European GdR Dynamo

Barcelona 2016 Meeting

Book of Abstracts

Contents

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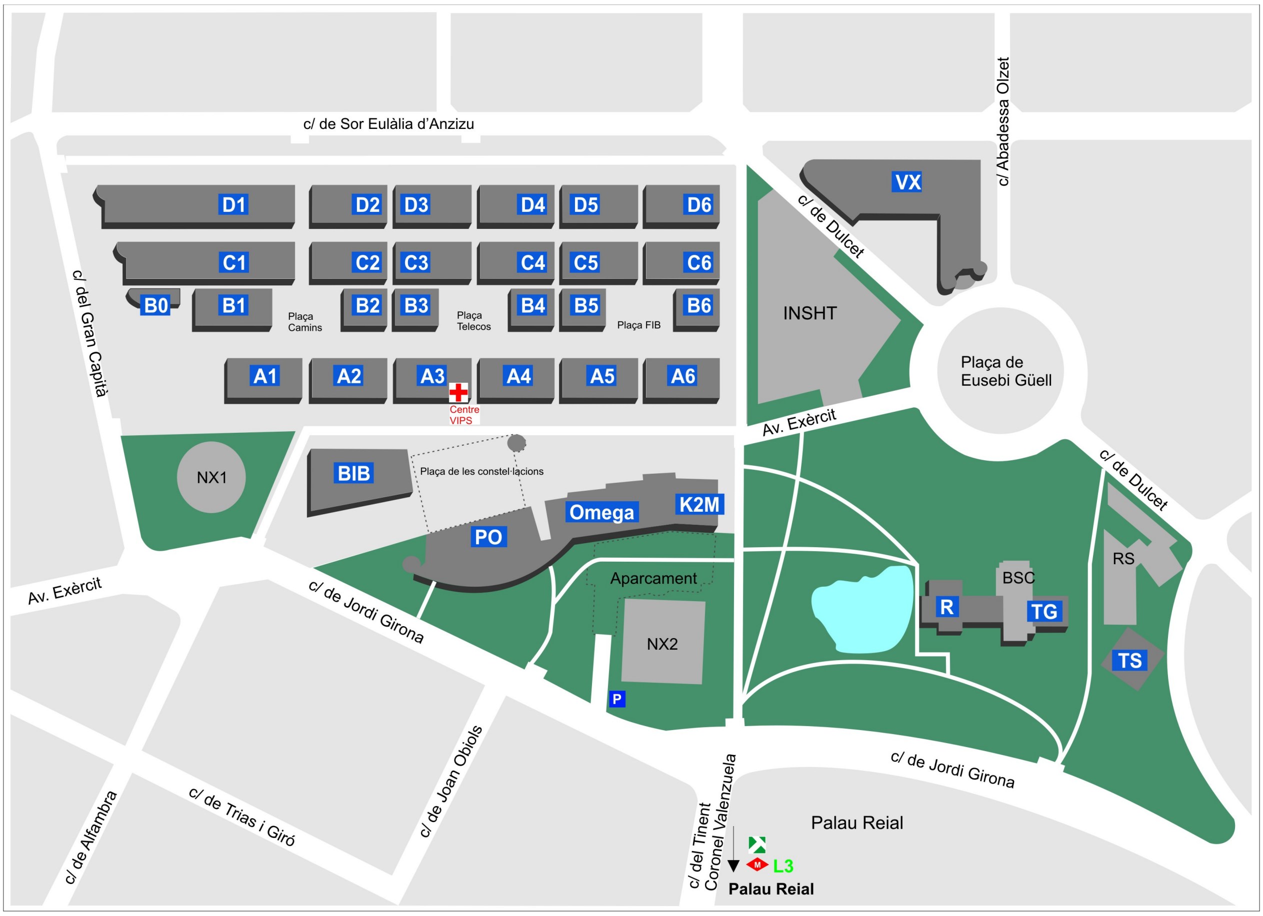
Conference site



The 2016 *GdR Dynamo Meeting* will be held in the Campus Nord of the Universitat Politècnica de Catalunya (UPC) which is located at the North-West corner of the city. The address is Jordi Girona 1-3, 08034 Barcelona. In order to reach the Campus by public transport, it is recommended to use the underground (metro).

- Metro: station "Zona Universitària" at Line 3 (green) and Line 9 (orange) and station "Palau Reial" at Line 3 (green).
- Tram: stop at "Palau Reial" or "Zona Universitària"
- Bus: There are many bus lines (7, 22, 33, 54, 60, 63, 74, 75, ...) which stop near the campus.

The conference site is around "Plaça Telecos" (square) in the midle of the campus:

- Conference room: Sala Àgora, ground floor **building B3** (see the map).
- Conference lunches: Sodexo Unity Restaurant, ground floor **building B4**.

Programme

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Geophysical and Astrophysical Applications

08:30-09:00h	Registration
09:00-10:00h	*Turbulence regimes in planetary cores.* H-C. Nataf
10:00-10:30h	*Excitation mechanism of waves in the Earth's core.* C. A. Jones
10:30-11:00h	Coffee break
11:00-11:30h	*Rotating magnetic shallow water waves in a sphere.* X. Marquez
11:30-12:00h	*Convective dynamos: symmetries and modulation.* R. Raynaud
12:00-12:30h	*Spin-down in a rapidly rotating cylinder container with mixed rigid and stress free boundary conditions.* A. M. Soward
12:30-14:30h	Lunch
14:30-15:00h	*Fluctuations of electrical conductivity: a new source for astro–physical magnetic fields.* C. Gissinger
15:00-15:30h	*Magneto-thermal evolution in a neutron star crust.* T. Wood
15:30-16:00h	Coffee break
16:00-16:30h	*Saturn's axisymmetric field: A low Rm nonlinear analysis.* J. Kirk
16:30-17:00h	*Anelastic dynamo models with variable conductivity - a model for Saturn?* W. Dietrich
17:00-17:30h	Discussion

Tuesday
Experiments and their Numerical Modelling

09:00-10:00h	*Liquid metal experiments on dynamo action and magnetically triggered flow instabilities.* F. Stefani
10:00-10:30h	*Numerical simulations for the precession dynamo experiment in the framework of the DRESDYN project.* A. Giesecke
10:30-11:00h	Coffee break
11:00-11:30h	*Dynamic regimes in simulations of magnetized spherical Couette flow.* E. J. Kaplan
11:30-12:00h	*Numerical simulation of the Von-Karman-Sodium dynamo experiment.* C. Nore
12:00-12:30h	*Numerical Von Karman dynamo.* Y. Ponty
12:30-14:30h	Lunch
14:30-15:00h	*A project for a turbulent dynamo experiment with scale separation.* S. Fauve
15:00-15:30h	*Precession-driven dynamos in a full sphere and the role of large scale cyclonic vortices.* J. Noir
15:30-16:00h	Coffee break
16:00-17:30h	Poster Session
17:30-18:00h	Discussion

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Simulations, Instabilities and Bifurcations

09:00-10:00h	*Bifurcation tracking techniques for periodic orbits of PDEs.* J. Sánchez-Umbría
10:00-10:30h	*Large-scale dynamo mechanism in nonhelical MHD: Energy transfers vs. alpha dynamo.* M. Verma
10:30-11:00h	Coffee break
11:00-11:30h	*Oscillatory large-scale dynamo action in rapidly-rotating convection.* P. Bushby
11:30-12:00h	*Scaling laws for numerical dynamos.* L. Oruba
12:00-12:30h	*Dipolar to non-dipolar transition and equatorial symmetry breaking in rotating spherical shells. Influence of the Prandtl number.* F. Garcia
12:30-14:30h	Lunch
16:00h	Visit

Thursday
Theoretical, Analytical and Turbulence Studies

09:00-10:00h	*Dynamo in plasmas: from magnetic islands to thermonuclear fusion reactors.* D. F. Escande
10:00-10:30h	*Linking dissipation-induced instabilities with nonmodal growth: the case of helical magnetorotational instability.* G. Mamatsashvili
10:30-11:00h	Coffee break
11:00-11:30h	*Progress towards the inertialess inviscid dynamo 1.* A. Jackson
11:30-12:00h	*Progress towards the inertialess inviscid dynamo 2.* K. Li
12:00-12:30h	*Kazantsev model for 2.5D flows.* K. Seshasayanan
12:30-14:30h	Lunch
14:30-15:00h	*Turbulent reconnection in large-scale dynamo in stratified turbulence.* I. Rogachevskii
15:00-15:30h	*Flow generation by inhomogeneous helicity and turbulent angular momentum transport.* N. Yokoi
15:30-16:00h	Coffee break
16:00-16:30h	*The optimized kinematic dynamo in a sphere.* L. Chen
16:30-17:00h	*Optimized dynamo action within a 'mean'-field approach.* W. Herreman
20:30h	Conference dinner

Friday
Instabilities, Bifurcations and Dynamo Scales

09:30-10:00h	*Subcritical convection in a rapidly rotating sphere at low Prandtl numbers.* C. Guervilly
10:00-10:30h	*Kinematic dynamos in spheroids and tri-Axial ellipsoids.* D. Ivers
10:30-11:00h	Coffee break
11:00-11:30h	*Transition from large- to small-scale dynamo in boxes of large aspect-ratio.* V. Shumaylova
11:30-12:00h	*Instabilities induced by the precession of spherical shell.* R. Laguerre
12:00-12:30h	*Strong field dynamos.* E. Dormy
12:30h	Lunch

Keynotes

Turbulence regimes in planetary cores

H-C. Nataf

ISTerre, CNRS/University Grenoble Alpes

The organization of fluid motions and magnetic field in planetary cores remains a puzzle. We know that the rotation of the planet plays a key role. So do the spherical boundaries of the liquid core, and the magnetic field itself, once produced by dynamo action. In these peculiar conditions, what kind of turbulence sets in? During my talk, I will address several questions that are directly linked to this problem. Such as: why is the magnetic energy E_M in the Earth's core much larger than the kinetic energy E_K? What controls the saturation of the magnetic field? What are the consequences of having $E_M >> E_K$? Which are the relevant asymptotic regimes? Is viscous dissipation negligible? Down to which length scale are motions quasigeostrophic? What happens at smaller scales? Is there a typical organization of the magnetic field? Are strong zonal flows incompatible with a strong magnetic field? Numerical simulations have shed a new light on convective dynamos. Yet they rarely display $E_M >> E_K$ and negligible viscous dissipation. Universal scaling laws have been derived from these numerical simulations. How relevant are they for planetary cores? E_M is limited by the available power in these laws. Is this incompatible with a magnetostrophic balance? Numerical simulations show a change in dynamo character when inertia balances Coriolis forces at the dominant length-scale. Should not it be when the Lorentz force balances Coriolis in planetary conditions? I will discuss all these important issues with the help of the tau-ell regime diagrams I introduced together with Nathanaël Schaeffer in the Treatise on Geophysics, second Edition (2015).

Liquid metal experiments on dynamo action and magnetically triggered flow instabilities

F. Stefani

Helmholtz-Zentrum Dresden-Rossendorf

The magnetic fields of planets, stars and galaxies are generated by self-excitation in moving electrically conducting fluids. However, magnetic fields also play an active role in cosmic structure formation by destabilizing rotational flows that would be otherwise hydrodynamically stable. For a long time, both effects, i.e. hydromagnetic dynamo action and magnetically triggered flow instabilities, have been the subject of purely theoretical investigations. This situation changed in 1999 when the threshold of magnetic-field self-excitation was exceeded in the two liquid sodium experiments in Riga and Karlsruhe. Since 2006, the VKS dynamo experiment in Cadarache has successfully reproduced many features of geophysical interest such as reversals and excursions. In the same year, the helical version of the magnetorotational instability (MRI) was observed in the PROMISE experiment in Dresden-Rossendorf. More recently, the azimuthal MRI was found at the same facility. First evidence of the current-driven Tayler instability in a liquid metal was obtained, too. The lecture gives an overview about liquid metal experiments on dynamo action and magnetically triggered instabilities. New results from the enhanced PROMISE facility with a strongly symmetrized azimuthal magnetic fields are presented. An outlook on future experiments, including a precession driven dynamo and a large-scale Tayler-Couette experiment to be set-up in the framework of the DRESDYN project, is also given.

Bifurcation tracking techniques for periodic orbits of PDEs

J. Sánchez* and M. Net

Departament de Física, Universitat Politècnica de Catalunya

Continuation methods are commonly used to track curves of solutions depending on parameters. These methods have been used in Fluid Mechanics mainly to compute bifurcation diagrams of steady solutions. More recently they have also been used for periodic orbits.

Following our previous work we have developed a new efficient methodology for the continuation of the codimension-one bifurcations of periodic orbits, including pitchfork bifurcations present in reflection-symmetric systems. It is based on the combination of Newton-Krylov techniques applied to extended systems, and the integration of systems of variational equations up to second order. The extended systems are adapted from those usually found in the literature for fixed points of maps. It will be shown that to evaluate the action of the Jacobian it is only necessary to integrate systems of ODEs of dimension at most four times that of the original system. This minimizes the computational cost.

The thermal convection of a mixture of two fluids in a two-dimensional rectangular box is used as test problem. It is known that the onset of convection is oscillatory below a certain negative value of one of the parameters (the separation ratio), giving rise to a rich dynamics. A non-trivial diagram of periodic orbits is first deployed, by varying only the Rayleigh number, and some of the bifurcations found on the main branch of periodic orbits are followed by adding as second parameter the Prandtl number. Several codimension-two points have been found.

Dynamo in plasmas: From magnetic islands to thermonuclear fusion reactors

D. F. Escande

Aix-Marseille Université, CNRS, PIIM, UMR 7345

Dynamos are present in several current-carrying plasmas. Indeed, an e. m. f. due to a self-generated (dynamo) velocity field complements the one generating this current. The simplest case corresponds to the tearing instability of resistive magnetized plasmas, which yields a magnetic island sustained by a self-generated quadrupolar vortex. A similar mechanism is at work in the reversed field pinch (RFP), a toroidal configuration for the magnetic confinement of thermonuclear plasmas. It is striking to note that the equilibrium reached after relaxation in the Von Karman Sodium experiment corresponds to a cylindrical version of the RFP.

Talks

Excitation mechanism of waves in the Earth's core

C. A. Jones*, R. J. Teed, K. Hori and S. M. Tobias
University of Leeds

Axisymmetric torsional waves have been observed in the Earth's core, and it has been suggested that the waves may originate near the tangent cylinder, the axial cylinder in the Earth's liquid core which touches the solid inner core. There is a theoretical expectation that the fluid inside the tangent cylinder will be more thermally and compositionally buoyant than the fluid outside the tangent cylinder. At the tangent cylinder, there will be strong thermal and compositional gradients, exciting convection in the form of travelling magnetic Rossby waves. These magnetic Rossby waves can have periods close to that of the torsional Alfven waves in the core, and hence they can trigger trains of torsional waves travelling outwards from the tangent cylinder region.

We have investigated this resonant excitation mechanism using a magnetoconvection based approach, which has been adapted from a spherical shell convection driven dynamo code. This enables us to get to a regime of strong fields and low Ekman numbers, at the cost of specifying the form of the magnetic field rather than allowing it to arise naturally from the dynamo model. Low Ekman number is essential to see the wave excitation, as the tangent cylinder convecting layer is expected to be only a few hundred kilometres thick, and viscosity must be small enough to allow convection on these scales. We are currently exploring the conditions under which the resonance between the convection and the torsional oscillations can occur.

We have also investigated non-axisymmetric magnetic Rossby waves in the outer core, as these wave also have frequencies which might be detectable by magnetic satellite observations in the near future.

Rotating magnetic shallow water waves in a sphere

X. Marquez*, C. A. Jones and S. M. Tobias
University of Leeds

It has been suggested that there may be a stably stratified layer a few hundred kilometres thick just below the Earth's core mantle boundary. Thin stable layer models can also give insight into the dynamics of the solar tachocline. We have examined the type of waves that occur in such shallow layers in the presence of a magnetic field. We generalise the method of Longuet-Higgins (1966) to solve the differential equations that arise in shallow water MHD (Zaqarashvili et al.2007). Using an expansion in associated Legendre polynomials, we reduce the differential system to a matrix eigenvalue problem. Taking the original system of five MHD equations, we find the coefficients of the polynomial expansion, which give the eigenvectors, and the eigenvalues which give the frequencies of the modes. We can then reconstruct the spatial form of the eigensolutions for each eigenvalue, giving a complete solution dependent on time, colatitude and longitude. The result of the model shows the presence of Fast and Slow Magnetic Rossby Waves, Magneto Inertial Gravity Waves and Magneto Kelvin modes. The Magnetic Rossby modes could be related to short time secular variation of the Earth's magnetic field.

Convective dynamos: Symmetries and modulation

R. Raynaud* and S. M. Tobias
IPM

We consider dynamo action driven by three-dimensional rotating anelastic convection in a spherical shell. Motivated by the behaviour of the solar dynamo, we examine the interaction of hydromagnetic modes with different symmetries and demonstrate how complicated interactions between convection, differential rotation and magnetic fields may lead to modulation of the basic cycle. For some parameters, Type 1 modulation occurs by the transfer of energy between modes of different symmetries with little change in the overall amplitude; for other parameters, the modulation is of Type 2 where the amplitude is significantly affected (leading to grand minima in activity) without significant changes in symmetry. Most importantly we identify the presence of 'supermodulation' in the solutions where the activity switches chaotically between Type 1 and Type 2 modulation; this is believed to be an important process in solar activity.

Spin-down in a rapidly rotating cylinder container with mixed rigid and stress free boundary conditions

A. M. Soward*, L. Oruba and E. Dormy
Newcastle University

Greenspan and Howard (J. Fluid Mech., 1963) studied the linear spin-down of a rapidly rotating viscous fluid at small Ekman number E inside a container with rigid boundaries, following an instantaneous small change in container angular velocity. Outside the Ekman layers, thickness $\mathrm{O}(E^{1/2})$, the mainstream is in almost rigid rotation (geostrophic) but spins down rapidly due to Ekman suction. Additionally, there are thickening quasi-geostrophic and very weak ageostrophic $E^{1/3}$ shear layers adjacent to the cylindrical side-wall. Motivated by applications to isolated atmospheric structures (e.g., tropical cyclones, tornadoes) without side and top boundaries, we study numerically and asymptotically a variant with stress-free side-wall and top boundaries, which leads to unexpected consequences. The mainstream no longer rotates rigidly, while the ageostrophic $E^{1/3}$ shear layer, far from being passive, determines a spin-down rate dependent on $\ln E$. It is linked to an $E^{1/2} \times E^{1/2}$ corner region, where the rigid base and the stress-free side-wall meet; a singularity that limits asymptotic progress.

Fluctuations of electrical conductivity: A new source for astrophysical magnetic fields

C. Gissinger*, F. Pétrélis and A. Alexakis
École Normale Supérieure – Paris

We consider the generation of a magnetic field by the flow of a fluid for which the electrical conductivity is nonuniform. A new amplification mechanism is found which leads to dynamo action for flows much simpler than those considered so far. In particular, the fluctuations of the electrical conductivity provide a way to bypass antidynamo theorems. For astrophysical objects, we show through three-dimensional global numerical simulations that the temperature-driven fluctuations of the electrical conductivity can amplify an otherwise decaying large scale equatorial dipolar field. This effect could play a role for the generation of the unusually tilted magnetic field of the iced giants Neptune and Uranus.

Magneto-thermal evolution in a neutron star crust

T. Wood
Newcastle University

Neutron stars have magnetic fields of up to 10^{16} Gauss, and the magnetic field plays a dominant role in their dynamics. In this talk we present numerical simulations of the coupled magneto-thermal evolution in the solid crust of a neutron star, and discuss the implications for pulsar observations.

Saturn’s axisymmetric field: A low Rm nonlinear analysis

J. Kirk*, D. W. Hughes and C. A. Jones
University of Leeds

Saturn’s magnetic field is remarkably axisymmetric. Stevenson (1982) suggested that differential rotation in a stable layer above the dynamo region might explain this strong axisymmetry. Stevenson’s model was linear, but we have extended his Cartesian plane layer model to include the additional flows driven by the magnetic field. These include a geostrophic flow that arises due to Taylor’s constraint.

Anelastic dynamo models with variable conductivity - a model for Saturn?

W. Dietrich* and C. A. Jones
Max Planck Institute for Solar System Research

The atmospheric interior of the solar system gas giants, Jupiter and Saturn can be separated into a hydrodynamic outer region and an electrical conducting inner region due to the molecular-metallic transition of hydrogen. The characteristic zonal flow pattern and the dynamo process might be strongly affected by these two dynamically very different regions. We use a fully nonlinear three-dimensional MHD code which evolves the turbulent flow, the entropy and the magnetic field induction in both shells. The physical properties of the giant planet atmosphere, such as electrical conductivity or density, are taken from an interior state model originally designed for Jupiter. In a systematic approach, we parametrise the conductivity drop-off radius (r_d) and investigate the interaction between hydrodynamic and magnetic regions, such as the emergence of differential rotation and induction of magnetic fields. Our results suggest that the inner magnetic region defines a cylindrical boundary (magnetic tangent cylinder - mTC) attached to r_d at the equator. Inside mTC the strong Lorentz force suppresses differential rotation, whereas outside mTC the fluid viscosity balances the Reynolds-stresses leading to fierce zonal flows. In terms of the induced dynamos we could, rather remarkably, distinguish numerous different self-consistent dynamo solutions in terms of the main equatorial symmetry and time dependence, e.g. steady dipolar dynamos, quadrupolar dynamos, octopolar dynamos, dipolar dynamo waves, hemispherical dynamo waves and many mixed modes, e.g. where the quadrupole is stable in time and the dipole periodically reverses. All of these rather different solution types seem to exist in close proximity in the covered parameter space regarding vigour of convection and r_d. However, we also found that models are either dominated by dipolar symmetry or by quadrupolar (equatorial symmetric) magnetic fields. Models set up Saturn-like (small r_d) reproduce the observations of Saturn’s Gauss coefficients to a large extend, but do periodically reverse over a time scale of 250 kyrs.

Numerical simulations for the precession dynamo experiment in the framework of the DRESDYN project

A. Giesecke* and F. Stefani

Helmholtz-Zentrum Dresden-Rossendorf

In a next generation dynamo experiment currently under development at Helmholtz-Zentrum Dresden-Rossendorf (HZDR) a fluid flow of liquid sodium, solely driven by precession, will be considered as a possible source for magnetic field generation.

I will present results from hydrodynamic simulations of a precession driven flow in cylindrical geometry. In a second step, the velocity fields obtained from the hydrodynamic simulations have been applied to a kinematic solver for the magnetic induction equation in order to determine whether a precession driven flow will be capable to drive a dynamo at experimental conditions.

It turns out that excitation of dynamo action in a precessing cylinder at moderate precession rates is difficult, and future dynamo simulations are required in more extreme parameter regimes where a more complex fluid flow is observed in water experiments which is supposed to be beneficial for dynamo action.

Dynamic regimes in simulations of magnetized spherical Couette flow

E. J. Kaplan*, H-C. Nataf and N. Schaeffer

Institut des Sciences de la Terre, Université Grenoble Alpes

The Derviche Tourneur Sodium Experiment (DTS) is a spherical Couette flow experiment with a liquid sodium medium between inner and outer spheres of copper and stainless steel, respectively. The apparatus has the same aspect ratio as the Earth, and a strong dipole magnetic field imposed from the inner sphere. The operation of the experiment reveals a collection of flow states dependent on the balance of inertial, Coriolis, and magnetic forces (represented by the Elsasser and Rossby numbers). The experimental diagnostics register the change between states, but don't provide a full picture of what these states actually look like inside the sphere. To rectify this the `xshells` code has been run in a similar range of Rossby (Ro) and Elsasser (Λ) numbers. For $Ro \sim 1$ (where the inner sphere rotates faster than the outer sphere) the mean flow is mostly quasigeostrophic, while counterrotating spheres transition from a regime dominated by an instability centered in the still point between outward and inward flowing jets to an instability occupying the return flow along the outer sphere as the differential rotation increases ($Ro \underset{\sim}{\in} (-2, -1)$). This talk will aim to explain these simulations, in particular the balances between the Coriolis and Lorentz forces (aka magnetostrophic regime), their underlying assumptions, and how their outputs relate to the physical system of the DTS.

Numerical simulation of the Von-Karman-Sodium dynamo experiment

C. Nore*, D. Castanon-Quiroz, L. Cappanera and J-L. Guermond
LIMSI-CNRS, Université Paris-Sud

For the first time, a direct numerical simulation of the incompressible, fully nonlinear, magnetohydrodynamic (MHD) equations for the Von-Karman-Sodium (VKS) experiment is presented with the two counter-rotating impellers realistically represented. Dynamo thresholds are obtained for various magnetic permeabilities of the impellers and it is observed that the threshold decreases as the magnetic permeability increases. Hydrodynamic results compare well with experimental data in the same range of kinetic Reynolds numbers: at small impeller rotation frequency, the flow is steady; at larger frequency, the fluctuating flow is characterized by small scales and helical vortices localized between the blades. MHD computations show that two distinct magnetic families compete at small kinetic Reynolds number and these two families merge at larger kinetic Reynolds number. In both cases, using ferromagnetic material for the impellers decreases the dynamo threshold and enhances the axisymmetric component of the magnetic field: the resulting dynamo is a mostly axisymmetric axial dipole with an azimuthal component concentrated in the impellers as observed in the VKS experiment.

Numerical Von Karman dynamo

Y. Ponty*, S. Kreuzahler, N. Plihon, H. Homann and R. Grauer
Université de la Côte d'Azur

We present a direct numerical simulation (DNS) of the Von Karman flow, forced by two rotating impellers. The cylinder geometry and the rotating objects are modeled via a penalization method and implemented in a massive parallel pseudo-spectral solver. The MHD equations are solved in the vessel and inside the impellers. We will present several common features with the VKS dynamo experimental campaigns, as the observed magnetic mode (m=0) and the variation with the magnetic permeability. But we will discuss also about news features involving transition from the mode (m=1) to a new mode (m=0) even at low magnetic permeability.

A project for a turbulent dynamo experiment with scale separation

S. Fauve

École Normale Supérieure – Paris

It has been reported in several numerical studies that large scale turbulent fluctuations can inhibit dynamo action. It is believed that this effect has prevented the observation of a dynamo in experiments with non constrained flows. We have recently shown that the increase of the dynamo threshold due to turbulent fluctuations almost disappears in the case of scale separation, i.e. when the flow is forced at small scale compared to the one at which the magnetic field can grow (see Sadek et al. (2016), Phys. Rev. Lett. 116, 074501). We will present an experimental set-up that will take profit of this observation in order to achieve a turbulent dynamo. We will then discuss some open questions that could be studied using this experiment. In particular, it will be possible to test the validity of some large scale turbulent flow modeling (see Prasath et al.(2014), Europhys. Lett. 106, 29002).

Precession-driven dynamos in a full sphere and the role of large scale cyclonic vortices

J. Noir*, Y. Lin and A. Jackson

ETH Zurich

Precession has been proposed as an alternative power source for planetary dynamos. Previous hydrodynamic simulations suggested that precession can generate very complex flows in planetary liquid cores [Lin et. al., Physics of Fluids 27, 046601 (2015)]. In the present study, we numerically investigate the magnetohydrodynamics of a precessing sphere. We show that precession can drive dynamos in different flow regimes, laminar and turbulent. In particular, we highlight the role played by large scale cyclonic vortices in the magnetic field generation, which has not been explored previously. In this regime, dynamos can be sustained at relatively low Ekman and magnetic Prandtl numbers, which paves the way for planetary applications.

Large-scale dynamo mechanism in nonhelical MHD: Energy transfers vs. alpha dynamo

M. Verma* and R. Kumar
Indian Institute of Technology Kanpur

The growth of the large-scale magnetic field is an important problem in dynamo research. It is typically assumed that the kinetic and magnetic helicities play an important role in this process. In this presentation we show that the large-scale magnetic energy can grow in nonhelical magnetohydrodynamics when random nonhelical forcing is employed at length 1/10 the box size. We performed a spectral simulation on 512^3 grid at Prandtl number of unity; the steady-state Reynolds number is 93.

We performed detailed energy transfer studies at different scales, and show that the growth of the magnetic energy at large-scale occurs due to energy transfers to the magnetic field from the large-scale velocity field, and from the small-scale magnetic field (inverse cascade). Our study is important for the large-scale dynamo mechanism. We will also present a preliminary report on symmetries of dynamo reversals.

Oscillatory large-scale dynamo action in rapidly-rotating convection

P. Bushby*, A. Brandenburg, B. Favier, C. Guervilly, P. Kapyla, M. Kapyla, Y. Masada and M. Rheinhardt
Newcastle University

It is well known that convection in electrically-conducting fluids can give rise to hydromagnetic dynamo action. In the absence of rotation, such a dynamo tends to produce a small-scale, intermittent magnetic field distribution. However if a convective layer is rotating very rapidly (such that the Coriolis force plays a leading-order role in the dynamics) it becomes possible, under certain circumstances, to excite a large-scale dynamo with a significant mean magnetic field. We investigate a convectively-driven dynamo in a rapidly-rotating compressible fluid, confined to a Cartesian domain. At moderately supercritical Rayleigh numbers, this system is (hydrodynamically) unstable to a large-scale vortex instability, which eventually leads to the rapid amplification of a seed magnetic field. As the magnetic field becomes dynamically significant, the large-scale vortex is suppressed, but the mean magnetic field continues to grow. The final nonlinear state is characterised by a large-scale (near-equipartition) horizontal magnetic field that oscillates with a period comparable to that of the ohmic decay time. This dynamo has been the subject of a benchmarking exercise, with three independent compressible codes producing quantitatively comparable results. We have also verified that a very similar dynamo can be found in the Boussinesq case. Strongly modulated large-scale oscillatory dynamos are found at higher Rayleigh numbers, with periods of reduced activity ("grand minima"-like events) occurring during transient phases in which the large-scale vortex instability temporarily re-establishes itself, before being suppressed again by the magnetic field.

Scaling laws for numerical dynamos

L. Oruba* and E. Dormy
École Normale Supérieure – Paris

The parameters regime relevant to dynamo action in natural objects is out of reach of present numerical models because of computational limitations. It is thus useful to derive scaling laws to extend numerical results to real world dynamos.

We show that traditional power based scaling laws for the magnetic field strength are too general. They mainly traduce the statistical balance between the energy production and dissipation, and are thus satisfied by any dynamo in statistical equilibrium. We show that predictive scaling laws (i.e. depending on input parameters only) can be derived for the magnetic field strength in numerical dynamos, by guiding our reasoning on physical arguments. We thus show that dipolar dynamos operate in a viscous dynamical regime, which is not relevant to natural objects. The issue of parameters being controlled or measured, depending on the thermal boundary conditions, will also be addressed. Finally we show that the dipolar-multipolar transition occurring in numerical models can be described by a single non-dimensional parameter corresponding to a three-terms balance.

Dipolar to non-dipolar transition and equatorial symmetry breaking in rotating spherical shells. Influence of the Prandtl number

F. Garcia*, L. Oruba and E. Dormy
Departament de Física, Universitat Politècnica de Catalunya

Previous numerical studies of convection driven dynamos in rotating spherical shells, mainly at large Prandtl number ($Pr \geq 1$), have shown that the transition between dipolar and multipolar dynamos take place when the local Rossby number approximately reaches the value of 0.1, and that this threshold seems to be very robust on changes of the boundary conditions, the shell geometry or the Ekman number, E. Recently, the transition was characterized in terms of a three term force balance of the nongradient part of the Coriolis, viscous and inertial forces and was accurately described by the hydrodynamic parameter $RoE^{-1/3}$, being Ro the Rossby number.

As a first step, we address the Prandtl number dependence of the dipolar/multipolar transition by considering $Pr < 1$ dynamo models. We have found that the local Rossby number, as well as $RoE^{-1/3}$, increase by decreasing Pr and that exist significant differences between large ($Pr > 1$) and small ($Pr < 1$) Prandtl numbers, pointing out the need of further research on low Prandtl number dynamos.

Because of the dipolar/multipolar transition is described by hydrodynamic parameters we perform non-magnetic simulations in a second step to see if a transition also exist when considering only purely convective flows. We have found that at a local Rossby number value slightly smaller than 0.1 the equatorial symmetry breaking of the flow takes place. In addition, the three terms balance is also satisfied. This makes tempting to link the polarity transition with the equatorial symmetry breaking. In contrast to the relatively large helicity needed to maintain dipolar fields at $Pr = 1$, low Prandtl number flows are characterized by a relative low helicity but still seem able to sustain dipole dynamos.

Linking dissipation-induced instabilities with nonmodal growth: the case of helical magnetorotational instability

G. Mamatsashvili* and F. Stefani

Helmholtz-Zentrum Dresden-Rossendorf

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 axial electrical 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 and the pseudospectrum of the underlying purely hydrodynamic problem.

Progress towards the inertialess inviscid dynamo 1

A. Jackson*, P. Livermore and K. Li

ETH Zurich

I introduce the background and equations governing Taylor's idea of neglecting inertia and viscosity in the Navier Stokes equation. This idea stems from the smallness of the Rossby and Ekman numbers. In the induction equation the diffusive term provides a source of dissipation, and in this approach all dissipation is Ohmic. I will introduce the approach we have developed in order that we remain on the Taylor manifold, in which the magnetic field is in a Taylor State.

Progress towards the inertialess inviscid dynamo 2

K. Li*, A. Jackson and P. Livermore
ETH Zurich

The Taylor state dynamo is understood as a reasonable approximation to Earth's dynamo system, in which the Coriolis, pressure and Lorentz forces dominate in Earth's core and the inertial force and viscous force are negligible. Taylor (1963) first proved the rationale of this theoretical limit and provided the mathematical proof and the initial numerical recipe for solving it. However, this approach exhibits considerable difficulties for a numerical scheme. We introduce a new approach for computing the Taylor state dynamo by utilizing the concept of the optimal control theory, such that Taylor state is satisfied in the entire simulation time window. We demonstrate our method in an illustrative 2D mean field dynamo and compare the numerical solution with the solution from torsional wave model of very small inertial.

Kazantsev model for 2.5D flows

K. Seshasayanan* and A. Alexakis
École Normale Supérieure – Paris

We study the dynamo instability of the Kazantsev model for a $2.5D$ flow with the flow defined by $(u(x, y, t), v(x, y, t), w(x, y, t))$. We are interested in dynamo instability for nonhelical flows. We derive here the governing equations for the second order magnetic field correlation function. We then study the growth rate of the dynamo instability as a function of the control parameters. We compare our results of the analytical calculation with numerical simulation of the model flow and with other time correlated flows.

Turbulent reconnection in large-scale dynamo in stratified turbulence

I. Rogachevskii*, S. Jabbari, A. Brandenburg, Dh. Mitra and N. Kleeorin
Ben-Gurion University of the Negev

We consider strongly stratified forced turbulence in a plane-parallel layer with helicity and corresponding large-scale dynamo action in the lower part and non-helical turbulence in the upper. The magnetic field is found to develop strongly concentrated bipolar structures near the surface. They form elongated bands with a sharp interface between opposite polarities. What is surprising is the long lifetime of the resulting bipolar regions, which exceeds several turbulent diffusion times. We show that the main reason why these intense magnetic structures survive longer is the magnetic reconnection phenomenon in the vicinity of the current sheet between opposite magnetic polarities. We determine the reconnection rate by measuring either the inflow velocity in the vicinity of the current sheet or by measuring the electric field in the reconnection region. We demonstrate that for large Lundquist

numbers, $S > 1000$, the reconnection rate is nearly independent of the Lundquist number. The reconnection rate is also weakly dependent on the Ohmic resistivity and Alfven Mach number.

Flow generation by inhomogeneous helicity and turbulent angular momentum transport

N. Yokoi* and A. Brandenburg
University of Tokyo

Statistical properties of non-mirror-symmetric turbulence is determined not only by the turbulent energy (intensity information) but also by turbulent helicity (structure information). Inhomogeneity of turbulent helicity density, which enters the Reynolds stress as the coupling coefficient of the mean absolute vorticity, can counterbalance the effective momentum transport due to the eddy viscosity directly connected to the intensity of turbulence. This helicity effect may contribute to induce and sustain large-scale inhomogeneous flow structures in turbulence. In realistic turbulent flows, the local turbulent helicity is expected to be non-uniformly distributed in space. The roles of inhomogeneous helicity effect in the sustainment of the large-scale vortical motions in atmosphere and the differential rotation in stellar convective motion are discussed.

The optimized kinematic dynamo in a sphere

L. Chen*, W. Herreman, K. Li and A. Jackson
ETH Zurich

The Earth's magnetic field is generated and sustained by the complex motion of a conducting fluid in the liquid outer core. This phenomenon can be understood in the framework of dynamo theory, which mathematically describes the interaction between the flow and the magnetic field. An outstanding question is which kind of flow can amplify a seed magnetic field. The growth rate of the magnetic field is determined by the competition between magnetic advection and magnetic diffusion. The ratio between the two effects is given by a dimensionless parameter called the magnetic Reynolds number (Rm). A seed magnetic field may grow at a sufficiently high Rm, but the precise threshold for a dynamo driven by a general type of flow is unknown. Given a conducting fluid confined in a domain, what is the lowest Rm to generate a dynamo? We base our Rm on the unit enstrophy norm for the flow, since Rm based on unit kinetic energy is known to have no lower bound from Proctor (2015) . We use an optimization method inspired by Willis (2012) to search for the most efficient dynamo solution. This method allows us to maximize the growth rate of the magnetic field over a time window T while imposing other constraints using Lagrange multipliers. We simultaneously look for the optimal steady flow field U and the optimal seed magnetic field B0. We reported the optimization results for flows confined in a cube in Chen et al. (2015). In this talk, I will present the new results in a sphere with electrically insulating boundary condition (BC). The flow satisfies no-slip BC. Compared with previously known dynamo models with the same BC, e.g., Livermore & Jackson (2004), our optimal flow has a lower critical Rm where the magnetic field becomes self-sustaining. We also compare it with other known dynamo models with low critical Rm which may have different flow BCs, e.g., Dudley & James (1989), again our optimal flow exhibits superior efficiency in driving a dynamo, yet still respect the lower bounds found by Backus (1958), Childress (1969) and Proctor (1977). The profile of this flow will be discussed supplemented with visualization.

Optimized dynamo action within a 'mean'-field approach

W. Herreman
LIMSI-CNRS, Université Paris-Sud

From the Zeldovich toroidal anti-dynamo theorem, we know that arbitrary parallel shear flows cannot act as kinematic dynamos for any value of the magnetic Reynolds number. This theorem is mathematically strict, but not physically robust: small flow perturbations in the flow can easily trigger dynamo action. Using a nonlinear optimization strategy inspired by [1,2], we measured just how big a flow perturbation needs to be as a function of Rm, in order to trigger kinematic dynamos in the Kolmogorov shear flow. This work was presented at earlier meeting and is now available in [3].

In this talk, I will present some ongoing work on these optimal perturbation flows. Given that both the optimal flow and the magnetic eigenmode have fairly simple spatial structures, we can search for optimal flows within a reduced 1 dimensional "mean"-field model. This method is conceptually similar to recent work on the problem of subcritical transition to turbulence [4,5]. Optimizing within this reduced (mean field) approach is much less costly and should allow to reach into the asymptotic regime of high R_m, that is unaccessible to the full 3D optimization technique we have been using before.

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[5] Pralits, J.O., Bottaro, A. & Cherubini, S. 2015 Weakly nonlinear optimal perturbations. *J. Fluid Mech.* **785**, 135–151.

Subcritical convection in a rapidly rotating sphere at low Prandtl numbers

C. Guervilly* and P. Cardin
Newcastle University

We study nonlinear convection for low Prandtl number fluids ($Pr = 10^{-1} - 10^{-2}$) in a rapidly rotating sphere with internal thermal heating. Our model assumes that the velocity is invariant along the axis of rotation due to the rapid rotation of the system, while the temperature is computed in 3D. We identify two separate branches of convection near the onset of convection: a well-known weak branch that is continuous at the linear onset of convection, and a novel strong branch at low Ekman numbers with large values of the convective and zonal velocities. For small Ekman numbers ($E < 10^{-7}$), the strong branch is subcritical.

Kinematic dynamos in spheroids and tri-axial ellipsoids

D. Ivers
University of Sydney

The self-exciting kinematic dynamo problem is considered in an electrically-conducting fluid, which occupies a spheroid or tri-axial ellipsoid and which is surrounded by an insulating exterior. Regeneration of the magnetic field is due to laminar flow or turbulent mean-field alpha-effect. Classes of spheroidal or ellipsoidal toroidal-poloidal solenoidal representations are used for the magnetic field and the velocity. The magnetic induction equation is transformed so that it differs from the spherical case by an anisotropic magnetic diffusion and an anisotropic alpha-effect in the mean field case. The equations are discretised spectrally in angle with finite differences in scaled radius. The current-free condition must be solved explicitly in the insulating exterior. Results are presented for various models.

Transition from large- to small-scale dynamo in boxes of large aspect-ratio

V. Shumaylova* and M. R. E. Proctor
University of Cambridge

Magnetic fields on the Sun exist on a vast range of spatial and temporal scales that coexist in the physical processes. They can be categorised as large-scale and small-scale fields. The Sun's large-scale magnetic field exhibits coherence in space and time on much larger scales than the turbulent convection that ultimately powers the dynamo. Moffatt (1978) and Krause (1980) introduced the framework of mean-field theory to describe the origin and self-sustainment of a large-scale magnetic field in astrophysical objects. The theory outlines how small-scale turbulent motions produce a coherent global field through the interaction with small-scale magnetic fields in the limit of high magnetic diffusivity.

We investigate the spatial scale selection for coherent structures of magnetic fields due to the dynamo action in the presence of a velocity field that has a single spatial scale (classic ABC flow) and a two-scale velocity field with a long modulation. Mean-field theory predicts long wavelength modes at the onset of dynamo action, whereas small scales are more energetic at larger R_m. The transition from large- to small-scale dynamo is of interest. We test this idea numerically by considering a cuboid that is extended in one direction and includes multiple copies of the periodic cell of the flow, to examine whether the magnetic field can grow on scales longer than that of the flow as the magnetic Reynolds number is increased.

By using spectral filtering we demonstrate that the scales responsible for dynamo action are consistent with those predicted by the asymptotic theory in the range it is expected to apply to. The simulations showed that the critical R_m is related to the longest scales in a box. The transition from large scales to small scales at different R_m for the two flows, so the mean-field approximation is valid for a varying range of magnetic diffusivities yet still limited to the low R_m regime.

Instabilities induced by the precession of spherical shell

R. Laguerre*, J. Noir, J. Rekier, S. Triana and V. Dehant
Royal Observatory of Belgium

The dynamics of the liquid core is known to be crucial to the planetary dynamics through angular momentum exchange with the surrounding mantle, kinetic energy dissipation and in some cases dynamo processes. It has been shown that mantle perturbations such as forced precession-nutations, librations can drive complex flows strongly influenced by the rotation in the form of parametric instabilities. In the present study we aim at shedding some light on the influence of an inner core onto the precesssional instabilities. We investigate numerically the flow in the outer liquid core at moderate Ekman numbers ($\sim 10^{-5}$) driven by the precession of the mantle and the inner core. We aim at deriving the stability diagram and at characterising the mechanism underlying the onset of the instabilities.

Strong field dynamos

E. Dormy
École Normale Supérieure – Paris

Numerical models of the geodynamo are usually classified into two categories: dipolar modes, observed when the inertial term is small enough; and multipolar fluctuating dynamos, for stronger forcing. We show that a third dynamo branch corresponding to a dominant force balance between the Coriolis force and the Lorentz force can be produced numerically. This force balance is usually referred to as the strong-field limit. This solution coexists with the often described viscous branch. Direct numerical simulations exhibit a transition from a weak-field dynamo branch, in which viscous effects set the dominant length scale, and the strong-field branch, in which viscous and inertial effects are largely negligible. These results indicate that a distinguished limit needs to be sought to produce numerical models relevant to the geodynamo and that the usual approach of minimising the magnetic Prandtl number (ratio of the fluid kinematic viscosity to its magnetic diffusivity) at a given Ekman number is misleading.

Posters

Ultrasonic velocimetry using integrated time of flight

F. Burmann* and J. Noir
ETH Zurich

Most common techniques in flow diagnostics rely on the presence reflectors in the fluid, either for light or acoustic waves. These methods fail to operate when e.g centrifugal or gravitational acceleration becomes significant, leading to a rarefaction of scatters in the fluid, as for instance in rapidly rotating fluids. Such conditions will occur in the upcoming liquid sodium experiment SpiNaCH, currently under construction at ETH Zurich. In this study we present a novel technique based on the time of flight principle to perform velocity measurements in the absence of scattering particles.

Quasi-linear approximation of the HMRI

A. Child*, R. Hollerbach, B. Marston and S. M. Tobias
University of Leeds

The magnetorotational instability (MRI) is one of the most important processes in astrophysics, and is the leading candidate for the mechanism by which outward angular momentum transport occurs in magnetised accretion disks. Notably, the presence of an axial magnetic field allows for instability when angular momentum profiles increase with radius, for which purely hydrodynamic flows are stable.

Unfortunately, it is not feasible to run direct numerical simulations (DNS) at the relevant parameters for an astrophysical disk, and so additional approaches are required when investigating the instability.

One such approach is the use of laboratory experiments, whereby an axial magnetic field is applied to liquid metal in the Taylor-Couette geometry. For instability, a magnetic Reynolds number $\mathrm{Rm} \geq O(10)$ is required, which, coupled with the fact that liquid metals typically have magnetic Prandtl number $\mathrm{Pm} \approx O(10^{-6})$, necessitates a Reynolds number $\mathrm{Re} \geq O(10^7)$. This is problematic; under such strong rotation the Taylor-Proudman theorem states that the flow will be dominated by the conditions at the end-plates. As such, this setup has not yet succeeded in producing the standard MRI (SMRI). However, by imposing an additional azimuthal magnetic field, the necessary requirement for instability changes from $\mathrm{Rm} \geq O(10)$

to Re $\geq O(10^3)$. The resulting helical MRI (HMRI) is continuously connected to the SMRI, has been experimentally reproduced, and is numerically well understood.

Another approach that has recently received much attention is that of direct statistical simulation (DSS), where the low-order statistics are obtained directly from a hierarchy of cumulant equations. It offers a number of advantages over DNS when probing the long time behaviour of astrophysical phenomena. However, it is not currently universally applicable, and there have been a number of examples of inconsistencies with fully nonlinear DNS; current research is focussed on improving the performance of DSS in such cases.

Motivated by this, we perform DNS on the HMRI under the generalised quasi-linear approximation (GQL), which is essentially equivalent to the cumulant expansions utilised by DSS. The GQL approximation improves upon the standard quasi-linear (QL) approximation by incorporating fully self-consistent interactions of large-scale modes, whilst still being formally linear in the small scales.

Here, we address whether GQL can produce the low-order statistics of axisymmetric HMRI more accurately than the corresponding QL approximation, via diagnostics such as the energy spectra in addition to the first and second cumulants. We find that GQL performs notably better than QL in producing the statistics of the HMRI, even with relatively few large-scale modes. We conclude that DSS based on GQL (GCE2) should be significantly more accurate than that based on QL (CE2).

Precessional-convectional instabilities in a spherical system

L. Echeverria*, N. Lardeli, F. Munch, P. Marti, J. Noir, and A. Jackson
ETH Zurich

The Earth's magnetic field has been used for centuries by navigators for orientation. This magnetic field protects our planet from cosmic radiation and solar wind, and it is an fundamental ingredient for life to thrive. Therefore, extensive research is essential to better understand the driving mechanisms of this magnetic shield within our planet and other celestial objects. In the early 50s, W. M. Elsasser proposed the dynamo theory to explain the generation of the Earth's magnetic field. Such theory states that the heat flux generated by a hot inner core triggers convective instabilities that deviate the flow from a solid body rotation, and these instabilities may induce a magnetic field. Brito et al. (2004) shown that an unstable thermal stratification might strengthen shear driven instabilities. Additionally, gravitational pulls from the Moon and other planets trigger precessional movements in the mantle. Such mechanism generates, even in thermally homogeneous systems, a steady centre-symmetric flow in a low Poincar number (Po) regime and can generate instabilities for larger Po (see Lin et al. (2015) and Hollerbach et al. (2013)). Previous research, such as the work of Wei and Tilgner (2013) showed the interaction of the aforementioned forcings for fairly large Ekman numbers(E). The present study aims at extending this analysis to moderately low Ekman numbers focusing on the unstable stratification of the flow, as proposed by Brito et al. (2004) on a similar configuration.

Evaluation of LES model of MHD turbulence

M. Kessar*, G. Balarac and F. Plunian
University of Leeds

In several geophysical and astrophysical fluids, turbulence is very strong, and involves a large range of scales. Despite the strong development of computational resources the last few decades, it remains impossible to simulate this range of scales for realistic configurations. One solution is known as Large Eddy Simulations (LES). While a LES is performed, only the large scales of the flow are resolved, and the interactions between large and small scales are modeled. Several turbulence models have been developed for LES of turbulence. Nevertheless, the limitations of these models are not always well known for magnetohydrodynamic (MHD) turbulence, i.e for conductive fluids that can be encoutered in geophysics and astrophysics. In the second part of this thesis we will evaluate the functional performances (see Sagaut (2002)) of these models for several flow configurations involving turbulent dynamo action, i.e when a magnetic field is amplified though the action of a turbulent conductive fluid. In particular we will study the capabilities of LES models to reproduce energy exchanges between large and small scales. In order to do so, we will perform several DNS, for both non-helical flows (i.e leading to small scale dynamo) and helical flows (i.e leading to large scale dynamo). Thanks to a filtering operation we will compute the exact subgrid-scale transfers and compare them to the predictions given by several models. Finally we will achieve LES using subgrid-scale models and we will compare them to filtered DNS.

Towards a 4D-Var MHD assimilation framework

N. Lardelli*, K. Li and A. Jackson
ETH Zurich

Numerical dynamo experiments cannot resolve MHD-systems past $E = 10^{-8}$. Hence, in the last decades, several Spherical Couette experiments were developed in order to achieve more Earth-like regimes. In these experiments, it is difficult to determine interior physical quantities such as flows and magnetic fields. One approach to resolving this differently is to use 4-dimensional variational data assimilation (4D-Var), a technique already successfully employed by Li et al. (2014) for the coupling between the induction equation and a diagnostic form of the Navier-Stokes (NS) equations. 4D-Var is also widely used in atmospheric physics to define optimal initial conditions for time-varying flow fields. Our goal is to couple the induction equation with a prognostic form of the NS equations and ultimately to present a method able to reconstruct flow fields of Spherical Couette experimental datasets.

Analytical solutions for quasi-geostrophic inertial modes and onset of thermal convection in rapidly rotating spheroids

S. Maffei*, A. Jackson and P. Livermore
ETH Zurich

The flows in the fluid cores of rapidly rotating planetary bodies can be conveniently described as being invariant along the direction parallel to the rotation axis. This description, also referred to as columnar, is based on the quasi-geostrophic approximation and it holds for timescales longer than the rotation period as long as other forces acting on the fluid are of secondary importance with respect to rotation. A significant effort of the community is presently spent in the development of quasi-geostrophic numerical models of planetary cores, the final goal being to run numerical simulations in realistic parameters regimes. The development of such models has proven fundamentally challenging, especially when magnetic forces are present. Therefore, analytical solutions to simple dynamical problems will be of paramount importance for benchmarking purposes.

We present an analytical and explicit solution to the problem of the columnar inertial modes in rapidly rotating sphere and spheroids in absence of viscosity. We find that the oblateness of the spheroid significantly alters the frequency of the low order inertial modes for high azimuthal wavenumbers. However the geometry of the flow is the same as for the spherical case. Excellent agreement with known 3-D solutions has been found. Typically, given the geometry of the columnar flows, the axial vorticity equation is assumed to be a valid description of the dynamics of quasi-geostrophic flows. Based on a recently developed projection technique, we found the axial vorticity equation to be appropriate only in the case of highly oblate spheroids.

This analytical solution can be used to calculate the critical Rayleigh number and the shape of the flow at the onset of thermal convection. We do so by following an asymptotic procedure already applied to the spherical case and for 3-D flows.

Dynamo generated by the centrifugal instability

F. Marcotte and C. Gissinger*
École Normale Supérieure – Paris

We present a new scenario for magnetic field amplification where an electrically conducting fluid is confined in a differentially rotating, spherical shell with thin aspect-ratio. When the angular momentum sufficiently decreases outwards, an hydrodynamic instability develops in the equatorial region, characterised by pairs of counter-rotating toroidal vortices similar to those observed in cylindrical Couette flow. These spherical Taylor-Couette vortices generate a subcritical dynamo magnetic field dominated by non-axisymmetric components. We show that the critical magnetic Reynolds number seems to reach a constant value at large Reynolds number and that the global rotation can strongly decrease the dynamo onset. Our numerical results are understood within the framework of a simple dynamical system, and we propose a low-dimensional model for subcritical dynamo bifurcations. Implications for both laboratory dynamos and astrophysical magnetic fields are finally discussed.

Instability of electromagnetically-driven liquid metal flow

M. Pereira*, S. Fauve and C. Gissinger

École Normale Supérieure – Paris

We present a new MHD experiment in which a flow of liquid metal (GaInSn) is driven in an annular channel by a Lorentz force due to a sinusoidal magnetic field traveling in the azimuthal direction. Both axial and azimuthal components of the velocity field are measured using ultrasound Doppler velocimetry and potential probes.

We show that the mean velocity profile is in agreement with some theoretical predictions, suggesting that flux expulsion due to the induction in the annulus plays an important role in the dynamics of the flow.

When the liquid metal is subject to two counter-propagative magnetic field, the flow becomes unstable and chaotic reversals of the mean azimuthal flow are observed: power spectrum of the velocity field exhibits $1/f$ noise on several decades and different regimes can be observed depending on the parameters. In particular, the occurrence of $1/f$ noise is related to the level of turbulence in the flow.

Kinematic dynamos in precession-driven cavities

S. Vantieghem* and A. Jackson

ETH Zurich

It has recently been argued that precession may provide an alternative energy source for the natural dynamos of planets and moons. Using a finite-volume code, we pursue a numerical investigation of precession-driven kinematic dynamos in whole spheroids and spheroidal shells. We find that laminar precession can power a dynamo and that the critical magnetic Reynolds number for the onset of dynamo action is lower if an inner core is present. Finally, we also discuss the spatial structure of the magnetic field.

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