European GDR Dynamo & MHD Days 2012

Nice : 1 - 4 October 2012

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Organizers : Y. Ponty, E. Dormy, J. Wicht

European GDR Dynamo & MHD Days
(Nice: 1st - 4th October 2012)

Monday October 1

9:30-9:40 Welcome and announcements

9:40-10:25 Sven Eckert [invited]

Investigations of unstable flows in magnetic fields relevant for industrial applications

10:25-10:50 Coffee

10:50-11:10 Jian Dandan (with Christian Karcher)

Time-of-Flight Lorentz force velocimetry: A non-contact electromagnetic surface velocity measurement

11:10-11:30 Chiara Mistrangelo and Leo Bühler

Buoyancy-driven magnetohydrodynamic flows in electrically coupled ducts

11:30-11:50 Marcus Gellert

Tayler instability & Taylor generator

11:50-12:10 Rainer Hollerbach

Electromagnetically driven zonal flows in a rapidly rotating spherical shell

12:10-12:30 Andre Giesecke

Parametric resonance in a periodically perturbed von-Karman flow

12:30-14:00 Lunch

14:00-14:50 Cary Forest [invited]

Stirring unmagnetized plasma

14:50-15:10 Bryan Taylor

Turbulent cascades and the alpha dynamo

15:10-15:30 Nathanael Schaeffer

DTS Sodium experiment A New findings and future developments

15:30-15:50 Franck Stefani

Towards a precession driven dynamo

15:50-16:10 Christophe Gissinger

Dynamo action in a turbulent Taylor-Couette flow

16:10-16:40 Coffee

16:40-17:00 Caroline Nore

Dynamo action in finite cylinders

17:00-17:20 Nicolas Plihon

Estimating dynamo threshold in the VKS experiment

17:20-18:05 Ansgar Reiners [invited]

Observations of stellar dynamos

19h00 Welcome party

Tuesday October 2

9:15-10:00 Andy Jackson [invited]

Fusion of core dynamics and observation

10:00-10:20 Francois Pétrélis

Plate tectonics controls reversal frequency of Earth's magnetic field

10:20-10:50 Coffee

10:50-11:10 Ulrich Christensen

Dipole reversals linked to hemispherical asymmetry in numerical geodynamo models.

11:10-11:30 Thomas Gastine

Anelastic dynamo models of Jupiter and Saturn

11:30-11:50 David Ivers

Dynamos in ellipsoidal geometrie

11:50-12:10 David Cebron

Magnetohydrodynamics of the elliptical instability

12:10-12:30 Stijn Vantieghem

An unstructured finite-volume method for the solution of the MHD equations

12:30-14:00 Lunch

14:00-16:00 **Poster session 1**

16:00-16:30 Coffee

19h30 Conference diner

Wednesday October 3

9:45-10:30 Matt Browning [invited]

Global simulations of stellar dynamos

10:30-10:50 Coffee

10:50-11:10 Axel Brandenburg

MHD turbulence under stratification the negative effective magnetic pressure instability

11:10-11:30 Andreas Tilgner

Transitions in rapidly rotating convection driven dynamos

11:30-11:50 Martin Schrinner

Rotational threshold in global numerical dynamo simulations

11:50-12:10 William Edmunds

How can large-scale twisted magnetic structures naturally emerge from buoyancy instabilities

12:10-12:30 Sebastien Galtier

A Kolmogorov law for compressible astrophysical turbulence

12:30-14:00 Lunch

14:00-16:00 **Poster session 2**

16:00-16:20 Coffee

16:20-16:40 Paul Bushby

Small-scale dynamo action in compressible convection

16:40-17:00 Gordon Ogilvie

Magnetic flux transport and outflows from accretion discs

17:00-17:20 Ludovic Petitdemange

Dipole collapse and dynamos waves in global direct numerical simulations

17:20-17:40 Laurène Jouve

On the interaction between differential rotation and magnetic fields in A-type stars

17:40-18:00 Alexandros Alexakis

Simulations of isotropic MHD turbulence

Thursday October 4

9:15-10:00 Michael Proctor [invited]

Effect of shear flows on dynamo action

10:00-10:20 Christina Davies

Stability properties of multiple equilibria derived from a single field configuration

10:20–11:50 Coffee

10:50-11:10 Giorgio Krstulovic

Axial dipolar dynamo action in the Taylor-Green vortex

11:10-11:30 Nobumitsu Yokoi

Cross-helicity dynamo and flow generation

11:30-11:50 *End of conference*

12:30 Lunch

Abstracts

Invited speakers

Matthew Browning (Univ. Exeter)
Global simulations of stellar dynamos
Magnetism is ubiquitous in stars, and in most cases this magnetism is thought to arise from convective dynamo action. But a comprehensive theoretical understanding of this process, and how it depends upon basic stellar parameters like mass and rotation rate, remains elusive. Recently, 3-D MHD simulations have begun to capture much of the essential physics of the dynamo process, though many difficulties remain. I will review some of the results of large-scale convective dynamo simulations, focusing in particular on what elements appear to play roles in establishing fields that are highly organized either in space or in time. I will discuss how these elements vary in different types of objects, and highlight some differences between the stellar and planetary regimes. I will also describe some of the considerable uncertainties that persist in these simulations (and in our understanding of stellar dynamos generally), and speculate about how to do better.

Sven Eckert (Helmholtz-Zentrum Dresden-Rossendorf, HZDR)
Investigations of unstable flows in magnetic fields relevant for industrial applications
Various types of magnetic fields are applied for electromagnetic flow control in many industrial applications such as metallurgy, casting, crystal growth or electrochemistry. The first part of this paper considers the electromagnetic damping of instabilities by DC magnetic fields (so-called "Electromagnetic Brakes"), which are exploited for casting of steel or aluminum. The magnetic field tends to damp 3D flow perturbations leading to the development of 2D flow structures aligned with the magnetic field direction. However, this effect is not equivalent to a complete damping of turbulent fluctuations as it might be expected at a first glance. The magnetic field application may even enhance local velocity fluctuations in the continuous casting process. This feature that a DC magnetic field may give rise to non-steady, non-isotropic flow structures has to be taking into account for designing of tailored magnetic fields in the continuous casting process. AC magnetic fields are used in metallurgy and crystal growth for melt stirring or the suppression of instabilities, respectively. The second part of this contribution provides a brief insight into flow phenomena in a liquid metal column resulting from the application of diverse AC magnetic fields, for instance time-modulated or superposed fields.

Cary Forest (University of Wisconsin, Madison)
Stirring Unmagnetized Plasma
Recently, a new concept for stirring a sufficiently hot (Te=10 eV), unmagnetized plasma has been demonstrated, making it possible to study the Dynamos and the Magnetorotational Instability for the first time in a laboratory plasma. In the Plasma Couette Experiment, plasma is confined by a cylindrical, axisymmetric multicusp magnetic field. The field vanishes rapidly away from the boundaries, leaving a large, unmagnetized plasma in the bulk. Azimuthal flows (6 km/s) are driven with JxB torque using biased, heated filaments located at a single toroidal position at the boundary. Measurements show that momentum couples viscously from the magnetized edge to the unmagnetized core, and that the flow is axisymmetric. In order for the toroidal velocity to couple inward, the collisional ion viscosity must overcome the drag due to ion-neutral collisions. Flow speeds can be adjusted by simply increasing the bias voltage of the electrodes. When flow is driven only from the outer boundary, the plasma rotates as a solid-body and the MRI is stable. However, the addition of electrodes at the inner boundary enables us to drive the sheared flow necessary for destabilizing the MRI. This experiment has already achieved magnetic Reynolds numbers of Rm~50 and magnetic Prandtl numbers of Pm ~0.3–6, which are approaching regimes shown to excite the MRI in local linear analysis and global Hall-MHD numerical simulations. Experiments characterizing the MRI will compare the onset threshold to theoretical and numerical predictions, look for altered velocity profiles due to momentum transport during nonlinear saturation, and identify two fluid effects expected to arise from the Hall term and plasma-neutral interactions (important in protoplanetary accretion disks).

While these experiments have been carried out, have also been constructing a much larger (3 m diameter) dynamo experiment based on a Von Kármán like flow in a sphere that should be capable of generating plasmas with Rm~1500. Several different scenarios have been investigated numerically to show that the experiment has a very good chance of being a dynamo, including steady von Kármán flow that generates an equatorial dipole, and a new Galloway-Proctor like flow that uses time dependent boundary conditions to generate smooth, but chaotic flows that give a fast dynamo. The experiment is now constructed and will be described in this talk. Initial results on plasma formation will be presented.

Andrew Jackson (ETH Zurich)
Fusion of core dynamics and observation
The dynamics of the core is thought to be dominated by rotation magnetic forces and buoyancy. I describe our efforts towards constructing a theory in which viscosity does not play a leading order role. I also describe our methodology and results from applying so-called 4D variational data assimilation for the core - the task of finding an initial state that evolves according to a reduced physics theory in best agreement with observations. End-to-end simulations will be used to demonstrate the possibilities such an approach offers.

Michael Proctor (Univ. Cambridge)
Effect of shear flows on dynamo action
There has been much recent work on the influence of shear flow on dynamo action due to different kinds of turbulence forced turbulence convection.... Apart from numerical simulation there have been attempts to model some aspects of the problem in terms of fluctuating alpha-effects. Different models of fluctuation yield different dependencies of the growth rate on the shear. I shall show how a simple model can clarify the relations between different models and give a new bound on the exponential growth rate that rules out persistent linear dependence of the growth rate on the shear. I will also present work with Hughes on the convective dynamo with shear.

Ansgar Reiners (Univ. Göttingen)
Observations of stellar dynamos
Stellar dynamos can generate magnetic fields in stars harboring significant convective areas. The Sun with its magnetic cycle is an example of a slowly rotating star with a convective envelope and a radiative core. Other, faster rotating sun-like stars reveal fields that are often much stronger and fully convective stars lacking a radiative core (and a tachocline) are known to show clear signs of significant dynamo-generated magnetism, too. I review observational evidence for stellar dynamos and lay out our current understanding of the principles behind stellar magnetism. In particular, magnetism in low-mass stars covering a broad range of physical properties can provide useful information on the connection between sun-like and planetary dynamos.

Oral presentations

Alexandros Alexakis (ENS Paris)
Simulations of isotropic MHD turbulence
High Reynolds number isotropic magneto-hydro-dynamic turbulence in the presence of large scale fields is investigated as a function of the magnetic field strength. For a variety of flow configurations the energy dissipation rate ε showed the Kolmogorov scaling ε~Urms^3/lu. Increase of the magnetic energy showed a transition to the ε~Urms^2 BL/L scaling implying that magnetic shear becomes more efficient at this point at cascading the energy than the velocity fluctuations. Strongly helical flows formed helicity condensates that deviate from this scaling. The weak turbulence scaling ε~ul4BLl was absent. Finally, the magnetic energy spectra showed support for the Kolmogorov spectrum k^−5/3 while kinetic energy spectra are closer to the Iroshnikov-Kraichnan spectrum k^−3/2.

Axel Brandenburg (Nordita)
MHD turbulence under stratification the negative effective magnetic pressure instability
We present the first numerical demonstration of the negative effective magnetic pressure instability in direct numerical simulations of stably-stratified externally-forced isothermal hydromagnetic turbulence in the regime of large plasma beta. By the action of this instability initially uniform horizontal magnetic field forms flux concentrations whose scale is large compared to the turbulent scale. We further show that the magnetic energy of these large-scale structures is only weakly dependent on the magnetic Reynolds number. Our results support earlier mean-field calculations and analytic work which identified this instability. Applications to the formation of active regions in the Sun are discussed.

Paul Bushby (Univ. Newcastle)
Small-scale dynamo action in compressible convection
Motivated by high resolution observations of convection and magnetic fields at the solar surface, we carry out numerical simulations of convectively-driven dynamo action in a wide Cartesian layer of compressible electrically-conducting fluid. In the absence of a magnetic field the convective motions produce a characteristic granular pattern with a clearly defined mesogranular scale. This flow drives a dynamo at moderate magnetic Reynolds number and the resulting near-surface vertical magnetic flux concentrations accumulate preferentially at the boundaries of mesogranules as observed in the quiet Sun.

David Cebron (ETH Zürich)
Magnetohydrodynamics of the elliptical instability
The elliptical instability can take place in planetary cores and stars elliptically deformed by gravitational effects where it generates large-scale three-dimensional flows. In this work we present the first magneto-hydrodynamic MHD numerical simulations of such flows using a finite-element method. We first validate our numerical approach by comparison with kinematic dynamic dynamos benchmarks of the literature. We then systematically study the magnetic field induced by various modes of the elliptical instability from an imposed external field in a triaxial ellipsoidal geometry relevant in a geo- and astrophysical context. Finally a new approach allowing spectral MHD simulations of the elliptical instability is presented. First numerical results on its dynamo ability at small Ekman numbers will be discussed.

Ulrich Christensen (Max Planck Institute for Solar System Research)
Dipole reversals linked to hemispherical asymmetry in numerical geodynamo models
It has been suggested that hemispherical asymmetry of the heat flow at the core-mantle boundary influences the reversal rate of the Earth's dipole field (Petrelis et al., Geophys. Res. Lett., 2011). Previous dynamo simulation with imposed non-uniform heat flow at the core-mantle boundary (Olson et al., Phys. Earth Planet. Inter., 2010) showed only a weak increase of reversal rate for a

hemispherically asymmetric heat flux compared to the case of uniform flux. Here reversing dynamo models with and without an imposed hemispherical asymmetry at Ekman number 3x10^{-4} are studied. In the homogeneous case spontaneous hemispherical symmetry breaking occurs intermittently. In such a state one hemisphere is significantly warmer (has lower mean co-density) than the other hemisphere. This is associated with an equatorially antisymmetric zonal flow (EAA mode, Landeau and Aubert, Phys. Earth Planet. Inter, 2011). A strong anticorrelation is found between the axial dipole moment and the degree of hemispherical temperature difference or the intensity of the antisymmetric component of zonal flow. All ~10 dipole reversals occuring during the run coincide with stages of strong symmetry breaking. Preliminary results for a model with imposed hemispherical asymmetry show a decrease in the mean axial dipole power and a moderate increase in reversal rate. The small degree of zonal flow antisymmetry seen in core flow inversions suggests that the probability for a impending reversal of the geomagnetic dipole is low.

Christina Davies (Univ. Leeds Maths)
Stability properties of multiple equilibria derived from a single field configuration
When conducting perturbation analyses to study effects such as magnetic buoyancy instability it is common to discuss the stability properties of a particular magnetic field configuration. The equilibrium state of such systems is magnetohydrostatic balancing gas pressure gravitational effects and magnetic pressure as such for a given magnetic field there are an infinite amount of different possible equilibria which can have different stability properties. Often a magnetohydrostatic equilibrium is constructed by adding the desired magnetic field to a system in hydrostatic equilibrium the properties of the system then determine which equilibrium will be arrived at for example by determining which variable will equilibrate most quickly. Here we consider three different methods for achieving equilibrium in a simplified system two commonly used in literature and a further case where the fluid is allowed to relax into a configuration of minimal energy and discuss the stability properties of the three equilibria achieved.

William Edmunds (University of Cambridge)
How can large-scale twisted magnetic structures naturally emerge from buoyancy instabilities
We consider the three-dimensional instability of a horizontal magnetic layer embedded in a weakly magnetised atmosphere. The direction of the field in the atmosphere can vary with respect to the strong unstable field below with the twist being concentrated at the upper interface. We show from the initial small-scale interchange instability large-scale twisted coherent magnetic structures are spontaneously formed with possible implications to the formation of active regions from a deep-seated solar magnetic field.

Detlef Elstner (Leibniz Institut für Astrophysik Potsdam)
The role of star formation for the galactic dynamo
Magnetic field amplification by a fast dynamo is seen in local box simulations of SN-driven ISM turbulence where the self-consistent emergence of large-scale fields agrees very well with its mean-field description. We accordingly derive scaling laws of the turbulent transport coefficients in dependence of the SN rate density and rotation. These provide the input for global simulations of regular magnetic fields in galaxies within a mean-field MHD framework. Using a Kennicutt-Schmidt relation between the star formation rate and midplane density we can reduce the number of free parameters in our global models. We consequently present dynamo models for different rotation curves and radial density distributions.

Sebastien Galtier (IAS Paris sud)
A Kolmogorov law for compressible astrophysical turbulence
It is well known that compressible turbulence is a dominant feature of interstellar clouds; it also plays a non negligible role in the evaluation of the local heating in the solar wind. Nevertheless due to the intrinsic difficulty to include compressible effects in theoretical models almost no serious result exists in compressible turbulence.
In this presentation, I will review results obtained from direct numerical simulations and then report a recent theoretical progress made on compressible isothermal turbulence in the asymptotic limit of a high Reynolds number: it is the derivation of the equivalent of the Kolmogorov law [1]. Our investigation concludes on the existence of a double inertial range where respectively super- and subsonic turbulences happen.
[1] Galtier & Banerjee, Phys. Rev. Lett. 107, 134501 (2011)

Thomas Gastine (Max Planck Institute for Solar System Research)
Anelastic dynamo models of Jupiter and Saturn
Interior models of the gas giants suggest that the internal structure of Jupiter and Saturn are separated into an outer non-conducting molecular envelope and an inner metallic region, where the dynamo takes place.
Typical numerical models for planetary dynamos have been developed with the geodynamo in mind and rely mainly on the Boussinesq approximation, that assumes that the background properties (temperature, density, ...) are constant with radius (Christensen & Aubert, 2006). While this approximation is suitable for liquid iron cores of terrestrial planets, it becomes questionable in gas giants, where density increases by several orders of magnitude (roughly rhobot/rhotop=5000, French et al., 2012). The anelastic approximation provides a more realistic framework to model the dynamics of gas giants as it allows to incorporate compressibility effects (Lantz & Fan, 1999). In addition, electrical conductivity varies significantly in the interiors of gas giants, being roughly constant in the metallic region and decaying exponentially in the molecular envelope. This variability is known to promote a rich dynamical behavior, as the significant zonal flows that develop in the molecular layer can influence the dynamo mechanism via the Omega-effect (Heimpel et al., 2011).
Here, I present the results of a systematic parametric study on the effects of both the background density stratification and the variable electrical conductivity. While the previous Boussinesq results suggested that the dipolarity of the magnetic field may be a direct consequence of the relative influence of inertia (through the local Rossby number criterion developed by Christensen and Aubert (2006)), anelastic dynamos tend to produce a broader range of field geometries, encompassing dipole-dominated and multipolar magnetic fields.

Marcus Gellert (Leibniz-Institut für Astrophysik Potsdam)
Tayler instability & Taylor generator

Andre Giesecke (Helmholtz-Zentrum Dresden-Rossendorf)
Parametric resonance in a periodically perturbed von-Karman flow
We have performed numerical simulations of the kinematic induction equation in order to examine the dynamo efficiency of an axisymmetric von-Karman-like flow subject to time-dependent non-axisymmetric velocity perturbations with an azimuthal wavenumber m=2. The numerical model is based on the setup of the French Von-Karman-Sodium dynamo and the flow measurements from a model water experiment conducted at the University of Navarra in Pamplona, Spain. We find two distinct regimes of dynamo action that depend on the azimuthal drift of an (m=2) vortex like flow perturbation. For comparatively slowly drifting vortices we observe a narrow window with enhanced

growth-rates and a drift of the magnetic eigenmode that is synchronized with the flow perturbation drift. The resonant-like enhancement of the growth-rates takes place when the vortex drift frequency roughly equals the drift frequency of the magnetic eigenmode in the unperturbed system.

For even larger vortex drift an abrupt transition to an independently drifting magnetic eigenmode occurs and the field amplitude is modulated with twice the vortex drift frequency. The sudden change between the resonant regime and the modulated regime is identified as an spectral exceptional point where eigenvalues (growth-rates and frequencies) and eigenfunctions of two previously independent modes collapse. In the present configuration the experimentally observed vortex drift is much larger than the fundamental drift frequency of the magnetic eigenmode and we conclude that the fulfillment of the resonance condition might be unlikely in present day experiments. However, a parametric resonance might be realized in the Earth's core where tidal forcing may generate the required flow perturbation or in future dynamo experiments that will allow a better control of periodic non-axisymmetric velocity modes in order to meet the resonance condition.

Christophe Gissinger (Ecole Normale Supérieure)

Dynamo action in a turbulent Taylor-Couette flow

Dynamo action is a mechanism by which a magnetic field is self generated by the turbulent flow of an electrically conducting fluid. It is believed to be responsible for the magnetic field of many astrophysical objects. However, a lot of questions remain concerning the generation of a dynamo magnetic field, in particular when the flow is strongly turbulent.

On the other hand, Taylor-Couette flow is one of the most studied problem in fluids dynamics, including the transition to turbulence as Re is increased. Surprisingly, only a few numerical work has been done on dynamo generated by Taylor-Couette flows.

I will present results of 3D direct numerical simulations of the magnetic field generated by a Taylor-Couette flow. I investigate the effect of turbulent fluctuations on the threshold of the dynamo and study the dynamical regimes obtained in the saturated state, depending on the flow patterns obtained in the flow. Different configurations are explored, by varying the geometry of the cylinders, the rotation ratio and the magnetic boundary conditions.

Finally, I will discuss the perspective of a large scale laboratory experiment based on the Taylor-Couette geometry.

Rainer Hollerbach (ETH Zürich)

Electromagnetically driven zonal flows in a rapidly rotating spherical shell

We consider the flow of an electrically conducting fluid confined in a rotating spherical shell. The flow is driven by a directly imposed electromagnetic body force created by the combination of an electric current flowing from the inner sphere to a ring-shaped electrode around the equator of the outer sphere and a separately imposed predominantly axial magnetic field. We begin by numerically computing the axisymmetric basic states which consist of a strong zonal flow. We next compute the linear onset of non-axisymmetric instabilities and fully three-dimensional solutions up to ten times super-critical. We demonstrate that an experimental liquid sodium device no greater than 30 cm in diameter could achieve and exceed these parameter values.

David Ivers (University of Sydney)

Dynamos in Ellipsoidal Geometrie

The kinematic dynamo is solved for a rotating uniformly electrically conducting fluid occupying a ellipsoidal volume with insulating exterior. The method uses a class of oblate ellipsoidal toroidal-poloidal fields in a non-orthogonal coordinate system. Scaling of coordinates and fields leads to a modified form of the magnetic induction equation with geometric anisotropic diffusion. The alpha-effect even if isotropic is transformed into anisotropic form. Angle is discretised using a spherical harmonic Galerkin method. Radial dependence is discretised using finite-differences on a grid centred at interior grid point and one-sided at the insulating boundary. Other forms of radial discretisation such as Chebychev collocation are possible. The current-free condition must be solved explicitly in the insulating exterior. Dynamo solutions are presented for several flows and alpha-effects in different ellipsoids.

Dandan Jian (lmenau University of Technology) (with Christian Karcher)
Time-of-Flight Lorentz force velocimetry: A non-contact electromagnetic surface velocity measurement
Information of liquid steel flow patterns inside the mold may be obtained from the velocity at the free surface (meniscus). This meniscus flow may be measured using the contactless electromagnetic technique termed Lorentz force velocimetry. It is a contactless measurement method which can be used for the determination the local velocities of electrically conductive liquid metal melt. In the present paper we explain a technique which is a modification of this method, namely, using two Lorentz force flowmeters (LFV) that are arranged in a certain distance one behind the other. This new technique is called Time-of-Flight Lorentz force velocimetry (ToF LFV). Here, free-surface velocity may be determined by just cross-correlating the signals delivered by the two flow meters. Hence, the measurement becomes independent of any fluid or material properties. It is suitable for measurements in high-temperature metallurgical processes because of its contactless feature. The goal of this research is to demonstrate the feasibility of ToF Lorentz force velocimetry.

Laurène Jouve (IRAP Toulouse)
On the interaction between differential rotation and magnetic fields in A-type stars
Some A stars (Ap stars) possess strong large-scale magnetic fields which seems to remain rather stable. Some recent observations now tend to show that another class of A stars exists, which exhibit a more complex and weak magnetic field, organized at smaller scales at their surfaces. We would like to understand this magnetic dichotomy by investigating the stability of magnetic fields created by differential rotation in the stellar radiative envelope. We numerically compute the joint evolution of the toroidal magnetic and velocity fields in a 2D axisymmetric spherical shell where the initial poloidal magnetic field and initial profile of the differential rotation are varied. In agreement with previously suggested scenarios, we find that after an Alfven time, a maximum for the ratio of toroidal to poloidal fields is reached. This ratio is closely related to the initial dipole strength and the stellar rotation rate. Depending on this value, we will show that such magnetic configurations may or may not be subject to the Tayler instability, which could explain the dichotomy between strong and weak observed magnetic fields in A-type stars

Giorgio Krstulovic (Observatoire de la Côte d'Azur)
Axial dipolar dynamo action in the Taylor-Green vortex
We present a numerical study of the magnetic field generated by the Taylor-Green vortex. We show that periodic boundary conditions can be used to mimic realistic boundary conditions by prescribing the symmetries of the velocity and magnetic fields. This gives insight in some problems of central interest for dynamos the possible effect of velocity fluctuations on the dynamo threshold the role of boundary conditions on the threshold and on the geometry of the magnetic field generated by dynamo action. In particular we show that an axial dipolar dynamo similar to the one observed in a recent experiment can be obtained with an appropriate choice of the symmetries of the magnetic field. The nonlinear saturation is studied and a simple model explaining the magnetic Prandtl number dependence of the super/sub critical nature of the dynamo transition is given.

Chiara Mistrangelo and Leo Bühler (Karlsruhe Institute of Technology)
Buoyancy-driven magnetohydrodynamic flows in electrically coupled ducts
In one of the proposed European blanket concepts to be tested in the experimental fusion reactor ITER, the liquid metal alloy PbLi is used primarily to breed the fuel component tritium, while the heat flux is removed by helium flowing in channels grooved into the steel structure. By using a separated coolant the liquid metal can flow in the blanket with small velocities of the order of 0.1 mm/s. This weak forced flow is required for tritium extraction. As a result it is expected that liquid metal blanket flows are mainly driven by buoyancy forces caused by non-uniform thermal conditions due to neutron volumetric heating and cooling of walls. Velocity distributions inside the blanket are significantly affected by the intense applied magnetic field that confines the fusion plasma. The understanding of buoyant magnetohydrodynamic flows becomes therefore a requirement to properly predict flow distribution in liquid metal blankets and to finalize the design of this type of fusion reactor

components. In the present study magneto-convective flows are numerically investigated in geometries related to liquid metal blankets in order to analyze the influence of various thermal boundary conditions and volumetric heat sources on the velocity distribution. Buoyancy effects can locally reverse the flow direction of liquid metal jets compared to flow conditions foreseen by the design causing the occurrence of recirculations and possible tritium accumulation. An interesting phenomenon that has to be taken into account is the electromagnetic coupling of flows in sub-channels that form the complex blanket module. This results from the exchange of electric currents through common electrically conducting walls. As a consequence of this coupling a strongly different velocity magnitude and non-homogeneous flow conditions are expected in adjacent ducts.

Caroline Nore (LIMSI Paris)
Dynamo action in finite cylinders
Using numerical simulations, we investigate two magnetohydrodynamics (MHD) problems in a cylindrical cavity, namely a precessing cylinder and a short Taylor-Couette set-up, both containers being filled with a conducting fluid. We use a parallel code denoted SFEMaNS (Guermond at al., JCP, 2011) to integrate nonlinear MHD equations for incompressible fluids in heterogenous domains with axisymmetric interfaces embedded in a vacuum. We numerically demonstrate that precession is able to drive a dynamo and that a short Taylor-Couette set-up with a body force can sustain dynamo action.
In the precessing cylinder, the generated magnetic field is unsteady and quadrupolar (Nore *et al.*, PRE, 2011). These numerical evidences may be useful for an experiment now planned at the DRESDYN facility in Germany. In the Taylor-Couette set-up, the nonlinear dynamo state is characterized by fluctuating kinetic and magnetic energies and a tilted dipole whose axial component exhibits aperiodic reversals during the time evolution (Nore et al., in revision for PoF, 2012). These numerical evidences may be useful for developing an experimental device. This work was performed using HPC resources from GENCI-IDRIS (Grant 2012-0254).

Gordon Ogilvie (DAMTP, University of Cambridge)
Magnetic flux transport and outflows from accretion discs
The local strength of the poloidal magnetic field in an accretion disc is very important in determining both the intensity of the turbulence resulting from the magnetorotational instability (MRI) and the efficiency with with jets are driven from the disc. I describe recent work with Jerome Guilet in which the radial transport of mass and magnetic flux are computed in models of turbulent discs in which the vertical structure is taken properly into account. I also discuss recent results on the launching of outflows from discs that are either stable or unstable with respect to the MRI.

Ludovic Petitdemange, (LRA Ecole Normale Supérieure)
Dipole Collapse and dynamos waves in global direct numerical simulations
Magnetic fields of low-mass stars and planets are thought to originate from self-excited dynamo action in their convective interiors. Observations reveal a variety of field topologies ranging from large-scale, axial dipole to more structured magnetic fields. In this article, we investigate more than 70 three-dimensional, self-consistent dynamo models obtained by direct numerical simulations. The control parameters, the aspect ratio and the mechanical boundary conditions have been varied to build up this sample of models. Both, strongly dipolar and multipolar models have been obtained. We show that these dynamo regimes can in general be distinguished by the ratio of a typical convective length-scale to the Rossby radius. Models with a predominantly dipolar magnetic field were obtained, if the convective length scale is at least an order of magnitude larger than the Rossby radius. Moreover, we highlight the role of the strong shear associated with the geostrophic zonal flow for models with stress free boundary conditions. In this case the above transition disappears and is replaced by a region of bistability for which dipolar and multipolar dynamos co-exist. We interpret our results in terms of dynamo eigenmodes using the so-called test field method. We can thus show that models in the dipolar regime are characterized by an isolated single mode. Competing overtones become significant as the boundary to multipolar dynamos is approached. We discuss how these findings relate to previous models and to observations.

Francois Petrelis (ENS Paris)
Plate tectonics controls reversal frequency of Earth's magnetic field
The reversal frequency of Earth's magnetic field varies with time. Currently it is around 4 per Myr while no reversal is reported for more than 40 Myr during the createceous superchron 100 Myr ago. We investigate data obtained from plate tectonics and identify a correlation with the reversal frequency. This correlation is understood through a model based on the competition between two modes that shows that breaking of equatorial symmetry controls the reversal frequency.

Nicolas Plihon (ENS Lyon)
Estimating dynamo threshold in the VKS experiment
Reaching dynamo self generation in conducting fluids experiments has been a long-lasting question over the last decades. The ability to predict dynamo self generation or to estimate the critical value of the control parameter has been a continuous challenge, partly due to the high level of turbulent fluctuations of conducting fluids flows in such experiments (with kinetic Reynolds number in excess of 10^6. We address the problem of dynamo threshold estimation in the VKS experiment. Threshold estimates from critical slowing-down and susceptibility divergence analysis are demonstrated in configurations for which dynamo action was reached. The influence of the applied magnetic mode on critical slowing down will be discussed. The two methods are then applied to configurations that failed to self-generate magnetic fields within the operational limits, and we analyze their potential ability to lead to dynamo action.

Nathanael Schaeffer (ISTerre Grenoble)
DTS Sodium experiment A New findings and future developments
On the DTS experiment a spherical couette flow using liquid sodium and a strongly magnetized inner-sphere, we have been observing spectra that exhibit bumps. Our last numerical simulations together with a new technique allowed us to exhibit this behaviour at moderate Reynolds number Re ~ 2600 for long enough time-series. We have also made progress in the description of the mean flow by the use of inversion techniques. Here we will present the experimental results the mean flow obtained by inversion and the numerical simulation and special techniques we used. Putting all the pieces together enables us to make significant progress towards the understanding of the physics behind the DTS flow. The future of DTS includes the exploration of the low Rossby number regime fast co-rotation of the inner and outer-sphere and the improvement of the inversion techniques toward data-assimilation. In particular we explore the possibility for the small heterogeneity of the imposed magnetic field to help us constrain the mean flow.

Martin Schrinner (Ecole Normale Superieure)
Rotational threshold in global numerical dynamo simulations
There is considerable observational evidence that magnetic activity on low mass stars increases with increasing stellar rotation rate until it saturates and reaches a constant level for very fast rotating stars. However until now theoretical arguments explaining the so-called activity-rotation relation are poorly developed and formulated only on a heuristic level. We examine the dependence of the field strength on rotation in global numerical dynamo models and interpret our results on the basis of energy considerations. Finally we discuss possible conclusions for the activity-rotation relation of stars.

Franck Stefani (Helmholtz-Zentrum Dresden-Rossendorf)
Towards a precession driven dynamo
Precession has been discussed since long as a complementary energy source of planetary dynamos. We present the status of preparations of a large-scale precession-driven dynamo experiment working with liquid sodium. The main focus is laid on the results of a down-scaled water experiment and on a number of constructional issues of the large machine.

J B Taylor (Radwinter)
Turbulent Cascades and the alpha Dynamo
The well known mean-field model of a turbulence driven dynamo is reviewed in relation to Laboratory experiments in which a turbulent cascade is created by a pair of large impellers. It is argued that in such experiments the alpha-effect driving a dynamo field will be much less than the dissipative beta-effect. Consequently a mean field dynamo cannot be sustained by a turbulent cascade in a laboratory experiment. This conclusion is supported by recent measurements of the alpha and beta effects in the Madison Dynamo Experiment.

Andreas Tilgner (Univ. Göttingen)
Transitions in rapidly rotating convection driven dynamos
Numerical simulations of dynamos in rotating Rayleigh-Benard convection in plane layers are presented. The parameters are chosen such that the flows are organized into columnar vortices by the Coriolis force and can be classified as rapidly rotating. Within this hydrodynamically uniform regime two different types of dynamos exist with different scaling laws for the amplitude of the magnetic field.

Stijn A. M. Vantieghem (ETH Zürich)
An unstructured finite-volume method for the solution of the MHD equations
Starting with the pioneering work of Bullard (1949), several authors have suggested that gravitational interactions between celestial bodies (precession, tides, libration) may be at the origin of, or at least affect, planetary dynamos. In the context of these mechanical forcings, spherically symmetric models of planetary cores are not very accurate from the fluid dynamics point of view. Numerical tools that can take into account deviations from spherical symmetry, are based on local approaches, like the finite-volume or finite-element method. These methods, however, are relatively new to the MHD community. In this talk, we discuss the implementation of a parallel, unstructured finite-volume code for the MHD equations. Particular points of interest are the ensurance of the solenoidal character of the magnetic field and the boundary conditions for the magnetic field. The concepts implemented are verified by benchmarking it against analytical solutions and results from pseudo-spectral codes.

Nobumitsu Yokoi (University of Tokyo)
Cross-helicity dynamo and flow generation
First the cross-helicity effect is explained in the context of dynamos. In the presence of the mean vortical motion, the cross-correlation between the velocity and magnetic fluctuations (turbulent cross helicity) contributes to the turbulent electromotive force parallel to the mean vorticity. This effect is expected to play an important role in suppression of turbulent magnetic diffusivity. One of the features of the cross-helicity dynamo is alignment of the mean electric current and the mean vorticity, which generally allows a finite mean Lorentz force. This is in strong contrast with the alpha dynamo, where the mean Lorentz force vanishes. At the same time, the cross-helicity effect appears in the Reynolds (and turbulent Maxwell) stresses. Coupled with the mean magnetic strain, the turbulent cross helicity may contribute to the suppression of turbulent or eddy viscosity. Several features of the cross-helicity effects in dynamos are summarized. Finally, recent developments in the study of the cross-helicity effects in the context of the magnetic reconnections are discussed.

Poster Session 1:

Thomas Boeck (TU Ilmenau)
Relaminarization thresholds in MHD channel flow with streamwise field
The effects of a streamwise magnetic field on conducting channel flow are studied by analyzing secondary linear perturbations evolving on streamwise streaks and by direct numerical simulations of relaminarization. By means of an optimal perturbation approach from hydrodynamic channel flow, magnetic damping is found to increase the streamwise wavelength of the most amplified secondary perturbations and to reduce their amplification level. Complete suppression of secondary instability is observed at a critical magnetic interaction parameter that depends on the streak amplitude and on the Reynolds number when the transient evolution of the streaky basic flow is taken into account. Relaminarization in the direct numerical simulation occurs at lower values of the interaction parameter than the critical values from the stability computations for the streak amplitudes considered. The dependence of these threshold values of the interaction parameters on the Reynolds number is fairly similar between simulations and stability analysis. Relaminarization thresholds from the simulations are in good agreement with experiments on pipe flow with streamwise magnetic field.

Leo Bühler and Chiara Mistrangelo (Karlsruhe Institute of Technology)
Influence of strong non-uniform magnetic fields on the liquid metal flow in the European fusion test blanket module for ITER
In the European concept for a test blanket to be inserted in the fusion reactor ITER the liquid metal alloy PbLi is foreseen as a breeder material. When this electrically conducting fluid is circulated through the breeder units of a blanket module, electromagnetic forces are created by the interaction of induced electric currents with the strong applied magnetic field that confines the fusion plasma. Previous analyses and experiments have been performed assuming that the blanket module is exposed to a uniform magnetic and major contributions to the total pressure drop have been identified. It has been observed that in the fusion relevant parameter range the resulting magnetohydrodynamic (MHD) flow is dominated by a balance between electromagnetic Lorentz forces and pressure forces while inertia is negligible in a large part of the breeder units. The test blanket module in ITER, however, is positioned in a region where the magnetic field is non-homogeneous. The influence of spatially varying magnetic fields on the MHD flow in two coupled breeder units is investigated by inertialess asymptotic analyses and complemented by numerical simulations for different gradients of the magnetic field. It is found that pressure and potential distributions are significantly affected by the non-uniformity of the field while the velocity distribution in the channels seems less sensitive to field gradients.

Wieland Dietrich, Johannes Wicht, Ulrich Christensen (Max Planck Institute for Solar System Research)
Boundary driven thermal winds and Parker Waves in Planetary Dynamos
One possible explanation for the hemispherical dichotomy in the magnetization pattern of the Martian crust is an intrinsic equatorially asymmetric dynamo field. In our 3D numerical MHD model, we enforce the emergence of such a hemispherical dynamo with an anomaly of the core mantle boundary heat flux of spherical harmonic degree one. Meridional circulation seeks to equilibrate the emerging temperature anomaly, but is detected by the Coriolis force into erce azimuthal thermal winds. Associated shear into the direction of the rotation axis facilitates a strong omega-effect. For the homogeneous CMB heat ux both, the poloidal and the toroidal magnetic field contributions
are produced by helical motions in a so called effect. When the relative strength of the boundary heat flux anomaly exceeds about 60%, however the omega-effect becomes more important than the alpha-effect for creating toroidal field. The dynamo changes from an alpha^2 to an omega-type. The magnetic field then starts to oscillate including polarity reversals.
These oscillations have been identified as Parker waves and follow the dispersion relation predicted by mean field theory. Parker waves are thought to be responsible for the 22-year solar cycle and typically have a period of roughly 10 kyrs in our simulations. In order to apply these simulations to Mars we have to explore how the thermal wind depends on the system parameters. Thermal winds are

proportional to Rayleigh number Ra and Ekman number E and the large scale latitudinal temperature gradient. While Ra and E can reasonably be estimated, this is more difficult for the temperature gradient, which not only depends in the imposed heat ux pattern and amplitude but also on Ra and E. Therefore we measure the latitudinal temperature gradients introduced by the boundary anomalies as function of Ra and E and try to compile the obtained results into a scaling law.

Santara Fatoumata Bintou (Ilmenau University)
Lorentz Force Velocimetry: study of an electromagnet system
Velocity measurement techniques constitute a challenging field in the metal industry, due to the aggressive environment which accompanied melting metals and holding them at high temperature. Several measurement technique for liquid metals are presented in the literature, including contactless method, but still not commercially available [1, 2]. In this context, a non-contact technique to measure both local velocity and flow rate in electrically conducting liquids was set up and termed Lorentz Force Velocimetry (LFV). It consists of exploiting the Lorentz Force resulting of the displacement of a conducting material under an electromagnetic field: in this event, an eddy current is created inside the material as a result of the interaction with the magnetic field. This eddy current interacts in its turn with the magnetic field that leads to the Lorentz force. A force with same magnitude but opposite direction acts upon the magnetic field source according to the reciprocity principle [3]. Velocity or flow rate are thus deduced from the measurement of this force. LFV was widely investigated during the last decade: [3-7]. Most of these studies were carried out for the case where the steady magnetic field was created by a small permanent magnet or a magnetic dipole, but this measurement system may become more expensive for wide and complex industrial installations. We propose here, as an alternative, to create magnetic fields by the means of electromagnets and we present a numerical study of so called ElectroMagnet Lorentz Force Velocimetry (EM-LFV). The Lorentz Force generated will be investigated as a function of the geometrical parameters of the problem.
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Konstantin Finke (Univ. Göttingen)
Simulations of the kinematic dynamo onset of spherical Couette flows with smooth and rough boundaries
We study numerically the dynamo transition of an incompressible electrically conducting fluid filling the gap between two concentric spheres. In a first series of simulations the fluid is driven by the rotation of a smooth inner sphere through no-slip boundary conditions whereas the outer sphere is stationary. In a second series a volume force intended to simulate a rough surface drives the fluid next to the inner sphere within a layer of thickness one tenth of the gap width. We investigate the effect of the boundary layer thickness on the dynamo threshold in the turbulent regime. The simulations show that the boundary forcing simulating the rough surface lowers the necessary rotation rate which may help to improve spherical dynamo experiments.

Corinna Koepke, Johannes Wicht, Wieland Dietrich (Max Planck Institute for Solar System Research)
Numerical Dynamo Simulations at large Ekman Numbers
Numerical simulations of planetary dynamo processes are studied with a 3D MHD code at relatively planetary-far parameters. Especially the Ekman number E is chosen very large compared to realistic planetary and stellar values. The Ekman number is the ratio of viscous and Coriolis forces and

proportional to the inverse rotation rate. The aim of this study is to examine the influence of the Coriolis force on the convection in the body's outer core. At smaller and more realistic Ekman numbers the Coriolis force forms convection columns parallel to the rotation axis after the Taylor-Proudman theorem and the magnetic field is dipolar in a regime where the local Rossby number, the ratio of inertia and Coriolis force, is about Rol = 0.1. We can show that the convective structure significantly changes and is no longer orientated along the rotation axis at larger Ekman numbers. Furthermore the existence of dipolar magnetic fields is studied. We consider values from E = 0.02 to the non rotating case E =infinity. We found the boundary for dipolar solutions between E =0.02 and 0.03. At larger Ekman numbers and in non rotating cases very large magnetic Prandtl numbers of Pm = 10 to 20 have to be considered to find stable dynamo solutions. The convective structures are dependent on velocity boundary conditions of the core shell: for no-slip boundaries two upwelling plumes and a downwelling ring can be found but surprisingly for stress-free boundaries the plumes are downwellings and the ring is in upwelling direction. We try to relate the convective structure and the induction process. The two plumes create a helical flow and thus are able to produce poloidal and toroidal fields via an alpha-effect. A strong omega-effect associated with the rigid boundary supports the induction of toroidal magnetic field. Therefore simulations are investigated with an inner stress-free and an outer no-slip boundary condition and also vice versa. It is observed that with the outer stress-free boundary no magnetic field can be preserved. Besides we want to know if a slowly rotating case at an Ekman number of E = 0.3 has the same characteristics as a non rotating. At larger Rayleigh numbers and decreasing magnetic Prandtl numbers the dynamo force balance become similar to that of many stars where Coriolis forces are also relatively small.

D.Krasnov, A.Thess, T.Boeck, Yu.Zhao and O.Zikanov (Ilmenau),
Numerical reconstruction of the classical Hartmann experiment

We present results of numerical analysis of Julius Hartmann's historical experiments on flows of mercury in tubes under the influence of magnetic fields. The relaminarization of magnetohydrodynamic pipe and duct flows under the influence of a uniform transverse field is examined by direct numerical simulations. The computed critical parameters for the laminar-turbulent transition as well as the friction coefficients are in excellent agreement with Hartmann's data. The simulations provide a first detailed view of the flow structures that are experimentally inaccessible. Novel flow regimes with localized turbulent spots near the side walls parallel to the magnetic field and otherwise laminar flow are discovered at the edge of laminarization. We also suggest how these new regimes can be checked in a transparent fluid using optical flow measurement.

Sebastian Kreuzahler, Rainer Grauer (Univ. Bochum),
Holger Homann, Yannick Ponty (Obs. de la Côte d'Azur)
Numerical Von Karman flow forcing by two rotating propeller using penalization method

Simulations of impeller-driven flows in cylindrical geometry are compared to the Von Karman velocity experiment. The geometry of rotating impellers assembled of several basic objects is modelled via a penalization method and implemented in a massive parallel pseudo-spectral Navier-Stokes solver, called LaTu. Simulations of impellers with different numbers of blades and different curvature radii, especially one resembling the so-called TM28 configuration used in the experiment, were performed. Though the obtained Reynolds numbers of about 300 to 400 at a resolution of 256^3 grid points are far smaller than experimental values, DNS offers the possibility of a spatially resolved analysis of the flow structure. Visualizations of the mean velocity fields as well as flow profiles along the symmetry axes of each simulated flow reveal that all considered blade configurations have the same general structure: two flow cells, one on each side of the cylinder, mostly equal to the simple s2t2 flow, which is meant to generate dynamo action. We analysed the flow structure close to the impeller blades and found large values of helicity, which might lead to the dynamo-relevant alpha effect. The decomposition into poloidal and toroidal components allows to compare quantitatively DNS with experimental results, especially for the TM28 flow.

Domenico Meduri, Johannes Wicht & Dieter Schmitt (Max Planck Institute for Solar System Research)

Statistical Analysis of Reversals and Stable Polarity Epochs in Geodynamo Models and Paleomagnetic Data

Paleomagnetic observations show a sequence of sudden and occasional global polarity reversals of the Earth's dipolar magnetic field. Recent self-consistent 3D numerical dynamo simulations replicate many features of the Earth's magnetic field and several of these models show reversals (see [5], [1]). In this context, we studied statistically different probability distributions of stable polarity epochs from Earth's paleomagnetic timescales ([2] and [4]) and from a numerical dynamo simulation (with around one thousand reversals). Paleomagnetic studies suggest that the field intensity drops significantly during a reversal (see, e.g., [3]). We identified reversal times of occurrence in our numerical simulation following this experimental evidence, using a threshold on the dipole moment. Stable polarity intervals are then defined as the time lapses between the starting time of a reversal and the ending of the previous one (thus excluding transitional times). We fitted both reversal durations and stable polarity intervals with different probability distributions and we quantified the goodness of fit using Kolmogorov-Smirnov and Anderson-Darling statistics. An exponential distribution (signature of a purely random Poisson process) gives a very good fit of stable polarity intervals, while a log-normal distribution describes reversal durations.

In order to construct a dataset from our numerical simulation directly comparable with the two-states paleomagnetic polarity sequence, we combined the duration of each reversal with the relative stable polarity interval giving the actual polarity state. In this case a log-normal distribution turns out to be the best fit, provided that we artificially remove around 5 % of the shortest events (miming the situation of poorly resolved paleomagnetic data). This is also the distribution which best describes paleomagnetic data.

In conclusion, according to our numerical simulation, reversals are events which happen randomly, being exponentially distributed, during a stable polarity interval. The finite time required by the dipole to build up introduce a short-term memory in the time series because the occurrence of a reversal must, for at least a short time, inhibit the future occurrence of another reversal. Therefore the complete process cannot be truly Poissonian and indeed we obtained a log-normal distribution fit for the complete polarity epochs (including reversal transitional times). Further numerical simulations in different parameter regimes are planned to be studied to confirm the observed statistical behavior. Furthermore, the development of mean-field dynamo models can play the key role of discriminating among different physical processes that can reproduce the observed distribution profiles.

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Sophie Miralles (ENS Lyon)

Saturation of the Bullard Von Kármán dynamo

We present here an experimental Bullard-Von Karman dynamo involving: first, an induction mechanism from turbulent motion of a Von Karman flow and second, current travelling in external wired coils as in the Bullard dynamo. The combination of these two mechanisms allows the observation of a semi synthetic turbulent dynamo, without requiring large mechanical power or large volume of liquid metal.

The setup is a Von Karman liquid Gallium flow (Rm = 1) with external coils which can impose a large transverse magnetic field B_A. Velocity gradients generate axial induced magnetic field B_i from transverse applied B_A field. B_i is measured with Hall probe at one location, the signal being amplified externally with constant gain to control the current in coils. This mechanism create a dynamo instability above a threshold controlled by the velocity of driven impellers and the feedback gain. The interaction parameter is high enough such that the Lorentz force balances flow inertia and saturates magnetic field. As a consequence, we will focus here on results in the saturated regime.

We will describe the different observed regimes as intermittency close to threshold and reversals of the dynamo magnetic field. The properties of this dynamo will also be compared to the one of the VKS dynamo.

Raphael Raynaud (ENS Paris)
On-off intermittency in spherical Couette flow
Performing 3D numerical simulations of dynamos generated in spherical Couette flow we showed that the magnetic field may display on-off intermittency at relatively low magnetic Prandtl number close to the onset of dynamo action. The phenomenon is mainly characterized by series of short bursts of the magnetic energy on phases separated by low energy phases off phases. Comparing our observations to the predictions of a canonical model we found it provides an accurate estimate of the threshold.

Antoine Riols-Fonclare (IRAP Toulouse)
Global bifurcations to magnetorotational dynamo action
Instability-driven dynamos are very interesting candidates to explain sustained magnetic activity and turbulence in a variety of differentially rotating astrophysical bodies such as stellar interiors or accretion disks. Our understanding of the physical mechanisms and conditions of existence of these unusual subcritical, non-kinematic dynamos remains very crude though. To make progress on these questions, we have been investigating the nature of the transition to long-lived dynamics in the prototypical problem of magnetorotational dynamo action in keplerian shear flow. In this talk, we present several new numerical results that reveal the fascinating complexity of this dynamo transition with unprecedented detail. First, we show that the system starts to exhibit features typical of a chaotic repeller such as fractal patterns in maps of turbulence lifetime as the magnetic Reynolds number is increased. We then attempt to identify what causes this transition by studying in detail the structure of the dynamics in the neighbourhood of the many nonlinear MRI dynamo cycles that we identify in the transitional regime. We show that the emergence of dynamo cycles through saddle-node bifurcations is quickly followed by a sequence of global heteroclinic and homoclinic bifurcations resulting in the creation of Poincare tangles linking these cycles and the emergence of chaos. The importance of individual dynamo cycles in the transition process opens new theoretical perspectives to understand the conditions of emergence of the MRI dynamo in Nature, such as its dependence on the magnetic Prandtl number.

Farzaneh Samsami (TU Ilmenau-Institute of Thermo- und Magnetofluiddynamik)
Visualization in Magnetic Obstacle
The structure of the liquid metal flow under the influence of a confined non-homogeneous magnetic field so called magnetic obstacle has been visualized. In this presentation we are going to talk about the visualization method the influencing parameters such as concentration time and velocity and their importance. The reliability of the pictures will be also discussed. At the end we are going to present some of our results which are mainly movie and pictures.

Martin Seilmayer (Helmholtz-Zentrum Dresden-Rossendorf)
Liquid metal Experiments on azimuthal MRI (AMRI) in a cylindrical Taylor Couette flow
For electrical conducting fluids a hydrodynamic stable regime in a Taylor-Couette flow becomes unstable in presence of magnetic fields. This phenomenon was first descovered by Velikhov (1959) and was later called magnetorotational instability (MRI). Since two decades MRI has been suspected to cause the angular momentum transport in accretion discs which is necessary to explain the accretion rates of stars and black holes.
Up to now only experiments on the helical version of MRI (HMRI) were clearly successful in the laboratory. This is mainly due to the fact that a helical magnetic field configuration, comprising an azimuthal and an axial magnetic field, leads to low critical Reynolds and Hartmann numbers. In the PROMISE experiment, for example, the required critical current for the generation of the azimuthal field is about 4 kA.
Closely related to the HMRI is the azimuthal MRI (AMRI), a non-axisymmetric MRI version that appears for magnetic fields with a purely or strongly dominant azimuthal component. Presently the modified PROMISE facility is able to supply axial currents of up to 20 kA to generate the azimuthal magnetic field that is necessary for the observation of MRI. First preliminary results that indicate the onset of AMRI in the PROMISE setup will be presented.

Andrey Sheyko (ETHZ)
Low latitude dynamics and secular variation in rapidly-rotating convection driven dynamos
Motions of liquid metal inside the Earth's outer core are responsible for generating the geomagnetic field in a dynamo process. Prominent features in the observed core surface field are intense equatorial flux patches drifting westwards at a rate of 17km/Fyr. We investigate the formation and dynamics of such flux features in numerical dynamo models. We study a set of numerical dynamo models varying the convection strength by a factor of 30 and ratio of magnetic to viscous diffusivities by a factor of 20 at fixed rapid rotation rate using a heat flux outer BC. This regime has been little explored aside from a pioneering study by Sakuraba & Roberts due to the significant computing resources required. Our simulations are carried out using a discretisation of degree and order 256 in spherical harmonics and 516 finite difference points in radius and parallelized on 516 processors. We present an analysis of the time-evolution force balance and show internal field structures associated with low-latitude magnetic flux concentrations.

Xing Wei (Univ. Göttingen)
Stably and unstably stratified precessional flow
We investigate numerically in spherical geometry the interaction of stratification and precession. Both the stable stratification and unstable stratification are studied. In the parameter regime we are concerned with, the main results are as follows. The stable stratification suppresses the precessional instability, whereas the unstable stratification and precession can either stablise or destablise each other at the different precession rates

Johannes Wicht (Max Planck Institute for Solar System Research)
Flow and Magnetic Instabilities in the Spherical-Couette System
The spherical-Couette system is a simple and interesting classical fluid dynamical problem. It consist of a spherical shell filled with a viscous (and electrically conducting) liquid. Differential rotation of the two boundaries drives a variety of different flow instabilities that can also yield dynamo action. We use numerical simulation to explore flow and magnetic instabilities in this system. At least three different regimes can be distinguished. The solutions for slowly rotating (Ekman number >> 1) and fast rotating outer spheres (Ekman number << 1) differ significantly and there is an interesting transition regime in between. For slow rotating outer spheres and slow rotating inner spheres viscous forces dominate and the fluid simply sticks to the inner boundary. We have found an analytical solution for this regime. When the inner sphere rotation rate increases the meridional circulation creates a cusp of fast rotating material attached to the inner sphere which ultimately becomes instable and non-axisymmetric flow instabilities arise that simply drift in azimuth. As the differential rotation is increased further, additional modes set in and the flow becomes first oscillatory, then chaotic. The non-axisymmetric instabilities can drive a dynamo for magnetic Prandtl numbers of 0.5 or larger. For a fast rotating outer sphere and slow rotating inner sphere the system obeys the axisymmetric Taylor/Stewardson solution where the fluid sticks to the outer boundary outside the tangent cylinder (TC), an imaginary surface attached to the inner core equator and aligned with the rotation axis. Inside the TC the fluid rotates with an rate intermediate between that of the outer and inner spheres. The Stewardson layer that matches the flow inside and outside the TC becomes instable when the differential rotation between inner and outer boundary is increased, once more leading to non-axisymmetric flows. These instabilities differ for super- and sub-rotating inner boundaries unless the outer boundary rotating is very fast (E$\le3\times10^{-5}$). Here, the instabilities become identical though sub-rotation still requires larger differential rotation rates. The differences and the scaling of the critical differential rotation with the outer boundary rotation (E) can be explained by potential vorticity arguments. As in the case for slow rotating outer boundaries, the instabilities can drive dynamos. The lowest magnetic Prandtl number we were able to reach so far is 0.05 at an Ekman number of E=1e-4. Lower values may be possible, but we are limited by our computer resources here. The results suggest that the Maryland dynamo experiments based on this setup may succeed to produce self excited dynamo action.

Poster Session 2:

Supratik Banerjee & Sebastien Galtier (IAS Paris sud)
Compressible MHD Turbulence
We will present a recent work on compressible MHD turbulence in which we have derived analytically an exact relation for some two-point correlation functions. This relation reveals new type of terms in comparison with the incompressible law derived by Politano & Pouquet 1998. We will discuss different limits relevant in the astrophysical context.. Galtier S. Banerjee PRL 2011. Banerjee & S. Galtier 2012.

Ismael Bouya (IMJ Jussieu)
Revisiting the ABC flow dynamo
The ABC flow is a prototype for fast dynamo action essential to the origin of magnetic field in large astrophysical objects. We investigate its dynamo properties varying the magnetic Reynolds number Rm. We identify two kinks in the growth rate, which correspond respectively to an eigenvalue crossing and to an eigenvalue coalescence. The dominant eigenvalue becomes purely real for a finite value of the control parameter. Finally we show that even for Rm~25000 the dominant eigenvalue has not yet reached an asymptotic behaviour and still varies significantly with the controlling parameter.

Laura Burgess (University of Leeds)
The driving of mean flows via convection
Convection is an important mechanism in the driving of mean flows in stars such as the Sun. The convection transports angular momentum drives mean flows. These flows can realise themselves as the differential rotation we observe from helioseismology. To study the driving of such flows, we look at rotating, Boussinesq convection in a plane layer where the rotation vector is oblique to gravity, representative of different latitudes on a spherical body. We present numerical simulations, firstly in the linear regime, concentrating on the role of the tilted rotation at small Prandtl number (*Pr*). Small *Pr* allows for the possibility of oscillatory modes to be preferred at onset. In the tachocline, a pole-equator temperature gradient has been proposed to account for the observed solar differential rotation. When latitudinal temperature gradients are present a thermal wind is produced which has vertical shear. The addition of a thermal wind to our model can change the preferences of convection rolls at onset and this is studied. Secondly, we extend this work to the nonlinear regime. We use a 2D numerical model to look at the effect of small *Pr* and tilted rotation vector on the driving of mean flows. In particular, we look at the size of the Reynolds stresses produced in different parameter regimes.

Simon Cabanes (ISTerre, Grenoble)
Turbulence in the magnetostrophic regime
Numerical models of the geodynamo are very successful in recovering the main characteristics of the Earth's magnetic field. Nevertheless, the structure and dynamics of unresolved small-scale motions remains enigmatic, and it is not known whether they contribute to the large-scale magnetic field or to its destruction. Both effects have been reported in laboratory experiments of very turbulent flows submitted to weak magnetic fields. In particular, the observation of a dipolar magnetic field aligned with the axis of the axisymmetric mean flow in the Madison experiment demonstrates an alpha-effect capable of producing a large-scale magnetic field (Spence et al, 2006). On the other hand, a large beta-effect, which increases magnetic diffusion and hence the dynamo threshold, has been measured in the Perm torus experiment (Frick et al, 2011). In both cases, symmetry reasons are invoked to exclude potential contributions of the mean flow itself.
However, little is known of such turbulent effects in flows that are constrained by both rotation and a strong magnetic field, the situation that prevails in planetary cores. We have addressed this issue, using data from the DTS experiment. The DTS has been designed to explore the magnetostrophic regime, in which the Coriolis and the Lorentz forces are comparable. Our approach is to compute the magnetic field that the mean flow should produce and compare it to actual measurements. Deviations reveal cooperative effects of turbulent fluctuations to the mean magnetic field. In particular, we have

analyzed the magnetic signal produced by the weak non-axisymmetric components of the applied magnetic field. When the inner sphere rotates, these components create a periodic signal, which is advected by the mean flow as it diffuses across the liquid sodium shell. We have modeled the advection by the mean flow in order to evaluate the effect of small-scale motions on the effective magnetic diffusivity.

Cara Donnelly (University of Cambridge)
Quasi-linear EMFs and the Accretion Disc Dynamo
Following Ogilvie and Lesur we calculate analytically the quasi-linear EMFs generated by the MRI undular instability similar in vein to the work by Davies and Hughes 2011. We recover an vertically advective term and a candidate for an alpha-Omega dynamo.

Johann Herault (LPS ENS PARIS)
Reverals of large flow generated in a turbulent background
The dynamo processes in the liquid metals occur in strongly turbulent flows in which the fluctuations of the velocity field can affect the dynamic of the large scale field. For example the reversals of the magnetic field in the VKS experiment are well explained by the effect of fluctuations in the vicinity of a saddle-node bifurcation Petrelis & Fauve. The understanding of the effect of turbulent fluctuation on the dynamic of the magnetic field is always an open question and some hydrodynamical systems such as Rayleigh-Bénard convection exhibit also the coexistence of a large scale field with a turbulent background. In this talk we consider a turbulent two dimensional flow in which a large scale circulation is generated in a turbulent 1D flow condensated regime. This LSC switches randomly between opposite directions of rotation. We present our experimental investigations. We focus on the bifurcation of the system from a zero mean rotation state to a global rotation state thanks to Landau approach to study a bifurcation in a turbulent state. We present also the study of the reversals mechanism.

Samuel Hunter (University Leeds)
Waves In Shallow Water Magnetohydrodynamics
Many electrically conducting fluids in astrophysical bodies contain a `thin' layer of plasma, perhaps present in planetary atmospheres or bounded by stratification. In this talk I will discuss the shallow water approximation, the disseverment of the analogy with compressible magnetohydrodynamics, and the properties of linear waves supported by such systems. Results will be applied to the tachocline in the solar interior; a transition layer between the radiative and convective zones in the sun.

Erik Johansson,
Leibniz Institute for Astrophysics (AIP)
Interaction of supernova remnants with interstellar clouds as a pre-stage to star formation
Cloud compression by external shocks is believed to be an important triggering mechanism for star formation in the interstellar medium. We have used the NIRVANA code to study the interaction between an interstellar cloud and a supernova remnant as a pre-stage to star formation by investigating whether it can produce the conditions for Jeans instability. The setup is a small, cold, spherical cloud with radius R=1.5 pc, mass M=7 M_Sun and 100 times denser than the background that is struck by a planar M=30 shock at different magnetic field strengths and orientations. The MHD simulations are in 3D with radiative heating and cooling (piecewise power law) as well as anisotropic heat conduction at a resolution of 100 cells per cloud radius using AMR. To our knowledge, no previous study of shock-cloud interaction has simultaneously combined all these physical effects at such a high resolution in 3D. Our simulations produce dense, cold fragments formed from the cloud similar to those of Mellema et al. 2002 and Fragile et al. 2004. We do not reach the conditions for Jeans instability but do observe lasting cloud density increases by a factor of typically ~10^3. In our set of simulations, the configuration that produces condensations closest to Jeans instability is that of a weak but non-zero initial magnetic field perpendicular to the shock normal, although the difference between configurations is small in this respect.

Samuel Jones (University of Exeter)
Utilising symmetries in kinematic dynamo simulations
This talk discusses the symmetries of the 1:1:1 ABC flow and how these symmetries can be utilised to simulate the kinematic dynamo problem. Due to the properties of this group of symmetries, the magnetic field can be deconstructed into five symmetry classes, each of which can be simulated independently in their respective fundamental domains. Results are discussed and visualised for *Rm* up to 5000, extending previous results on the ABC dynamo and allowing the structure of dominant fields to be better understood.

Christian Karcher, D. Jian (Technische Universität Ilmenau)
Velocity measurement in free-surface liquid metal flow using time-of-flight Lorentz force velocimetry: numerical modeling
T.B.A.

Todor Kondic (Univ. Leeds)
Influence of a weak magnetic field on its turbulent diffusion
We investigate the decay of the magnetic field in the context of 2D MHD turbulence. It is already known that in this case a mean field much below the equipartition value induces a small-scale component strong enough to bring the total field close to the equipartition consequently producing a significant back-reaction on the flow. We impose a homogeneous constant mean field and observe how the turbulent magnetic diffusivity changes as a result of this back-reaction for a wide range of Reynolds numbers.

Shiva Kumar (Univeristy of Leeds)
Understanding Structure function of Solar Flares through DNS of 3D-MHD Turbulence
Structure function analysis of photospheric turbulent magnetic field of the Sun, especially the so-called Active Regions (ARs) has been performed, from the line-of-sight data of Magnetograms of SOHO and several other instruments e.g. Abramenko et. al.., (2002, APJ, 577, pp487 & 2003 APJ, 597, pp1135). In this analysis, the order of structure function Vs structure function exponent plot; which is a measure of intermittency; deviated from the non-intermittent K41 (Kolmogorov, 1941) model by a significant extent in many observations. It has been noted that the deviation from the K41 theory is small in the AR before the flareup and the deviation becomes highly significant once the flare has started. But, it is now well known that the MHD turbulence is highly intermittent and in recent years it has been shown that Log-Poisson model is more effective for modeling the intermittency in MHD turbulence (see e.g. Biskamp, Cambridge Univ.Press, 2003).
Hence, we first replot the above mentioned observations, by taking Log-Poisson model as reference. Then using structure function data from the direct numerical simulations of isotropic, homogeneous, incompressible 3D-MHD turbulence in two cases namely forced and decaying, we try to offer an explanation for the observed behaviour of the structure functions and their exponents. We also compare other statistical properties like super flatness and correlation functions in both DNS and observations. It is suggested from this analysis, that an AR can be treated as forced 3D-MHD turbulent system in its simplest form and that the flaring stage is representative of decaying 3D-MHD turbulence. Fractal behaviour of the magnetic field structures and their evolution, the role of the inverse cascade of magnetic helicity are also discussed

Angelo Limone, Facilitating dynamo action via large-scale turbulence control
The magnetohydrodynamic dynamo effect is considered to be the major cause of magnetic field generation in geo- and astrophysical systems. Recent experimental and numerical results show that turbulence constitutes an obstacle to dynamos; yet its role in this context is not totally clear. Via numerical simulations, we identify large-scale turbulent vortices with a detrimental effect on the amplification of the magnetic field in a geometry of experimental interest, and propose a strategy for facilitating the dynamo instability by manipulating these detrimental “hidden” dynamics.

Pankaj Mishra, Christophe Gissinger, Emmanuel Dormy, Stephan Fauve (ENS Paris)
Energetics of dynamo reversals
Using direct numerical simulation in a spherical geometry we present the dynamics of injected power, kinetic and magnetic energy, and dissipation rates during the reversal of the magnetic field generated by a Von Karman type flow driven by two counter rotating propellers fixed in the northern and southern hemisphere. We consider various magnetic Prandtl numbers, Pm=0.5, 1.0, and 2.0, for the study. For Pm=0.5, the decrease in magnetic energy during reversals is accompanied by the decrease in ohmic dissipation and Lorentz flux. Also, we observe a significant increase in injected power and viscous dissipation during the reversal. However, as soon as dipole starts recovering, the ohmic and Lorentz flux increase, while injected power and viscous dissipation decrease. Cross correlation between different energy terms indicates that the Lorentz flux is in advance compared to the other spatially averaged quantities. For large magnetic Prandtl numbers (Pm = 1, 2) energy dynamics does not show any of the features as observed at low magnetic Prandtl number (Pm = 0.5).
Furthermore we find that the magnetic energy is localized in northern hemisphere, i.e., the region of faster rotating propeller. During reversals the localized energy drifts towards the southern region and comes back to its original position once the dipole recovers its mean value. The temporal dynamics of the localized energy during reversal is consistent with the experimental observations of the VKS experiment.

Jorge Morales (École Centrale de Lyon)
Intrinsic rotation of toroidally confined magnetohydrodynamics
Time-dependent 3D toroidal visco-resistive MHD computations are performed using the recently developed penalization method for enforcing the boundary conditions. An imposed toroidal magnetic field is present and the current is driven by an imposed toroidal electric field. Both poloidal and toroidal rotation result and depend strongly on the shape of the toroidal cross section and the value of the Hartmann number. Net toroidal rotation results from a departure from up down symmetry in the cross-sectional boundary shape. By increasing the Hartmann number the plasma seeks out a characteristic configuration in which the velocity aligns approximately with the magnetic field lines. The resulting flow is characterized by both toroidal and poloidal rotation starting from initial conditions in which such flows are absent. Ideal MHD equilibrium considerations appear not to play an important role.

Thierry Passot (Observatoire de la Côte d'Azur, Nice)
Rogue waves in Alfvenic turbulence
An equation for Alfvén waves propagating in the solar wind at a small angle with respect to the ambiant magnetic field is numerically integrated in one space dimension. This equation takes the form of the classical integrable Derivative NonLinear Schrödinger (DNLS) equation with the addition of a random force modelling energy injection due to ions reflected from the Earth bow shock and of a dissipative term orginating from ion Landau damping and/or the presence of weak collisions. Global energetic properties as well as spectral energy transfer are analyzed. Energy dissipation displays highly intermittent events associated with the breaking of large solitonic structures (giant breathers). These very high amplitude "rogue waves" form by merging of quasi-solitons followed by a viscous quasi-collapse (Laveder et al. Phys. Letters A 375 (2011) 3997-4002). The latter phenomenon also takes place in the unforced case where an initial DNLS oblique breather is perturbed by a weak dissipation (Sanchez et al., Phys. Rev E 82 (2010) 016406). The distribution of the instantaneous global maxima of the Alfvén wave intensity fluctuations is seen to be accurately fitted by power laws, which contrasts with the integrable regime (absence of dissipation and forcing) where the behavior is rather exponential. As the dissipation is reduced, freak waves form less frequently but reach larger amplitudes. These events are possibly related to SLAMS (Short Large Amplitude Magnetic Structures) observed upstream of quasi-parallel shocks.

Pierre-Louis Sulem (Laboratoire Lagrange UNS/CNRS/Observatoire de la Côte d'Azur)
Temporal intermittency of Alfvenic turbulence dissipation effect of intermediate shock instabilities

We present numerical simulations of the turbulent regime that establishes when a random driving is supplemented to the Cohen-Kulsrud (CK) equation for non-dispersive Alfvén waves, in the presence of small viscosity and magnetic diffusivity. CK equation appears as a paradigm for systems that, like the MHD equations, are non strictly hyperbolic. In this case, Rankine-Hugoniot conditions do not uniquely specify the shock dynamics, and the zero-viscosity limit is not necessarily well defined. This situation leads to the possibility of existence of intermediate shocks (simultaneous jumps of the amplitude and of the direction of the magnetic field). Such structures are unstable when the phase variation exceeds π. A front characterized by a change of the magnetic-field direction by an angle $\pi < \Delta\theta < 2\pi$ steepens and undergoes reconnection through a quasi gradient collapse, leading to a reduction of $|\Delta\theta|$ by an amount of 2π (a process often called phase slip). A fast shock is simultaneously emitted. Afterwards, as $|\Delta\theta| < \pi$, the intermediate shock broadens and dissipates slowly. This viscosity-induced quasi-collapse has a significant impact on the turbulent regime. It provides a specific mechanism of energy transfer towards small scales significantly different from the usual Kolmogorov turbulent cascade. It in particular leads to a strongly intermittent dissipation, characterized by isolated bursts displaying a power-law distribution function and that are more intense and less frequent as the viscosity is reduced.

Rakesh K. Yadav, Thomas Gastine, and Ulrich Christensen (Max Planck Institute for Solar System Research)
Scaling relations in dynamos with stress-free boundaries.

Scaling laws, which are obtained by a consistent scaling of physical quantities with some physical parameters, have proven to be very useful in our understanding of dynamo mechanism in astrophysical objects. For instance, numerical models of Geodynamo have been used to deduce scaling relations for Rossby number and magnetic field strength (Christensen and J. Aubert (2006)). And, surprisingly, there is a good agreement between such numerical predictions and the magnetic field strengths observed in Jupiter and in some rapidly-rotating low-mass stars (Christensen et al. (2010)). Density stratification and free-surface flows are important properties which have not been explored in this context. What are the effects of incorporating these properties in current numerical models on the dynamo mechanism, and especially on the scaling laws, is a very interesting question. As a first step, we compare the earlier Boussinesq models with rigid boundaries with new simulations that have stress-free boundaries. Our analysis shows that the scaling exponents of different scaling relations in free-slip boundary dynamos are similar to those in the earlier rigid-boundary simulations. We find many bistable cases, i.e. dipolar and multipolar dynamos exist for same parameter values. Such bistability breaks down the local Rossby number criterion which has been used to differentiate between dipolar and multipolar dynamos. We also report that even multipolar dynamos follow consistent scaling relations which are similar to those found in our dipolar dynamos.”