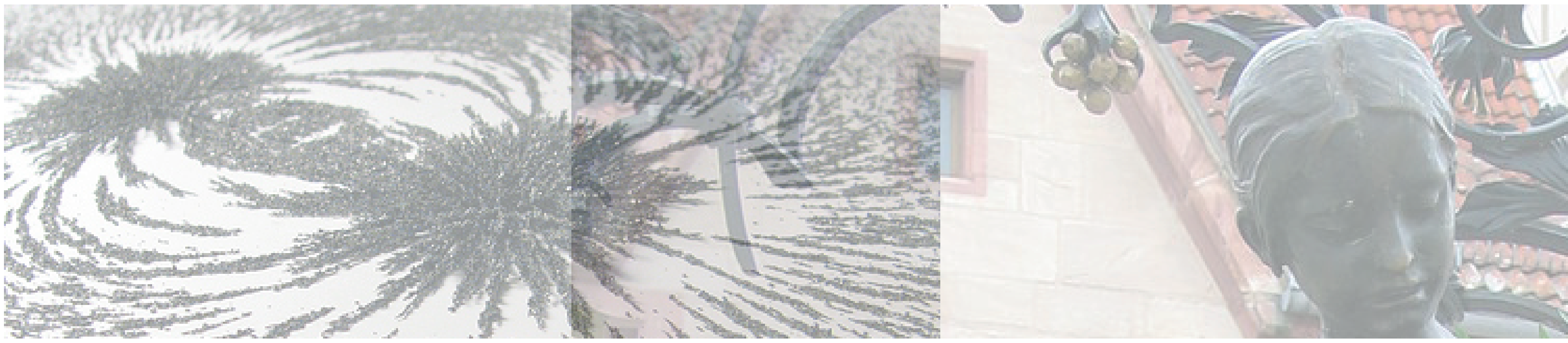

17th MHD Days

MPS Göttingen

Nov. 30 - Dec. 2 2016

Book of Abstracts

17th MHD Days

MPS Göttingen

Nov. 30 - Dec. 2 2016

Book of Abstracts

Editors:
Ankit Barik
Johannes Wicht
Jörn Warnecke

Table of contents

Control of Transient Growth in Hartmann Flow

G. Algrabli [1], S. Arogeti [1], Michael Mond * [1]

[1] Ben-Gurion University of the Negev (BGU) – Israel

The feedback control of perturbations of Hartmann flow is considered. Due to the non normal nature of the operator that underlay the evolution of small perturbations the latter experience transient growth before decaying to zero in a spectrally stable regime. For high enough amplitudes, the path to zero is blocked by exciting nonlinear effects, a process that leads to turbulence. The linearised magnetohydrodynamic (MHD) equations that govern the perturbations are transformed into a finite-dimensional state-space representation by an appropriate choice of a collocation method and base functions. Lorentz forces that are created by the interaction of the constant wall-normal magnetic field and electric currents that are fed into the flow through electrodes placed on the boundaries serve as the actuation agents. The electrodes time dependent electric potential is determined by the linear-quadratic regulator (LQR) control scheme through an appropriate algebraic Riccati equation (ARE) that seeks the optimised trade off between transient energy reduction and control effort. Numerical experiments demonstrate that the titling mechanism that is responsible for the transient growth is indeed effectively blocked as result of the substantial reduction (by an order of magnitude) of the perturbed stream wise vorticity. As a result, the transient energy response magnitudes are significantly reduced compared with the uncontrolled case. The control scheme is currently being embedded in numerical simulations of the full nonlinear three dimensional MHD equations.

*Speaker

Numerical Investigation of Magnetically Induced Instabilities

Thomas Arlt * , Leo Bühler [1], Janis Priede [2]

[1] Karlsruhe Institute of Technology (KIT) – Campus North Hermann-von-Helmholtz-Platz 1 76344 Eggenstein-Leopoldshafen, Germany
[2] Applied Mathematics Research Centre – Coventry University, United Kingdom

Magnetohydrodynamic (MHD) flows in electrically conducting rectangular ducts exhibit jet-like velocity profiles in thin boundary layers near the side walls, which are parallel to the magnetic field. It is known that these layers may become unstable or even turbulent for sufficiently high Reynolds numbers.
A linear stability analysis has been performed for such flows in ducts with thin electrically conducting walls in a uniform constant magnetic field. The present analysis is an extension of previous studies [1] and results apply now for flows with general wall conductance and very high Hartmann numbers. Results are presented for the critical Reynolds number depending on Hartmann number, wall conductivity and aspect ratio.

The onset of MHD-instabilities was additionally investigated by direct numerical simulations using OpenFoam. Simulations show a good agreement with results of the linear stability analysis. With increasing Reynolds number a sudden increase of turbulent kinetic energy by several orders of magnitude is observed, which indicates the bifurcation to another flow regime. Similar phenomena have been observed in experiments and previous numerical simulations (see e.g. [2]).

Acknowledgement: Financial support of this research by the German Helmholtz Association in the frame of the Helmholtz-Alliance LIMTECH is gratefully acknowledged.

Bibliography

[1] J. Priede, S. Aleksandrova and S. Molokov, "Linear stability of Hunt's flow," *Journal of Fluid Mechanics,* vol. 649, pp. 115-134, 2010.

[2] M. Kinet, B. Knaepen and S. Molokov, "Instabilities and transition in magnetohydrodynamic flows in ducts with electrically conducting walls," *Physical Review Letters,* vol. 103, p. 154501, 2009.

*Speaker

The Lie-Taylor Approach to MHD Transients

Wayne Arter * [1]

[1] Culham Centre for Fusion Energy (CCFE) – D3 Culham Science Centre Abingdon, Oxon OX14 3DB, United Kingdom

The linear fields model of ideal compressible MHD, introduced by Dungey[1] has been extended to 3-D (and renamed the 'affine motions' model), and to higher field spatial order[2].
In consequence, issues relating to the finiteness of model energy have been successfully addressed.
Dissipation has also been added, making it possible to consider implications for the problem of fast reconnection relevant to both laboratory and coronal MHD. Refs.

[1] J.W.Dungey, 'Cosmic Electrodynamics', CUP, 1958.
[2] W.Arter, 'Beyond Linear Fields: the Lie-Taylor Expansion', http://arxiv.org/abs/1606.08763, 2016.

*Speaker

A homopolar disc dynamo experiment with liquid metal contacts

Raúl Avalos-Zúñiga *† [1], Janis Priede [2], Carla Bello Morales [1]

[1] CICATA Qro. Instituto Politécnico Nacional (IPN) – Mexico
[2] Applied Mathematics Research Centre – Coventry University, United Kingdom

We present experimental results of the homopolar disc dynamo device constructed at CICATA-Querétaro in Mexico. Its design consists of a flat, multi-arm spiral coil, which is placed above a fast-spinning metal disc and connected to the latter by sliding liquid-metal electrical contacts. The theoretical calculations for this experiment have shown a magnetic Reynolds number of 45, at which the dynamo is self-excited. This corresponds to a critical rotation frequency of 10:5Hz. We report measurements of the induced magnetic field and voltage drop on the coil for rotation rates up to 14Hz. The device did not work as a self-excited dynamo, as was expected, but an oscillatory behavior of the measured quantities was observed. This behavior seems to be due to a fluctuating electrical resistance of the sliding contacts. It could be originated by the free surface dynamics of the liquid-metal along the outer annular gap. We have estimated a rotation frequency of around 20Hz at which the dynamo should be self-excited. However, due to leakage problems of the liquid metal, we were not able to run the experiment beyond rotation rates of 14Hz.

*Speaker
†Corresponding author: ravalosz@ipn.mx

Hydrodynamic regimes of the spherical Couette flow

Ankit Barik * [1], Johannes Wicht [1], Santiago Triana [2], Michael Hoff [3]

[1] Max Planck Institute for Solar System Research (MPS) – Justus-von-Liebig-Weg 3 37077 Göttingen, Germany
[2] Royal Observatory of Belgium – Belgium
[3] Department of Aerodynamics and Fluid Mechanics, Brandenburg University of Technology Cottbus - Senftenberg – Germany

The spherical Couette flow consists of two concentric spheres differentially rotating with a fluid filled in between. This is a system with potential applications to the interiors of terrestrial planets, stars, atmospheric and oceanic circulations and industrial problems. We investigate this system using numerical simulations using two independent codes - MagIC and XSHELLS and compare the results with experiments at BTU Cottbus-Senftenberg. Keeping the rotation rate of the outer boundary constant, increasing the differential rotation causes the system to transition through three hydrodynamic regimes, as observed experimentally by Hoff et al. (2016). We refer to the three regimes are broadly as (i) Fundamental instability, (ii) Inertial Modes, (iii) Turbulence, and we address problems related to each regime. Inertial modes are Coriolis-restored oscillations in a rotating fluid. Their onset in this system has been a pertinent question with several attempts to explain it using theory of overreflection (Kelley et al. 2010) or the drift of a shear layer (Rieutord et al. 2012), each having their own pitfalls. We find the onset of inertial modes to take place in the form of a triadic resonance with the fundamental instability. Drift frequencies and mode structures observed in simulations are compared to experiments and an excellent agreement is found. An artificial excitation is used to explain the differences of the drift frequencies observed in simulations and experiments to those predicted analytically for a full sphere (Greenspan, 1968; Zhang, 2001) or from eigenmode computations (using SINGE; Vidal and Schaeffer, 2015).

*Speaker

Maximum electromagnetic drag configurations for a translating conducting cylinder with distant magnetic dipoles

Thomas Boeck * [1], Dzulia Terzijska [2], Gabriele Eichfelder [2]

[1] Technische Universität Ilmenau – TU Ilmenau Ehrenbergstr. 29 98693 Ilmenau, Germany
[2] Technische Universität Ilmenau (TU Ilmenau) – Germany

We report a semi-analytical and numerical investigation of the maximal induced Lorentz force on an electrically conducting cylinder in translation along its axis that is caused by the presence of multiple distant magnetic dipoles. The problem is motivated by Lorentz force velocimetry, where induction creates a drag force on a magnet system placed next to a conducting flow. The magnetic field should maximize this drag force, which is usually quite small. Our approach is based on a long-wave theory developed for a single distant magnetic dipole. We determine the optimal orientations of the dipole moments providing the strongest Lorentz force for different dipole configurations using numerical optimization methods. When an increasing number of dipoles is arranged on a circle surrounding the cylinder axis with equidistant spacing we observe that the optimal orientations of the dipole moments approach a limiting distribution. It differs from the so-called Halbach distribution that provides a uniform magnetic field in the cross-section of the cylinder. We also study evenly spaced dipoles along one or two lines parallel to the cylinder axis. The patterns of optimal magnetic moment orientations are fairly similar for different dipole numbers when the inter-dipole distance is within a certain interval. This behavior can be explained by reference to the magnetic field distribution of a single distant dipole on the cylinder axis.

*Speaker

Stellar dynamo models with harmonic coronal fields

Alfio Bonanno * [1]

[1] INAF Catania Astrophysical Observatory (OACt) – Italy

Recent spectro-polarimetric observations of solar-type stars have shown the presence of photospheric magnetic fields with a predominant toroidal component. If the external field is assumed to be current-free it is impossible to explain these observations within the framework of standard mean-field dynamo theory. In this work it will be shown that if the coronal field of these stars is assumend to be harmonic, the underlying stellar dynamo mechanism can support photospheric magnetic fields with a prominent toroidal component even in the presence of axisymmetric magnetic topologies. In particular it is argued that the observed increase in the toroidal energy in low mass fast rotating stars can be naturally explained with an underlying $\alpha\Omega$ mechanism.

*Speaker

Testing of MHD generator prototype for Space applications

Artūrs Brēķis * [1], Jānis Freibergs† [1], Agris Gailītis‡ [1]

[1] Institute of Physics of University of Latvia (IPUL) – Latvia

This paper describes a machine based on coupled thermo acoustic (TAc) and magnetohydrodynamic (MHD) generators, which are an innovating technology ideally free of moving parts. In Europe there is a strong expertise in thermo acoustic and MHD. But these technologies have never been coupled. Both engines have been manufactured and tested in Institute of Physics of University of Latvia (IPUL). At first MHD generator and TAc generator were tested separately and then both together. The aim of these tests was a validation of possibility of making sodium oscillations with external force, testing free surface stability of gas-liquid sodium and studying of TAc and an AC MHD generator working principles in different conditions.

*Speaker
†Corresponding author: jf@sal.lv
‡Corresponding author: gailitis@sal.lv

Dynamos in stably stratified rotating stars

Friedrich Busse * [1]

[1] Universität Bayreuth – Germany

.

*Speaker

Coherent Structures of Turbulence Modelled by Sequences of Bifurcations

Friedrich Busse * [1]

[1] Universität Bayreuth – Germany

Thermal convection in a fluid layer heated from below will be used as an example since it represents the simplest fluid dynamical system for the study of the transition to turbulence. It is characterized by the Rayleigh number R as a measure of the applied temperature difference and by the Prandtl number as the second dimensionless parameter describing the ratio of the two nonlinearities governing the system. The transition from simple roll like fluid motions to complex flows with increasing R may occur either through gradual evolution from uncontrolled initial conditions. Or it may occur through sequences of subsequent bifurcations from simple to more complex spatially regular and time periodic states when started with controlled initial conditions. The regular patterns obtained in the latter case often turn out to be reflected in the coherent structures exhibited by fully developed turbulent convection as realized, for instance, in the atmosphere. To demonstrate the two scenarios numerical simulations and experimental demonstrations may be used. For the latter purpose a laboratory movie will be shown.

*Speaker

Electrically coupled 3D MHD flows in manifolds for helium cooled lead lithium fusion blankets

Leo Bühler *† [1], Chiara Mistrangelo [1]

[1] Karlsruhe Institute of Technology (KIT) – Campus North Hermann-von-Helmholtz-Platz 1 76344 Eggenstein-Leopoldshafen, Germany

In support of design activities for a helium cooled lead lithium (HCLL) blanket for a future DEMO fusion reactor [1] and for a prototype to be tested in ITER, it is necessary to estimate pressure losses in liquid metals caused by electromagnetic forces. The latter ones are due to the interaction of the electrically conducting liquid breeder lead lithium (PbLi) with the magnetic field that confines the fusion plasma. Previous experimental and theoretical analyses of magnetohydrodynamic (MHD) flows in simplified HCLL geometries suggest that the major fraction of pressure drop arises in the manifolds that distribute and collect the liquid metal into and from the breeder units [2]. Flows in feeding and draining manifolds are mutually electrically coupled via leakage currents, which may cross the common electrically conducting wall that hydraulically separates the channels. This results in complex 3D current paths, peculiar velocity distributions with partially reversed flow, and additional pressure drop. Flow properties have to be determined by appropriate experiments and by theoretical analyses for developing a reliable design of a HCLL blanket module and for assessing its operating conditions and performance. The present work investigates MHD effects caused by electromagnetic flow coupling in a prototypical model geometry of a manifold. Results for pressure drop, distribution of electric potential and velocity are presented. It turns out that the flow path may be rather complex with regions of partially reversed flow.

Acknowledgement: This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

References

[1] G. Aiello, J. Aubert, N. Jonquères, A. L. Puma, A. Morin and G. Rampal, "Development of the Helium Cooled Lithium Lead blanket for DEMO," *Fusion Engineering and Design,* vol. 89, no. 7-8, pp. 1444-1450, 2014.

[2] C. Mistrangelo and L. Bühler, "Magnetohydrodynamic pressure drops in geometric elements forming a HCLL blanket mock-up," *Fusion Engineering and Design,* vol. 86, pp. 2304-2307, 2011.

*Speaker

†Corresponding author: leo.buehler@kit.edu

The surprising simplicity of the global solar dynamo

Robert Cameron [1], Manfred Schüssler * [1]

[1] Max Planck Institute for Solar System Research (MPS) – Goettingen, Germany

Notwithstanding the complex dynamics of turbulent magneto-convection, the global nature of the 11-year cycle (as exhibited, for instance, by Hale's polarity laws, the reversing axial dipole field, and the butterfly diagram) admits a description of the dynamo process in terms of relatively simple concepts and mathematical models (alpha-omega-type dynamos in all their various guises). Since the structure of magnetic fields and flows (apart from differential rotation) in the convection zone so far can neither be reliably observed or simulated, we have to rely on surface observations of the Sun and studies of the activity of other stars in order to connect the models to reality.

It was recently shown that the relevant process for regenerating the poloidal field (the alpha-effect) actually is a near-surface process related to the tilt of the sunspot groups and the transport of emerged magnetic flux by convective flows (random walk) and meridional flow to build up the polar fields, as already suggested by Babcock and Leighton in the 1960s. It turns out that the key features of the so-called Babcock-Leighton Flux Transport Dynamos can be condensed into a simple quasi-1D model (akin to Leighton's 1969 model) with a small number of parameters. A full parameter study then provides 'reasonable' parameter values for the solar dynamo.

Observations of solar-like stars have revealed that the level of magnetic activity decreases strongly with rotation rate. The relatively slow rotation of the Sun puts it near to the threshold for which global dynamo action ceases. Almost all dynamo models exhibit the onset of dynamo excitation in terms of a supercritical Hopf bifurcation (a fixed point losing stability and spawning a limit cycle). This gives the possibility to define a generic model of the solar cycle in terms of the normal form for a weakly nonlinear system near a Hopf
bifurcation. Including the inherent randomness brought about by the flux emergence process leads to a stochastic differential equation for a noisy limit cycle, whose parameters are fixed by observations. The model results are fully consistent with the variability of the solar cycle amplitudes from decadal to millennial time scales. Since the variability solely resuts from randomness, this severely limits the scope for predictions of future activity levels.

*Speaker

A sandwich stable layer in Saturn's deep interior

Wieland Dietrich * [1], Johannes Wicht [2], Thomas Gastine [3]

[1] Max Planck Institute for Solar System Research (MPS) – Justus-von-Liebig-Weg 3 37077 Göttingen, Germany
[2] Max Planck Institute for Solar System Research (MPS) – Justus-von-Liebig-Weg 3 37077 Göttingen, Germany
[3] Institut de Physique du Globe de Paris (IPGP) – Université de la Réunion, Université Paris VII - Paris Diderot, IPG PARIS, INSU, CNRS : UMR7154 – IPGP, 1 rue Jussieu, 75238 Paris cedex 05 ; Université Paris Diderot, Bât. Lamarck A case postale 7011, 75205 Paris CEDEX 13, France

The observation of Saturn's magnetic field and surface winds challenged interior models for decades. The magnetic field is much more axisymmetric than simpler 3D MHD models typically reproduce. The surface winds inferred by cloud tracking show a strong equatorial prograde (eastwards) jet and several much weaker jets closer to the poles. Both features might be explained by a sandwiched stably stratified layer (S3L) between a deeper convective dynamo and a shallower turbulent convective, but non-magnetic region. Such a layer will then axisymmetrise the dynamo-generated magnetic field and alter the surface manisfestation of the differential rotation, e.g. creating numerous high-latitude jets.

Saturn's atmosphere consists mainly of helium and hydrogen. Both are thought to be well mixed by rapid convective flows in the outer convective region, where hydrogen is molecular. However, at greater depth (r/$r_S = 0.65$, or at 1Mbar) hydrogen becomes metallic and immiscible with helium. Helium then rains out and sinks downwards. At even greater depth, the temperature and helium abundance are much higher such that helium and hydrogen are miscible again (immiscibility gap). This will lead to a helium-depleted outer and a helium-enriched inner convective zone. In between a strong helium gradient establishes and defines a compositional stable stratification suppressing convection, magnetic field generation and differential rotation.

We therefore numerically model the effect of a S3L on convection and the generation of differential rotation. The S3L is implemented by defining a background entropy profile. Our results suggest, that the S3L efficiently damps the convection, alters the differential rotation and leads to a more Saturn-like surface zonal flow profile.

*Speaker

The role of helicity inversion in cyclical magnetism in global dynamo simulations

Lucia Duarte *† [1], Matthew Browning‡ [2], Johannes Wicht [3]

[1] College of Engineering , Mathematics and Physical Sciences [Exeter] (CEMPS) – Stocker Road, EX4 4QL, United Kingdom
[2] University of Exeter – Exeter, UK, United Kingdom
[3] Max Planck Institute for Solar System Research (MPS) – Justus-von-Liebig-Weg 3 37077 Göttingen, Germany

In the Sun, active regions emerge first at midlatitudes, and appear nearer the equator over the course of a cycle. Most previous global-scale dynamo simulations have instead exhibited poleward propagation of toroidal field (if cyclical at all). In Duarte et al. 2016, we discussed a hydrodynamical mechanism to invert the sign of the kinetic helicity, which in some cases plays a key role (together with the differential rotation) in determining the direction of propagation of the magnetism. We showed that in certain cirumstances the kinetic helicity could be positive throughout much of the Northern hemisphere, in sharp contrast to the situation that prevails in either highly columnar (rapidly rotating) or strongly stratified local convection. Here, we analyse the consequences of this helicity inversion for cyclical magnetic activity in a series of global MHD simulations. In particular, we analyze the relative roles of differential rotation and kinetic helicity in setting the direction of propagation.

*Speaker
†Corresponding author: lduarte@astro.ex.ac.uk
‡Corresponding author: browning@astro.ex.ac.uk

Saturation of the Dynamo in the turbulent ISM

Detlef Elstner * [1], Abhijit Bendre , Oliver Gressel

[1] Leibniz-Institut für Astrophysik Potsdam (AIP) – Germany

Direct MHD-Simulations of the turbulent interstellar medium are analysed with the test field method. Algebraic relations between mean field and turbulent electromotive force are presented. Comparison with mean field models enlightens the saturation process in dependence of the supernovae rate.

*Speaker

Exploring a new regime of a delayed Babcock-Leighton dynamo

Yori Fournier * [1]

[1] Leibniz Institute for Astrophysics (AIP) – An der Sternwarte 16, 14482 Potsdam, Germany

Thank to the implementation of a non-linear delay-term into a standard Babcock-Leighton dynamo model, we identified unexpected dynamo solutions. Along this talk, we will present the particularity of the model, explore the various characteristics of the new dynamo solutions, and finally show some later results aiming to explain this new dynamo regime.

*Speaker

Formation of dense gas cores due to supernova remnant-cloud interactions

Philipp Gast * [1]

[1] Leibniz Institute for Astrophysics Potsdam (AIP) – Leibniz-Institut für Astrophysik Potsdam (AIP)
An der Sternwarte 16 14482 Potsdam Germany, Germany

Triggered star formation is a dynamical process where the critical compression of an interstellar gas cloud is induced by external force. One possible cause for this compression is the impact of a supernova shockfront originating from a dying massive star upon an already condensed gas cloud. Because it effectively abbreviates the 'usual' ISM cycle and thereby increases the star formation rate and chemical evolution this process has the potential to influence whole galaxies.
In this talk I will present the setup and planned outline of our currently ongoing simulation project to study triggered star formation in unprecedented detail utilizing the finite volume AMR NIRVANA code. Special features are the inclusion of anisotropic heat conduction, self-gravity and a self-consistent chemistry/cooling model.

*Speaker

Scaling regimes in spherical shell rotating convection

Thomas Gastine * [1], Johannes Wicht [2], Julien Aubert [1]

[1] Institut de Physique du Globe de Paris (IPGP) – Université de la Réunion, Université Paris VII - Paris Diderot, IPG PARIS, INSU, CNRS : UMR7154 – IPGP, 1 rue Jussieu, 75238 Paris cedex 05 ; Université Paris Diderot, Bât. Lamarck A case postale 7011, 75205 Paris CEDEX 13, France
[2] Max Planck Institute for Solar System Research (MPS) – Justus-von-Liebig-Weg 3 37077 Göttingen, Germany

Rayleigh-Benard convection in rotating spherical shells can be considered as a simplified analogue of many astrophysical and geophysical fluid flows. Here, we use three-dimensional direct numerical simulations to study this physical process. We construct a dataset of more than 200 numerical models that cover a broad parameter range with Ekman numbers spanning $3 \times 10^{-7} \leq E \leq 10^{-1}$, Rayleigh numbers within the range $10^3 < Ra < 2 \times 10^{10}$ and a Prandtl number unity. We investigate the scaling behaviours of both local (length scales, boundary layers) and global (Nusselt and Reynolds numbers) properties across various physical regimes from onset of rotating convection to weakly-rotating convection. Close to critical, the convective flow is dominated by a triple force balance between viscosity, Coriolis force and buoyancy. For larger supercriticalities, a small subset of our numerical data approaches the asymptotic diffusivity-free scaling of rotating convection $Nu \sim Ra^{3/2}E^2$ in a narrow fraction of the parameter space delimited by $6Ra_c \leq Ra \leq 0.4E^{-8/5}$. Using a decomposition of the viscous dissipation rate into bulk and boundary layer contributions, we establish a theoretical scaling of the flow velocity that accurately describes the numerical data. In rapidly-rotating turbulent convection, the fluid bulk is controlled by a triple force balance between Coriolis, inertia and buoyancy, while the remaining fraction of the dissipation can be attributed to the viscous friction in the Ekman layers. Beyond $Ra \sim E^{-8/5}$, the rotational constraint on the convective flow is gradually lost and the flow properties continuously vary to match the regime changes between rotation-dominated and non-rotating convection. We show that the quantity $RaE^{12/7}$ provides an accurate transition parameter to separate rotating and non-rotating convection.

*Speaker

Towards a new liquid metal experiment in super-rotating TC flows

Marcus Gellert * [1]

[1] Leibniz Institute for Astrophysics Potsdam (AIP) – Germany

One of the most stable configurations in hydrodynamics is a Taylor-Couette flow with super-rotating outer cylinder, thus a co-rotating outer cylinder faster than the inner with the limit of a resting inner cylinder. Surprisingly, by adding a toroidal magnetic field, such flows become easily unstable. We show that this instability does not depend much on the radial profile of the magnetic field, that it is double-diffusive and needs therefore a large or small magnetic Prandtl number, and is suitable for a liquid metal experiment. Compared to the AMRI experiment with negative shear, it needs roughly a factor of three for the current and nearly the same rotation rates.

*Speaker

Simulations for the precession experiment at HZDR

Andre Giesecke *† [1], Thomas Gundrum [1], Tobias Vogt [1], Frank Stefani [1]

[1] Helmholtz-Zentrum Dresden Rossendorf [Allemagne] (HZDR) – Bautzner Landstraße 400 - 01328 Dresden, Germany

The project DRESDYN (DREsden Sodium facility for DYNamo and thermohydraulic studies) conducted at Helmholtz-Zentrum Dresden-Rossendorf (HZDR) provides a new platform for a variety of liquid sodium experiments devoted to problems of geo- and astrophyscal magnetohydrodynamics.
Most ambitious experiment will be a precession driven dynamo experiment which consists of a large cylindrical cavity filled with liquid sodium that will simultaneously rotate around two axis. The experiment is motivated by the idea of a precession-driven flow as a complementary energy source for the geodynamo or the ancient lunar dynamo. My presentation addresses corresponding numerical examinations aimed at an optimization of the precession driven flow with regard to improve the dynamo process in the planned experiment.

*Speaker
†Corresponding author: a.giesecke@hzdr.de

Dynamos in precessing cubes

Oliver Goepfert * [1], Andreas Tilgner [1]

[1] University of Goettingen – Germany

We investigate the ability of precession driven flows to generate magnetic fields due to the dynamo effect in a cuboid . Numerical simulations of rotating flows are often limited by effects in the boundary layer, which need a very high time consuming grid resolution. This is why we use free-slip boundary conditions in a cubic geometry instead of more problematic no-slip conditions while calculating a finite-differences DNS system on GPU-computing machines. We were able to identify different flow regimes inside a cube with varying effect on critical magnetic Prandtl number needed for dynamo action.

*Speaker

Large eddy simulations of decaying supersonic MHD turbulence

Philipp Grete *† [1], Dimitar Vlaykov [2], Wolfram Schmidt [3], Dominik Schleicher [4]

[1] Michigan State University (USA) (MSU) – Department of Physics & Astronomy Michigan State University Biomedical Physical Sciences 567 Wilson Road, Room 3248 East Lansing, MI 48824, United States
[2] Max-Planck-Institut für Dynamik und Selbstorganisation – Germany
[3] Hamburger Sternwarte – Germany
[4] Universidad de Concepción - UDEC (CHILE) – Chile

Magnetic fields and turbulence play an important role in many astrophysical processes. The resulting large dynamical range prohibits direct simulations with realistic parameters in most situations. Large eddy simulations (LES), which only simulate large and intermediate scalesdirectly, are an alternative approach. However, they rely on a subgrid-scale (SGS) model to incorporate the effects from the smallest, unresolved scales. We present comparative statistics of LES with different SGS models of eddy-viscosity, scale-similarity and nonlinear type. In the realm of decaying supersonic isotropic MHD turbulence we find that only the eddy-viscosity and the nonlinear model improve higher-order statistics such as distributions of vorticity and current density, or structure functions. Moreover, we test the necessity of an explicit filter, i.e. to calculate the SGS model quantities at a scale larger than the grid scale. We find that (a small) explicit filter is required for all SGS models to make a statistically significant impact on the evolution of the flow.

*Speaker
†Corresponding author: grete@pa.msu.edu

Ultrasonic flow measurements in a 1:6 downscaled water mockup of the DRESDYN dynamo experiment

Thomas Gundrum * [1], Tobias Vogt [1], Frank Stefani [1], Andre Giesecke [1]

[1] Helmholtz-Zentrum Dresden-Rossendorf (HZDR) – Bautzner Landstraße 400 - 01328 Dresden, Germany

The project DRESDYN (DREsden Sodium facility for DYNamo and thermohydraulic studies) conducted at Helmholtz-Zentrum Dresden-Rossendorf (HZDR) provides a platform for a variety of liquid sodium experiments.
Most ambitious experiment will be a precession driven dynamo experiment which consists of a large cylindrical cavity filled with liquid sodium that will simultaneously rotate around two axis. The experiment is motivated by the idea of a precession-driven flow as a complementary energy source for the geodynamo or the ancient lunar dynamo.
The detailed knowledge of the flow structure in the precessing cylindrical vessel is of key importance for the prediction of the dynamo action. My presentation addresses experimental examinations with ultrasonic Doppler velocimetry in the low Reynolds region to validate numerical simulations.

*Speaker

Magnetorotational instability in Taylor-Couette flow: transport properties and dynamo action

Anna Guseva * [1], Rainer Hollerbach [2], Ashley Willis [3], Marc Avila [4]

[1] Center of Applied Space Technology and Microgravity, University of Bremen (ZARM) – Am Fallturm, 29359 Bremen, Germany
[2] School of Mathematics, University of Leeds – Woodhouse Lane, Leeds LS2 9JT, United Kingdom
[3] School of Mathematics and Statistics [Sheffield] (SoMaS) – University of Sheffield Hicks Building Hounsfield Road Sheffield S3 7RH, United Kingdom
[4] Center of Applied Space Technology and Microgravity, University of Bremen (ZARM) – Am Fallturm, 28359 Bremen, Germany

The magnetorotational instability (MRI) is considered to be the most probable source of turbulence in accretion disks. In this talk we will address two important questions related to magnetorotational instability in Taylor–Couette geometry. First, we will present our results on the turbulent transport of angular momentum in the flow under imposed azimuthal magnetic field. We will discuss how Reynolds, Maxwell and viscous stresses contribute to the total angular momentum transport, distinguishing between "hydrodynamic" turbulence (where Maxwell stresses are negligible) and "magnetohydrodynamic" turbulence (with Maxwell stresses dominating). The boundary between the two regimes was found to be at about Rm _~100. The second question to be adressed is the observation of subcritical MRI turbulence outside of the region where flow is linearly unstable. This will be followed by the simulation results, demonstrating the possibility of MRI turbulence to sustain magnetic fields in Taylor–Couette geometry even in the absence of imposed external magnetic field. The respective growth of magnetic and kinetic energy supports the idea of existence of self-sustained dynamo in quasi-Keplerian flows.

*Speaker

Observing Stellar Dynamos in Action

Thomas Hackman * [1]

[1] University of Helsinki – Finland

Dynamo activity of late-type stars manifests itself in the same way as the Suns activity: Spots, active chromosphere and corona, flares etc. Thus by studying the evolution of e.g. spots and surface magnetic fields of late-type stars, we can both check predictions from MHD simulations and retrieve observational constraints for the modelling. The presentation will focus on some results obtained through optical observations analysed by time series and inversion methods.

*Speaker

Local Lorentz force velocimetry at a continuous casting model

Daniel Hernández * [1], Christian Karcher [1], Thomas Wondrak [2]

[1] Technische Universität Ilmenau (TU Ilmenau) – Ehrenbergstraße 29, Ilmenau, Germany, Germany
[2] Helmholtz-Zentrum Dresden-Rossendorf (HZDR) – Bautzner Landstraße 400 - 01328 Dresden, Germany

Local Lorentz force velocimetry is a local velocity measurement technique for liquid metals. Due to the interaction between an electrically conductive liquid and an applied magnetic field, eddy currents and flow-braking Lorentz forces are induced within the fluid. Due to Newton's third law, a force of the same magnitude acts on the source of the applied magnetic field, which is in our case a permanent magnet. The magnet is attached to a force/torque sensor that has been especially developed to record all three force and three torque components acting on the magnet. This new-generation local Lorentz force flowmeter (L2F2) has already been tested at a test stand for continuous casting with a 15 mm cubic magnet providing an insight into the three-dimensional velocity distribution of the model melt GaInSn near the wide face of the mold. However, the torque component perpendicular to this surface was not accessible at all. In the present paper, we describe the numerical model and the corresponding results that show that with a cross-shaped magnet we are able to measure this torque in liquid metals with our sensor. According to our results, this torque correlates with the curl of the velocity in this direction.

*Speaker

The dynamics of magnetic Rossby waves in spherical dynamo simulations

Kumiko Hori * [1], Chris Jones [2], Rob Teed [3]

[1] Department of Applied Mathematics, University of Leeds – Woodhouse Lane, Leeds LS2 9JT, United Kingdom
[2] Department of Applied Mathematics, University of Leeds – United Kingdom
[3] DAMTP, University of Cambridge – United Kingdom

We extend the investigation of slow magnetic Rossby waves in convection-driven dynamos in rotating spherical shells. These waves can account for observed westward drifts of the geomagnetic field and have the potential to infer the toroidal field strength within the planetary fluid core. With preferred wavenumbers and background mean flows varying, a predicted dispersion relation fits well with longitudinal drifts observed in our simulations. We also discuss the role of nonlinear Lorentz terms in the waveforms. These wave motions are mostly excited by convective instability, determining the preferred azimuthal wave numbers. Studies of rotating magnetoconvection have suggested that slow magnetic Rossby modes would emerge in the magnetostrophic regime, in which the Lorentz force balances the Coriolis force. This predominant balance for the slow wave propagation is signified in our dynamo simulations. The identification of these waves, as well as convective spatial patterns, could reveal a signature of hypothesized magnetostrophic dynamos.

*Speaker

MHD sloshing instability in liquid metal batteries

Gerrit Horstmann * [1]

[1] Helmholtz-Zentrum Dresden Rossendorf [Allemagne] (HZDR) – Bautzner Landstraße 400 - 01328 Dresden, Germany

Liquid metal batteries (LMBs) are discussed today as a cheap grid scale energy storage, as required for the deployment of fluctuating renewable energies. LMBs incorporate stratified three-layer fluid systems consisting of two liquid metal electrodes separated by a thin molten salt electrolyte. Due to the high electrical conductivities of the liquid metals, LMBs are highly susceptible for becoming unstable by MHD interactions of magnetic fields induced by internal and external currents. Besides the Tayler instability and the electrovortex instability, the so-called sloshing instability, also known as the metal pad roll instability in aluminum reduction cells, was identified as a key instability mechanism capable to cause short-circuits. Dimensionless stability parameters derived from inviscid two-layer system can predict the onsets for sloshing and short-circuits with some success for a limited parameter range, but the two-layer description is far from perfect. To quantify the two-layer limitations, a three-layer dispersion relation was derived and deviations from the two-layer system were discussed. On this basis it is planned to extract three-layer stability criteria additionally including viscous damping to predict instability onsets in direct dependence of the geometrical parameters and material properties of LMBs. Further to this, three-layer experiments are under development aiming to measure the interaction and stability of interfacial waves using Doppler Ultrasound Velocimetry (DUV) and Magnetic Field Tomography (MFT) for checking the validity of different stability criteria.

*Speaker

A deep-seated mechanism for cycle-dependent sunspot group tilt angles

Emre Isik *† [1]

[1] Max Planck Institute for Solar System Research – Germany

The cycle-averaged tilt angle of sunspot groups is an important quantity in determining the magnetic flux diffusing across the equator in a given cycle, which is highly correlated with the strength of the subsequent cycle. This quantity has recently been reported to be anti-correlated with the strength of the solar cycle. I suggest that a deep-seated thermodynamic cycle in phase with the activity cycle can be responsible for the observed correlation. Motivated by helioseismic indications, I calculate the effect of cooling of the convective overshoot region on the stability and dynamics of magnetic flux tubes. I find that cycle-to-cycle variations in the range 5-20 K at the base of the convection zone can explain the observed range of tilt angle fluctuations among different cycles. This mechanism can play a role in the nonlinear saturation and amplitude fluctuations of the solar dynamo.

*Speaker
†Corresponding author:

Spreading of magnetic reconnection at electron scales: Electron-magnetohydrodynamic simulations

Neeraj Jain *† [1], Joerg Buechner [1]

[1] Max Planck Institute for Solar System Research (MPS) – Germany

Magnetic reconnection is considered to be the cause of the release of magnetic energy in solar flares, sub-storms in Earth's magnetosphere, sawtooth crashes in tokamaks and many astrophysical systems, e.g., accretion disk. In many plasmas of interest, magnetic reconnection first takes place in a localized region of space and then spreads away from the localized region. For example, in solar observations of two ribbon flares, flare brightening indicative of reconnection has been observed to spread bidirectionally along the polarity inversion line. Laboratory experiments in Versatile Toroidal Facility (VTF) with a strong guide field also show bidirectional spreading of localized reconnection along the guide field. In collisionless plasmas, e.g., solar flares, reconnection of field lines takes place in self-consistently formed electron current sheets and couples to ion, and then further to very large magnetohydrodynamic scales. We present simulations of the spreading of magnetic reconnection at electron scales using an electron-magnetohydrodynamic model (eMHD)- a magnetohydrodynamic like model for electron scales. We show that on electron scales a patch of the localized magnetic reconnection spreads bi-directionally in a wave like fashion when an external magnetic field in the direction of the electron current is present. The spreading is caused by the propagation of the electron flow induced and whistler wave modes away from the localized patch. For small external fields, the spreading is asymmetric being faster in the direction of the electron flow. On increasing the external field, the spreading becomes increasingly symmetric due to the dominance of the whistler group speed in determining the speed of the spreading. The wave-like spreading of reconnection causes the alternate formation of X- and O-points in the reconnection planes separated by half the wavelength of the reconnection wave.

*Speaker

†Corresponding author: jain@mps.mpg.de

Investigation of the Electrovortex Flow in the External Magnetic Field

Irina B Klementyeva * [1], Igor Teplyakov , Dmitriy Vinogradov , Yuri Ivochkin

[1] Joint Institute for High Temperatures of RAS – Russia

Electrovortex flows (EVF) significantly affect many processes in mechanical engineering and electrometallurgy (electro-welding, electro-slag and electro-arc remelting). In particular, the EVF determines the hydrodynamic structure of the melt in the bath of DC arc furnaces, which are widely used in industry. The electrovortex flow under consideration is formed as a result of the interaction of the non-uniform electric current, passing through liquid metal, with the own magnetic field of that current. In the paper we investigate the influence of external magnetic field (MF) on the EVF structure of the liquid metal in a hemispherical container.
The experimental studies were carried out with the setup of the following construction. Eutectic indium-gallium-tin alloy is used as the working liquid in the experiments. The alloy fills the copper hemispherical container which also serves as a large electrode. The small electrode is a copper or steel cylinder with a hemispherical tip. It is immersed into the alloy on the axis of the working area. The electric current is generated with the power source developed on the basis of a three-phase AC rectifier. The external magnetic field is created by a solenoid.
Numerical and experimental investigations of the EVF structure in the external magnetic field were carried out. The time moment of the secondary vortex formation on the external magnetic field value for the wide range of the own electric current was determined. The boundary curve was constructed.

*Speaker

From solar to stellar dynamos combining observations and modelling

Maarit Käpylä * [1]

[1] Max Planck Institute for Solar System Research (MPS) – Germany

Recent advances in understanding solar and stellar dynamos from the point of view of theory and numerical simulations, trying to make a match with what is observed, are reviewed.

*Speaker

Searching for asymptotics in convection-driven dynamos

Petri Käpylä * [1,2,3]

[1] Leibniz-Institut für Astrophysik Potsdam – Germany
[2] ReSoLVE Centre for Excellence, Department of Computer Science, Aalto University – Finland
[3] Max-Planck-Institut fur Sonnensystemforschung – Germany

Convection-driven dynamos in spherical wedges at varying thermal andmagnetic Prandtl numbers are presented. We show that cyclic dynamos are excited at low and moderate magnetic Reynolds numbers with either poleward or equatorward migrating activity belts. The migration directions are consistent with the Parker-Yoshimura rule. At high magnetic Reynolds numbers the cyclic solutions give way to more irregular or quasi-stationary solutions with simultaneous strong quenching of differential rotation. Both effects often coincide with the excitation of a small-scale dynamo. We find no evidence of declining large-scale field strength even at the highest magnetic Reynolds numbers explored. Our results also suggest that the current simulations are not approaching an asymptotic regime with respect to the diffusion coefficients.

*Speaker

Mass loss of massive stars with strong surface magnetic fields

Manfred Küker * [1]

[1] Leibniz-Insitut für Astrophysik Potsdam (AIP) – An der Sternwarte 16 14482 Potsdam, Germany

We study the interaction of line-driven winds from massive stars with the magnetic field rooted in these stars by carrying out numerical simulations using the Nirvana MHD code in 2D in spherical polar coordinates. The code's adaptive mesh refinement feature allows high spatial resolution across the whole simulation box. We study stars for a range of magnetic field strengths from weak to strong as measured by the confinement parameter. For weak fields our simulations show that the initially dipolar field opens up far away from the star and a thin disk-like structure forms in the equatorial plane of the magnetic field. For stronger fields the disk is disrupted close to the stellar surface and closed field lines persist at low latitudes. For very strong fields a pronounced magnetosphere forms where the gas is forced to move along the field lines and eventually falls back to the stellar surface.

*Speaker

Dynamics of solar supergranulation

Jan Langfellner * [1], Aaron Birch , Laurent Gizon

[1] Max-Planck-Institut für Sonnensystemforschung (MPS) – Justus-von-Liebig-Weg 3 37077 Göttingen, Germany

Supergranulation is a prominent pattern of solar near-surface turbulent flows on a spatial scale of _˜30 Megameters and thus much larger than the well-known granulation. Although our knowledge of supergranules dates back more than 50 years, their origin is still unknown. Using data from the Solar Dynamics Observatory spacecraft, we constructed the average supergranule and studied the evolution of the flow pattern, its intensity contrast and magnetic field, revealing time lags between the occurrences of maxima in these quantities. The results are consistent with a convective origin of supergranulation and passive advection of magnetic field.

*Speaker

Activity cycles and active longitudes on stolar-type stars

Jyri Lehtinen * [1]

[1] Max Planck Institute for Solar System Research (MPS) – Germany

Spot and chromospheric activity can be observed on numerous stars and several observing programmes have gathered extended photometric and spectroscopic time series that reveal complex behaviour on many of the observed stars. Activity cycles and the presence of active longitudes specifically show systematic dependence from the stellar rotation and activity level. I will present results on the spot activity of active solar-type stars and consider what the observed activity cycles and active longitudes seem to require from dynamo theory.

*Speaker

Direct numerical simulations of turbulent natural convection with strong vertical magnetic field

Wenjun Liu * [1], Dmitry Krasnov [1], Jörg Schumacher [1], Christian Karcher [1], Andre Thess [2]

[1] TU Ilmenau – Germany
[2] Institute of Engineering Thermodynamics, DLR, Stuttgart, Germany – Stuttgart, Germany

We investigate the interaction between magnetic fields and buoyancy-driven flows in electrically conducting fluids, which is known as magnetoconvection. Specifically, we consider pure natural convection in liquid metal within a closed square box under influence of uniform vertical magnetic fields. The box is heating from the bottom and cooling from the top. The lateral walls are adiabatic and all walls are perfectly electrically insulating. The system can be relevant to the design of liquid metal blankets for fusion reactor, especially the HCLL blanket, where the liquid metal is used only for breeding and only a weak forced flow is foreseen. But at present, we focus on fundamental analysis, and we conduct direct numerical simulations to investigate the basic features of the flow behavior resulting from the interaction between strong magnetic field and strong buoyancy forces.

*Speaker

Non-contact electromagnetic flow measurement in liquid metal two-phase flow using Lorentz force velocimetry

Ze Lyu * [1], Christian Karcher [1]

[1] Institute of Thermodynamics and Fluid Mechanics, Technische Universität Ilmenau. – Germany

Lorentz force velocimetry (LFV) is a contactless measurement techinique for electrically conductive liquid flows. The basic idea of LFV is that the force acting on the permanent magnet (or magnet systems) is proportional to velocity (or mass flux) of the electrically conductive flows under the condition of low magnetic Reynolds numbers. LFV is normally global static measurement. As a subdivision of LFV, local Lorentz force velocimetry (LLFV) miniaturized the permanent magnet until the dimensions of the permanent magnet are significantly smaller than that of the flow and it detects only the flow in the vicinity of the sensor. Motivated by extending the applications of LLFV to liquid metal two-phase flows, in a first test, we investigated the transient responce of Lorentz force to a simple arrangement of bubble/particle injected into liquid GaInSn at rest. Thus we exclude the effects of a turbulent liquid metal basic flow and bubble interactions between each other. The results show that Lorentz force oscillate strongly and the values of them are different for each rising bubble/particle. The shapes of Lorentz force signals depends on local liquid flow structures and non-conductive volume effects, both of which are dominated by bubble/particle rising positions.

*Speaker

Nonmodal dynamics of helical magnetorotational instability

George Mamatsashvili * [1], Frank Stefani [1]

[1] Helmholtz-Zentrum Dresden-Rossendorf – Germany

The helical magnetorotational instability is known to work for resistive rotational flows with comparably steep negative or extremely steep positive shear. The corresponding lower and upper Liu limits of the shear are continuously connected when some axialelectrical current is allowed to flow through the rotating fluid. Using a local approximation we demonstrate that the magnetohydrodynamic behavior of this dissipation-induced instability is intimately connected with the nonmodal growth of the underlying purely hydrodynamic problem.

*Speaker

Non-axisymmetric evolution of the Sun's toroidal flux

David Martin Belda * [1], Robert Cameron [1]

[1] Max Planck Institute for Solar System Research – Germany

Aims: We aim to infer the sub-surface, non-axisymmetric distribution of the Sun's toroidal magnetic flux from observable quantities, such as the surface magnetic field and the large scale plasma flows. We try to determine possible relationships between the structure of the toroidal flux and the properties of emerged active regions.

Methods: We build a kinematic model of the transport of magnetic flux in the Sun, based on the Babcock-Leighton dynamo framework. The source term is constrained by SOLIS magnetograms spanning three solar cycles. We run numerical simulations to obtain the toroidal flux below the surface and compare it to the properties of oberved active regions.

Results: We produce maps of the angular distribution of sub-surface toroidal flux. The non-axisymmetric structure of the toroidal flux caused by the emergence process represents about a 8% of the total, and is probably unrelated to the triggering of new emergences and the amount of flux contained in them.

*Speaker

Non-axisymmetric magnetorotational instability in the spherical Couette system

Domenico Meduri *† [1], François Lignières [1], Laurène Jouve [1]

[1] Institut de Recherche en Astrophysique et Planétologie (IRAP) – CNRS : UMR5277 – France

The origin and evolution of the magnetic fields detected in main-sequence stars of intermediate mass, like A-type stars, is still a matter of debate. The chemically peculiar Ap/Bp stars represent about 10% of the intermediate-mass star population and host a dipolar, long-term stable magnetic field with intensities ranging from about 300 G to 30 kG. Recent spectropolarimetric surveys revealed another class of magnetic A-type stars in which the photospheric field is much weaker (. 1 G) and organized on smaller scales. Tentative explanations for the observed dichotomy involve magnetic instabilities occurring in the outer
radiative region of these stars which is likely to be differentially rotating.

In this context we investigated numerically the magnetic instabilities occurring in a spherical Couette setup when an initial dipole field is applied. We firstly describe the basic axisymmetric toroidal field solutions obtained shearing the initial dipole field via the
imposed differential rotation. We find that the different field solutions are determined by the dimensionless product $RmE^{1/2}$, where Rm is the magnetic Reynolds number and E the Ekman number.

The stability of the different field configurations is then studied. For larger values of the azimuthal Alfvén frequency to the rotation rate ratio a magnetic instability develops. The unstable cases show clear signatures of a non-axisymmetric magnetorotational instability (MRI). The instability location and the modes growth rates are in good agreement with
predictions obtained from a local linear analysis. We found cases in which the instability reaches the level of the background axisymmetric state and may potentially suppress the differential rotation. Further studies are required to characterize the non-linear evolution of the instability and its efficiency in the redistribution of angular momentum.

*Speaker
†Corresponding author:

CFD study of the magnetic field effect on flow of liquid sodium in Taylor-Couette system

Abdelkrim Merah * [1], Faiza Mokhtari [2], Adel Lalaoua , Abderrachid Hamrani [1]

[1] Département de Génie Mécanique, Faculté des Sciences de l'Ingénieur, Université de Boumerdes (DGM, FSI, UMBB) – Faculté des sciences de l'ingénieur, Cité Frantz. Fanon, 35000 Boumerdès, Algeria

[2] Laboratoire de Thermodynamique et Systèmes Energétiques, Faculté de Physique, Université des Sciences et de la Technologie, Houari (LTSE, USTHB) – BP 32 EL ALIA 16111 BAB EZZOUAR ALGER., Algeria

Taylor-Couette flow is that which develops in the annular space between two coaxial relatively rotating cylinders. Velikhov (1959) and Chandrasekhar (1960) have studied the effect of axial magnetic field on Taylor-Couette flow. Balbus and Haley (1991) have found that magnetohydrodynamics instability plays a role in wide of astrophysics. In this work, we focus on the numerical investigation of the magnetic field effect on sodium metal in conical Taylor-Couette flow in the case of insulating walls. Angular momentum and pressure field are compared in the cases without and with magnetic field.

*Speaker

Magneto-convective flows in rectangular ducts with internal cylindrical obstacles

Chiara Mistrangelo * [1], Leo Bühler [1]

[1] Karlsruhe Institute of Technology (KIT) – Campus North Hermann-von-Helmholtz-Platz 1 76344 Eggenstein-Leopoldshafen, Germany

One of the liquid metal blanket concepts considered as an option for a DEMOnstration nuclear fusion reactor is the water cooled lead lithium (WCLL) blanket. It consists of relatively small modules attached to a common back supporting structure. In each module liquid lead lithium, PbLi, is used as tritium breeder, neutron multiplier, and heat transfer medium. The released fusion heat is removed by water at 155 bar that flows through cooling pipes immersed in the liquid-metal breeding zone. In order to withstand the enormous forces that may occur under accidental conditions, the breeding zone is stiffened by internal plates that form rectangular ducts in which PbLi flows. The geometric configuration of cooling tubes is a critical issue in DEMO WCLL blankets, since the spatial distribution of water pipes in the breeding zone has to ensure an efficient heat power removal from the liquid metal, avoiding the occurrence of local hotspots in the thermal field.

Different concepts have been proposed. According to a design developed at CEA, a large number of C-shaped cooling pipes arranged in vertical parallel planes are immersed in the liquid metal, which results in a complex flow path for the breeder [1]. An alternative configuration is currently under study in which the water tubes are positioned in horizontal planes [2].

Numerical simulations are performed to predict liquid metal flows in a model geometry relevant for WCLL blankets consisting in a rectangular duct with an internal coaxial cooling tube. The flow may be driven by an applied pressure gradient and/or by buoyancy due to the presence of volumetric heat sources in the fluid and heat transfer at the pipe. Magnetic fields of different strengths, various thermal conditions, and orientations of the assembly with respect to gravity are analyzed.

Acknowledgement: This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

References

[1] J. Aubert, G. Aiello, N. Jonqures, A. L. Puma, A. Morin and G. Rampal, "Development of the water cooled lithium lead blanket for DEMO," *Fusion Engineering and Design,* vol. 89, no. 7-8, pp. 1386-1391, 2014.

[2] P. Di Maio, P. Arena, G. Bongioví, P. Chiovaro and R. Forte, "Optimization of the breeder zone cooling tubes of the DEMO Water-Cooled Lithium Lead breeding blanket," *Fusion Engi-*

*Speaker

neering and Design, Vols. 109-111, no. Part A, pp. 227-231, 2016.

Kinetic scale turbulence and magnetic reconnection in laboratory and space plasmas

Patricio A. Muñoz Sepúlveda * [1], Jörg Büchner [1], Neeraj Jain [1], Patrick Kilian [2]

[1] Max Planck Institute for Solar System Research (MPS) – Germany
[2] Centre for Space Research, North-West University – South Africa

Most of the laboratory, space and astrophysical plasmas are collisionless, where the basic mechanisms leading to heating, dissipation and transport are due to long-range wave-particle interactions and self-generated turbulence due to kinetic instabilities. Those intrinsically kinetic processes have very different properties to those in MHD, valid in (resistive) collision-dominated plasmas and at large scales. For example, there is an absence of scale invariance and non-universal power laws of the turbulent spectra beyond the transition between ion and electron scales. Thus, a kinetic description is essential to understand, for example, the dissipation range of turbulence, particle acceleration and many other processes beyond a fluid description.
In particular, we focus in dissipation processes taking place in magnetic reconnection, a phenomena closely related to turbulence capable to dissipate quickly magnetic field energy into other forms of energy. We discuss some results related to kinetic effects and turbulence in magnetic reconnection by using, as computational tools, a fully-kinetic and hybrid Particle-in-Cell (PiC) simulation codes. We compare our results with laboratory experiments and recent high-resolution in-situ spacecraft measurements in the solar wind, Earth's magnetosphere and comment about their application to other astrophysical scenarios such as the Solar corona.

*Speaker

Solar Mechanics: Sun activity and its magnetic fields flip synchronize with the moves of its system planetary center of mass

Maxime Pelerin * [1]

[1] Centre National de Recherche Scientifique (Université de Lille - CNRS) – Université de Lille, Université des Sciences et Techniques de Lille1 – Université de Lille1 Bât P5 Cité Scientifique 59655 Villeneuve d'Ascq Cédex, France

Sun cycles like used nowadays seem to obey some sort of rules. In this work I present only a lot of observations that show that all its activity and its magnetic pole fields flip is linked by the center of mass of its planetary system and permit a precised defined cycle. It's only observations that have to be grounded by mathematical and physical more deeper examinations that could conduct to the simple and incredible fact, in a real concordance way to the Musica Universalis, that the sun is like a dynamo supply by the center of mass of its own planetary system.

*Speaker

Numerically modelling coronal structures associated with rotating sunspots

Mayukh Panja * [1,2], Dibyendu Nandy [2]

[1] Max Planck Institute for Solar System Research, Goettingen (MPS Goettingen) – Germany
[2] Center of Excellence in Space Sciences India, IISER Kolkata (CESSI, IISER Kolkata) – India

The solar corona spews out vast amounts of magnetized plasma into the heliosphere which has a direct impact on the Earth's magnetosphere. Thus it is important that we develop an understanding of the dynamics of the solar corona, especially coronal structures associated with rotating sunspots which are frequently the source of eruptive events like flares and CMEs. However, the lack of 3D magnetic maps of the solar corona presents a problem and this warrants the use of numerical simulations to study the evolving coronal magnetic field. To this end, we have developed a 3D magnetofrictional model in spherical polar co-ordinates which solves the magnetic induction equation in the solar corona. Taking advantage of the fact that the plasma-beta ratio is low in the corona, we assume that the velocity is simply proportional to the Lorentz force. Using this new model, we have modelled rotating spots and their coronal field lines, driving the spots kinematically in the photosphere. Here we present studies on the formation of flux ropes and their subsequent ejection.

*Speaker

On the inverse transfer of nonhelical magnetic energy in a decaying magnetohydrodynamic turbulence

Kiwan Park * [1]

[1] University of Heidelberg (ITA) – Albert-Ueberle-Str. 2 and Philosophenweg 12 69120 Heidelberg, Germany

The inverse transfer of magnetic energy is thought to occur when the velocity field 'u' or magnetic field 'b' is helical or magnetorotational instability exists in a magnetohydrodynamic (MHD) system. These well known phenomena are considered as bases for the large scale magnetic field in universe. However it has been reported that nonhelical magnetic field without a driving force may be able to migrate toward the large scale. This holds vital clues to the origin of large scale magnetic field in a quiescent astrophysical system. The possibility of inverse transfer of nonhelical magnetic field was initially suggested in a two dimensional stationary MHD system followed by couple of simulations and analytic models in 3D. However none of the models clearly explain the mechanism yet. To show the principle of energy migration more intuitively we suggest a field structure model based on the magnetic induction equation. This structure indicates the growth and migration of magnetic field are basically the induction of magnetic field through the mutual interaction between plasma and magnetic eddy. In an equilibrium state energy transfer is related to the minimum or conbservation of system variables in principle. However in a decaying turbulent system, there is no such strict constraint on the direction of energy migration. Rather it depends on the interaction between the spatially inhomogeneous plasma and magnetic field. With the analytic theory, related simulation results, and the field structure we will show how this model explain the transfer of magnetic energy, alpha, beta effect, and generation & conservation of magnetic helicity.

*Speaker

Numerical aspects of Large eddy simulations for turbulent magnetohydrodynamic duct flows

Sebastian Prinz * [1], Thomas Boeck [1], Dmitry Krasnov [1], Jörg Schumacher [1]

[1] Technische Universität Ilmenau (TUI) – TU Ilmenau Ehrenbergstr. 29 98693 Ilmenau, Germany

Large eddy simulation (LES) is a promising tool for the simulation of turbulent flows. In simple terms, the turbulent velocity field is separated into different scales. While only the large scales of the turbulent motion are resolved, the influence of the small and more isotropic scales on the main flow are modeled by subfilter scale (SFS) models. This reduces the computational demand significantly. In the last three decades LES gained a lot of attention in the scientific CFD community and promising results were obtained for isotropic turbulence and simple shear flows like the flow in plane channels. However, one serious drawback for LES is the strong dependency on the type and the accuracy of the numerical scheme. Most classical models were developed in the framework of Fourier spectral methods and often simply transferred to local numerical techniques like finite-differences or finite-volume methods. For the latter, discretization errors are an inherent property in particular for coarse grids commonly used in LES. This is why many user prefer high-order numerical discretization schemes. However, these schemes are unsuitable for many technical problems that are dealing with complex geometries.
In this work, we use a second-order finite difference solver with colocated variable arrangement [1,2] and carry out LES for turbulent magnetohydrodynamic duct flows at high Reynolds and Hartmann numbers. We adapt well-established SFS models and provide a detailed grid sensitivity study to demonstrate the impact of the numerical error. By comparison with DNS data [3], we find that a comparably high resolution for the LES is required to obtain reliable results. Of course these results are exclusive for our discretization scheme. However, a general conclusion of this work is that reliable results obtained from LES should always be provided by a detailed grid resolution study with and without usage of SFS models. This is often ignored by many authors, and introduces a strong source of uncertainty since the influence of the numerical scheme on the results is hidden and a generalization of the results is not possible.

[1] Krasnov, Dmitry, Oleg Zikanov, and Thomas Boeck. "Comparative study of finite difference approaches in simulation of magnetohydrodynamic turbulence at low magnetic Reynolds number." *Computers & Fluids* 50.1 (2011): 46-59.

[2] Morinishi, Yohei, et al. "Fully conservative higher order finite difference schemes for incompressible flow." *Journal of computational physics* 143.1 (1998): 90-124.

[3] Krasnov, Dmitry, Oleg Zikanov, and Thomas Boeck. "Numerical study of magnetohydrodynamic duct flow at high Reynolds and Hartmann numbers." *Journal of Fluid Mechanics* 704 (2012): 421-446.

*Speaker

Mean-field electrodynamics and dynamo theory: the old concept and some recent developments

Karl-Heinz Raedler * [1]

[1] Leibniz Institute for Astrophysics Potsdam – Germany

The basic ideas of electrodynamics and magnetohydrodynamics of mean fields in turbulently moving conducting fluids are presented. The connection of the mean electromotive force with the mean magnetic field and its first spatial derivatives is in general neither local nor instantaneous. Quite a few claims concerning pretended failures of the mean-field concept result from ignoring this aspect. In addition to the mean-field dynamo mechanisms of α^2 and $\alpha\Omega$ type several other mechanisms are possible. Much progress in mean-field electrodynamics and magnetohydrodynamics results from the test-field method for calculating the coefficients that determine the connection of the mean electromotive force with the mean magnetic field. As an important example of a non-instantaneous connection between the mean electromotive force and mean magnetic field the memory effect in homogeneous isotropic turbulence is mentioned. In magnetohydrodynamic turbulence there is the possibility of a mean electromotive force that is primarily independent of the mean magnetic field, labeled as Yoshizawa effect.

*Speaker

The time asymmetry of the magnetic field variations

Maxim Reshetnyak *† 1

1 Institute of the Physics of the Earth of RAS (UIPE) – Schmidt Institute of Physics of the Earth of the Russian Academy of Sciences Bolshaya Gruzinskaya str., 10-1, Moscow 123242, Russia

The analysis of the last five reversals of the geomagnetic field reveals that the decay time of the magnetic moment is five times larger than the time of its recovery after the reversal [1]. The predominance in a few percents of the decay time over the recovery time still presents between the reversals as well [2]. It looks like that the difference between the magnitudes of the asymmetry during the reversals and at the regime of the quiet field reflects the basic properties of the MHD system. Whether asymmetry in the later case can be concerned with some nonlinearity in the system, the former is only started to be understood. One of the suggestions is that the large decay time is concerned with the break of the generation process and is determined by the diffusion process [1]. Then the quick generation of the magnetic dipole with the opposite sign starts. We test the factor of asymmetry in the simple 1D dynamo Parker's as well as in the 3D MHD model in the box. We emphasize that the are at least two kinds of asymmetry which can be interesting for discussion. The first one is the break of the time derivative of the signal at the "mean" level. For the reversal process the mean level is zero. The other kind of asymmetry take place at the extremum. It corresponds to the case where the absolute values of the decay and growth rates near the extremum are different. We show that such asymmetries introduce restrictions to the modeling of the geomagnetic reversals.

References

1. Valet, J.P., Meynadier, L., Guyodo, Y. Geomagnetic dipole strength and reversal rate over the past two million years. Nature. 2005. 435. 802–805.

2. Zieger, L.B., Constable, C.G. Asymmetry in growth and decay of the geomagnetic dipole. Earth Planet. Sci. Lett. 2011. 312. 300-304.

*Speaker

†Corresponding author: m.reshetnyak@gmail.com

50 years of alpha effect, a short look back

Matthias Rheinhardt * [1]

[1] RESOLVE, Aalto University – Finland

A short introduction of Karl-Heinz Rädler and his achievements.

*Speaker

A new MHD-assisted Stokes inversion technique

Tino Riethmüller * [1]

[1] Max-Planck-Institut für Sonnensystemforschung (MPS) – Justus-von-Liebig-Weg 3, 37077 Göttingen, Germany

We present a new method of Stokes inversion of solar spectropolarimetric data and evaluate it by taking the example of a SUNRISE/IMaX observation. An archive of synthetic Stokes profiles is obtained by the spectral synthesis of state-of-the-art MHD simulations and a realistic degradation to the level of the observed data. The definition of a merit function allows the archive to be searched for the synthetic Stokes profiles that match the observed profiles best. In contrast to traditional Stokes inversion codes, which solve the Unno-Rachkovsky equations for the polarized radiative transfer numerically and fit the Stokes profiles iteratively, the new technique provides the full set of atmospheric parameters. This gives us the ability to start an MHD simulation that takes the inversion result as initial condition. After a relaxation process of half an hour solar time we obtain physically consistent MHD data sets with a target similar to the observation. The new MHD simulation is used to repeat the method in a second iteration, which further improves the match between observation and simulation, resulting in a factor of 2.2 lower mean χ^2 value. One advantage of the new technique is that it provides the physical parameters on a height scale. It constitutes a first step towards inversions giving results consistent with the MHD equations.

*Speaker

On the effects of helicity in magnetohydrodynamic turbulence

Ganapati Sahoo * [1], Moritz Linkmann , Luca Biferale

[1] University of Rome "Tor Vergeta" – Italy

Magnetic helicity and cross helicity together with total energy are the inviscid invariants of the three-dimensional magnetohydrodynamic equations [1]. The energy transfer at different scales among the fluid and magnetic field is linked to the helicity content of the system. In non-conducting fluids kinetic helicity, which is a conserved quantity, plays a pivotal role [2] in determining the direction of energy transfer across the scales. In this study we explore the cascade process of the kinetic energy and magnetic energy to understand the growth of large scale and small magnetic fields based on the helicity contents of the Fourier modes. Our study [3] highlights the effects of the Lorentz force on the cascade of kinetic energy for different helical content in the magnetic field. Our results from the numerical simulations attempt to verify recent analytical results and predictions [4] on the spectral energy transfer processes by disentangling the helical mode interactions.

[1]Biskamp D., (2003): Magnetohydrodynamic Turbulence, Cambridge University Press, Cambridge, UK.
[2]Sahoo G., Bonaccorso F. and Biferale L., (2015), Role of helicity for large- and small-scale turbulent fluctuations, Phys. Rev. E, vol. 92, pp. 051002.
[3]Linkmann M., Sahoo. G. et al, (2016), Effects of magnetic and kinetic helicities on the growth of magnetic fields in laminar and turbulent flows. arXiv:1609.01781
[4]Linkmann M. et al. (2016), Helical mode interactions and spectral transfer processes in magnetohydrodynamics turbulence, J. Fluid Mech., vol. 791, pp. 61-96.

*Speaker

Using geomagnetic data and dynamo models to constrain the Earth's magnetic field through the last three millennia

Sabrina Sanchez * [1]

[1] Max-Planck Institute for Solar System Research (MPS) – Max Planck Institute for Solar System Research, Justus-von-Liebig-Weg 3,37077 Göttingen, Germany

The magnetic field measured at the Earth's surface is the product of a superposition of a plurality of sources, the main component of which originates in the core. The core field is generated by a natural dynamo mechanism, which evolves on a variety of time scales. Its longer term dynamics are only accessible by indirect observations, the archeomagnetic data. The heterogeneous spatial and temporal character of the archaeomagnetic data catalog, however, does not allow for a well-constrained inversion of the core field. Instead, the inverse problem is generally regularized by imposing prior constraints limiting the complexity of the field. Here we introduce the concept of using prior information derived from numerical dynamo models in order to constrain the long-term Earth's core dynamics given surface magnetic data. For that, we use a sequential data assimilation framework, seldom applied in meteorology and oceanography. The algorithm is based on a sequence of forecast-and-analysis steps. In the forecast step, an ensemble of dynamo models is propagated in time given a set of initial conditions in order to provide the statistics of the model state. Whenever observations are available, the forecast is stopped and the algorithm performs a correction of the model state in view of the new data, the analysis. The constant feeding of observations through the sequence of forecasts-and-analysis cycles can allow for the estimation of not only the observable, but also of the hidden variables of the dynamo system, such as the magnetic field in depth and the flow throughout the core for instance. In this work, the assimilation of archaeomagnetic-like synthetic data is tested by means of closed-loop experiments. The estimation shows a good retrieval of the large-scale features of the simulation through an assimilation interval of a few millennia, despite the clustering of data over the Northern Hemisphere, more specifically over Europe. This result shows the efficient propagation of information through the hemispheres due to the high degree of equatorial symmetry of the underlying model. This work opens up the possibility for the assimilation of real archaeomagnetic observations and the subsequent estimation of the physical processes operating in the core on secular time scales. However, the application to real data is challenging, since the archaeomagnetic observations are affected by considerable dating and experimental errors. Further development of this work will consider ways to better take these errors into account.

*Speaker

Heat and momentum transfer for magnetoconvection in a vertical external magnetic field

Joerg Schumacher * [1], Till Zürner [1], Wenjun Liu [1], Dmitry Krasnov [1]

[1] Technische Universität Ilmenau (TU Ilmenau) – Ehrenbergstraße 29, Ilmenau, Germany, Germany

The scaling theory of Grossmann and Lohse (J. Fluid Mech. 407, 27 (2000) for the turbulent heat and momentum transfer is extended to the magnetoconvection case in the presence of a (strong) vertical magnetic field. The comparison with existing laboratory experiments and direct numerical simulations in the quasistatic limit allows to restrict the parameter space to very low Prandtl and magnetic Prandtl numbers and thus to reduce the number of unknown parameters in the model. Also included is the Chandrasekhar limit for which the outer magnetic induction field is large enough such that convective motion is suppressed and heat is transported by diffusion. Our theory identifies four distinct regimes of magnetoconvection which are distinguished by the strength of the outer magnetic field and the level of turbulence in the flow, respectively.

*Speaker

First experimental insights into the transition from AMRI to HMRI

Martin Seilmayer * [1]

[1] Helmholtz-Zentrum Dresden-Rossendorf (HZDR) – Bautzner Landstraße 400 - 01328 Dresden, Germany

In the last years the magnetorotational instability (MRI) was focused intensively by theory and experiments. It turns out that investigating the standard MRI (SMRI) is very hard, with its magnetic field pointing perpendicular to the rotation direction. The only chance for this type of instability are experiments in rather large (1 m -scale) or fast rotating (f>10 Hz) cylinders. Beside that two other types of MRI were discovered [1,2]. The helical and azimuthal MRI, which where successfully investigated in the laboratory with the PROMISE2 facility. This setup consists of two concentric cylinders, a current carrying rod on the axis producing B[ϕ] and a cylindrical coil providing B[z] to the fluid. In the past, experiments proved the theory of each individual instability [3, 4].

With the improved magnetic field system the PROMISE3 setup gains advantage of a more homogeneous field. So it becomes possible now to observe the transition between these two instabilities. First we like to give a prove of function and show how the velocity distribution and other properties changed with the new magnetic field configuration. Next to that we like to present very first results on the mode transition form the AMRI unstable m=1 regime to the HMRI unstable m=0 case. Here we start in a AMRI unstable parameter set (Re=1500, Ha=100 and $\mu = \Omega$[out]/ Ω[in]=0.26). By increasing the axial magnetic field Bz the AMRI m=1 mode is disturbed successively until it is completely damped. At a certain field strength the other m=1 mode emerges which also disappears at higher fields.

Finally we can conclude that AMRI and HMRI still work in the modified experiment according to the theory. There is a possible transition region between these two instabilities. One open question is why the flow structure changes so significantly for AMRI in comparison to the PROMISE2 campaign [3]. And would it be better to improve the field further?

[1] G. Rüdiger et al.; AN, 328(10):11581161,2007.

[2] G. Rüdiger et al.; AN, 329(7):659666, 2008.
[3] M. Seilmayer et. al.; PRL, 113(2):024505, 2014.
[4] F. Stefani et al.; NJP, 9(8):295, 2007.

*Speaker

Magnetohydrodynamic Turbulence and the Geodynamo

John Shebalin * [1]

[1] National Aeronautics and Space Administration, Johnson Space Center (NASA JSC) – 2101 NASA Parkway, Mail Code XI3, Houston, Texas 77058-3696, USA, United States

Recent research results concerning forced, dissipative, rotating magnetohydrodynamic (MHD) turbulence will be discussed. In particular, we present new results from long-time Fourier method (periodic box) simulations in which forcing contains varying amounts of magnetic and kinetic helicity. Numerical results indicate that if MHD turbulence is forced so as to produce a state of relatively constant energy, then the largest-scale components are dominant and quasi-stationary, and in fact, have an effective dipole moment vector that aligns closely with the rotation axis. The spectral distribution of magnetic and kinetic helicities, as well as their connection to the amount of injected helicity will be discussed. The relationship of this work to established results in ideal MHD turbulence, as well as to models of MHD turbulence in a spherical shell will also be presented. These results appear to be very pertinent to understanding the geodynamo and the origin of its dominant dipole component. Our conclusion is that MHD turbulence, per se, may well contain the origin of the Earth's dipole magnetic field.

*Speaker

Flux rope stability analysis

Jan Skala *† [1], Joerg Buechner [2]

[1] Max-Planck-Institut für Sonnensystemforschung (MPS) – Max Planck Institute for Solar System Research Justus-von-Liebig-Weg 3 37077 Göttingen, Germany
[2] Max-Planck-Institut für Sonnensystemforschung (MPS) – Max Planck Institute for Solar System Research Justus-von-Liebig-Weg 3 37077 Göttingen, Germany

Solar eruptions, flares and CME ejection seem to be due to a sudden loss of equilibrium after energy and helicity has built up in the non-potential magnetic fields of solar flux ropes. Most of the accumulated free energy to be released is stored in long-living magnetic arcade structures, twisted magnetic flux ropes. Flux ropes in the solar corona are potentially prone to at least two ideal magnetohydrodynamic instabilities: kink and torus (lateral kink) instability. In order to investigate the stability of solar coronal flux ropes we have performed numerical simulations of nearly ideal solar coronal plasmas using our GOEMHD3 code. As initial conditions we use analitical flux rope equilibrium wich allows us to test various magnetic field geometries.

*Speaker
†Corresponding author: skala@mps.mpg.de

Angular momentum transport by magnetic instabilities in post-main sequence low-mass stars

Federico Spada * [1], Marcus Gellert [2], Rainer Arlt [3], Sebastien Deheuvels [4]

[1] Leibniz-Institut fuer Astrophysik Potsdam (AIP) – Germany
[2] Leibniz Institute for Astrophysics Potsdam (AIP) – Germany
[3] Leibniz Institute for Astrophysics Potsdam – East Germany
[4] Observatoire Midi-Pyrénées, Toulouse – Observatoire Midi-Pyrénées - OMP (FRANCE) – 14 Avenue Edouard Belin, France

Asteroseismology constrains the angular momentum transport efficiency in post-main sequence cool stars. The moderate core-to-envelope rotation rate ratio of early giants, together with the core spin-down observed at later times on the red giant branch, implies that the angular momentum transport efficiency varies in time. We investigate the possibility of a rotational coupling coefficient that depends on the degree of internal differential rotation, physically motivated by numerical simulations of the azimuthal magneto-rotational instability. This hypothesis leads to a satisfactory agreement of the models with the data, provided that the main sequence solid-body rotation regime is preserved into the early post main-sequence, until the shell hydrogen burning is established.

*Speaker

Tidally synchronized Tayler-Spruit dynamos

Frank Stefani * [1], Vladimir Galindo , Andre Giesecke , Norbert Weber , Tom Weier

[1] Helmholtz-Zentrum Dresden-Rossendorf – Germany

The dynamo loop in Tayler-Spruit models for the generation of stellar magnetic fields can only be closed if the kink-type Tayler instability (TI) goes along with some alpha effect. While for large magnetic Prandtl numbers (Pm) some finite alpha can easily result from spontaneous symmetry breaking, low Pm systems show typically a vanishing or an oscillatory alpha effect [1]. If the TI, with its typical m=1 azimuthal dependence, is exposed to an m=2 tidal forcing, we observe a sharp resonance if the tidal frequency equals the frequency of the intrinsic alpha oscillation. In the framework of a very simple alpha-Omega dynamo model we further show that this resonance can lead to synchronization of the dynamo [2,3]. We also discuss the hypothetical possibility that this mechanism could link the 11.07 year periodicity of the tidally dominant Venus-Earth-Jupiter system with the Hale cycle of the solar magnetic field.

[1] N. Weber et al., New J. Phys. 17 (2015), 113013
[2] F. Stefani et al., Solar Phys. 291 (2016), 2197–2212
[3] F. Stefani et al., arxiv.org/1610.02577

*Speaker

Effects of a guided-field on particle diffusion in magnetohydrodynamic turbulence

Yue-Kin Tsang * [1]

[1] Centre for Geophysical and Astrophysical Fluid Dynamics, University of Exeter – Harrison Building, University of Exeter, Exeter EX4 4QF, U.K., United Kingdom

We consider incompressible magnetohydrodynamic turbulence in a three-dimensional periodic box with a background magnetic field in the vertical direction. We drive the system by a large-scale isotropic forcing and examine the Lagrangian properties of the system by numerically tracking the position of a large number of passive massless particles. We find that the mean-squared-displacement grows linearly in time indicating diffusive behaviour. However, as the strength of the background guided-field increases, the diffusion becomes anisotropic with larger diffusivity in the field-parallel direction. Associated with such transition are changes in the behaviour of the energy spectrum and the Lagrangian velocity correlation function. In particular, the Lagrangian velocity decorrelation time exhibits a power-law scaling with the root-mean square velocity and the scaling exponent shifts from -1 to -2 as anisotropy develops in the system.

*Speaker

Studying the transition from axi- to nonaxisymmetric dynamos using semi-global convection models

Mariangela Viviani * , Elisabeth Cole , Petri Kapyla [1,2], Maarit Käpylä , Nigul Olspert , Jörn Warnecke [3]

[1] Nordic Institute for Theoretical Physics (Nordita) – Albanova University Center Roslagstullsbacken 23 106 91 Stockholm Sweden, Sweden
[2] Physics Department, Helsinki University – Gustaf Hällströmin katu 2a, PO Box 64, FI-00014 University of Helsinki, Finland
[3] Max-Planck-Institut für Sonnensystemforschung (MPS) – Germany

Rotation is one crucial parameter that stellar magnetic activity is known to depend on. There is also growing evidence (both observational and from models, e.g., [1] and [2]) that the rotation rate also regulates the transition from solar-type axisymmetric dynamo modes to non-axisymmetric modes in more rapidly rotating stars. We investigate this transition using semi-global magnetocon- vection models, where rotation rate is systematically varied. We have run several high-resolution models including the full azimuthal extent of the star, while still neglecting the stellar poles, and analyze the properties of the dynamo solutions from the models.

We compare the magnetic energy to the kinetic energy, to estimate the dependence of the dy- namo efficiency on rotation. We also study the efficiency of the large-scale dynamo by comparing the energy contained in the mean field to the one in the fluctuations. We decompose the magnetic field into axi- and nonaxisymmetric parts, analyze their time behavior, and the type of the dynamo solutions, and locate the transition point from axi- to nonaxisymetric dynamo activity in terms of the simulation parameters. The ultimate goal is to understand the physical processes behind the transition.

*Speaker

Understanding dynamo mechanisms and torsional oscillations from 3D convection simulations of the Sun

Jörn Warnecke * [1]

[1] Max-Planck-Institut für Sonnensystemforschung (MPS) – Germany

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. We simulate a solar-type star, where the interplay between convection and rotation self-consistently drives large-scale magnetic field. We apply the test-field method to characterize the dynamo mechanism acting in this simulation by determining 27 turbulent transport coefficients of the electromotive force, of which 9 are related to the α effect tensor. We find that the alpha-effect has a complex nature and does not follow the profile expected from kinetic helicity. Besides the dominant α-Ω dynamo, also an α^2 dynamo is locally enhanced. The turbulent pumping velocities significantly alter the effective mean flows acting on the magnetic field and therefore challenge the flux transport dynamo concept. All coefficients are significantly affected due to dynamically important magnetic fields with quenching as well as enhancement being observed. This leads to a modulation of the coefficients with the activity cycle. We will also present recent results on mechanisms producing torsional oscillations, the cyclic variations of the differential rotation. Besides large-scale Lorentz force also the cyclically varying
Maxwell and Reynolds stresses have strong influence in the angular momentum balance. In contrast to previous findings, the small-scale contribution to the mass flux plays a significant role in transporting angular momentum. This gives us important insights on the magnetic field generation and torsional oscillation production in the Sun and other stars.

*Speaker

Physical Conditions for Jupiter-like Dynamos

Johannes Wicht * [1], Lucia Duarte [2], Thomas Gastine [3], Richard Holme [4,5]

[1] Max Planck Institute for Solar System Research (MPS) – Justus-von-Liebig-Weg 3 37077 Göttingen, Germany

[2] Dep. Physics and Astronomy, College of Engineering , Mathematics and Physical Sciences – Stocker Road, Exeter, EX4 4QL, United Kingdom

[3] Institut de Physique du Globe de Paris (IPGP) – Université de la Réunion, Université Paris VII - Paris Diderot, IPG PARIS, INSU, CNRS : UMR7154 – IPGP, 1 rue Jussieu, 75238 Paris cedex 05 ; Université Paris Diderot, Bât. Lamarck A case postale 7011, 75205 Paris CEDEX 13, France

[4] Gauss professor, AdW and MPS Göttigen – Max Planck Institute for Solar System Research Justus-von-Liebig-Weg 3 37077 Göttingen, Germany

[5] Department of Earth Ocean and Ecological Sciences [Liverpool] – School of Environmental Sciences, University of Liverpool, 4 Brownlow Street, Liverpool L69 3GP, United Kingdom

With Juno orbiting Jupiter, new insights on the planet's magnetic field and interior structure can be expected within the next months. We conduct numerical simulations of the internal dynamo process to help interpreting the measurements. The simulations were performed with the MHD code MagIC and explore various parameter combinations as well as different internal density and electrical conductivity profiles. Surface magnetic fields closely resemble known magnetic field models when the convective driving is intermediate. Weak driving yields too simplistic field geometries while strong driving promotes multipolar rather than dipole dominated magnetic fields. The combination of strong background density stratification and an electrical conductivity profile that incorporates the weakly conducting outer molecular hydrogen layer is another important ingredient of Jupiter-like dipole dominated dynamos. While details of the density profile hardly matter, the specific form of the electrical conductivity profile determines the depth of the dynamo region and thus influences the relative importance of the magnetic dipole (magnetic spectrum). The simulations suggest that the outer radius RD of the dynamo region is roughly located where the convective flow magnetic Reynolds number exceeds 50. Since the higher harmonic spectrum beyond degree 6 is roughly white at this radius, the slope of the magnetic spectrum at planetary surface can be used to estimate RD. When using the Juno mission trajectory and assuming an isotropic measurement error of 100 nT we could recover our numerical model fields to spherical harmonic degree 18. This should suffice to reasonably constrain the depth of the dynamo region.

*Speaker

Realistic force balance in geodynamo simulations

Rakesh Yadav* [1], Ulrich Christensen † [2], Thomas Gastine [3]

[1] Harvard-Smithsonian Center for Astrophysics (CFA) – 60 Garden Street, Cambridge, MA 02138, United States

[2] Max-Planck Institute for Solar System Reseach (MPS) – Justus-von-Liebig-Weg 3 37077 Göttingen, Germany

[3] Institut de Physique du Globe de Paris (IPGP) – Université de la Réunion, Université Paris VII - Paris Diderot, IPG PARIS, INSU, CNRS : UMR7154 – IPGP, 1 rue Jussieu, 75238 Paris cedex 05 ; Université Paris Diderot, Bât. Lamarck A case postale 7011, 75205 Paris CEDEX 13, France

Flow in the Earth's core is supposed to be governed by a balance of magnetic forces, buoyancy or Archimedian force and Coriolis force (MAC-balance). Although geodynamo simulations can reproduce many properties of the geomagnetic field, they have been suspected to do so for the wrong reasons, as the Lorentz force may be subdominant and has little influence on the flow, whereas viscosity and inertia can be significant. We show by direct comparison of the volume and time-averaged forces that at an Ekman number of 10^{-6} Lorentz force, buoyancy and uncompensated (by pressure) Coriolis force can balance to first order, whereas viscosity and inertia are smaller by a factor of at least 20 in the bulk of the fluid. In this regime the flow pattern is significantly altered by magnetic forces compared to pure hydrodynamic flow, i.e. it is of larger scale and is less geostrophic. The heat transfer is enhanced by a factor of up to two. We conclude that a regime governed by the MAC balance is approached in these simulations.

*Corresponding author:

†Speaker

Flow Patterns in a Spherical Annulus Subjected to a Magnetic Field

Lalaoua Adel * [1]

[1] Sciences and Technology University Houari Boumedien (USTHB) – Bp 32 El Alia, Bab Elzzouar, Algiers, Algeria

The flow patterns in an annulus between two concentric rotating spheres, known as spherical Couette flow (SCF), has a major interest in many branches of physics and technology where centrifugal force plays a dominant role. On the other hand, Magneto-hydrodynamic spherical Couette flow, when a magnetic field is imposed on flow, offers the possibility to understand the geophysics and astrophysics phenomena. In this work, an electrically conducting liquid, gallium, fills the gap between two concentric spheres and is sheared through the differential rotation of the inner sphere is investigated numerically using a three-dimensional computational fluid dynamics (CFD). The outer sphere is kept stationary while the inner one rotates freely about a vertical axis through its centre. The inner and outer spheres are considered insulating. The numerical studies are performed for the medium gap width β=0.18, and carried out for a wide range of Hartmann numbers. Special attention is given to the effect of magnetic field on the stability of Taylor vortices and azimuthal traveling waves. Computations for the onset of Taylor vortices and wavy mode for non-magnetic spherical Couette flow show a good agreement with experimental data available in the literature. Pressure and tangential velocity distributions are also computed as well as the meridional streamlines. It is established that the imposed magnetic field radically alters the flow structures leading to significant topological changes on the flow patterns. In particular, we found that depending on the magnetic field imposed, the basic state consists of either a shear layer or a counter-rotating jet and both becoming thinner and thinner for increasingly strong imposed fields, but with the jet also becoming stronger.

*Speaker

Role of droplets in interfacial MHD instabilities

Abdellah Kharicha * [1]

[1] Montan Universität Leoben – A-8700 Leoben, Franz-Josef-Strasse 18, Austria

Droplets are present in multiple metallurgical processes involving Magnetohydrodynamics. In many cases metallic droplets are immersed in low conductivity media, such as slags or plasma. When an electric current is applied, the current favors all the paths flowing through the highly conducting droplet. This represents the first mechanism on how droplets can interact with the Electromagnetic field. The second mechanism occurs when the droplet is in a movement through a magnetic field. In this case an electric current is induced, which in turn, interacts with the magnetic field to produce the Lorentz force. This force is at the origin of all MHD effects. In the present study we investigate the stability of an interface between two stratified liquids when a strong vertical current is applied. A layer of low conducting liquid(electrolyte) lies over a heavier and very conducting liquid metal. This configuration is encountered in aluminium reduction cells, in electroslag remelting processes, and in the recent technologies dedicated to liquid metal batteries. For this purpose a Magneto-hydrodynamic (MHD) model was built using a Phi-A electromagnetic potential formulation. The flow is modelled with the Navier-stokes equations, the interface is tracked with the geometrical reconstruction (PLIC) scheme. The calculation domain was built with 5 millions control volumes, allowing extremely accurate prediction of the turbulence and the interface tracking. The results show that if the imposed current reaches a certain magnitude, liquid metal droplets start to depart from the interface. A cloud of droplets is quickly generated, that attracts more electric current. The interaction between the cloud, the interface, and the electromagnetic field was found to be extremely complex. The most important finding is that the distribution of the droplets in the electrolyte induces the presence of a strong horizontal component of the electric current (in the electrolyte) and generates a vertical component of the induced magnetic field. The coupling between the interface movement and droplets distribution was found to be the main actor of this new mechanism of MHD instability.

*Speaker

Effect of aspect ratio on steady liquid metal through the Graëtz flow system in MHD

Sabrina Lecheheb * [1]

[1] Laboratory of Thermodynamics and energetic systems, Faculty of Physics, USTHB, BP 32 El alia, Babezzouar Algiers, Algeria – Algeria

This work dealt with the geometrical effect on the Graëtz flow system following the influence of the duct length to width ratio, aspect ratio Γ, on heat-transfer rates, pressure distribution and thermal performances as local and mean Nusselt numbers of molten metal flow through horizontal rectangular channel in the Poiseuille flow conditions subjected to uniform transversal magnetic field. We modeled the process to establish the properties related to heat transfer involving the both thermal regions of Graëtz system in MHD. Thus, using a computational fluid dynamics procedure based on finite volume method (Fluent Code), we studied numerically the problem in order to characterize and control the viscous MHD flow according to an imposed axial temperature gradient. As a result of the effect of aspect ratio on the liquid metal for the considered geometry this one is connected with the sensitive parameters, namely, the Brinkman number Br, the Hartmann number Ha and the Peclet number Pe. The advantage of such modifications will directly affect the probability distribution of the temperature field, with or without a magnetic field effect. Under these conditions, we note that an early transition regime [1] from the laminar flow to turbulence and therefore by decreasing Γ to enhance both heat transfer rates and flow mixing by pressure drop as Γ deceases.

Keywords: Graëtz flow system, Thermal performance, Poiseuille flow, Aspect ratio, Nusselt number

Reference

[1] R.N. Mondal, 'Effect of Aspect ratio on unsteady solutions through curved duct flow', Appl. Math. Mech. Engl, Ed., 34(9), 1107-1122(2013)

*Speaker

List of posters

A1: Studying the transition from axi- to nonaxisymmetric dynamos using semi-global convection models. *Mariangela Viviani, Elisabeth Cole, Petri Kapyla, Maarit Käpylä, Nigul Olspert, Jörn Warnecke*

A2: Spreading of magnetic reconnection at electron scales: Electron-magnetohydrodynamic simulations. *Neeraj Jain, Joerg Buechner*

A3: Flow patterns in a spherical annulus subjected to a magnetic field. *Lalaoua Adel*

A4: Solar Mechanics: Sun activity and its magnetic fields flip synchronize with the moves of its system planetary center of mass. *Maxime Pelerin*

A5: Non-axisymmetric magnetorotational instability in the spherical Couette system. *Domenico Meduri, François Lignières, Laurène Jouve*

A6: Onset and Nonlinear Dynamics of the Solar Eruption. *Satoshi Inoue*

A7: Closed form hydrostatic equilibrium with Kramers conductivity. *Matthias Rheinhard*

E1: Control of Transient Growth in Hartmann Flow. *G. Algrabli, S. Arogeti, Michael Mond*

E2: Direct numerical simulations of turbulent natural convection with strong vertical magnetic field. *Wenjun Liu, Dmitry Krasnov, Jörg Schumacher, Christian Karcher, Andre Thess*

E3: Local Lorentz force velocimetry at a continuous casting model. *Daniel Hernández, Christian Karcher, Thomas Wondrak*

E4: Numerical Investigation of Magnetically Induced Instabilities. *Thomas Arlt, Leo Bühler, Janis Priede*

E5: Effect of aspect ratio on steady liquid metal through the Graëtz flow system in MHD. *Sabrina Lecheheb*

E6: MHD sloshing instability in liquid metal batteries. *Gerrit Horstmann*

L1: Non-contact electromagnetic flow measurement in liquid metal two-phase flow using Lorentz force velocimetry. *Ze Lyu, Christian Karcher*

L2: CFD study of the magnetic field effect on flow of liquid sodium in Taylor-Couette system. *Abdelkrim Merah, Faiza Mokhtari, Adel Lalaoua, Abderrachid Hamrani*

L3: A homopolar disc dynamo experiment with liquid metal contacts. *Raúl Avalos-Zúñiga, Janis Priede, Carla Bello Morales*

List of participants

1	Adel	Lalaoua	University of Sciences and Technology Houari Boumedienne
2	Alili	Rachid	
3	Arlt	Rainer	Leibniz Institute for Astrophysics Potsdam
4	Arter	Wayne	UKAEA
5	Avalos-Zuniga	Raul a.	Instituto Politecnico Nacional
6	Barekat	Atefeh	Max Planck Institute for Solar System Research
7	Barik	Ankit	Max Planck Institute for Solar System Research
8	Boeck	Thomas	TU Ilmenau
9	Bonanno	Alfio	INAF Catania Astrophysical Observatory
10	Brēķis	Artūrs	Institute of Physics of University of Latvia
11	Buechner	Joerg	Max Planck Institute for Solar System Research
12	Bühler	Leo	Karlsruhe Institute of Technology
13	Busse	Friedrich	University of Bayreuth
14	Cameron	Robert	MPS
15	Christensen	Ulrich	Max Planck Institute for Solar System Research
16	Dietrich	Wieland	Max Planck Institute for Solar System Research
17	Duarte	Lucia	University of Exeter
18	Ellahouny	Nada	Helwan University
19	Elstner	Detlef	Leibniz-Institut für Astrophysik Potsdam (AIP)
20	Fabbian	Damian	Max Planck Institute for Solar System Research
21	Fournier	Yori	Leibniz-Institut für Astrophysik Potsdam (AIP)
22	Gast	Philipp	Leibniz-Institute for Astrophysics Potsdam (AIP)
23	Gastine	Thomas	IPGP
24	Gellert	Marcus	Leibniz-Institut für Astrophysik Potsdam
25	Gent	Frederick	Aalto University
26	Giesecke	Andre	Institute of Fluid Dynamics
27	Goepfert	Oliver	University of Göttingen
28	Grete	Philipp	Michigan State University
29	Gundrum	Thomas	Helmholtz-Zentrum Dresden-Rossendorf
30	Guseva	Anna	Center of Applied Space Technology and Microgravity
31	Guseva	Anna	Center of Applied Space Technology and Microgravity (ZARM)
32	Hackman	Thomas	University of Helsinki
33	Hernández	Daniel	Technische Universität Ilmenau
34	Hori	Kumiko	University of Leeds
35	Horstmann	Gerrit	Helmholtz-Zentrum Dresden - Rossendorf e.V.
36	Inceoglu	Fadil	Leibniz-Institute for Astrophysics Potsdam
37	Inoue	Satoshi	Max Planck Institute for Solar System Research (MPS)
38	Isik	Emre	Max Planck Institute for Solar System Research
39	Jain	Neeraj	Max Planck Institute for Solar System Research
40	Kaiser	Ralf	Universität Bayreuth
41	Käpylä	Maarit	MPS
42	Käpylä	Petri	Leibniz-Institut für Astrophysik Potsdam
43	kharicha	abdellah	Montan Universität Leoben
44	Klementyeva	Irina B	Joint Institute for High Temperatures of Russian Academy of Sciences
45	Küker	Manfred	Leibniz-Institut für Astrophysik Potsdam
46	Lakoundji	Roland Riphat Geoffroy	
47	Langfellner	Jan	Max-Planck-Institut für Sonnensystemforschung
48	lecheheb	sabrina	University of Science and Technology Houari Boumediene USTHB
49	Lehtinen	Jyri	Max Planck Institute for Solar System Research

50	Liu	Wenjun	Technische Universität Ilmenau
51	Lyu	Ze	Technische Universität Ilmenau.
52	Mamatsashvili	George	Helmholtz Zentrum Dresden Rossendorf
53	Mamatsashvili	George	HZDR
54	Martin Belda	David	Max Planck Institute for Solar System Research
55	Meduri	Domenico	Institut de Recherche en Astrophysique et Planétologie (IRAP)
56	Merah	Abdelkrim	Université de Boumerdes
57	Mistrangelo	Chiara	Karlsruhe Institute of Technology
58	Mond	Michael	Ben-Gurion University
59	Muñoz Sepúlveda	Patricio	Max Planck Institute for Solar System Research
60	Panja	Mayukh	Max Planck Instittute for Solar System Science, Gottingen
61	Park	Kiwan	ITA Uni-Heidelberg
62	Pelerin	Maxime	CNRS
63	Pérez-Barrera	James	Renewable Energy Institute, UNAM
64	Prinz	Sebastian	TU Ilmenau
65	Raedler	Karl-Heinz	Leibniz-Institut für Astrophysik Potsdam (AIP)
66	Reshetnyak	Maxim	Schmidt Institute of Physics of the Earth, Russian Academy of Sciences
67	Rheinhardt	Matthias	Aalto University
68	Riethmüller	Tino	Max-Planck-Institut für Sonnensystemforschung
69	Ruediger	Guenther	Leibniz-Institut fuer Astrophysik
70	Sahoo	Ganapati	University of Rome Tor Vergata
71	Sanchez	Sabrina	Max Planck Institute for Solar System Research
72	Schumacher	Joerg	TU Ilmenau
73	Schüssler	Manfred	Max Planck Institute for Solar System Research
74	Seilmayer	Martin	Helmholtz-Zentrum Dresden-Rossendorf
75	Shebalin	John	George Mason University
76	Skala	Jan	MPS
77	Spada	Federico	Leibniz-Institut fuer Astrophysik Potsdam (AIP)
78	Stefani	Frank	Helmholtz-Zentrum Dresden-Rossendorf
79	Teplyakov	Igor	Joint Institte for High Temperatures RAS
80	Thompson	Michael	NCAR
81	Tigrine	Zahia	University of Science and Technology Houari Boumediene USTHB
82	Tilgner	Andreas	University of Göttingen
83	Tsang	Yue-Kin	University of Exeter
84	Valliappan	Senthamizh Pavai	Leibniz Institute for Astrophysics Potsdam
85	Vitas	Nikola	Instituto de Astrofisica de Canarias
86	Viviani	Mariangela	Max Planck Institute for Solar System Research
87	Warnecke	Jörn	Max Planck Institut für Sonnensystemforschung
88	Wicht	Johannes	Max Planck Institut für Sonnensystemforschung

Max Planck Institute for Solar System Research
Justus-von-Liebig-Weg 3
37077 Göttingen
www.mps.mpg.de