluster. More than 200 spectra were analysed to derive fundamental parameters, $T_{\rm eff}$, log g and log $N(\rm He)/N(\rm H)$, by fitting them with a grid of non-LTE model atmospheres. That way we provide consistent atmospheric parameters for 150 EHB stars in ω Cen, which is the largest set of such stars to have been spectroscopically analyzed in a globular cluster. The position of our stars in the $T_{\rm eff}$ – log g plane matches very well that of the theoretical EHB band and we find about 2/3 of the sample to be part of the He-enriched sub-classe, sitting at the very hot end of the EHB. The ω Cen stars also show interesting characteristics that are significantly different than that of the field population. Thus I will present the first results of our on-going project dedicated to the spectroscopic study of clusters' EHB population.

Contributed Talk

Splinter Populations

MUSE spectroscopy of Horizontal Branch stars in ω Cen and NGC 6752

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The blue horizontal branch (BHB) population in globular clusters is different from that observed in the galactic field and also differs from one cluster to another. Since globular clusters are ideal objects to study stellar populations and evolution, it is important to characterize their horizontal branch morphology in order to understand their evolutionary history. The BHB stars included in previous spectroscopic studies have been limited in number and were mostly restricted to the outer regions of clusters. The MUSE integral field spectrograph at the VLT provides a unique view on the stellar population of globular clusters, with its capability to provide thousands of individual stellar spectra from the crowded inner regions of clusters.

We will present our spectral analysis of blue- and extreme-horizontal branch stars observed with MUSE in the globular clusters ω Cen ($\sim$100 stars) and NGC 6752 ($\sim$40 stars). The spectra were fitted with grids of model atmospheres in order to derive effective temperatures, surface gravities as well as helium abundances. We will also compare our results with those of previous analyses of the HB population of these two clusters. Finally we aim at providing a glimpse into the possibilities that MUSE offers for the study of horizontal branch stars in globular clusters, despite its rather "red" wavelength range (4650$-$9000 Å) that is not optimal for the analysis of hot stars.

Contributed Talk

Splinter Populations

Binary stars in Galactic globular clusters

Benjamin Giesers, Stefan Dreizler, Sebastian Kamann, Tim-Oliver Husser, and students.

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From globular clusters we can learn how stars evolve over time, how the dynamical star system functions, and what influence they have on their hosting galaxy. We are currently realising a massive spectroscopic survey in 25 Galactic globular clusters with MUSE at the VLT. MUSE gives us the possibility to extract spectra of some thousand stars per exposure. One of our aims is to create a stellar census of binaries in globular clusters. Binary stars have a strong influence on the core collapse and stellar evolution in globular clusters and are therefore important for their overall evolution. With different epochs on a specific globular cluster, we use the radial velocity method to find variable stars. There are several aspects of binaries that are worth to examine. One is the statistical approach on how the binary fraction differs in various spatial or stellar parameter regions. For example a study of Blue Stragglers in binary systems could help to get a better understanding on the link between the stellar and dynamical evolution of globular clusters. Another aspect is the study of single binary systems to learn more about period and mass distributions of host and companion stars in specific globular clusters. Recently we found a detached stellar-mass black hole candidate in a globular cluster which is an important constraint for binary and black hole evolution models in globular clusters as well as in the context of gravitational wave sources.

Contributed Talk

Splinter Populations

The Magellanic Clouds

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The talk will review the status of surveys in the Magellanic Clouds and what these studies have taught us about these intriguing galaxies.

Contributed Talk

Splinter Populations

Morphology and Spatial distribution of Stellar Populations in the Magellanic Clouds from the VMC survey

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The Magellanic Clouds are nearby dwarf irregular galaxies whose morphologies, dynamics and evolution are highly complex and must have been heavily influenced by their interaction with each other as well as with the Milky Way. Tidal forces caused structural changes in the galaxies and so the study of their morphology and structure is important to understand the effect of these interactions.

Traced by different stellar populations, the morphology of the Magellanic Clouds show different properties. While young stars in the Large Magellanic Cloud (LMC) exhibit a rather irregular structure characterized by spiral arms and tidal features, older stars dominating the mass of the galaxy tend to be more smoothly and regularly distributed. Both theoretical and observational studies in the Small Magellanic Cloud (SMC) indicate that old and intermediate-age stars are distributed in a spheroidal or slightly ellipsoidal component while young stars and gas are rather distributed in a disc. Despite the regularity of the older stars, different tracers and methods yield centres that are not mutually consistent.

We are using the VMC Survey to investigate the spatial distribution of different stellar populations across the Magellanic Clouds. We will present a comprehensive and detailed study of the morphology of the central regions of the galaxies by obtaining their surface density maps and using isopleth contours of the stellar surface density to determine the centroids of each stellar population. Furthermore, we will construct projected radial density profiles through star counts and fit different models (Exponential Disk, Sersic profile, King and Plummer sphere models) to them which will allow us to derive structural parameters that best describe each stellar population.

Contributed Talk

Splinter Populations

Stellar population of the superbubble N 206 in the LMC

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Clusters of early-type stars are often surrounded by a 'superbubble' of hot gas. The formation of such superbubbles and shells is thus directly linked to the stellar feedback from massive stars. Consequently, quantitative analyses of massive stars are required to understand how the feedback of these objects shapes/ creates these large scale structures of the ISM. We present the quantitative spectroscopic analysis, energy feedback, and chemical yields of young stellar populations associated with the superbubble N 206 in the LMC. The complex contains the young cluster NGC 2018 and OB associations LH 66 and LH 69. We obtained optical spectra with the muti-object spectrograph FLAMES at the ESO-VLT. When possible, the optical spectroscopy was complemented by UV spectra from the HST, IUE, and FUSE archives. Detailed spectral classifications are presented for our sample. For the quantitative spectroscopic analysis we use the Potsdam Wolf-Rayet (PoWR) model atmosphere code. The physical and wind parameters obtained from the PoWR modelling are used to calculate the ionizing and mechanical energy input from the OB stars to the ISM. The ages of these stellar populations are estimated from the HR diagram. The total energy input obtained from the spectral analyses are also compared with the properties of the diffuse X-ray emission observed in this region with *XMM-Newton*.

Contributed Talk

Splinter Populations

E-ELT/MOSAIC: Exploring massive star populations in the Local Group and beyond

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MOSAIC is the multi-object spectrograph under study for the Extremely Large Telescope, the biggest eye on the sky. Currently, an international consortium led by Francois Hammer (Paris Observatory) is concluding a phase A study that should demonstrate the scientific potential and technical feasibility of the MOS that is expected to see first light in 2026. Science cases range from the most distant galaxies to resolved stellar populations in nearby galaxies. MOSAIC is expected to become a workhorse instrument for the spectroscopic follow-up of e.g. targets identified by the James Webb Space Telescope at optical to near-infrared wavelengths (380 - 1900 nm). With E-ELT/MOSAIC it will become possible to study massive stars in thousands of galaxies up to the Virgo cluster.

Contributed Talk

Splinter Populations

The Wolf-Rayet population in the Magellanic Clouds and implications on star formation

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Classical Wolf-Rayet (WR) stars are hot, evolved, hydrogen-poor stars characterized by powerful, radiation-driven stellar winds. Through their energenic and chemical input, WR stars play a decisive role in shaping the evolution and star-formation history of their host galaxy. Massive stars are understood to reach the WR phase after having shed much material via either stellar winds or mass-transfer in binary systems. Current evolutionary models predict that the majority of WR stars at the low metallicity environments of the Magellanic Clouds form via binary mass-transfer.

Using the PoWR code, we performed a non-LTE spectral analysis of the complete population of WR binaries in the Small and Large Magellanic Clouds (SMC and LMC), testing mass-luminosity relations against orbital masses, and constraining evolutionary channels for each system using the BPASS and BONNSAI tools. We find that, while mass-transfer in binaries may have played a role in their detailed evolution, it does not dominate the formation of WR stars in the Magellanic clouds. In my talk, I will discuss the implications and constraints set by our study on the initial mass function and the star formation history in the Magellanic Clouds.

Contributed Talk

Splinter Populations

Spectacular details of resolved stellar populations in NGC300 revealed through the combination of ACS with MUSE

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Already a decade ago, the Advanced Camera for Surveys Nearby Galaxy survey Treasury (ANGST) has provided spectacular images and photometry of individual stars in nearby galaxies, with the expectation to gain deep insight into star formation histories and the chemical evolution of galaxies. However, the known limitations of photometry have remained an obstacle to fully exploit the angular resolution of HST in analyzing resolved stellar populations in galaxies such as the sculptor group galaxy NGC300. We have selected NGC300 as the target of our MUSE GTO program at the VLT to explore the potential of IFUs for crowded field 3D spectroscopy, utilizing PSF-fitting techniques. With the input of stellar centroids obtained from the ANGST catalogue, we are demonstrating that the PampelMuse PSF-fitting tool is capable to extract more than 500 spectra for individual stars of luminosity class I…III from a single MUSE pointing (1.5 h exposure time). These spectra are well deblended and allow for spectral type classification and the measurement of radial velocities. Next to stars of spectral types O…M, we find numerous carbon stars, blue emission line stars, LBV and symbiotic star candidates. The excellent image quality and sensitivity of MUSE has also enabled the discovery of extremely faint HII regions, planetary nebulae, supernova remnants, and substructure of the diffuse ionized gas (DIG).

Contributed Talk

Splinter Populations

Abundance gradients in the Milky Way disk

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Abundance gradients provide sound constraints for the chemo-dynamical evolutionary models of the Milky Way. For a long time they were studied via specific tracers (e.g., HII regions, Cepheids, open clusters, Planetary Nebulae) for which good distances could be derived. With the advent of asteroseismology and even more the Gaia astrometric mission, accurate distances can also be determined for field red giants, and they are the preferred targets of recent and upcoming multi-object spectroscopic surveys.

In this talk I will discuss the pros and cons of the different tracers used to study the distribution of the metal abundances in the Milky Way. I will focus in particular on recent results concerning the gradients in the inner and the outer disk.

Contributed Talk

Splinter Populations

The AMBRE Project: r-process element abundances in the Milky Way thin and thick discs

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Chemical evolution of r-process elements in the Milky Way disc is still a matter of debate. We took advantage of high resolution HARPS spectra from the ESO archive in order to derive precise chemical abundances of 3 r-process elements Eu, Dy & Gd for a sample of 4 355 FGK Milky Way stars. The chemical analysis has been performed thanks to the automatic optimization pipeline GAUGUIN. Based on the [α/Fe] ratio, we chemically characterized the thin and the thick discs, and present here results of these 3 r-process element abundances in both discs. We found an unexpected Gadolinium and Dysprosium enrichment in the thick disc stars compared to Europium, while these three elements track well each other in the thin disc.

Contributed Talk

Splinter Populations

Hypervelocity stars

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Hypervelocity (HVS)stars travel so fast, that they overcome the Galaxy's gravitational attraction. Such stars were predicted in 1988 to exist if a supermassive black hole acts as a slingshot by disrupting a binary via its tidal interaction and releasing one stellar component at a velocity well above 1000 km/s (the socalled Hills mechanism). Only by 2005 three stars were discovered serendipitously as B- and O/type star far out in the halo (to as much as 60kpc) from radial velocity surveys to exceed the local excape velocity. Because such stars would be important tracer of Galactic dark matter halo as well as for the stellar popuation near the Galactic centre, a systematic survey was carried out, whcih increased the number of known HVS to two dozen today.

Recently it has become obvious that ejection mechanisms other than the Hills mechanism are required to eject stars at sufficiently high velocities. These mechanisms include binary supernova ejection, dynamical ejection from stellar clusters and from disrupted satellite galaxies. The fastest HVS, US 708, is the only known highly evolved low mass star (a hot subdwarf star), for which the Hills mechanism can be excluded because proper motion measurements both from ground as well as form HST rule out an origin in the Galactic centre. The star can be explained as the surviving remnant of a SN Ia explosion. This implies that the progenitor sytem was a close binary consisting of a helium star (hot subdwarf) and a massive white dwarf. When Roche Lobe Overflow started, helium was transfered to the white dwarf until it led to a helium detonation. This inn turn triggered the explosion of the C/O core of the white dwarf as a SN Ia. The subdwarf was released at about its orbital speed. Recently, a few subdwarfs similar to US 708 have been found, for which this scenario is attractive.

Besides a Galactic origin of the HVS stars, HVS of spectral-type B have been suggested to actually come from the LMC, which could explain a striking

Poster

Splinter Populations

Photometric variability in globular clusters

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It is well known, that most globular clusters (GC) contain photometric variable stars. Using differential photometry on MUSE data, we were able to detect most of the RR Lyrae stars and other bright variables in the studied GCs. The used broadband filters V and I were reconstructed from the MUSE spectra. The photometric precision achieved is in the range of 0.03 mag.
Since the MUSE data provides us with the whole spectral information, the Balmer lines H_α and H_β could also be examined for variability. Although only the two Balmer lines were analysed, the used algorithm can be easily extended to other spectral lines.
Possible candidates of new variable stars were found in both, the broadband and the narrowband filters, but further research is needed to eliminate false positives.

Poster

Splinter Populations

Multiple stellar populations in globular clusters

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Recent studies of globular clusters (GC) show that all clusters consist of multiple stellar populations. These populations are subgroups inside the clusters which differ in their stellar and possibly dynamical properties. By using high-precision photometry of red-giant branch (RGB) stars in 14 GCs, it is possible to identify their multiple stellar populations. Following an idea of Piotto et al. (2013), for each cluster color-magnitude diagrams (CMD) in suitable combinations of mostly optical filters have to be produced which maximize the split of the RGB. A clustering algorithm is implemented to achieve the full separation of the multiple populations in a pseudo two-color diagram (also called chromosome map). These populations are further characterized by spectroscopic MUSE data. A significant difference in metallicity is found between the populations. Our results confirm a correlation between RGB width and cluster metallicity.

Poster

Splinter Populations

Mass-dependent dynamics in globular clusters

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The analysis of mass-dependent dynamics in globular cluster mainly hinges on the number of stars observable and the ability to resolve main-sequence stars. Using crowded field 3D spectroscopy on MUSE data, we were able to spectroscopically resolve at least 10^3 stars for 25 globular clusters each, including main-sequence stars. This enabled us to study the mass-dependency of the velocity dispersion for all of these clusters, but in particular NGC 104, NGC 3201, NGC 5139, NGC 6254, NGC 6656 and NGC 6752. Velocity dispersion, meaning the statistical dispersion of velocities around the mean velocity of the cluster, is thereby used as the dynamic's characteristic quantity of each globular cluster. Our results show agreement with theoretical expectations for some clusters. However we also find disagreement for other clusters, namely NGC 6656 and NGC 5139.