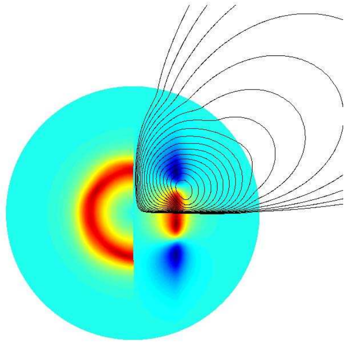
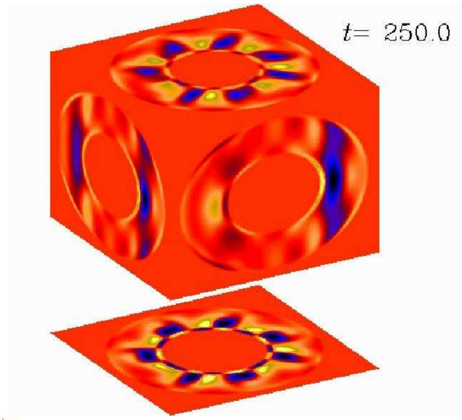
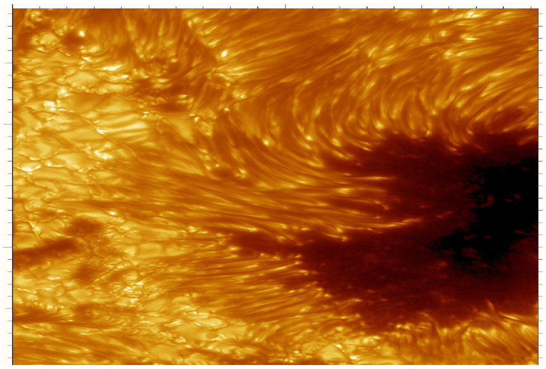
UK MHD 2004

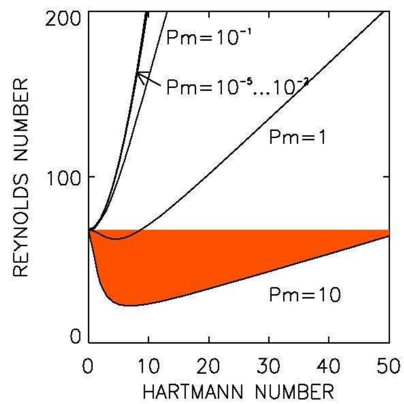
6 - 7 May Nice

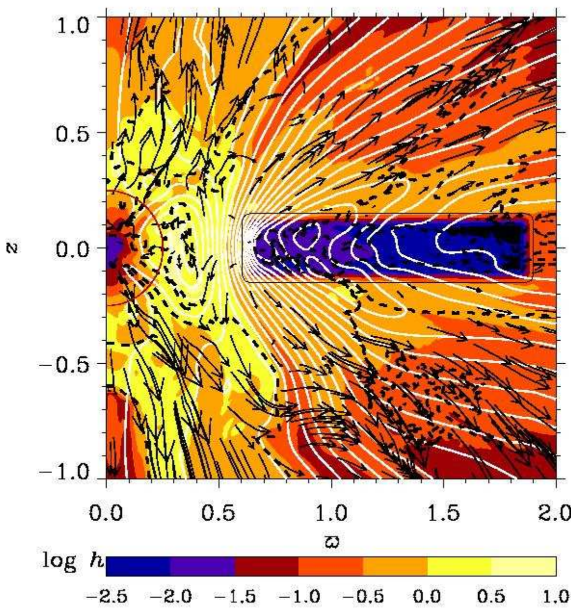
Observatoire de la côte d'Azur (O. C. A.)
Laboratoire Cassiopée CNRS UMR 6202

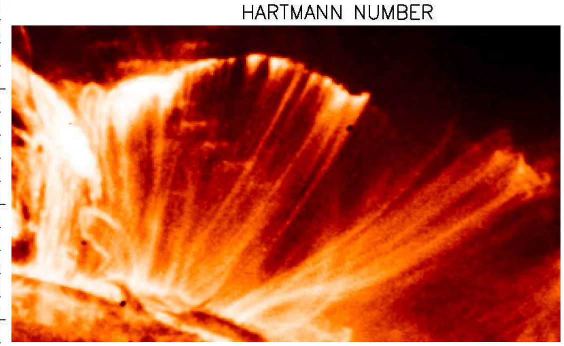


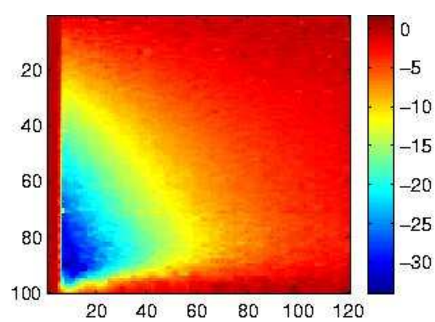












Organised by : Y. Ponty, H. Politano & V. Pellegrini

Sponsors : **BQR O.C.A.**, **UMR 6202**, **GDR Dynamo**, **PNST CNRS**, **SPI CNRS**

Programme

Thursday 6th May

9:00 - 10:00 : REGISTRATION

10:00 - 11:00 **Turbulence Session : Chairman Jacques Léorat**

Chris Jones : Turbulence models and plane layer dynamos
Alexander Schekochihin : Is there a small-scale dynamo in low-Pm MHD?
Nicolas Leprovost : Statistical mechanics of axisymmetric MHD flow

11:00 - 11:30 : Coffee Break (Poster session)

11:30 - 12:30 : **Geodynamo Session : Chairman Emmanuel Dormy**

Philip Livermore : Transient Magnetic Energy Growth in Kinematic Geodynamo Models
Nathanael Schaeffer : Quasi-geostrophic dynamos
Bérangère Deleplace : Magnetic and viscous torques at the core mantle boundary

12:30 - 14:15 : **BUFFET-LUNCH**

14:15 - 16:00 : **1er Solar Plasma session : Chairman Eric Priest**

Valentina Zharkova : Magnetic field dissipation during the solar flare 23rd July 2002
Alan Hood : Coronal Heating by Coronal Tectonics Interactions
Stephen Thompson : Magnetoconvection in the penumbra of a sunspot
Allan Sacha Brun : Magnetic Dynamo Action in the Solar Envelope
Erwin Verwichte : Transverse oscillations in a coronal loop arcade

16:00 - 16:30 : Tea Break (Poster session)

16:30 - 18:00 :**Numerical session : Chairman Laurette Tuckman**

Keke Zhang : A three-dimensional, spherical, nonlinear interface dynamo
Emmanuel Dormy : Magnetic induction in bounded domains.
Caroline Nore : A new Finite Element Method for magnetodynamical problems : two-dimensional results
Graeme Sarson : Dynamo Simulations Using a High Order Cartesian Magnetohydrodynamics Code
Axel Brandenburg : Does hyperviscosity spoil the inertial range ?

19:30 onward **APERITIF - CONFERENCE DINNER**

Friday 7th May

8:30 - 9:30 : UK MHD Consortium Meeting (Chair by : Alan Hood)

9:30 - 11:00 : **Experimental session : Chairman Francois Daviaud**

Nicolas Gillet : Experimental and Numerical study of Rotating Magneto-Convection
Jacques Léorat : What limit magnetic Reynolds number may be experimentally achieved ?
Daniel Brito : Measurement of apparent viscosity in rapidly rotating fluid
Francois Pétrélis : Diffusion of sound by a magnetic field

11:00 - 11:30 : Coffee Break (Poster session)

11:30 - 12:30 : **MHD session : Chairman Andrew Gilbert**

Alastair Rucklidge : Mean flow instabilities of two-dimensional convection in strong magnetic fields
David Fearn : Nonlinear magnetic instability
David Hughes : Dynamo Action in Rotating Convection

12:30 - 14:15 : **BUFFET-LUNCH**

14:15 - 16:30 : **2nd Solar Plasma session : Chairman Bernie Roberts**

Pu Zhang : Dynamo action driven by three dimensional convective flow with an Ekman layer
Maria Dymova : Non-axisymmetric oscillations of thin inhomogeneous magnetic tube
Paul Bushby : Torsional oscillations in a non-linear solar dynamo model
Adam Kelly : Acoustic Oscillations in Solar and Stellar Flaring Loops
James McLaughlin : MHD Wave Propagation in the Neighbourhood of Coronal Null Points.

16:00 - 16:30 : Tea Break (Poster session)

16:30 - 18:10 : **MHD Plasma session : Chairman David Hughes**

Michael Ruderman : Stability of solitons in Hall plasmas
David Simpson : Absolute and convective instabilities of circularly polarized Alfvén waves: Decay instability
Guenther Ruediger : MHD Taylor-Couette flow, also with Hall effect
Manuel Baptista : Stability to large-scale perturbations of thermoconvective MHD steady states in a layer
Raul Avalos-Zuniga : Mean electromotrice force for a ring of helical vortices

Posters

Gert Botha : Dynamics of convection around axisymmetric magnetic flux tubes

Daniel Brito :The DTS experiment

Alice Courvoisier : Linear and Non Linear alpha-effect in chaotic flows

Andrew Jackson : Double Fourier series for pdfs on the sphere

Eun-jin Kim : Phase Space Density Holes, Anomalous Resistivity and Fast Reconnection

Nuno Loureiro : Fast and slow nonlinear tearing mode reconnection

Shona Maclean : Nonlinear alpha-omega dynamos

Hiroaki Matsui : Sub-grid scale modeling in a MHD simulation in rotating plane layer

Christiane Normand : Galerkin analysis of cylindrical dynamos

Yannick Ponty : Simulation of induction at low magnetic Prandtl number
using Large Eddy Simulation (LES)

Brigitta von Rekowski : MHD simulations of dynamo driven stellar and disc wind

Jon Rotvig : Compressible models of planetary cores in spherical geometry

Bryan Simon : A Hybrid Approach to Magnetic Holes

Valentina Zharkova : Particle acceleration asymmetry in a reconnecting non-neutral current sheet

Abstracts

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Mean electromotrice force for a ring of helical vortices

Raul Avalos-Zuniga, LEGI, Grenoble
Co-authors: Franck Plunian (LEGI, France) and Karl-Heinz Raedler (AIP, Germany)

We study the dynamo mechanism for a flow made of a ring of stationary helical vortices in an electrically conducting media. The choice of this flow is related to the one obtained in thermal convection in a rotating shell which is also expected in the Earths outer-core. This choice is also related to a sodium experiment, carried out in Grenoble, based on a spherical Taylor-Couette model. Applying the mean field approach and relying on the second order correlation approximation we derive the mean electromotive force (e.m.f.) produced by such a flow. We find that such a ring of helical vortices may produce, from an azimuthal mean magnetic field, an azimuthal mean e.m.f. leading to the generation of a poloidal magnetic field.

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The DTS experiment

Daniel Brito, LGIT Grenoble

In order to prepare a large scale experiment and explore the magnetostrophic balance, a small scale liquid sodium experiment (50 litres) has been set-up. It consists of a rapidly rotating shell filled with liquid sodium, in which motions are set by spinning at a different rotation rate an inner core permeated by a strong magnetic field. We will discuss the processes that will be explored with this device.

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Stability of thermoconvective MHD steady states in a layer to large-scale

Manuel Baptista , University of Porto

We are considering perturbations of MHD steady states in a horizontal rotating layer, which satisfy (i) the Navier-Stokes equation with the Lorentz force and thermal buoyancy force taken into account in the Boussinesq approximation, (ii) the magnetic induction equation and (iii) the heat transfer equation, with production of heat by electric currents (Joule effect) taken into account (though this restricts the symmetries consistent with the steady state).

Linearised equations for small perturbations of thermoconvective magneto-hydrodynamic steady states of an electrically conducting fluid in a layer are analysed by multiple-scale expansion methods [1,2,3,4,5. Periodic boundary conditions are imposed in horizontal directions. On horizontal boundaries temperature is assumed to be constant, stress-free boundary conditions are imposed for the flow and perfect conductor boundary conditions for the magnetic field.

An eigenvalue problem for perturbations is analysed. The eigenmodes and the eigenvalues are supposed to depend on both small- (fast) and large-scale (slow) spatial variables. They are expanded in power series of the scale ratio and a hierarchy of equations is derived. Solvability of the zeroth and first order problems in this hierarchy is assured by symmetry arguments. Solvability conditions at the second order yield a closed set of equations for the leading terms in the expansions of the dominant mode and its growth rate.

Simulations are done with our code employing pseudo-spectral methods.

[1] V.A. Zheligovsky, O.M. Podvigina. Generation of multiscale magnetic field by parity-invariant time-periodic flows. Geophys. Astrophys. Fluid Dynamics 97, 2003, 225-248 http://xxx.lanl.gov/abs/physics/0207112.

[2] V.A. Zheligovsky. On the linear stability of spatially periodic steady magnetohydodynamic systems with respect to long period perturbations. Izvestiya, Physics of the Solid Earth 39 N5, 2003, 409-418.

[3] V.A. Zheligovsky, O.M. Podvigina, U. Frisch. Dynamo effect in parity-invariant flow with large and moderate separation of scales. Geophys. Astrophys. Fluid Dynamics 95, 2001, 227-268 [http://xxx.lanl.gov/abs/nlin.CD/0012005].

[4] A. Lanotte, A. Noullez, M. Vergassola, A. Wirth. Large-scale dynamo produced by negative magnetic eddy diffusivities. Geophys. Astrophys.Fluid Dynamics 91, 1999, 131-146.

[5] Bérengère Dubrulle, Uriel Frisch. Eddy viscosity of parity-invariant flow. *Physical Review A*, Vol. 43, No.10, 1991.

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Does hyperviscosity spoil the inertial range?

Axel Brandenburg Nils Erland L. Haugen , Nordita Copenhagen

Since the work of Biskamp and Mueller (2000, Phys. Plasmas 12, 4889) there has been serious concern that a major part of the inertial range is spoiled by using simulations with hyperviscosity. We present a series of high resolution simulations to show that the inertial range is unaffected by hyperviscosity. The bottleneck effect (i.e. a shallower spectrum near the end of the dissipation range) is a physical effect and its spectral width is the same with and without hyperviscosity. In nonhelical MHD, hyperviscous simulations are presented that show a trend towards asymptotic equipartition in the inertial range.

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Magnetic Dynamo Action in the Solar Envelope

Allan Sacha Brun, DSM/DAPNIA/SAp CEA Saclay

We present recent results of 3-D MHD numerical simulation of the bulk of the solar convective envelope in spherical geometry. In particular we assess the role of the Reynolds and Maxwell stresses in establishing the differential rotation seen in our simulations. We quantify the respective role of the mean vs fluctuating magnetic fields in our simulated turbulent dynamo and present a probable scenario for the working of the solar dynamo.

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Torsional oscillations in a non-linear solar dynamo model

Paul Bushby , DAMTP University of Cambridge

Cyclic variations are observed in the solar differential rotation profile. The 11 year periodicity of these (so-called) torsional oscillations is consistent with the idea that they are magnetically driven. It is possible to investigate this process by considering a simple mean-field model for the solar dynamo which incorporates the non-linear feedback of the Lorentz force upon the angular velocity. It is shown that it is possible to reproduce a solar-like pattern of torsional oscillations, even in models where the dynamo action is strongly modulated.

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Magnetic and viscous torques at the core mantle boundary

Berangere Deleplace and Philippe Cardin, LGIT Grenoble

Differential rotation between the liquid core and the solid mantle generates a thin layer at the top of the core where the lorentz and viscous forces may balance the coriolis forces and play a major role. We solve the induction and the momentum equation to compute the velocity and the magnetic field in boundary layer. Different regimes are possible. On a hand, when the difference of conductivity between the mantle and the core is small, a pure magnetic case may take place where induced electrival currents are produced in a skin layer and loop into a conductive solid layer in the mantle. On an other hand , given that the fluid in the outer core is likely to be subject to high convection, we can assume an Ekman layer based on eddy viscosity of $10^{-1}m^2/s$, such a pure viscous case where an Ekman layer generate a vicous skin at the base of the mantle is possible as well. A visco-magnetic regime where both, viscous and magnetic torques work togheter to balance the change in angluar momentum and influence the Earth's axis of rotation is also investigated.

Using the result of the nutation theory (Mathews et al, 2002) we show that in order to retrieve VLBI (Very Long Baseline Interferometry) data, the magnetic field at the C.M.B has to be smaller than the value find by previous authors with a similar inviscid analysis(Buffet et al, 2002).

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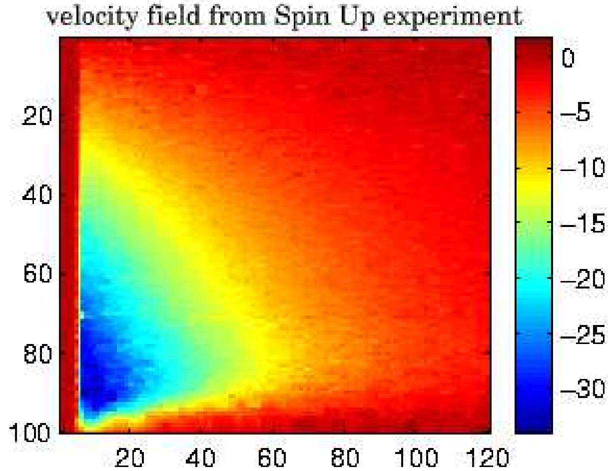
Linear and Non Linear alpha-effect in chaotic flows

Alice Courvoisier , University of Leeds

In the framework of kinematic dynamo theory we calculate the alpha-effect for two different z-independent chaotic flows periodic in space and time, namely the Galloway-Proctor flow (1992) and the MW+ flow (Otani 1993). Two different methods are used. First we compute monochromatic magnetic field solutions of the form $H(x, y, k, t)exp(p(k)t + ikz)$ and evaluate the alpha-effect by computing the limit of the k-dependent alpha-tensor as k tends to zero. Then we also solve the induction equation for a z-independent field and impose a mean-field Bo in the x-direction to evaluate the alpha-effect. These methods are related in the sense that the second method corresponds to solving the induction equation for a monochromatic solution to 0th order in k (Roberts 1970). They show reasonnable agreement for low magnetic Reynold number Rm (¡30) whereas for higher Rm only the 2nd method seems reliable as it prooves harder to reach the asymptotic regime for small k. In addition some fully nonlinear calculations were performed using the 2nd method and varying the strength of the imposed mean-field Bo. Results show that the alpha-effect is quenched in an Rm-dependent way while sometimes displaying an unexpected behaviour as Bo is varied.

Measurement of apparent viscosity in rapidly rotating fluid

Berangere Deleplace and Daniel Brito, LGIT Grenoble



Modelling small scales in fluid dynamics is a main task for geophysicists. In atmospheric physics, the concept of turbulent diffusivities is largely used to face that issue and the range of values of this parameter can be evaluated throught observation of Ekman layers. As far as the Earth's core is concerned, such an observation is not possible, so experimental modelling may help to determine this mixing parameter. Our experimental apparatus used is a sphere of radius 11 cm with a central cylindrical pipe. The outer sphere is heated whereas the central pipe is cooled. Using an ultrasonic velocimetry doppler technic, we get quantitative results concerning the fluid velocity when convection takes place, in gallium as well as in water. In order to determine turbulent diffusivities, our experiments consist in quantitatively comparing velocity fields of purely conductive and convective regimes. This experiments are Spin up (respectively Spin down) type that is to say a sudden increase (respectively decrease) of the rotation speed of the container starting from a state of solid body rotation. Through a measure of the velocity field during the transient time, we deduce a synchronisation time for each set of experiment. These times are compared with the theoritical linear prediction made by Greenspan (1969). The observations fit perfectly with the theory when the starting state is purely conductive (experiments without turbulence). A relatively precise measurement of the molecular viscosity (within a maximum error of 2%) is deduced with that technique. Comparison with experiments starting from a convective state superimposed over the body rotation shows on one hand that ,for the water, in order to retrieve the synchronisation time predicted by theory, we need to used a viscosity up to 43% bigger than the molecular viscosity (depending on the vigour of the convection). On an other hand, experiments using gallium at higher reynolds number show no significant effects of apparent viscosity. Similar experiments performed at Oxford (Atmospheric Oceanographic and Planetary Physics) using a particules imagery velocimetry technic on a cylindrical container forced by thermal convection between the top and the bottom boundaries show as well a weak apparent viscosity effect. Results show that the apparent viscosity in rapidly rotating system is not only dependant of the local Reynolds number but could depend on parameter such as the Prandlt number. This priliminary study shows that even if we have not yet interpreted our results in term of process, through different experimental appartus we are able to iddentify some regimes where the apparent viscosity play a major part.

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Dynamics of Helicity Transport and Taylor Relaxation

Patrick Diamond , University of California, San Diego

The Taylor hypothesis posits that a system in a state of MHD turbulence will relax so as to minimize its magnetic energy subject to the constraint of conserved global magnetic helicity. A simple model of the dynamics of Taylor relaxation is derived from the basic MHD equations using symmetry principles alone. The model constrains the form of the turbulent helicity flux, but no statistical closure approximations are invoked, and no detailed plasma model properties are assumed. The model yields a one space (i.e. radius) - one time dimensional pde for excursions of the current profile from the Taylor state. Notably, the model predicts several classes of non-diffusive helicity transport phenomena, including traveling nonlinear waves and super-diffusive turbulent pulses. A 'universal' structure for the scaling of the effective turbulent magnetic Reynolds number of a system undergoing Taylor relaxation is derived. Some basic properties of intermittency in helicity transport are examined. Numerical solutions of the model equation and extensions beyond the MHD model will be discussed.

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Magnetic induction in bounded domains

Emmanuel Dormy, I.P.G.P./E.N.S
joint work with A.Iskakov and S.Descombe

Simulations of magnetohydrodynamic (MHD) flows in bounded domains using spectral methods can suffer from a number of serious limitations. Alternative methods based on local discretisation raise the problem of non-local boundary conditions implementation for the magnetic field. We propose a strategy for the numerical solution of MHD problems in bounded conducting domains, which combines the flexibility of a local discretisation with a rigorous formulation of magnetic boundary conditions next to an insulator in arbitrary geometries. Following the nature of underlying equations, we apply a global integral approach (B.E.M.) at the boundary and differential approach (V.F.) inside the conducting domain. We illustrate the approach in a sphere as well as in a finite cylinder.

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Statistical mechanics of axisymmetric MHD flow

N. Leprovost[1], B. Dubrulle[1], P-H. Chavanis[2]
[1] DRECAM/SPEC/CEA Saclay, CNRS (URA2464), F-91190 Gif sur Yvette Cedex, France
[2] Laboratoire de physique quantique (UMR C5626), Université Paul Sabatier, Toulouse, France

The recent success of two experimental fluid dynamo [1, 2] has renewed the interest in the mechanism of dynamo saturation, and, thus, of equilibrium configuration in MHD. At the present time, there is no general theory to tackle this problem, besides dimensional theory. For example, in a conducting fluid with typical velocity V, density ρ , Reynolds number Re and magnetic Prandtl number Pm, the typical level of magnetic field reached at saturation is necessarily [3]:

$$B^2 = \mu_o \rho V^2 f(Re, Pm),$$

where f is a priori an arbitrary function of Re and Pm. Many numerical simulation [4] lead to $f = 1$, i.e. equipartition between the magnetic and turbulent energy. This is therefore often taken as a working tool in astrophysical or geophysical application. However, this result is far from applying to any saturated dynamo. Moreover, it does not give any information about possible anisotropy of the saturated field. It would therefore be interesting to build robust algorithm to derive the function f. By robust, we mean which depends on characteristic global quantities of the system (like total energy) but not necessarily on small-scale dissipation, or boundary conditions.

In this talk, we present strategies based upon extremization principles, in the case of the axisymmetric MHD equations. We study the equilibrium shape by using a minimum energy principle under the constraints of the MHD axisymmetric equations. We also propose a numerical algorithm based on a maximum energy dissipation principle to compute in a consistent way the equilibrium states. Then, we develop the statistical mechanics of such flows and recover the same equilibrium states giving a justification of the minimum energy principle. We find that fluctuations obey a Gaussian shape and we make the link between the conservation of the Casimirs on the coarse-grained scale and the process of energy dissipation.

References

[1] A. Gailitis *et al.*, Phys. Rev. Lett. **86**, 3024 (2001).

[2] R. Stieglitz and U. Müller, Phys. Fluids **13**, 561 (2001).

[3] F. Pétrélis and S. Fauve, Eur. Phys. J. B, **22**, 273 (2001).

[4] V. Archontis, PhD University of Copenhagen (2000).

Non-axisymmetric oscillations of thin inhomogeneous magnetic tubes.

Maria Dymova , University of Sheffield

We consider non-axisymmetric oscillations of a thin straight magnetic tube. The tube is modeled by a magnetic cylinder with the background quantities discontinuous at the cylinder boundary. The unperturbed state is axisymmetric and the background quantities are independent on the radial coordinate both inside and outside the cylinder. However they do depend on the coordinate along the cylinder. The magnetic field lines are assumed to be frozen in dense plasma at the cylinder bases. To simplify the problem we use the cold plasma approximation. The assumption that the cylinder is thin enables us to fine the dependence of perturbed quantities on the radial coordinate. After that, using the boundary conditions at the cylinder boundary we reduce the problem to a simple Sturm-Leuville problem for a second order ordinary differential equation. We solve this problem in two particular cases and apply the obtained results to oscillations of cylindrical prominence fibrils.

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Nonlinear magnetic instability

David Fearn , University of Glasgow

Studies of the stability of prescribed magnetic fields in rapidly rotating systems have clearly established the relevance of the mechanism of magnetic field instability to the dynamics of planetary cores. The present study investigates the nonlinear development of such instabilities and their feedback on the field generation process. The non-axisymmetric instability of a mean magnetic field $\bar{\mathbf{B}}$ generated by a prescribed α-effect has been investigated in a rapidly rotating fluid spherical shell. The mean field drives a flow through the Lorentz force in the momentum equation and this flow feeds back on the field-generation process in the magnetic induction equation, equilibrating the field at some finite amplitude. This amplitude increases with α_0, the strength of α. Above some critical value of α_0 the mean field becomes unstable to a non-axisymmetric instability. We are particularly interested in how the instability affects the mean field generated. We find that instability can dramatically reduce the strength of the mean field and significantly constrains the growth of $\bar{\mathbf{B}}$ with α_0

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Phase Space Density Holes, Anomalous Resistivity and Fast Reconnection

Eun-jin Kim , University of California, San Diego

Release of magnetic energy and change of magnetic topology via 'fast reconnection' processes are crucial to the understanding of a number of natural phenomena, the heating of the solar corona being one prominent example. However, classical MHD reconnection rates are pathetically slow, and are not predicted to be dramatically enhanced by turbulent spatial diffusion and transport of magnetic fields, on account of the severe topological constraints imposed on the dynamics of those of processes [1]. Thus, one is powerfully motivated to explore other mechanisms for fast reconnection. One such mechanism particularly relevant to low collisionality regimes, is the enhancement of electron-ion momentum exchange via kinetic processes and turbulence [2]. Note this contributes a TRUE 'anomalous resistivity', and not merely the course-grained transport of magnetic field lines which are still individually constrained by the frozen-in condition of MHD. In practice, such resistivity anomalies are usually linked to the current-driven ion-acoustic instability, driven by inverse Landau resonance on a shifted Maxwellian distribution function. In this paper, we present a novel theory of anomalous resistivity based upon the exchange of parallel momentum between ions and electron phase density holes. Special emphasis is placed upon the interplay between phase space dynamics and macroscopic physics, such as reconnection-layer structure. Phase space density holes are self-bound, rather like Jeans equilibria (NB: The 'depletion' is due to the sign of the background dielectric screening constant). Holes do not require linear instability for their formation, and can, in fact, extract free energy from the mean distribution function in the absence of linear waves [3]! Thus, this theory is not heavily tied to the details of the linear theory of current driven ion-acoustic instability, as are most previous theories of anomalous resistivity. Also, the hole growth mechanism is intrinsically nonlinear. Holes formation has been observed in recent numerical simulations [4].

The research work performed is concerned with three issues:

i) calculation of the acceleration and growth of an electron hole via scattering off ions ii) the implications of (i) for non-collisional momentum and energy exchange between species, for a given parallel electric field (iii) the implications of (i) and (ii) for the macroscopic reconnection and heating rates in simple configurations. Special attention is given to reconciling the cross-field hole size with reconnection layer width, and to the possibility of bursty reconnection.

[1] E. Kim and P.H. Diamond, Astrophys. J., **556**, 1052 (2001) [2] T.H. Dupree, Phys. of Fluids, **25**, 277 (1982) [3] R.H. Berman, et al, Phys. Rev. Lett., **48**, 1249 (1982) [4] J.F. Drake, Science, **299**, 873 (2003)

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Dynamics of convection around axisymmetric magnetic flux tubes

Gert Botha , University of Leeds

Pores and sunspots are some of the magnetic features observed on the surface of the solar photosphere. In this presentation numerical models are used to study idealised pores and sunspots. Vertical flux tubes are placed in a compressible convecting photosphere in an axisymmetric cylindrical box with radius up to 4 times its depth [1]. The PDEs solved are those considered by Hurlburt and Toomre [2]. Large convection cells form in the photosphere that push magnetic field lines towards the centre (at $r = 0$). We found convection cells with clockwise and anti-clockwise rotations - which may respectively give an indication to processes associated with pores and the perumbral flow around sunspots. In this presentation the structure of the flows is investigated in terms of the values of the physical parameters of the problem and the possible influence of the numerical boundaries of the domain.

[1] N.E. Hurlburt A.M. Rucklidge, 2000, MNRAS 314, 793-806.
[2] N.E. Hurlburt J. Toomre, 1988, ApJ, 327, 920-32.

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Experimental and Numerical study of Rotating Magneto-Convection

Nicolas Gillet , Grenoble Observatory - LGIT

We have experimentally and numerically studied finite-amplitude magneto-convection in a rotating spherical shell filled with gallium (Prandtl number Pr=0.027). We impose an azimutal magnetic field (up to 10^{-2} T) on convective motions where Rayleigh number is a few times critical. The thermal Ekman number Et reaches $0(10^{-6})$, and the Elsasser number $0(10^{-2})$; thus we explore the "weak field" case where Elsasser is of order $Et^{1/3}$. Ultrasonic Doppler velocimetry is used to measure quantitatively the velocities in the equatorial plane: a strong decrease of the motion is observed as the intensity of the imposed field increases. We present a comparative evolution of zonal and convective flows as the Elsasser number varies. Then with the help of quasi-geostrophic numerical simulations we propose a scaling of the velocities including the effect of the magnetic field on the onset parameters. A physical interpretation that link together the velocity distributions and the heat transport is proposed. Prospects for further experiments and numerical simulations are then discussed.

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Sub-grid scale modeling in a MHD simulation in rotating plane layer

Hiroaki Matsui, University of Chicago

The fluid motion and the magnetic field in the Earth's outer core have small scale components which cannot be resolved in numerical simulations because of the small Ekman number and large Rayleigh number. Many geodynamo simulations have been performed with much larger viscosity or hyper diffusivity, but more realistic sub-grid scale (SGS) modeling is required. We model the influence of sub-grid scale motion using the nonlinear gradient model by Leonard (1974). This method is implemented in a dynamo simulation code the finite-element method. To investigate basic behavior of the SGS terms, we compare the SGS terms in the present model with the results obtained from a fully resolved simulation on a finer grid.

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Coronal Heating by Coronal Tectonics Interactions

Alan Hood , University of St Andrews

Coronal Heating by Coronal Tectonics Parker suggested that the corona could be heated by the dissipation of magnetic energy stored in numerous small current sheets and he suggested that these currents sheets would form when random photospheric motions braid a uniform magnetic field. However, another method, called Coronal Tectonics, assumes that the photospheric magnetic field arises from discrete sources and smooth velocities will automatically produce coronal current sheets. This alternative method is investigated through a 3D MHD simulation and the results are compared with a simple analytical model. Significant ohmic heating occurs, suggesting that this mechanism can heat the corona.

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Dynamo Action in Rotating Convection

David Hughes, University of Leeds

The nature of linear and nonlinear dynamo action driven by highly supercritical rotating convection is examined. Strong (approximately equipartition) small-scale fields are generated, but only very weak large-scale fields. The results also suggest that this system acts as a fast small-scale dynamo, but as a slow large-scale dynamo.

Double Fourier series for pdfs on the sphere

Andrew Jackson , University of Leeds

Spectral methods have been the mainstay of numerical solution of partial differential equations for many years. On the sphere the spactral basis of choice has been the spherical harmonics. Here we present a new representation - double Fourier series defined on a new coordinate system. We show that the new basis is complete, in that a finite number of terms can reresent any arbitrary spherical harmonic. The advantage of this basis is in the speed of the transform between physical and spectral space, needed for the computation of nonlinear terms. The prospects for implementation in representations of fluid flow on the sphere are explored.

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Turbulence models and plane layer dynamos

Chris Jones , University of Exeter

Small-scale motions that significantly influence the dynamo mechanism cannot be numerically resolved. Two approximate ways that have been suggested for incorporating these "sub-grid scales" are investigated here: the addition of hyperdiffusion and the application of Camassa-Holm-alpha theory. These proposals were tested by comparing their consequences, not only for marginal convection but also for finite amplitude dynamos, with corresponding 'exact' results . Plane layer models were studied because of their numerical advantages.

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Acoustic Oscillations in Solar and Stellar Flaring Loops

Adam Kelly, V.M. Nakariakov and T.D. Arber, University of Warwick

Observations of flaring loops in radio, visible and x-ray bands show quasi-periodic pulsations with periods in the range 10-300s. Recent numerical studies have shown that these oscillations can be interpreted as standing slow magnetoacoustic waves. Energy deposition from the flare, through the chromospheric evaporation, excites the second standing harmonic, with the period determined by the temperature and the loop length. The excited longitudinal oscillations are practically dissipationless and can, possibly, be considered as MHD autowaves. Numerical simulations with a wide range of flare durations and choices of heat deposition location show that the second harmonic is a common feature of flaring loops.

What limit magnetic Reynolds number may be experimentally achieved ?

Jacques Léorat, Observatoire de Paris-Meudon

The two successfull fluid dynamo experiments of Riga and Karlsruhe in november 1999 had magnetic Reynolds numbers just above criticality, around 50. Sodium flow experiments now use containers without internal walls , with expected Rm closer to 100. What is the limit Rm reachable in a MHD wind tunnel ?

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Transient Magnetic Energy Growth in Kinematic Geodynamo Models

Philip Livermore , University of Leeds

Kinematic theory is a simplification of the full MHD problem in which the flow of conducting fluid in the Earth's outer core is prescribed, and only the time evolution of the magnetic field is sought. Traditionally, linear stability analysis has been used with a certain amount of success, although typical results show critical dependence on the precise choice of flow. Fluid dynamical studies have shown that finite time transient behaviour, differing from the results of linear analysis, may be of fundamental importance in understanding the growth of instabilities in non-magnetic flow. I present results of applying similar techniques to the magnetic case, in particular demonstrating robust growth of axisymmetric fields which may go some way in explaining their dominance in the geomagnetic field

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Fast and slow nonlinear tearing mode reconnection

Nuno Loureiro, Imperial College

We study the nonlinear evolution of resistive tearing mode reconnection using the equations of reduced-MHD. For island widths larger than the resistive scale, existing theory predicts under certain assumptions that the linear (exponentially fast) stage of the mode evolution is replaced by a nonlinear stage of algebraic island growth (the so-called Rutherford regime). Numerical evidence of this regime's existence has been elusive and it has been questioned that this regime is at all realized. We show numerically that the Rutherford regime exists even at large values of the instability parameter D'. It is further shown that for D' and island width above certain critical values, the Rutherford stage gives way to a period of extremely fast growth (followed by saturation of the instability). This speed-up is accompanied by a topological rearrangement of the region around the magnetic null, from X to Y shape, i.e., the tearing-mode reconnection is replaced by Sweet-Parker reconnection.

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Nonlinear alpha-omega dynamos

Shona Maclean , University of Glasgow

We consider a non-linear axisymmetric mean-field $\alpha\omega$-dynamo model, where α, the parametrisation of the small-scale non-axisymmetric flow takes the form $\alpha = \alpha_o \cos\theta \sin(\pi(r - r_i))$. Θ, the parametrised buoyancy force is taken as $\Theta = -\Theta_o r \cos^2\theta$, such that it drives a differential rotation ω of the form $\omega = \Theta_o r$. We solve the coupled system of equations in a spherical shell with a finitely conducting inner core, using a spectral method decomposition. Equilibration of the system is achieved through the non-linear Lorentz force in the momentum equation. We investigate the effect of reversing the direction of the imposed buoyancy force and find that quadrupole parity solutions are produced for Θ_o positive and dipole parity solutions for Θ_o negative. Through fixing the magnitude of the buoyancy force, Θ_o, we are able to find how the characteristics of the solutions change with increasing α_o, and find very different behaviour depending on the sign of Θ_o. Even at the onset of dynamo action when the system is linear, we find that the system can not be defined by the product of α_o and Θ_o alone; these parameters must be specified separately as they are both important in characterising the types of solutions found.

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MHD Wave Propagation in the Neighbourhood of Coronal Null Points

James McLaughlin, University of St Andrews

n the low β solar corona, the nature of fast magnetoacoustic and Alfvén waves is investigated. It is found that when coronal null points exist, the fast wave is attracted to such points and the front of the wave slows down as it approaches the null point, causing the current density to accumulate there and rise rapidly. Ohmic dissipation will extract the energy in the wave at this point. This illustrates that coronal null points play an important role in the rapid dissipation of fast magnetoacoustic waves. The Alfvén wave behaves in a different manner in that the wave energy is dissipated along the separatrices. However, the phenomenon of dissipating the majority of the wave energy at a specific place is a feature of both wave types.

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A new Finite Element Method for magnetodynamical problems : two-dimensional results

Caroline Nore, LIMSI-CNRS Universite Paris 11, Orsay

A mixed Lagrange finite element technique to solve the Maxwell equations in the magnetohydrodynamic (MHD) limit in an hybrid domain composed of vacuum and conducting regions is presented. The originality of the approach is that no artificial boundary condition is enforced at the interface between the conducting and the insulating regions and the non-conducting medium is not approximated by a weakly conducting medium as is frequently done in the literature. As a first evaluation of the performance of the method, we study two-dimensional (2D) configurations, where the flow streamlines of the conducting fluid are planar, *i.e.* invariant in one direction, and either the magnetic field (”magnetic scalar” case) or the electric field (”electric scalar” case) is parallel to the invariant direction. Induction heating, eddy current generation, and magnetic field stretching are investigated showing the usefulness of finite element methods to solve magneto-dynamical problems with complex insulating boundaries.

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Galerkin analysis of cylindrical dynamos

Christiane Normand, CEA Saclay

An alternative approach to direct numerical simulations is presented to determine the dynamo threshold in cylindrical containers with von Karman type flows. It is based on a Galerkin approximation of the solution of the induction equation.

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Diffusion of sound by a magnetic field

Francois Petrelis , LPS ENS Paris

We study the effect of a magnetic field on the propagation of sound. The sound appears to be scattered by a localized magnetic field. Measurements of the scattering pattern is thus a probe of the magnetic field.

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Simulation of induction at low magnetic Prandtl number using Large Eddy Simulation (LES)

Yannick Ponty, Hélène Politano & Jean-François Pinton
Observatoire de la Côte d'Azur & ENS Lyon

We consider the induction of magnetic field in flows of electrically conducting fluid at low magnetic Prandtl number and large kinetic Reynolds number. Using the separation between the magnetic and kinetic diffusive length scales, we propose a new numerical approach. The coupled magnetic and fluid equations are solved using a mixed scheme, where the magnetic field fluctuations are fully resolved and the velocity fluctuations at small scale are modelled using a Large Eddy Simulation (LES) scheme. We study the response of a forced Taylor-Green flow to an externally applied field: topology of the mean induction and time fluctuations at fixed locations. The results are in remarkable agreement with existing experimental data; a global $1/f$ behavior at long times is also evidenced [1].

[1] Y. Ponty, H. Politano & J-F Pinton *Phys. Rev. Lett.* **92**, 144503 (2004). "Simulation of Induction at Low Magnetic Prandtl Number"

Compressible models of planetary cores in spherical geometry

Jon Rotvig , Max-Planck-Institute for Solar System Research, Germany

The Boussinesq approximation is commonly used,with a few exceptions, to model the dynamics of planetary cores. On this poster, I describe a recent pseudo-spectral implementation of a model of thermal compressible convection in a spherical shell. The compressibility is described within the anelastic framework.This model is based on the non-turbulent and single-fluid part of Anufriev *et al.* (in preparation, 2004). From seismology and experimental high-pressure physics on iron, the reference state of the fluid outer core of the Earth is well-known. I use this reference state as basis for the perturbed state. The system is driven by asuper-adiabatic heat flux at the ICB, and the bulk heat source is neglected. Later the magnetic counterpart of this system will be considered.

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Mean flow instabilities of two-dimensional convection in strong magnetic fields

Alastair Rucklidge , University of Leeds

In strong magnetic fields, it is well known that two-dimensional convection takes the form of narrow rolls, and can be treated in the asymptotic limit as a nonlinear eigenvalue problem. We examine the stability of this solution when the Prandtl number is also asymptotically small. At leading order, the linear stability problem turns out to be the linearisation of the same nonlinear eigenvalue problem, and as a result, it is necessary to go to higher order to obtain a stability criterion.

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Stability of solitons in Hall plasmas

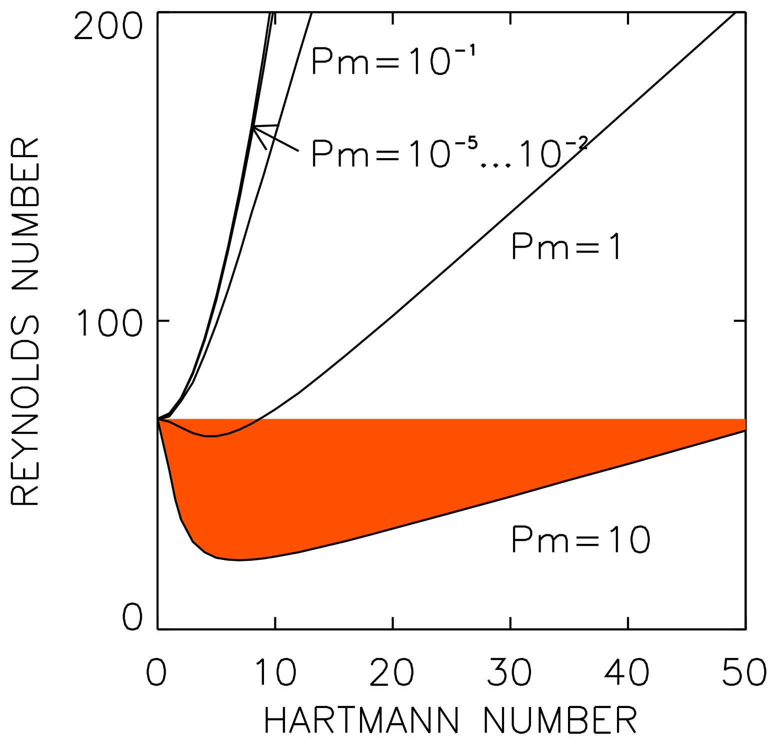
Michael Ruderman , University of Sheffield

Depending on the direction of propagation with respect to the ambient magnetic field, solitons in Hall plasmas are decribed either by the KdV, the modified KdV (mKdV), or the DNLS equation. All these are well-known soliton equations of mathematica physics. The stability of solitons propagating in Hall plasmas with respect to weakly non-onedimensional perturbations are studied with the use of non-onedimensional modifications of the KdV (KP equation), mKdV, or DNLS equations.

MHD Taylor-Couette flow, also with Hall effect

Guenther Ruediger , AIP Germany

For a verification of the magnetorotational instability in the laboratory the critical Reynolds numbers have been computed for MHD Taylor-Couette flow experiments. The resulting values are of order 10^6 so that the fluid is certainly turbulent. With Hall effect also TC flows with superrotation become linearly unstable but only for one orientation of the external magnetic field.



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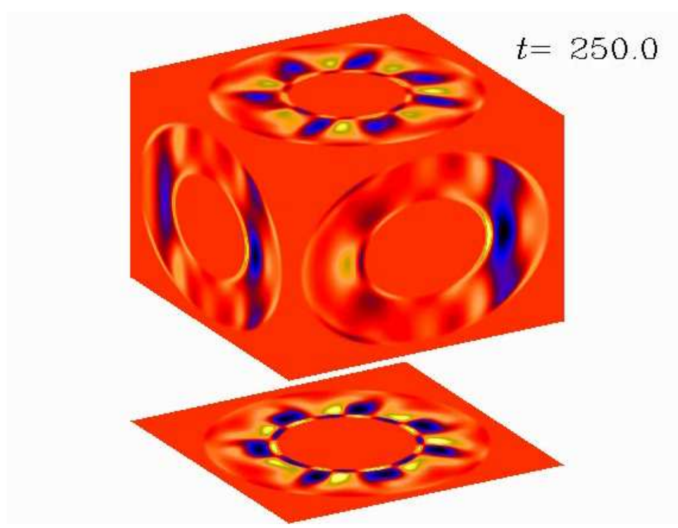
Dynamo Simulations Using a High Order Cartesian Magnetohydrodynamics Code

Graeme Sarson , University of Newcastle

Most numerical simulations of the geodynamo are cast in spherical geometry, using a spherical harmonic representation for lateral variations and an expansion in Chebyshev polynomials or discretisation in radius. A number of research groups have produced time dependent, three dimensional, self-consistent solutions to the geodynamo problem using this pseudospectral methodology. Computational limitations currently place a practical bound on the parameter regime that can be explored in this context, with values appropriate for Earth out of reach by several orders of magnitude. For the spherically pseudospectral codes, the absence of an efficient Legendre transform is a strong factor contributing to this limitation. As a first step towards alternative computational methods for geodynamo modelling, we have adapted an existing, efficiently parallelised magnetohydrodynamics (MHD) code, originally developed for weakly compressible, turbulent astrophysical MHD problems. The Pencil Code (www.nordita.dk/data/brandenb/pencil-code) is a Cartesian code that uses sixth-order finite differences, applied to "pencils" (i.e. array sections) in the x direction in a cache-efficient way. The domain is tiled in the y and z directions, with the communication of boundary elements handled by Message Passing Interface (MPI). Time stepping is via a third order Runge-Kutta method. The code's modular structure allows a flexible selection of various physical processes and variables, making it easily adaptable for many types of MHD problems, including spherical dynamos. We demonstrate dynamo action driven by thermal convection in a spherical shell of ideal gas, for comparison with Kageyama et al. (Phys. Plasmas, 2, 1421-1431, 1995). More realistic modelling of terrestrial dynamos requires the implementation of Boussinesq or anelastic approximations. We report on our progress in this direction, and initial attempts to reproduce the geodynamo benchmark (Christensen et al., Phys. Earth Planet. Int., 128, 25-34, 2001) by this approach.



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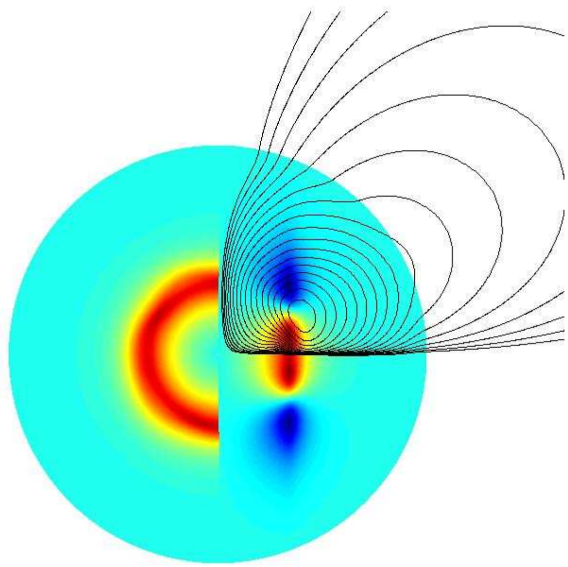
Quasi-geostrophic dynamos

Nathanael Schaeffer, LGIT Grenoble

Taking advantage of the properties of liquid metals and of rapidly rotating flows, we are able to compute dynamos at high Reynolds number ($Re > 100000$) and low magnetic Prandtl number ($Pm < 0.01$)

We developped a numerical model that uses a quasi-goestrophic approximation to compute the flow (whithout subgrid scale model), leading to two-dimensional equations. The induction equation for the magnetic field is fully resolved in 3D, in a sphere. This approach proves quite efficient for low magnetic Prandtl number and suitable flows, for which there is a scale separation between magnetic field and velocity field, allowing to compute the magnetic field on a coarser grid and whith larger time steps than for the velocity field. We show results of these calculations applied on the turbulent flow produced by the destabilization of a Stewartson shear layer



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Is there a small-scale dynamo in low-Pm MHD?

Alexander Schekochihin , University of Cambridge

We report a series of numerical simulations showing that the critical magnetic Reynolds number Rm_c for the nonhelical small-scale dynamo depends on the Reynolds number Re. Namely, the dynamo is shut down if the magnetic Prandtl number $Pm = Rm/Re$ is less than some critical value Pm_c even for Rm for which dynamo exists at $Pm > 1$. We argue that, in the limit of $Re- > infinity$, a finite Pm_c may exist. The second possibility is that $Pm_c- > 0$ as $Re- > infinity$, while Rm_c tends to a very large constant value inaccessible at current resolutions. If there is a finite Pm_c, the dynamo is sustainable only if magnetic fields can exist at scales smaller than the flow scale, i.e., it is always effectively a large-Pm dynamo. If there is a finite Rm_c, our results provide a lower bound: $Rm_c > 220$ for $Pm < 1/8$. This is larger than Rm in many planets and in all liquid-metal experiments

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A Hybrid Approach to Magnetic Holes

Bryan Simon , University of Warwick

Magnetic Holes (MH) are isolated dips in magnitude in an otherwise unperturbed magnetic field. Their study has attracted a great deal of attention in recent years following an influx in data from new space missions. To model MHs, we use a hybrid code, which treats the electrons as a Hall-MHD fluid, but retains ion particles to accommodate kinetic effects. As part of ongoing investigations, we use the code to explore the possibility of obliquely propagating Alfvén waves or fast magnetoacoustic waves developing into stable slow moving structures in high-β, mirror stable plasmas that fit recent satellite data. Parametric studies of the MH evolution were performed and compared with observational data.

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Absolute and convective instabilities of circularly polarized Alfvn waves: Decay instability

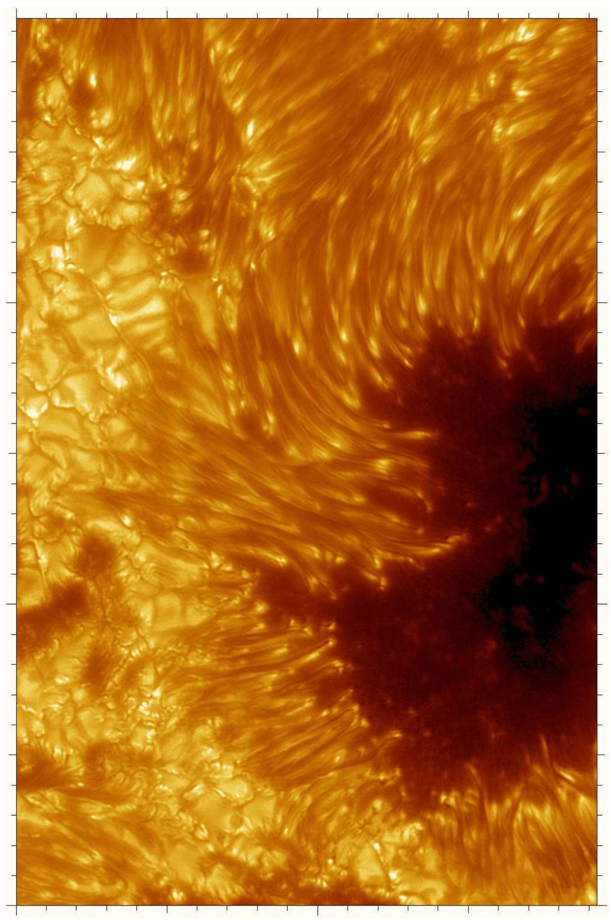
David Simpson, University of Sheffield

The absolute and convective instabilities of a circularly polarized Alfvn wave propagating parallel to the ambient magnetic field are studied. We impose the restriction that the plasma beta is less than 1 and that the amplitude of the wave, a, is small in order to make analytical progress. We find an interval for the velocity of the reference frame with respect to the rest plasma where the wave absolutely unstable. When the wave is convectively unstable we show that spatially amplifying waves exist in two symmetric frequency bands of order a. The implication of the results on the interpretation of observational data is discussed.

Magnetoconvection in the penumbra of a sunspot

Stephen Thompson , University of Cambridge

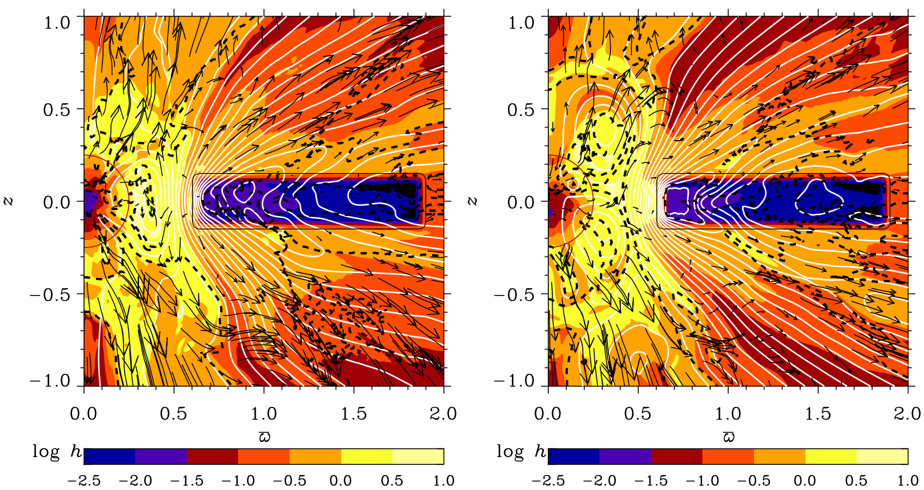
Recent high resolution observations of sunspots have shown their structure and magnetic field configuration in unprecedented detail. The penumbra, with its tilted field lines and complex interlocking-comb structure, is particularly challenging to model. This work begins with a simple linearised model of magnetoconvection in an inclined field, before moving on to more detailed, nonlinear, calculations.



MHD simulations of dynamo driven stellar and disc winds

Brigitta von Rekowski , Department of Astronomy Space Physics, Uppsala University

Magnetohydrodynamic (MHD) simulations have been carried out of a physical model to study accretion processes and outflows in a global system comprised of a central object and a surrounding cool dense accretion disc embedded in a hot rarefied corona. The model is applied to a protostellar star–disc system. Both the star and the disc have mean-field dynamo activity, and these dynamos are considered to be the only mechanism for the generation and maintenance of the entire magnetic field in the star–disc system. Using this magnetic dynamo model, the outflow structure and the wind driving mechanisms as well as the accretion flow and accretion rates are studied. In order to address the question of stellar spin-down or spin-up, the accretion and magnetic torques exerted on the star are calculated. The results of the axisymmetric numerical computations (cf. Fig.1) are compared with first results obtained in three dimensions.



caption of Fig.1: Poloidal velocity vectors (black) and poloidal magnetic field lines (white) superimposed on a colour scale representation of log10(h) at times of about 1171 days (LEFT) and about 1183 days (RIGHT). Specific enthalpy h is directly proportional to temperature T, and log10(h)=(-2,-1,0,1) corresponds to T approx. (3x103,3x104,3x105,3x106) K. The black dashed line shows the surface where the poloidal velocity equals the Alfvén speed from the poloidal magnetic field. The accretion disc boundary is shown with a thin black line, and the stellar surface is marked in red. This is an axisymmetric model where the magnetic field is solely generated and maintained by mean-field dynamos that are active in both the star and the surrounding accretion disc. The model is applied to a protostellar star–disc system. The resulting symmetry of the disc dynamo generated magnetic field is roughly dipolar whereas the stellar dynamo generates a field that switches periodically with time between dipolar (LEFT) and quadrupolar (RIGHT) symmetry.

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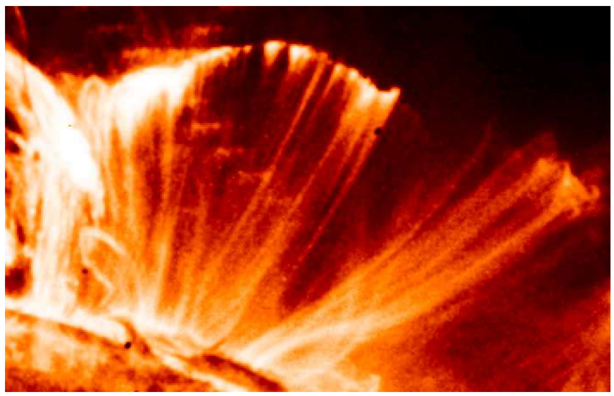
Transverse oscillations in a coronal loop arcade

Erwin Verwichtee , University of Warwick

The analysis of TRACE observations of transverse oscillations in a coronal post flare loop arcade are presented. The oscillation parameters for nine loops are deduced as a function of distance along the loop. The oscillations are interpreted as standing fast magnetoacoustic kink oscillations and the coronal magnetic field strength is derived from the phase speed. Furthermore, the relationship between the oscillation decay time and the period is explored, compared with previous observations and is discussed in terms of proposed mechanisms that explain the rapid decay times.



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A three-dimensional, spherical, nonlinear interface dynamo

Keke Zhang, University of Exeter

A fully three-dimensional, nonlinear, time-dependent spherical interface dynamo is investigated using a finite element method based on the three-dimensional tedrahedralization of the spherical system. The spherical interface dynamo model consists of the four zones: an electrically conducting and uniformly rotating core, a thin differentially rotating tachocline, a turbulent convection envelope and a nearly insulating exterior. The four regions are coupled magnetically through the matching conditions at the interfaces. We shall report various results of the fully three-dimensional, nonlinear, kinematic spherical interface dynamos

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Dynamo action driven by three dimensional convective flow with an Ekman layer

Pu Zhang , University of Exeter

The linear and nonlinear dynamo actions in a box have been studied by using a fully three dimensional code. Two different fluid motions are considered: convective flow with and without spiralling shear flow near the bottom boundary. Results from kinematic and dynamic dynamos are compared.

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Magnetic field dissipation during the solar flare 23rd July 2002

Valentina Zharkova , Bradford University

We analyze the SOHO/MDI high-cadence magnetic field variations occurring prior and during the 2002 July 23 flare $2B/X4.8$ and their association with the hard X-ray and H_α emission observed with RHESSI and BBSO. The line-of-sight (LOS) magnetic field variations associated with the flare 23 July 2002 occurred in a bipolar area around the magnetic inversion line, or apparent neutral line (ANL), located with the automated morphological edge detection technique. There were 4 hard X-ray sources observed by RHESSI payload in different energy bands, three of them were associated with magnetic field changes. In the hard X-ray footpoints located on the south-east of the ANL with the strongest negative LOS magnetic field and north-west from the ANL with positive polarity, the irreversible descrease of magnetic field (or increase in absolute value) was measured starting 2 minutes prior the flare, decreasing by 120 G and staying at this level after the flare offset. The magnetic field changes in the whole area were irreversible showing an increase of magnetic flux from 6.7×10^{21} Mx up to 7.9×10^{21} Mx lasting for 6 minutes until 00:30:00 UT when the magnetic field returned to noise fluctuations about the new magnitude. Before the flare occurrence there were 9 pre-existing sources of a strong magnetic field of the positive and negative polarities about 400-600 G and 6 new emerging sources: 2 negative of -580 G and -380 G and 4 positive of 100-160 G which were found to be associated with the 3 hard X-ray footpoints. The emerging negative sources appeared in a close location and at the time when the ANL was moved towards the positive polarity with a speed of 250 km/s. Based on the global magnetic reconnection models, the rates of magnetic field changes (a reconnection rate) deduced from the total area around the ANL and from the area of the hard X-ray footpoint with irreversible changes were found to be about 3.1×10^{18} Mx/s, the average Poynting flux was$5 \cdot 10^{11}$ $erg/cm^2/s$. This resulted in the magnetic energy of $\sim 1.2 \times 10^{31}$ erg released during this flare in one magnetic source associated with the hard X-ray footpoint, which can be increased to $\sim 2.3 \cdot 10^{31}$ erg, if the other two footpoints are taken into account.

Particle acceleration asymmetry in a reconnecting non-neutral current sheet

Valentina Zharkova , Bradford University

Electrons and protons acceleration caused by a super-Dreicer electric field directed along the longitudinal component B_y of magnetic field is investigated. The three-component magnetic field in a non-neutral current sheet occurring at the top of the reconnecting flaring loops on the charged particle trajectories and energies is considered. Particle trajectories in reconnecting current sheet and their energy spectra at the point of ejection from the reconnecting current sheet (RCS) are simulated from the motion equation for different sheet thicknesses. A super-Dreicer electric field of the current sheet is found to accelerate particles to coherent energy spectra in a range of 10 - 100 keV for electrons and 100-400 keV for protons with energy slightly increasing with the sheet thickness. A longitudinal B_y-component was found to define the gyration directions of particles with opposite charges towards the RCS midplane, i.e. the trajectory symmetry. For the ratio $B_y/B_z < 10^{-6}$ the trajectories are fully symmetric that results in particle ejection from a RCS as neutral beams. For the ratio $B_y/B_z > 10^{-2}$ the trajectories completely loose their symmetry towards the RCS midplane leading to the separation of particles with opposite charges into the opposite halves from a RCS midplane and the following ejection into different legs of the reconnecting loops. For the intermediate values of B_y/B_z the trajectories are partially symmetric towards the midplane leading to electrons prevailing in one leg and protons in the other.

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