UKMHD 2026 Meeting Programme

4th June

08:30–09:00 Arrival and badge collection

09:00–09:15 Welcome from Head of School and organisers

09:15–10:00 **Invited Speaker:** Tamara Rogers (Chair: Radostin Simitev)
Bridging MHD and Asteroseismology

Session 1: Convection (Chair: Radostin Simitev)

10:00–10:15 Paraskevi Katsiavria: *Heat transport in rotating, sheared convection*

10:15–10:30 Yue-Kin Tsang: *Oscillatory double-diffusive convection in a rotating spherical shell at high Rayleigh numbers*

10:30–10:45 Martin Gray: *Fingering convection in planetary cores*

10:45–11:00 Luke Gostelow: *The effect of the magnetic field on flow symmetry (and vice-versa) in spherical-shell dynamos*

11:00–11:30 *Tea/Coffee Break*

Session 2: Dynamos (Chair: Rob Teed)

11:30–11:45 Val Aslanyan: *Matching solar differential rotation with dynamo models*

11:45–12:00 Krzysztof Mizerski: *Geomagnetic reversals from non-equilibrium wave turbulence in the Earth's core*

12:00–12:15 Sadokat Malikova: *Non-stationary turbulence and geomagnetic reversals*

12:15–12:30 Francesca Coke: *Weak- and strong-field dynamos in spherical shells of different aspect ratios*

12:30–12:45 Alex Skillen: *Direct numerical simulations of rotating convection-driven dynamos in the plane layer geometry*

12:45–13:00 Jean Kempf: *Dynamo effects in galaxy clusters*

13:00–13:05 Chris Jones: *A tribute to Andrew Soward*

13:05–14:15 *Lunch*

Session 3: Instabilities (Chair: Laura Currie)

14:15–14:30 Jakub Szymankiewicz: *From Turbulence to Large Scale Magnetic Fields: Analytic form of transport coefficients from weak to strong rotation using τ approximation*

14:30–14:45 Zhao Guo: *Tidal dissipation and magneto-inertial modes in rotating stars: exploring various magnetic field configurations*

14:45–15:00 Adrian Barker: *The stability of inertial waves in rotating fluids*

15:00–15:15 Scott Hopper: *MRI and Magnetic Buoyancy in the Solar Tachocline*

15:15–15:30 Stephen D. Griffiths: *A shear-flow instability induced by a localised field in ideal MHD*

15:30–15:45 Sonny Burrell: *Instabilities in Radiative Zones of Stars*

15:45–16:00 Dimitris Ntotsikas: *Three-dimensional magnetic instabilities in two-fluid neutron star cores*

16:00–16:15 Devika Tharakkal: *Shear-driven magnetic buoyancy in the solar tachocline using anelastic MHD models*

16:15–16:45 *Tea/Coffee Break*

16:45–17:30 Poster Session

- Val Aslanyan: *Calculating the Slip Rate of Field Lines in Magnetised Plasmas*
- Erin Goldstraw: *Energy flux decomposition in RMHD*
- Sam Kay: *Analytic, axisymmetric solutions for magnetic switchbacks*
- Rashmi Sarwal: *Wave Propagation in a Horizontally Stratified Two-Layer Polytropic Model*
- Ayesha Sarwar: *Force-balance transitions in dynamos*
- Soham Sanyashiv: *Is convection diffusion-free?*
- Sage Stanish: *Identification of field line topology: Applications to the magnetotail*
- Francis Swan: *The role of magnetic diffusion on the onset of magnetoconvection in a spherical shell*
- Marianna Szambelan: *Interactions between Tidally-Excited Internal Gravity Waves and Magnetic Fields*
- Peter Wyper: *Switchback generation from the evolution of Torsional Alfvén waves*

17:30–18:30 Career chat (in the pub)

19:00 Conference dinner (Fonn Mór in Òran Mór)

5th June

09:00–09:45 Invited Speaker: Ravindra Desai (Chair: David MacTaggart)
Global MHD Modelling of Planetary Magnetospheres

Session 4: Theoretical MHD (Chair: Christopher Osborne)

09:45–10:00 Anthony Yeates: *Energy bounds from relative helicity*

10:00–10:15 Gunnar Hornig: *Revisiting the Parker problem*

10:15–10:30 David MacTaggart: *Magnetic field line slippage rate*

10:30–10:45 Wayne Arter: *Catastrophic MHD theory*

10:45–11:00 Erin Goldstraw: *Tearing Instability Evolution in MHD and RMHD*

11:00–11:30 *Tea/Coffee Break*

Session 5: Magnetic Reconnection (Chair: Val Aslanyan)

11:30–11:45 Sage Stanish: *On turbulent magnetic reconnection: fast and slow mean steady-states*

11:45–12:00 Nick Williams: *Plasma turbulence produced via magnetic reconnection*

12:00–12:15 Alex Russell: *Flux-rope-mediated Turbulent Magnetic Reconnection*

12:15–12:30 Qihui Ming: *Distinct Strong and Weak Shear Regimes of Turbulent Magnetic Reconnection*

12:30–12:45 Jack Reid: *Turbulent magnetic reconnection in braided coronal magnetic fields*

12:45–13:00 Luiz Schiavo: *Wave Generation via 3D Oscillatory Reconnection at a Magnetic Null Point*

13:00–14:15 *Lunch*

Session 6: Solar/astrophysical modelling 1 (Chair: Sage Stanish)

14:15–14:30 Jamie Jones: *The Inverse MHD Problem for Magnetic Fields in Spiral Galaxies*

14:30–14:45 Nicolás Moraga: *Multifluid Effects in Neutron Star Magnetic Evolution*

14:45–15:00 Sergey Belov: *Non-local thermal transport model for solar MHD simulations*

15:00–15:15 Christopher Osborne: *Initial Investigation of Thermal Instability Including Non-Equilibrium Radiative Losses in Solar Coronal Condensations*

15:15–15:30 Ben Snow: *The Solar Atmospheric Modelling Suite: First Release and Next Stages*

15:30–16:00 *Tea/Coffee Break*

Session 7: Solar/astrophysical modelling 2 (Chair: David MacTaggart)

16:00–16:15 Oliver Rice: *Outflow Fields - A potential alternative to potential fields*

16:15–16:30 Ryan Smith: *Fast Magnetoacoustic Wave Behaviour within Gravitationally Stratified, Magnetically Inhomogeneous Media*

16:30–16:45 OPM Aslam: *Photospheric Magnetic Topology and Energy Injection: Key Precursors for a Real-Time Solar Flare Forecasting Framework*

16:45–17:00 Asif Nawaz: *Multistability and Pattern Formation in Liquid Metal Magnetoconvection*

17:00 *Closing Remarks/End of Meeting*

Bridging MHD and Asteroseismology

Tamara Rogers
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Newcastle University

4$^{\text{th}}$ & 5$^{\text{th}}$ June 2026

Abstract

Asteroseismolgy has revolutionised stellar astrophysics with the advent of space missions such as Kepler and TESS and more breakthroughs are expected with ESA's upcoming PLATO mission. With these missions astronomers can infer the properties of stellar interiors, including rotation chemical mixing and, more recently, magnetism. In this talk I will discuss some of the inferences from asteroseismology on internal magnetic elds, some of the shortcomings of these inferences and where dynamo theory and simulations could aid in guiding future asteroseismic measurements.

Heat transport in Rotating, Sheared Convection

Paraskevi Katsiavria, Laura Currie
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4$^{\text{th}}$ & 5$^{\text{th}}$ June 2026

Abstract

Thermal convection plays an important role in astrophysical and geophysical flows. While the effects of rotation and shear on convection have been studied separately, their combined influence remains largely unexplored. Existing theoretical models of rotating convection agree with numerical simulations when zonal flows are weak, but the predictions diverge significantly in strongly sheared regimes — which are particularly relevant to magnetohydrodynamic processes such as stellar and planetary dynamos.

Using a combination of linear analysis and nonlinear numerical simulations, we investigate the interaction between convection, rotation and shear in a plane fluid layer. We explore the parameter space by varying the Rayleigh, Taylor and Reynolds numbers, examining how an imposed shear modifies convective flow structure and influences heat transport across different regimes.

We find that shear initially suppresses convective motions, but beyond a critical shear strength the heat transport increases and large-scale flow structures emerge. These results provide insight into shear-driven dynamics in rotating convection and offer a hydrodynamic foundation for future magnetohydrodynamic studies.

Oscillatory double-diffusive convection in a rotating spherical shell at high Rayleigh numbers

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4^{th} & 5^{th} June 2026

Abstract

We consider oscillatory double-diffusive convection (ODDC) in a rotating spherical shell where the fluid density depends on two scalars: the fast-diffusing temperature and slow-diffusing composition (concentration of a heavy element in the fluid). High temperature and high composition are set up at the inner boundary with gravity pointing inwards. Thus, temperature has a destabilising effect characterised by a Rayleigh number $Ra_T > 0$, whereas composition has a stabilising effect characterised by $Ra_C < 0$. We focus on values of Ra_T much larger than the critical Rayleigh number of pure thermal convection.

For a fixed Ra_T, we investigate the behaviour of the system at different Ra_C. At small $|Ra_C|$, compositional effect is negligible and we observe overturning convection similar to that in the pure thermal case ($Ra_C = 0$). As we gradually turn up the stabilising effect of composition by increasing $|Ra_C|$, the squared buoyancy frequency N_0^2 changes from negative to positive, meaning the equilibrium state changes from top-heavy to bottom-heavy. Surprisingly, the thermal-like overturning convection persists even at some $N_0^2 > 0$. Eventually at large enough $|Ra_C|$, the system undergoes a very sharp transition and displays properties that are fundamentally different from those of pure thermal convection. We shall discuss this transition in details.

Fingering convection in Planetary cores

Martin Gray
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4th & 5th June 2026

Abstract

Double diffusive instabilities can occur in stably stratified fluids when two fields with different diffusivities affect the fluid density. The most well-known examples are from the Earth's oceans, but here we are motivated by planetary cores: in both cases, the density is differentially affected by temperature and composition. We consider the fingering regime of double diffusive convection, where the background temperature gradient is stable but the composition gradient is unstable. We perform hydrodynamic simulations in a rotating thick spherical shell at low Prandtl number, varying the stratification via the thermal and compositional Rayleigh numbers, and varying the influence of rotation via the Ekman number. We focus on the effect of rotation on the dynamics of the system, in particular for large-scale flows."

The effect of the magnetic field on flow symmetry (and vice-versa) in spherical-shell dynamos

Luke Gostelow, Rob Teed
University of Glasgow

4^{th} & 5^{th} June 2026

Abstract

In studying dynamos, a central question is how rapidly swirling convective motions in an electrically conducting fluid can generate a large-scale, long-lived magnetic field. A key part of this process is the impact of the magnetic field on the flow morphology; as the field develops, it promotes larger-scale motions that in turn reinforce its own growth. This feedback is most clearly illustrated by recent studies demonstrating bistability between the so-called weak-field and strong-field dynamo branches,[1] which differ in several properties including their respective degrees of equatorial symmetry.[2]

In the bistable parameter regime identified so far, weak-field convective flows are dominated by a primary equatorially symmetric (magneto-)convective mode.[3] As the flow transitions into a strong-field state, however, the single dominant mode breaks down and the magnetic field strength increases, which can lead to the emergence of a wider set of convective modes, including anti-symmetric modes. By comparing magnetoconvection and dynamo simulations, we examine the properties of the anti-symmetric modes that onset near this transition and discuss their potential role both in sustaining the strong-field branch in simulations and in the broader operation of the geodynamo.

References

[1] Dormy, E., "Strong-field spherical dynamos," *Journal of Fluid Mechanics*, Vol. 789, 2016, pp. 500–513.

[2] Gostelow, L. J. and Teed, R. J., "Magnetoconvection in a spherical shell: Equatorial symmetry during the transition from the weak-to the strong-field regime," arXiv:2603.08261.

[3] Teed, R. J. and Dormy, E., "Toward scale-separated weak-field spherical dynamos," *Physical Review Fluids*, Vol. 10, No. 10, 2025, pp. 103702.

Matching Solar Differential Rotation with Dynamo Models

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4$^{\text{th}}$ & 5$^{\text{th}}$ June 2026

Abstract

Helioseismic inversions show homogeneous rotation in the radiative core of the sun and strongly varying differential rotation in its convection zone. Models of the solar dynamo, which self-consistently reproduce phenomena such as the sunspot cycle achieve varying success in also reproducing the differential rotation profile. We present metrics to evaluate the accuracy of a given model in this respect, and apply them to recent studies. We present parameter scans which optimize the differential rotation in an anelastic magnetohydrodynamic model.[1]

References

[1] Featherstone, N. A., Edelmann, P. V. F., Gassmoeller, R., Matilsky, L. I., and Wilson, C. R., "Rayleigh 1.2.0," 2024.

Geomagnetic reversals from non-equilibrium wave turbulence in the Earth's core

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4th & 5th June 2026

Abstract

We investigate the effect of statistically non-stationary turbulence in the Earth's outer core on the effective turbulent electromotive force generated by the convectively driven flow of liquid iron and the evolution characteristics of the geomagnetic field. The non-stationarity means that interactions of distinct waves are crucial, and the effect of beat induces a slow time variation of the large-scale electromotive force. This provides an attractive and fairly simple physical mechanism for the random appearance of short-lived geomagnetic excursions and reversals separating long periods of relatively stable field, through non-synchronized evolution of the amplifying α-effect and turbulent diffusion. This implies rare and random appearance of simultaneous suppression of the α-effect and enhancement of diffusion which leads to a sudden magnetic energy drop, i.e. an excursion. The turbulent field of what is termed MAR waves (Magnetic-Archemedean-Rossby) is analysed. The dispersion relation and structure of such waves involving the joint effect of the Lorentz, buoyancy, and Coriolis forces together with curvature of the core-mantle boundary are obtained and utilized for estimation of the non-stationary electromotive force in the core. The solutions for the large-scale dipole possess an Earth-like behaviour, magnitude, and timescales, and the physical mechanism of the process, including identification of two dynamically important parameters, is discussed. Similar ideas concerning the dynamics of waves within the so-called Stratified Ocean at the top of the Core (SOC) are also considered. The SOC is an important but thin, strongly stratified layer near the core-mantle boundary, and here, both, the possibility of global non-equilibrium dynamo mechanisms and those localized within the SOC are analysed. It is possible that the surface and bulk mechanisms coexist in the core, both adding to the complexity of the observed picture of reversal occurrences (cf.[1–3]).

A selected solution for the evolution of the geomagnetic energy throughout a period of one million yeras, with one reversal/excursion occurence is shown on figure 1.

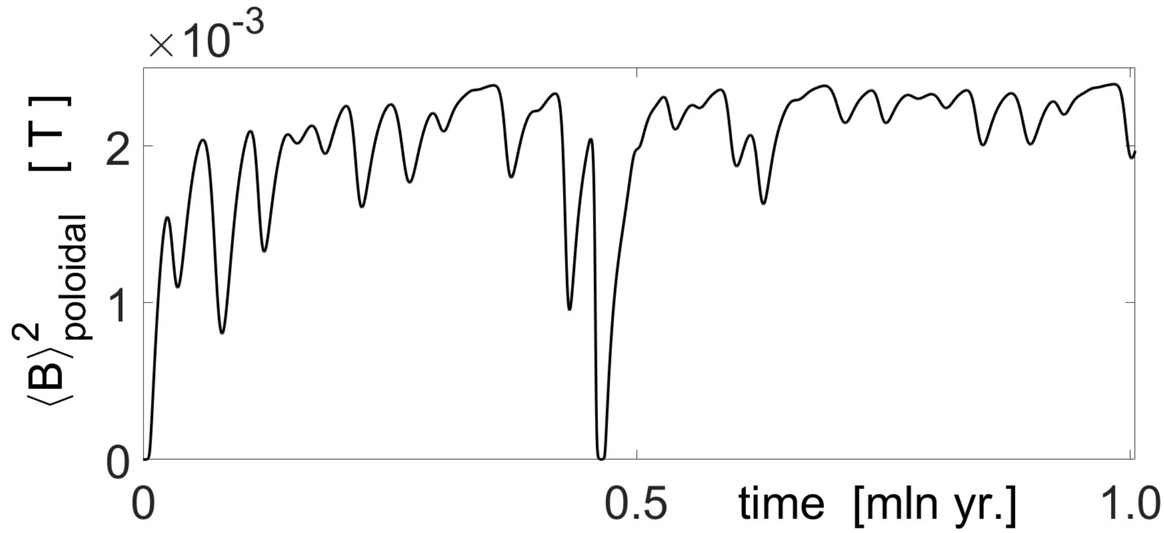

Figure 1: Evolution of the energy of the poloidal magnetic field in the Earth's core. The short-lived, lasting for $\sim 10^4\, yrs$, drop of the magnetic energy indicates strong geomagnetic excursion. The stable periods, are characterized by the field intensity at the level $\langle \mathbf{B} \rangle \sim 10^2\, G$.

References

[1] Mizerski, K. A., *Non-equilibrium hydromagnetic dynamos*, IOP Publishing, Bristol, UK, 2023.

[2] Mizerski, K. A., "Geomagnetic reversals and excursions as an outcome of non-equilibrium wave-turbulence and beating MAC waves in the core," *J. Geoph. Res.: Solid Earth*, Vol. 130, 2025, pp. e2024JB030679.

[3] Mizerski, K. A., "Geomagnetic reversals and excursions as an outcome of non-equilibrium bulk turbulence in the Earth's core," *Geoph. J. Int.*, Vol. 244, 2026, pp. 1–19.

Non-stationary turbulence and geomagnetic reversals in mean-field dynamo models

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4th & 5th June 2026

Abstract

We simulate the evolution of the large-scale magnetic field in a three-dimensional mean-field dynamo model to investigate the role of non-stationary turbulence and modal interactions in geomagnetic reversals. The model is based on the theoretical framework of Mizerski,[1,2] where interactions of Magnetic–Archimedean–Coriolis (MAC/MAR) waves lead to temporal variability of the large-scale electromotive force. We solve the mean-field induction equation using Dedalus,[3] incorporating dynamically quenched α-effect, turbulent diffusivity, and a prescribed shear flow, where the non-equilibrium components are modulated through time-dependent frequencies. We perform simulations with an increasing number of temporal modes in the non-stationary transport coefficients and analyse the resulting magnetic field evolution. In low-mode cases, the dynamo exhibits regular, nearly periodic cycles. As the number of modes increases, the system transitions to a quasi-periodic regime with modulated amplitudes, shortened reversal durations, and increased variability in cycle timing. In the most resolved case, the field shows irregular reversals. We find that shear sets the fundamental cycle period, while multi-mode interactions introduce non-stationarity, leading to irregular reversals. These results support the interpretation that geomagnetic variability arises from intrinsic nonlinear dynamics of a non-stationary turbulent dynamo.

References

[1] Mizerski, K. A., "Possible Role of Non-Stationarity of Magnetohydrodynamic Turbulence in Understanding of Geomagnetic Excursions," *Symmetry*, Vol. 13, No. 10, 2021.

[2] Mizerski, K. A., "Geomagnetic reversals and excursions as an outcome of non-equilibrium bulk turbulence in the Earth's core," *Geophys. J. Int*, Vol. 244, No. 2, 2026, pp. 1–16.

[3] Burns, K. J., Vasil, G. M., Oishi, J. S., Lecoanet, D., and Brown, B. P., "Dedalus: A Flexible Framework for Numerical Simulations with Spectral Methods," *Physical Review Research*, Vol. 2, No. 2, Apr 2020, pp. 023068.

Weak- and strong-field dynamos in spherical shells of different aspect ratios

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4^{th} & 5^{th} June 2026

Abstract

Earth's inner core has been growing since its nucleation, and throughout this time the electrically conducting fluid outer core has sustained a convection driven dynamo providing Earth with a magnetic field. Numerical models with an inner/outer core aspect ratio appropriate for the present-day geodynamo have produced two distinct dipolar branches of solutions in parameter space: the viscously-dominated "weak-field" regime and the magnetically-dominated "strong-field" regime.[1] The strong-field regime, expected to be operating in Earth's core, can be classified by a measure of the Lorentz force compared to the Coriolis force, the "Elsasser number". Regions of bistability between the strong- and weak-field regime exist[2] across a range of parameter values in models appropriate for present-day Earth. It is easier to drive a dynamo with a larger aspect ratio,[3] however, the existence of dipole-dominated solutions becomes constrained by the geometry, and multipolar dynamos are preferred.[4] In this work, through numerical simulations, we investigate whether bistability between the strong- and weak-field regimes exists in models of Earth with a varying aspect ratio. Provided the magnetic diffusivity is low enough, dipolar dynamos can persist in large aspect ratio shells.

References

[1] Dormy, E., "Strong-field spherical dynamos," *Journal of Fluid Mechanics*, Vol. 789, 2016, pp. 500–513.

[2] Teed, R. J. and Dormy, E., "Scaling of strong-field spherical dynamos," *Geophysical Research Letters*, Vol. 52, No. 20, 2025, pp. e2025GL118078.

[3] Heimpel, M., Aurnou, J., Al-Shamali, F., and Perez, N. G., "A numerical study of dynamo action as a function of spherical shell geometry," *Earth and Planetary Science Letters*, Vol. 236, No. 1-2, 2005, pp. 542–557.

[4] Goudard, L. and Dormy, E., "Relations between the dynamo region geometry and the magnetic behavior of stars and planets," *Europhysics Letters*, Vol. 83, 2008, pp. 59001.

Direct numerical simulations of rotating convection-driven dynamos in the plane layer geometry.

Alex Skillen
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Krzysztof Mizerski
Polish Academy of Sciences, Warsaw, Poland.

4th & 5th June 2026

Abstract

Direct numerical simulations of rotating convection-driven dynamos in a plane layer geometry have been conducted at an Ekman number of $E = 10^{-5}$ and a reduced Rayleigh number of $\widetilde{Ra} \equiv E^{4/3}Ra = 64.6$. The thermal and magnetic Prandtl numbers are set to $Pr = 1$ and $Pm = 0.1$, respectively.

The momentum and induction equations are discretised via the spectral element method and solved within a $2 \times 2 \times 1$ domain comprising 200,000 macro-elements at 9th-order polynomial resolution. The velocity boundaries are stress-free, with a pseudo-vacuum condition applied to the magnetic field.

Our initial results demonstrate the formation of a Large-Scale Vortex (LSV) (Figure 1), driven by the inverse energy cascade characteristic of low Ekman number convection with stress-free walls. Domain-averaged energy histories (Figure 2) indicate that the ongoing simulations are currently in the pre-saturation kinematic phase; the kinetic energy has plateaued into the LSV state. The LSV is starting to quench from the action of the Lorentz force, while the magnetic energy is undergoing exponential growth.

The full presentation will feature extended time integrations as the dynamo matures toward saturation. We will also present a detailed analysis of the energy budgets, topological helicity, and the temporal evolution of the horizontal mean magnetic fields.

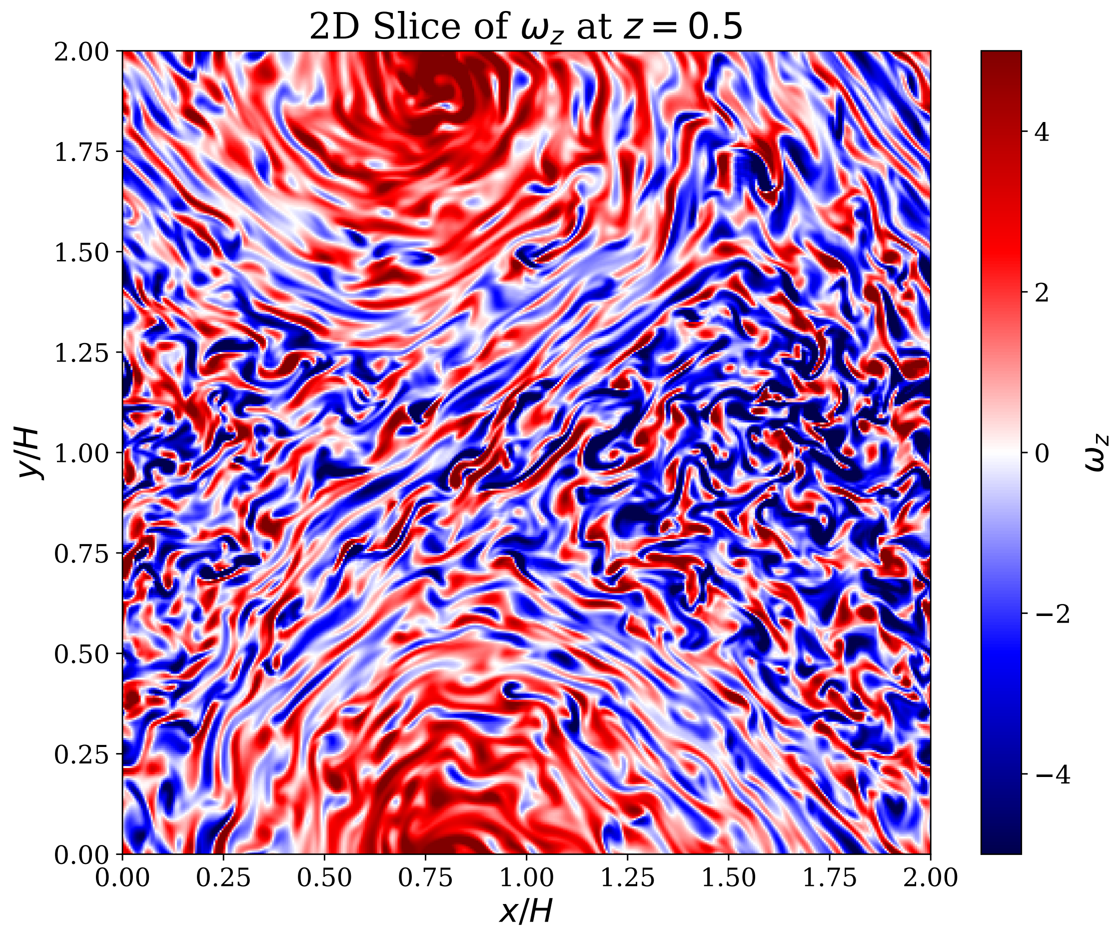

Figure 1: Z-Vorticity in the midplane showing the formation of a large scale vortex due to the inverse cascade.

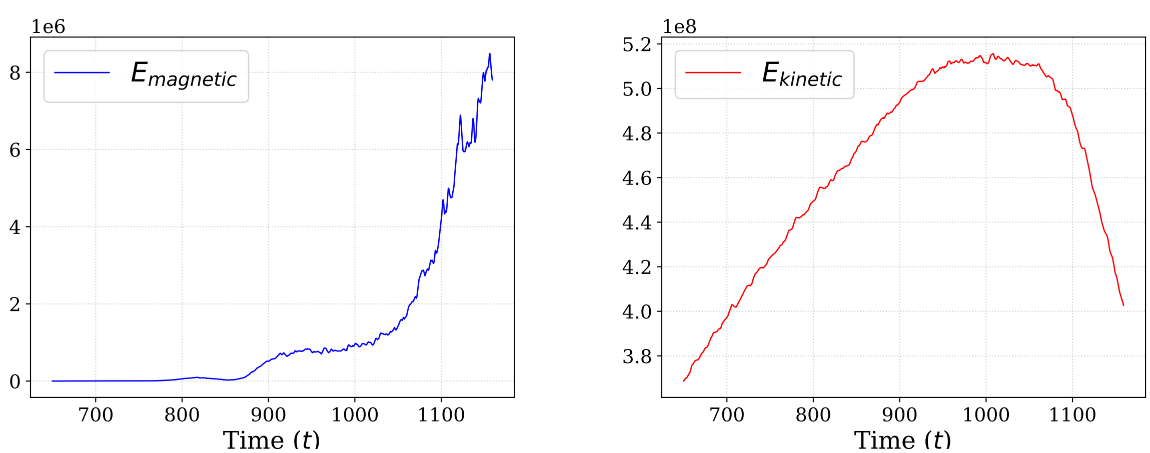

Figure 2: Domain average magnetic energy (left) and kinetic energy (right) at the initial growth phase of the dynamo.

Dynamo effects in galaxy clusters

Jean, Maël Kempf & François Rincon
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4th & 5th June 2026

Abstract

The origin of cosmic magnetism remains so far an open question. The intracluster medium – the very hot and tenuous baryon gas trapped within galaxy clusters – could have played a critical role in that respect. Indeed, clusters may be the first place in the Universe where magnetic fields would have been generated and amplified.

In this talk, I will introduce a 3D global spherical model of stratified intracluster medium, based on the Braginskii-MHD equations (i.e. with anisotropic diffusion along magnetic field lines only). This model will enable the study of diverse configurations of a small-scale fluctuation dynamo effect. Thus, two forcing modes will be considered, according to the stability or the instability of buoyant perturbations ; two types of viscosity (isotropic and/or anistropic) will also be examined. Despite the diversity of non-linear processes accounted for and their possible interplay, I will characterise as much as possible the resulting dynamo effects. The critical parameters of the flow for the onset of such effects will be highlighted, as well as the various complex spatial structures of the emerging magnetic fields.

To conclude, I will put back these theoretical results into their astrophysical and observational context, mentioning at the same time the possible synergies with the futur big observatories NewAthena/X-IFU and SKA.

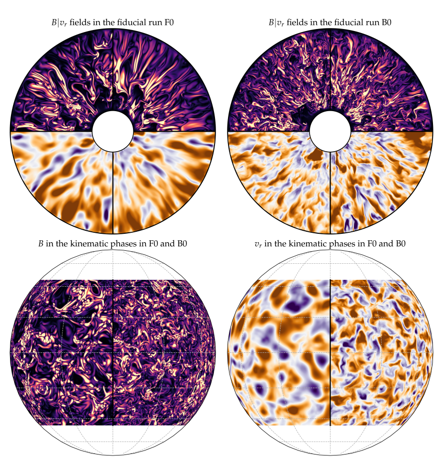

Figure 1: Multiple visualisations of the magnetic strength and radial velocity.

From Turbulence to Large Scale Magnetic Fields: Analytic form of transport coefficients from weak to strong rotation using τ approximation.

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4th & 5th June 2026

Abstract

We present an analytical calculation of the large-scale electromotive force (EMF) and associated transport coefficients within the framework of mean-field magnetohydrodynamics (MHD). Utilizing the τ-approximation as a closure for the statistical moments equations, we investigate the influence of the Coriolis force on the turbulent dynamo action. Our derivation focuses on the regime of weak large-scale magnetic fields, providing explicit expressions for the transport coefficients in two distinct rotational limits: (i) the limit of weak rotation, and (ii) the fully nonlinear contribution of arbitrary rotation rates. We demonstrate how the Coriolis force induces significant anisotropy in the α-effect and influences turbulent transport coefficients. These analytical expressions provide a practical way to model magnetic field evolution in natural dynamos, such as the Sun and the Earth, valid from weak to strong rotation limits.

Tidal dissipation and magneto-inertial modes in rotating stars: exploring various magnetic field configurations

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Abstract

We investigate the tidal dissipation in the convective envelope of stars using a linear model of magnetized, uniformly rotating, incompressible fluid in a spherical shell. We compute both the complex eigenfrequency spectrum and the frequency-dependent tidal dissipation in the corresponding forced problem. We focus in particular on the origin of resonance peaks and on the structure of eigenmodes responsible for the response beyond the inertial range.

For dipole backgrounds, the spectrum outside the inertial range is dominated by fast magneto-Coriolis/Alfvénic modes that organize into regular families. The eigenfrequencies form distinct branches labelled by radial order, with an approximately constant inter-branch spacing $\Delta\omega_r$. Within each branch, a dense ladder of modes is produced by successive horizontal orders, yielding an intra-branch spacing $\Delta\omega_\theta$. The least-damped modes in these families are strongly trapped in polar caps, forming Alfvénic waveguides whose cavity size controls the intra-branch spacing. A WKB/Alfvén dispersion model quantitatively accounts for both inter- and intra-branch spacings and their dependence on magnetic strength and shell geometry. Mode damping rates inferred from energy budgets agree with eigenvalue solutions and scale approximately as $|\omega_i| \propto \omega_r^2$. In the forced problem, resonance peaks in the dissipation align closely with these eigenfrequencies; because the dipole spectrum extends well beyond the inertial range and remains densely populated, the dissipation decreases only gradually for $\omega/\Omega_{rot} > 2$.

In contrast, for a Malkus-type purely toroidal field, the magneto-inertial spectrum is effectively capped near the inertial band and exhibits only weak leakage beyond $\omega/\Omega_{rot} = 2$. As a result, forcing frequencies outside the inertial range are strongly detuned from available modes, leading to a rapid decline of the dissipation with forcing frequency. We quantify how the transition between these behaviours depends on the Lehnert number Le, shell aspect ratio α, and diffusivities.

Our results provide a physically interpretation of magnetically extended tidal dissipation and suggest that in low-diffusivity (astrophysical) regimes, even relatively weak large-scale fields can significantly modify the frequency dependence of tidal dissipation beyond the inertial range.

References

The stability of inertial waves in rotating fluids

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4$^{\text{th}}$ & 5$^{\text{th}}$ June 2026

Abstract

Inertial waves transport energy and momentum in rotating (and magnetised) fluids and are a major contributor to mixing and tidal dissipation in Earth's oceans, planetary cores, giant planet envelopes and stellar interiors. However, their stability and breakdown mechanisms are not fully understood. I will present some recent joint work[1] examining the linear stability and nonlinear breakdown of finite-amplitude propagating plane inertial waves using Floquet theory and direct numerical simulations. Our analysis generalizes previous studies by being valid for arbitrary perturbation wavelengths and primary wave amplitudes. We find that the wave vector orientation of the most unstable perturbations depends strongly on the wave frequency and weakly on the wave amplitude. The most unstable perturbations have wavelengths that are small relative to the primary wave wavelength for low wave amplitudes, but become comparable for large wave amplitudes. Direct numerical simulations following the nonlinear breakdown of the wave reveal how wave energy is either dissipated in a forward cascade or accumulated into long-lived geostrophic modes. The conversion efficiency into geostrophic modes increases with increasing wave amplitude, as expected for pumping of geostrophic modes by nearly-resonant triadic interactions. We also find that the conversion efficiency increases with decreasing primary wave frequency, which may be due to the more efficient coupling of quasi-2D waves to geostrophic modes. These results on the stability and breakdown of single plane inertial waves provide an additional foundation for understanding the role of inertial waves in rotating (and magnetised) turbulence, transport properties of inertial wave beams, and inertial wave propagation in more complex environments, such as those with magnetic fields or shear flows.

References

[1] Skoutnev, V., Astoul, A., and Barker, A. J., "Stability of propagating plane inertial waves in rotating fluids," *Physical Review Fluids*, Vol. 11, No. 2, Feb. 2026, pp. 024802.

MRI and Magnetic Buoyancy in the Solar Tachocline

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4th & 5th June 2026

Abstract

It is widely believed that magnetic buoyancy is acting within the solar tachocline, often attributed as the mechanism by which magnetic flux is transported to the surface. Magnetorotational instability (MRI) is also thought to be occurring within the tachocline on account of the strong radial and latitudinal shear there. Recently, it has been suggested that the interaction of these two instabilities could be responsible for the lack of sunspots observed above $\sim \pm 30^\circ$ latitude on the solar surface,[1,2] the argument being that the radial shear in the tachocline is of the "correct sign" for MRI above this latitude, and hence MRI may well be disrupting the ordered field required for magnetic buoyancy there. Recent simulations[3,4] have examined the possible contribution of magnetic buoyancy to the solar dynamo by winding up a non-uniform horizontal field with a shear and a vertical field within a rotating system. We build upon this work, and show that MRI can actually co-exist with magnetic buoyancy.

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A shear-flow instability induced by a localised field in ideal MHD

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4th & 5th June 2026

Abstract

An important paradigm problem in astrophysical fluid dynamics is determining the linear stability of a parallel shear flow with an aligned magnetic field. For normal-mode disturbances and within the approximation of ideal two-dimensional MHD, it is well known that flows that are hydrodynamically unstable can be stabilised by adding a magnetic field that is everywhere sufficiently strong. However, flows that are hydrodynamically stable can be destabilised by adding a magnetic field with a carefully chosen strength and cross-stream profile, leading to a so-called joint instability.[1] For the Sun, where the differential rotation profile is thought to be hydrodynamically stable, it has been demonstrated numerically that a joint instability is possible when potentially realistic magnetic field profiles are imposed.[2,3]

Here we investigate a marvellously simple joint instability that arises when a localised magnetic field is embedded within a shear layer, without background rotation, in Cartesian geometry. For a particular choice of field (Witch of Agnesi) and flow (uniform shear), it is possible to conduct an asymptotic analysis in the limit of strong yet narrow field. Despite the simplicity of the configuration, the asymptotic analysis turns out to be 'rather' complicated, with matching required across four regions and unexpected fractional scalings. The outcome is an explicit analytical prediction for the growth rate and wavenumber of the most unstable mode, which agree with numerical results. The possible relevance of this joint instability to the dynamics of the solar tachocline will be discussed, thus making a link to earlier studies.[2,3]

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Instabilities in Radiative Zones of Stars

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4$^{\text{th}}$ & 5$^{\text{th}}$ June 2026

Abstract

Hydrodynamic instabilities arising in differentially rotating fluids in stellar radiative zones are studied in the presence of buoyancy forces due to both thermal and chemical composition gradients. These instabilities may lead to turbulence, which can have an impact on angular-momentum transport and chemical mixing in stars. Our local Cartesian Boussinesq model incorporates the effects of viscous, thermal and chemical diffusion processes. We perform a linear stability analysis of axisymmetric modes under stabilising thermal and chemical compositional stratification. We rediscover that the presence of a stabilising chemical composition gradient significantly modifies or suppresses the Goldreich-Schubert-Fricke (GSF) instability, which is a diffusive instability of differential rotation previously studied without compositional gradients (see also Knobloch and Spruit, 1983). Our model exhibits the GSF instability, an oscillatory Axisymmetric BaroClinic Diffusive (ABCD) instability, a triply diffusive instability and various adiabatic instabilities depending on the parameter regime.

We draw similarities between these instabilities and ones arising in oceanography, such as salt-fingering convection and oscillatory double-diffusive convection (Garaud, 2021).

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Three-dimensional magnetic instabilities in two-fluid neutron star cores

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4th & 5th June 2026

Abstract

We investigate the stability of mixed poloidal–toroidal magnetic field configurations in neutron-star cores using fully three-dimensional, nonlinear two-fluid magnetohydrodynamic simulations [1], with realistic background profiles drawn from the HHJ equation of state [2]. Focusing on a reference model with $\mathrm{A_m} = 10^{-4}$, $\mathrm{R_m} = 100$ and initial toroidal energy $E_{\rm tor} = 0.2E_{\rm total}$, we identify a clear five-stage evolution and characterize the onset, exponential growth and saturation of a non-axisymmetric instability driven by ambipolar diffusion.

Two-fluid model.

We treat the neutron star core as two fluids coupled by collisional drag: a charged component (protons and electrons, electromagnetically locked) and a neutral component (neutrons). Magnetic stresses act directly only on the charged fluid; their influence on the neutrons is mediated by inter-fluid friction. The relative drift between the two components (ambipolar diffusion) is the dominant channel for magnetic flux evolution in mature neutron star [3, 4]. In dimensionless form, the momentum equation for fluid $s \in \{c, n\}$ reads [1]:

$$\mathrm{A_m}\, \rho_s\, \partial_t \mathbf{u}_s = -\rho_s \nabla\delta\mu_s + \delta_{sc}\, \mathbf{J}\times\mathbf{B} + \gamma_{np}\rho_c\rho_n\, (\mathbf{u}_{\bar{s}} - \mathbf{u}_s) + \mathbf{F}_{\nu,s}, \quad (1)$$

with $\mathbf{J} = \nabla\times\mathbf{B}$, $\delta_{sc} = 1$ for the charged fluid and 0 for the neutrons, and $\bar{s}$ denoting the opposite species. The Lorentz force therefore acts only on the charged fluid, and the drag couples the two with opposite sign. The induction equation,

$$\partial_t \mathbf{B} = \nabla\times(\mathbf{u}_c\times\mathbf{B}) + \mathrm{R_m}^{-1}\nabla^2\mathbf{B}, \quad (2)$$

involves only the charged fluid velocity; the system is closed by $\nabla\cdot(\rho_s\mathbf{u}_s) = 0$. The system is evolved with the spectral framework `Dedalus` 3 in a spherical geometry, starting from an axisymmetric mixed poloidal–toroidal equilibrium seeded with random non-axisymmetric perturbations of amplitude $10^{-4}B_0$.

Energy evolution.

Figure 1 reveals five phases: *(I) acceleration* — relaxation into two-fluid force balance, with both kinetic energies rising rapidly; *(II) slow resistive redistribution* — $E_m^{\rm tor} \to E_m^{\rm pol}$, with the non-axisymmetric energy damped by an order of magnitude, sharpening the subsequent onset; *(III) instability* — $E^{\rm mag}_{\rm nonax}$ grows exponentially across seven decades at $\gamma_{\rm fit}\tau_A \simeq 0.24$, a factor of two below the purely-poloidal benchmark $\gamma\tau_A = 0.5$ [1]; *(IV) magnetic turbulence* — mode coupling arrests the growth, kinetic energies peak near 10^{-2}, and the charged–neutral gap narrows as the Lorentz force directly accelerates the charged fluid; and *(V) resistive decay* — monotonic decay under Ohmic and ambipolar dissipation. The work extends this benchmark to a parameter survey in $(\mathrm{A_m}, \mathrm{R_m}, E_{\rm tor})$.

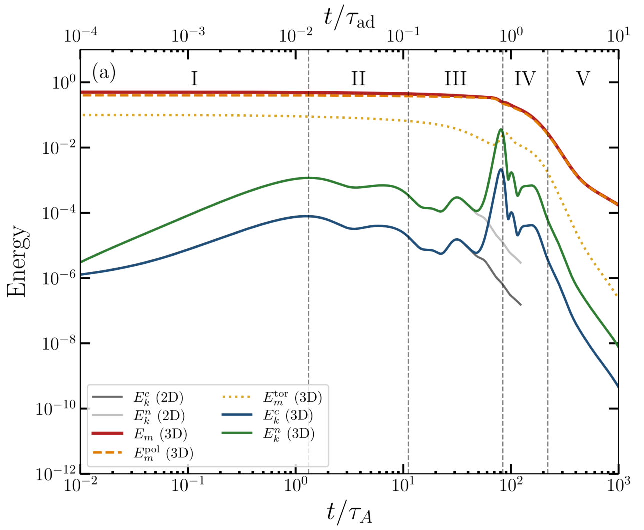

Figure 1: Magnetic and kinetic energies. The 3D and 2D kinetic curves diverge at the onset of stage III, isolating the non-axisymmetric contribution. Vertical dashed lines mark the five evolutionary phases (I–V).

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Shear-driven magnetic buoyancy in the solar tachocline using anelastic MHD models

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4th & 5th June 2026

Abstract

The complex nature of the dynamo that sustains and drives the Sun's magnetic cycle is not completely understood. While differential rotation supports the large-scale toroidal magnetic field generation, there is some evidence suggesting that cyclonic convection (α-effect) may not fully account for the generation of large-scale poloidal fields. We explore magnetic buoyancy instability (MBI) as a potential alternate mechanism to support the helical twisting of the toroidal fields and completion of the dynamo cycle. Previous studies have investigated the effect of MBI in solar-like models, using imposed and shear-generated magnetic layers in the absence of rotation, providing insight into the mechanism and parameter ranges over which MBI is excited. Recently, Duguid et al.[[1,2]] studied MBI, including the effects of rotation, using three-dimensional, compressible magnetohydrodynamical (MHD) models in a local Cartesian box with a forced shear flow. Here, the shear-generated magnetic layer was susceptible to MBI and produced significant electromotive forces. We extend this study to a global model by solving the three-dimensional anelastic MHD equations for an ideal gas in a rotating spherical shell with a toroidal shear flow using the pseudo-spectral code MagIC. We maintain the hydrodynamic stability of the system with an external volumetric force to oppose the toroidal flow. To study MBI, we seed the system with a weak poloidal field, which produces strong toroidal magnetic fields through differential rotation. In this ongoing work, we carefully investigate scenarios in which this shear-generated magnetic layer can lead to MBI and study potential signatures of the MBI-driven dynamo in a solar tachocline-like model.

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Calculating the Slip Rate of Field Lines in Magnetised Plasmas

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4th & 5th June 2026

Abstract

Magnetised plasmas in the laboratory and space are frequently studied with the paradigm of ideal magnetohydrodynamics, whereby matter is frozen-in to magnetic field lines. In recent years, expressions have been derived for a "slip vector"[1,2] indicating the nonideal movement of field lines relative to the background fluid. We have made public a tool – `USlip`, a Universal Slippage calculator[3] – which allows slip vector fields to be rapidly calculated from a magnetic field, defined by a user numerically or loaded directly from a range of high performance codes. We demonstrate that the slip vector computed by our tool from simulations of both the continuous, long-term magnetic reconnection occurring in the corona, as well as rapid transient events such as solar eruptions, does indeed correspond to the nonideal motion of field lines. Thus, regions of interest in studies of magnetic reconnection can be more easily identified.

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Energy flux decomposition in RMHD

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4th & 5th June 2026

Abstract

Complex dynamics of a broad range of astrophysical, industrial plasmas and magnetofluids are well described by the MHD equations. However, due to this inherent complexity, further assumptions are often required to gain results with available resources.

A common feature of many plasmas is a strong magnetic field. One approximation that uses this assumption is called Reduced MHD (RMHD).[1] This model is described as a non-linear, low-frequency incompressible approximation to 3D compressible MHD. It illustrates many known features of the strong mean-field limit of MHD, but clearly cannot capture the full picture. Which dynamical processes are fully and correctly described and which are neglected?

To identify the physical processes governing turbulent energy cascades that are retained in RMHD, we leverage an energy flux decomposition, that has recently been extended from hydrodynamics[2] to MHD.[3] This technique provides a clear framework to identify the processes present in 3D incompressible MHD turbulence by splitting the energy flux into sub-fluxes that originate from vortex stretching, strain self-amplification, current-sheet thinning or current-filament stretching, and to quantify their contribution to the energy cascade.

This framework is applied to the RMHD equations to identify the physical processes that are captured at leading order. We consider the general case of RMHD, when parallel fluctuations are retained which is the case for a high-β approximation.

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Analytic, axisymmetric solutions for magnetic switchbacks

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4th & 5th June 2026

Abstract

Magnetic switchbacks are high-amplitude, Alfvénic structures in the solar wind and are of great current interest. While we have known of their ubiquitous existence within 0.2 AU of the Sun since the launch of Parker Solar Probe (PSP) in 2018, their true origins are still unknown. Leading theories suggest that the effects of torsional Alfvén waves launched in the lower corona, evolving radially outwards, naturally develop switchbacks as they propagate into the expanding solar wind. In this work we have constructed new analytic solutions that could represent magnetic switchbacks in 3D. The purpose of inventing analytic models is to primarily build an intuition on what switchbacks look like; current PSP observations are purely a time series of point measurements made at the spacecraft, and this work cements the gap between models that work and matches with observations.

Wave Propagation in a Horizontally Stratified Two-Layer Polytropic Model

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4th & 5th June 2026

Abstract

Gravity modes (g-modes) provide a powerful diagnostic of stellar interiors, yet their interaction with magnetised atmospheric layers remains poorly understood. In this work we investigate buoyancy-driven magnetohydrodynamic (MHD) waves[1] in a horizontally stratified atmosphere using a simplified two-layer model that couples a non-magnetic polytropic layer representing the solar interior with a magnetic isothermal layer modelling the solar atmosphere. The analysis is carried out within the Boussinesq approximation, assuming a horizontal magnetic field perpendicular to gravity, which enables analytical treatment of the governing equations and the derivation of eigenfunctions and dispersion relations describing wave propagation.

Using analytical, asymptotic, and numerical approaches, we examine how the presence of a magnetic atmosphere modifies the behaviour of internal gravity waves. The results reveal two distinct branches of solutions: a buoyancy-dominated branch corresponding to g-type slow modes and a magnetically dominated branch that emerges at larger horizontal wavenumbers. The model also demonstrates the existence of frequency cut-offs that constrain wave propagation. In particular, the Alfvén speed introduces a lower propagation threshold, while the properties of the polytropic interior influence the lower frequency limit of the g-mode branch.

These findings highlight the important role of atmospheric magnetic fields in shaping gravity-wave dynamics and provide a theoretical framework for studying the coupling between solar interior oscillations and magnetised atmospheric structures.

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Is convection in stars diffusion-free?

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4^{th} & 5^{th} June 2026

Abstract

Convection is an efficient way of transferring energy through stellar interiors. In astrophysics, it is usually described by "mixing-length theory" (MLT), which provides a simple yet effective description of the heat transport in terms of local physical conditions. In the efficient regime that prevails through most of a stellar interior, MLT is a "diffusion-free" theory: the transport of heat is independent of thermal and viscous diffusivity, and follows a scaling law of the form $N \propto S^{1/2}$, where S equals the product of the Prandtl number and a locally-defined Rayleigh number and N is a dimensionless measure of the convective efficiency. However, in many simulations and laboratory experiments of convection the transport is seen to remain diffusion-dependent; equivalently, the heat transport obeys relations of the form $N \propto S^{\gamma}$, where $\gamma \neq 1/2$. Here, we investigate whether stellar observations rule out diffusion-dependent convective transport of this form. More specifically, we aim to determine which power-law indices γ are consistent with such observations. We construct 1D stellar models with the Modules for Experiments in Stellar Astrophysics (MESA) code, modifying the MLT prescription to examine a range of γ values inspired by simulation, theory, and experiment. We present preliminary results showing that, consistent with prior theory, less-efficient convection results in stellar radii that are systematically larger and temperatures that are lower than those produced by diffusion-free MLT. Our results show that, for Solar-type stellar models evolved to the Sun's present age, a variety of values of γ (including diffusion-limited and diffusion-free convection theories) can be calibrated to yield models consistent with the observations.

Identification of field line topology: Applications to the magnetotail

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4th & 5th June 2026

Abstract

Magnetic reconnection is a fundamental process of plasma physics. A common procedure in the study of astrophysical plasmas is the identification of plasma regions that are either susceptible to reconnection or actively reconnecting. These regions are often associated with specific field line topologies (e.g. X-lines or seperatirix layers). Identifying such regions in large data-sets is a challenge that requires a metric of susceptibility to reconnection. In this poster, we demonstrate a new method to identify potential reconnection regions via a combination of the field line slippage rate[1] and persistent homology. These two techniques are used to classify the last 25 years of strong magnetosphereic storms in the magnetotail based on their field line topology.

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The role of magnetic diffusion on the onset of magnetoconvection in a spherical shell

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4th & 5th June 2026

Abstract

Earth's magnetic field is maintained by a self-exciting dynamo driven by convection in the liquid iron outer core. Numerical dynamo studies at high magnetic Prandtl number P_m (ratio of viscous to magnetic diffusivity) reveal two distinct dipolar regimes: weak-field dipolar (WD) and strong-field dipolar (SD),[1] the latter of which is the most relevant for modelling natural dynamos. A sufficiently strong magnetic field can relax the onset condition in rapidly rotating convection.[2] It has been proposed that this effect triggers the emergence of the strong-field dynamo regime. To analyse this, the structures of the most unstable linear modes ("onset modes") are considered, motivated by Sakuraba's detailed spherical study.[2] The emergence of distinct dynamo branches encourages a systematic study of how the variety of onset modes in magnetoconvection changes as P_m is varied. Although the onset of magnetoconvection in spherical geometry with an axial field has been studied previously, our work places emphasis on the understudied effect of varying P_m. All computations are performed using the Dedalus project framework.[3] We aim to demonstrate the relationship between onset mode structure and P_m, and consider implications for our understanding of the mechanism that underpins the emergence of the SD regime.

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Interactions between Tidally-Excited Internal Gravity Waves and Magnetic Fields

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4$^{\text{th}}$ & 5$^{\text{th}}$ June 2026

Abstract

Magnetic fields can play a substantial role in energy dissipation and angular momentum transfer in solar interiors, significantly altering the tidal dissipation experienced by the star over the course of its lifetime. However the interplay between tides and magnetic fields has been poorly explored to date, with most work concentrating on inertial waves. Both Lin and Ogilvie in 2018,[1] and Astoul and Barker in 2025[2] considered tidally-excited inertial waves in the presence of a dipole magnetic field, and found behavior that varied from the purely hydrodynamical case, indicating that there is a rich variety of effects at play. In this work, we consider tidally-excited internal gravity waves (IGW) in the presence of a uniform axial magnetic field in the radiative core of a Sun-like star. We apply a spherical Boussinesq model to the MHD equations, and derive a critical radial magnetic field strength criterion $B_{r,crit}$ similar to that presented in Fuller et al. in 2015,[3] at which we expect a significant change in the character of IGW. We carry out 3D MHD simulations using the spectral-methods `Dedalus` framework for several different magnitudes of magnetic field strengths all the way up to $B_{r,crit}$, and find a variety of nonlinear effects, including wave breaking, resonant Alfven waves, etc. These preliminary results represent the first simulations and analysis of tidally-excited IGW in the presence of magnetic fields.

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Switchback generation from the evolution of Torsional Alfvén waves

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4^{th} & 5^{th} June 2026

Abstract

Switchbacks are high amplitude Alfvénic deflections, or even reversals, of the magnetic field in the solar wind. Here we present a new parameter study of how Torsional Alfvén wave pulses evolve into switchbacks when propagating from the solar surface into a super-radially expanding solar wind. Our study is motivated by the fact that Torsional Alfvén waves are produced by both interchange reconnection via coronal jets and jet-lets as well as surface convective motions. We find that during the early evolution the wave amplitude grows in accordance with linear theory, before entering an approximately self-similar expansion phase in the non-linear regime. Once non-linear the waves evolve into a vortex ring-like configuration with a cylindrical switchback region at the centre elongated along the radial field direction. We show that the maximum deflection in the switchback volume is relatively insensitive to the initial wave amplitude, but rather is dictated by the total twist within the initial wave pulse. We also find empirical scalings for the parallel and perpendicular length scales of the switchback volume. Overall, our findings support the idea that Torsional Alfvén waves launched by various processes within coronal holes form seed perturbations that subsequently evolve into switchbacks as they propagate within the solar wind.

Global MHD Modelling of Planetary Magnetospheres

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4th & 5th June 2026

Abstract

Large-scale three-dimensional magnetohydrodynamic (MHD) simulations provide a powerful framework for modelling the global structure and dynamics of planetary magnetospheres. These models form a key part of modern space weather forecasting, enabling the propagation of solar wind conditions through coupled magnetosphere-ionosphere systems in real time. Despite their success, magnetospheres are inherently multi-scale and multi-physics environments, containing processes that extend beyond the assumptions of ideal or resistive MHD. In this talk, I will introduce the fundamental principles underpinning global MHD simulations, including the governing equations, numerical approaches, operational parameter regimes, and the boundary conditions required to model planetary systems. I will then focus on the Gorgon code and its application to simulations of severe space weather events, highlighting its implementation for operational forecasting at the Met Office as part of the SWIMMR programme. Finally, I will discuss current efforts to move beyond conventional MHD approaches, including the incorporation of kinetic and hybrid physics necessary to capture key magnetospheric processes unresolved by fluid models alone.

References

Energy bounds from relative helicity

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4$^{\text{th}}$ & 5$^{\text{th}}$ June 2026

Abstract

Relative magnetic helicity[1] is commonly used in solar physics to avoid the well-known gauge ambiguity of standard magnetic helicity $H = \int_V \boldsymbol{A} \cdot \boldsymbol{B} \, dV$ in magnetically open domains. However, its physical interpretation is challenging, owing to the invocation of a reference field. I will outline recent work confirming that relative helicity (with the usual potential reference field) can play a dynamical role. Specifically, it obeys a generalisation of the classical Arnol'd inequality, $\|\boldsymbol{B}\|^2 \geq C|H|$. This inequality is celebrated because it connects magnetic field topology (measured by H) with dynamics (measured by the magnetic energy $\|\boldsymbol{B}\|^2$). Versions of this inequality with H replaced by the relative helicity have been newly obtained for both free magnetic energy[2] and the original magnetic energy,[3] in suitable domains.

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UKMHD 2026

Revisiting the Parker Problem

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4/5th June 2026

Abstract

We have a fresh look at the Parker Problem, i.e., whether a braided magnetic field can relax under ideal plasma dynamics to a smooth force-free equilibrium. Parker's original hypothesis was that the answer is "No", and he used this to explain the onset of reconnection in braided magnetic fields. The question is closely related to the formation of thin or singular current sheets that are required to account for the heating of the solar corona. Today's answer to the original problem with line-tied boundary conditions is likely "Yes".[?] However, we also know that certain types of braided fields under periodic boundary conditions can't relax to smooth force-free equilibria. We explore which topological structures prevent relaxation to a smooth equilibrium in the periodic case and what this can teach us about the line-tied case.

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Magnetic field line slippage rate

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4th & 5th June 2026

Abstract

In this talk, I introduce the concept of the field line slippage rate as a diagnostic of magnetic field line connectivity changes relative to ideal motion. The slippage rate provides a direct link between magnetic geometry and non-ideal effects, yielding a physics-weighted measure for identifying reconnection. I demonstrate how this quantity can be applied to nonlinear force-free field extrapolations, where it serves as a proxy for reconnection activity. In particular, I examine its relationship to the squashing factor of quasi-separatrix layers (QSLs). While QSLs identify regions that are geometrically susceptible to reconnection, the slippage rate distinguishes those where reconnection is physically active at a given time.

Catastrophic MHD theory

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4^{th} & 5^{th} June 2026

Abstract

The talk aims to clear up confusion which has arisen in the application of catastrophe theory to MHD. 'MHD catastrophe' has been invoked to explain sudden violent transient behaviour both in astrophysical plasmas such as solar flares and CMEs, and also in laboratory experiments such as tokamak sawteeth and ELMs. Nonlinear 1-D models may capture key features sufficiently to provide useful surrogates in many cases, whence it is argued that, since every such 1-D model may be reduced to a gradient system, catastrophe theory covers most likely possibilities. Unfortunately, whilst the equivalence is correct in a certain mathematical sense, it does not extend as completely to detailed time-dependent behaviour. In particular it fails adequately to capture the overtopping instability, 'escape from a potential well',[1] which is one of the most violent to be expected generically, see Figure. This leads on to discussion as to what is meant by generic in this context, aiming to resolve additional confusion concerning the behaviour to be expected at 'tipping points' as described by catastrophe theory.

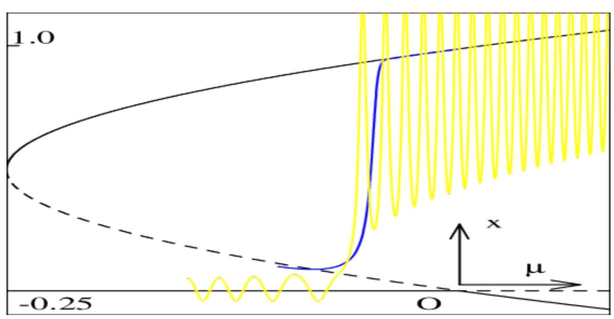

Figure 1: Overtopping (yellow curve) dynamic faster than catastrophe (blue curve), superimposed on bifurcation diagram for tipping point problem ($\mu \propto$ time t).

Work funded by the EPSRC[grant number EP/W006839/1]

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Tearing Instability Evolution in MHD and RMHD

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4th & 5th June 2026

Abstract

Storage of magnetic energy and its subsequent release through reconnection are important processes in many solar, stellar, astrophysical and industrial plasmas. One particular application of this is a potential coronal heating mechanism in coronal loops. Convective photospheric motions stress the magnetic field, until an instability, such as the tearing instability, occurs and the stored energy is rapidly released as heat.

It seems natural that this process of storing and releasing magnetic energy might occur in a cyclic manner, with the system evolving through sequences of equilibria. However, previous simulations,[1] using the approximate method of Reduced MHD (RMHD),[2] have shown that this process only happens once, after which the magnetic energy does not build up again.

In this talk we aim to clarify whether the same evolution is true in general by using 3D compressible MHD simulations to investigate this evolution as in.[3] A modelled coronal loop is subject to continuous footpoint motions involving a steady shearing and an additional perturbation in the form of kink waves. This shear motion results in dynamically created current sheets, which are then perturbed by the kink waves to provoke the onset of the tearing instability.

We will compare the general evolution of this system to incompressible MHD and RMHD simulations.

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On turbulent magnetic reconnection: fast and slow mean steady-states

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4th & 5th June 2026

Abstract

We investigate a model of turbulent magnetic reconnection introduced by Higashimori, Yokoi and Hoshino[1] and show that the classic two-dimensional, steady-state Sweet-Parker and Petschek reconnection solutions are supported. We present evidence that these are the only two steady-state reconnection solutions, and we determine the criterion for their selection. Sweet-Parker reconnection occurs when there is no growth in turbulent energy, whereas Petschek reconnection occurs when the current density in the reconnecting current sheet is able to surpass a critical value, allowing for the growth of turbulent energy that creates the diffusion region. Further, we show that the Petschek solutions are self-similar, depending on the value of the turbulent time scale, and produce a universal steady reconnection rate. The self-consistent development of Petschek reconnection through turbulence, within the model, is an example of fast and steady magnetic reconnection without an explicit need for the collisionless terms in an extended Ohm's law.

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Plasma turbulence produced via magnetic reconnection

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4th & 5th June 2026

Abstract

Magnetic reconnection and magnetohydrodynamic turbulence are intrinsically linked physical processes present in astrophysical and magnetically confined fusion plasmas, however the exact link between these processes remains poorly understood.

To understand how reconnection can inject energy into a turbulence cascade, we performed an ensemble of direct numerical simulations of an unstable plasma jet. We apply a Reynolds average to the incompressible MHD equations to derive transport equations for the turbulent kinetic and turbulent magnetic energies:

$$\begin{aligned}\underbrace{\partial_t k}_{\substack{\text{time}\\\text{derivative}}} + \underbrace{\overline{u_j}\partial_j k}_{\substack{\text{mean-field}\\\text{advection}}} - \underbrace{\overline{b_j}(\overline{u_i'\partial_j b_i'})}_{\substack{\text{mean-field}\\\text{transfer}}} = - \underbrace{\overline{u_i'\partial_i p'}}_{\substack{\text{kinetic pressure}\\\text{transport}}} + \underbrace{\nu(\overline{u_i'\partial_{jj} u_i'})}_{\substack{\text{kinetic}\\\text{dissipation}}} \\ - \underbrace{\overline{u_i'u_j'}\partial_j\overline{u_i} + \overline{u_i'b_j'}\partial_j\overline{b_i}}_{\substack{\text{kinetic}\\\text{production}}} - \underbrace{\overline{u_i'u_j'\partial_j u_i'}}_{\substack{\text{turbulent}\\\text{transport}}} + \underbrace{\overline{u_i'b_j'\partial_j b_i'}}_{\substack{\text{turbulent}\\\text{transfer}}} - \underbrace{\frac{1}{2}\overline{u_i'\partial_i b_j'b_j'}}_{\substack{\text{magnetic pressure}\\\text{transport}}} ,\end{aligned} \tag{1}$$

$$\underbrace{\partial_t m}_{\substack{\text{time}\\\text{derivative}}} + \underbrace{\overline{u_j}(\overline{b_i'\partial_j b_i'}) - \overline{b_j}(\overline{b_i'\partial_j u_i'})}_{\substack{\text{mean-field}\\\text{transfer}}} - \underbrace{\overline{b_i'b_j'}\partial_j\overline{u_i} + \overline{b_i'u_j'}\partial_j\overline{b_i}}_{\substack{\text{magnetic}\\\text{production}}} - \underbrace{\overline{b_i'b_j'\partial_j u_i'} + \overline{u_j'b_i'\partial_j b_i'}}_{\substack{\text{turbulent}\\\text{transfer}}} = \underbrace{\eta(\overline{b_i'\partial_{jj} b_i'})}_{\substack{\text{magnetic}\\\text{dissipation}}} . \tag{2}$$

We find that turbulence production is dominated by the turbulent electromotive interaction with the mean magnetic shear, meaning the bulk of turbulence energy is generated as Alfvén waves before entering the multi-domain cascade. A small selection of figures is presented on page 2, with Figure 1 showing a visualisation of the turbulence transition and Figure 2 showing a collated turbulence energy budget. Further results can be found in our preprint paper.[1]

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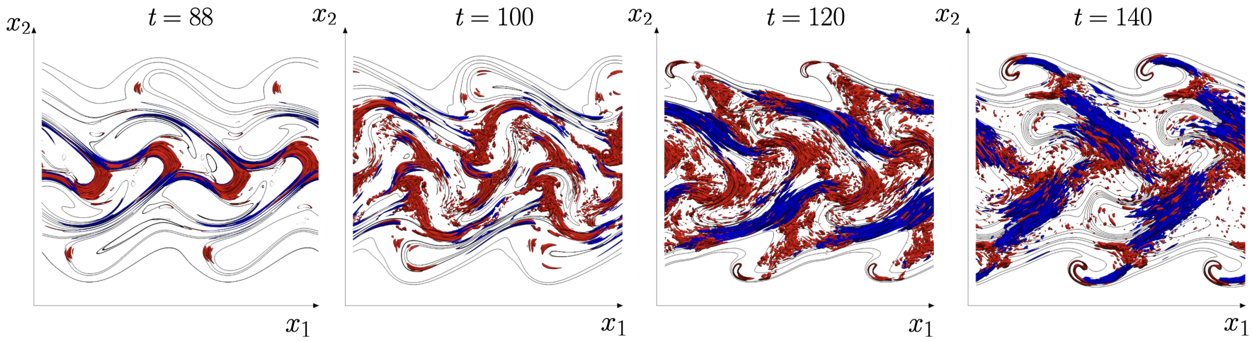

Figure 1: Time evolution of the transitioning plasma jet. Mean magnetic field lines (black) are shown with the 99th percentile of Q-criterion (red) and current density magnitude (blue).

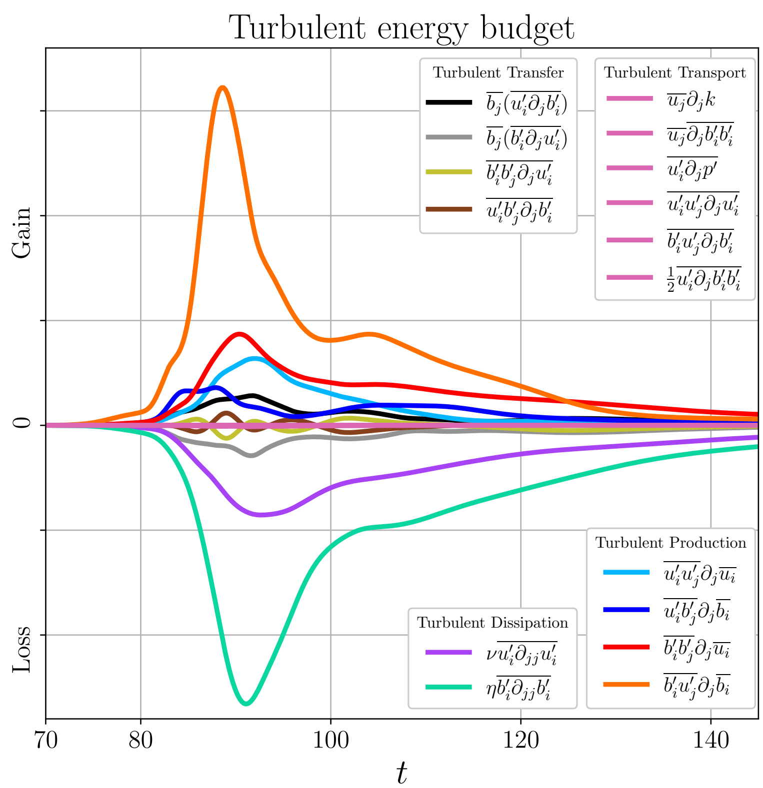

Figure 2: Collated turbulent energy budget throughout the turbulence transition. Turbulent energy is produced mainly as magnetic fluctuations through the $\overline{b_i'u_j'}\partial_j\overline{b_i}$ mode before cascading between domains.

Flux-rope-mediated Turbulent Magnetic Reconnection

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4$^{\text{th}}$ & 5$^{\text{th}}$ June 2026

Abstract

3D direct numerical simulations have recently opened an important window into the role of self-generated turbulence in magnetic reconnection at high Lundquist numbers. In the absence of strong magnetic shear, these simulations exhibit both features associated with the Lazarian-Vishniac model of 3D turbulent reconnection (turbulence and field line dispersion) and features associated with 2D plasmoid mediated reconnection (flux ropes and reconnection rates). Motivated by this "duality",[1] this talk presents a new model of magnetic reconnection in the presence of turbulence, recently published as [2]. Starting from the same equations as Lazarian and Vishniac,[3] we show that the properties of magnetic field line separation in turbulent plasma permit the existence of locally coherent magnetic structures. Local coherence allows storage of magnetic helicity inside the reconnection layer, typically in the form of locally coherent twisted flux ropes that fray over longer distances. We then introduce the "Alfvén horizon" to explain why the global reconnection rate can be governed by locally coherent magnetic field structure instead of by field line wandering, formally extending to 3D the principle that reconnection can be made fast by fragmentation of the global current layer. Coherence is shown to dominate over field line dispersion if the turbulence is sufficiently anisotropic at the perpendicular scale matching the thickness of a marginally stable current layer. Finally, we conjecture that turbulence generated within the reconnection layer may produce a critically balanced state that maintains the system in the flux-rope mediated regime. The new model successfully accounts for the major features of 3D numerical simulations of magnetic reconnection with self-generated turbulence, including reconnection rates of 0.01 in resistive MHD and 0.1 with collisionless physics.

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Distinct Strong and Weak Shear Regimes of Turbulent Magnetic Reconnection

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4th & 5th June 2026

Abstract

Magnetic reconnection can become fast in three-dimensional turbulent layers, but the mechanism that controls the fast state remains unclear. Existing guide-field simulations of self-generated turbulent reconnection show locally coherent flux-rope structures embedded in a stochastic layer, motivating a flux-rope-mediated picture with reconnection rates of order $V_{\mathrm{rec}}/V_A \sim 10^{-2}$. Here we use 3D resistive-MHD simulations at $S_L = 10^5$ to test how magnetic shear changes this regime. We vary the guide field while keeping the initial reconnecting field strength fixed, comparing a guide-field configuration (weak magnetic shear) with the anti-parallel limit (strong magnetic shear). We find that the strong-shear regime is qualitatively distinct from the flux-rope-mediated guide-field regime: rather than retaining a narrow layer containing locally coherent flux-rope-like structures, the current layer develops short-wavelength corrugations over a broader region, and the reconnection electric field is sustained mainly by turbulent EMF. The reconnection rate rises to $V_{\mathrm{rec}}/V_A \sim 0.03$, about three to four times the guide-field value. These results indicate that magnetic shear can select the mechanism controlling fast 3D turbulent reconnection, shifting the system from a guide-field regime consistent with flux-rope mediation toward a turbulence-broadened regime. This transition may help explain the sudden switch-on of fast reconnection in eruptive solar flares.

Turbulent magnetic reconnection in braided coronal magnetic fields

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4th & 5th June 2026

Abstract

Magnetic reconnection has a key function in altering the topology of complex, braided magnetic fields in general MHD plasmas, and as a facilitator of heating in solar coronal loops in particular. As such, it is desirable to be able identify the locations at which magnetic reconnection occurs, the properties of reconnection sites, and the nature of the change in magnetic connectivity in complex magnetic fields. In order to do so, we perform a detailed analysis of a three-dimensional MHD simulation in which simple, ordered boundary motions applied to an initially straight coronal magnetic field bring about ideal MHD instabilities that lead to ongoing magnetic reconnection. Reconnection occurs at sites away from the traditional locations of null points, separators, and quasi-separatrix layers, and thus we find a distinctive new mode of three-dimensional reconnection. Statistically, the sizes of reconnection sites follow a power-law distribution. Geometrically, these sites are elongated along the direction of the magnetic field, in long, narrow, loop-aligned current sheets. Typically, field lines reconnect with a small, but significant angle of misalignment between them. Reconnection takes place effectively continuously, with individual field lines seen to reconnect several times along their lengths in very short intervals in time, as they pass through many small current concentrations. We illustrate the flipping of the footpoints of reconnecting field lines, as well as their three-dimensional interaction. Overall, we find magnetic reconnection in turbulent, braided magnetic fields to be more complex and subtle than has previously been discussed, and to have characteristics very different from those of previous models. Constraining these characteristics is important in order to understand the onset, location, and consequences of reconnection in MHD models.

Wave Generation via 3D Oscillatory Reconnection at a Magnetic Null Point

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4th & 5th June 2026

Abstract

This work conducts a three-dimensional (3D), nonlinear magnetohydrodynamic (MHD) simulation to investigate wave-generating, time-dependent reconnection around a magnetic null point.[1] A nonperiodic perturbation (in the xz-plane) triggers oscillatory reconnection (OR) at the 3D null, resulting in a self-sustained oscillation with a constant period P. We investigate the response of the system using three distinct wave proxies (compressible parallel, compressible transverse, and incompressible parallel) as well as spectral proper orthogonal decomposition for decoupling and analyzing the resultant MHD wave behavior. We find that OR generates a slow magnetoacoustic wave of period P that propagates outward in all directions along the spine and fan plane of the 3D null point. We also find the generation of a propagating Alfvén wave of period P, exclusively along the y-axis in the fan plane, i.e., in the direction perpendicular to the spine motion.[2] These findings provide new insights into waves generated from a 3D null point and their implications for coronal seismology.

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The Inverse MHD Problem for Magnetic Fields in Spiral Galaxies

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4^{th} & 5^{th} June 2026

Abstract

In this work we dissect the dynamo model of disc galaxies. Such spiral galaxies consist of a turbulent, rotating disc of ionised gas that gives rise to a large-scale magnetic field. From observations, the magnetic field itself is fairly well known,[1,2] as is the large-scale velocity of the interstellar gas.[3] The evolution of the large-scale magnetic field is governed by the mean-field dynamo equation (MFDE) and involves two poorly understood parameters, α and β, quantifying turbulent helicity and magnetic diffusivity respectively and collectively known as the turbulent transport coefficients (TTC's). Only order of magnitude estimates of α and β are known: approximately 1 kpc/Gyr and 1/3 kpc^2/Gyr respectively.[4] Our aim is to calculate them directly from observational data of large-scale magnetic and velocity fields. First, we include only the lowest order (axisymmetric) mode of the magnetic field and calculate the axisymmetric background values of α and β. We then reintroduce the higher order modes and invert the MFDE, leading to a first order ODE that we solve numerically using a perturbation theory approach.[5] The resulting solution also depends on the large scale rotation $\mathbf{V}$ of the galaxy. We consider three cases: a magnetic field frozen into the interstellar gas, solid-body rotation of the magnetic field aligned with the spiral pattern and solid-body rotation of the magnetic field for a general angular momentum. We show that the average values of α and β are not sensitive to this choice and are well described as a perturbation above the axisymmetric background. Furthermore, they agree excellently with the order of magnitude estimates. The choice of rotation does affect $\alpha(\phi)$ and $\beta(\phi)$ within each radius and we discuss this effect.

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Multifluid Effects in Neutron Star Magnetic Evolution

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4th & 5th June 2026

Abstract

Neutron stars (NSs) are compact remnants of the stellar evolution. They host the strongest magnetic fields observed in the Universe, with typical magnitudes $B \sim 10^8 - 10^{15}\,\mathrm{G}$ (1), they also exhibit rapid rotation periods spanning milliseconds to seconds, and with masses $\sim 1.4\,M_\odot$ in a radius $\sim 12\,\mathrm{km}$ they reach supranuclear densities in their interiors. Much of their rich observational phenomenology is believed to be driven by the evolution and decay of their magnetic fields. Understanding this magnetic evolution under such extreme physical conditions poses a major theoretical challenge. Significant progress has been achieved in modeling magnetic evolution in the magnetosphere and crust, where the relevant microphysics is comparatively well understood (2; 3). In contrast, the magnetic evolution within the core remains far more uncertain and complex, largely because the underlying physical processes are still not fully understood. The neutron star core is composed primarily of neutrons, together with a smaller fraction of protons, electrons, and muons. Modeling the magnetic evolution in such an environment therefore requires a multifluid magnetohydrodynamic (MHD) framework, in which the different particle species interact through a variety of fundamental processes operating across a wide range of timescales. Historically, and largely for simplicity, the case of a neutron star core composed solely of neutrons, protons, and electrons has been extensively studied (4). In this talk, we will present preliminary results obtained with the `Dedalus` code, exploring the impact of muons on the magnetic evolution of the neutron star core.

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Non-local thermal transport model for solar MHD simulations

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4th & 5th June 2026

Abstract

Although laser and solar plasma physics are traditionally studied separately, both involve many of the same physical processes. During solar flares, rapid magnetic energy release heats plasma to extreme temperatures, where classical local thermal transport breaks down because the electron mean free path becomes sufficiently long. In this regime, non-local heat fluxes suppress energy transport at the heating site while pre-heating neighbouring regions. While extensively studied in laser-fusion plasmas, these effects remain largely overlooked in solar MHD modelling, where classical transport models may overestimate conductive fluxes and fail to reproduce key flare signatures.[1] This presentation introduces the implementation of a non-local thermal transport model in the MHD code LareXd and the HD code Freyja, and investigates its impact on coronal phenomena such as flares and waves. Non-local transport suppresses the formation of the isothermal regime and alters the damping of standing slow waves in the solar corona.[2] Furthermore, 1D[3] and 2D flare simulations show that non-local transport produces more localised and intense temperature peaks, together with reduced and delayed chromospheric evaporation, compared to classical local models. These results demonstrate the importance of including non-local effects in solar plasma modelling and highlight the strong links between solar and laser-plasma physics.

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Initial Investigation of Thermal Instability Including Non-Equilibrium Radiative Losses in Solar Coronal Condensations

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4th & 5th June 2026

Abstract

The thermal instability,[1] often as a component of thermal non-equilibrium cycles, plays a key role in the formation of cool condensations in the solar corona.[2] The trade-off between optically thin radiative losses and thermal conduction are key to forming these structures, however, as they cool below $\sim 30\,\mathrm{kK}$, partial ionisation and optical depth effects become important. The former of these significantly reduces the pressure for a given mass density and temperature relative to that predicted by the ideal gas law, whilst the latter can dramatically modify the radiative losses, potentially providing a stabilising energy source term.

Recent work[3] has shown that in static radiative models, including the effects of non-equilibrium ionisation and optically thick radiative losses produces transient states much cooler than those predicted by an instantaneous relaxation to ionisation equilibrium, followed by a slow reheating phase towards the radiative equilibrium state. Here, we discuss the potential importance of these terms and present initial 1D radiation hydrodynamic and 2.5D radiation magnetohydrodynamic models of these instabilities applied to idealised cases representing solar coronal condensations, considering the effects of detailed optically thick radiative losses and non-equilibrium ionisation.

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The Solar Atmospheric Modelling Suite: First Release and Next Stages

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4$^{\text{th}}$ & 5$^{\text{th}}$ June 2026

Abstract

The Solar Atmospheric Modelling Suite (SAMS) is an STFC-funded project to develop the next generation of UK solar simulation software, developed by researchers at Exeter, Glasgow, Sheffield, Cambridge and Warwick. SAMS will feature packages which can be combined, or run in isolation, covering at a minimum non-local NLTE physics, chromospheric modelling, flux emergence, advanced diagnostics. Ahead of the first public release of the SAMS project, this talk outlines the first results, current capabilities and upcoming developments. In particular, this talk will present the multi-fluid and time-dependent ionisation aspects, and the performance against established codes.

Outflow Fields - A potential alternative to potential fields

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Abstract

Potential-Field Source-Surface models[1] are perhaps the most commonly-used method for modelling the global, steady-state magnetic field in the solar corona, to a very basic first approximation. These models are fast to compute and require very few assumptions or boundary data, but have some major flaws. We have introduced a variation on PFSS, called 'Outflow Fields',[2] which take into account the effect of the solar wind on the magnetic field but are otherwise almost as simple to compute. These fields have numerous advantages over PFSS, namely more accurate streamer shapes, better comparisons to measured Open Flux values and less dependence on the location of the model's upper boundary. We present some examples of the uses of the model, including comparison to field line shapes in eclipse photographs and the optimisation of the solar wind parameters using an evolutionary algorithm. We find that the well-known discrepancy between predicted and measured magnetic field strengths at 1AU (the Open Flux problem) is reduced by around half when the solar wind is accounted for,[3] and that solar wind speed forecasts can be made more resilient using Outflow fields relative to PFSS equivalents.

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Fast Magnetoacoustic Wave Behaviour within Gravitationally Stratified, Magnetically Inhomogeneous Media

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4th & 5th June 2026

Abstract

The nature of MHD waves within inhomogeneous media is fundamental to understanding wave behaviour in the solar atmosphere. We investigate fast magnetoacoustic wave behaviour within magnetically-inhomogeneous, gravitationally-stratified media in the presence of magnetic null points. We find that the addition of gravitational stratification fundamentally changes the nature of the system by introducing two competing effects: the stratified density profile acts in opposition to the strong magnetic field close to the dipoles, creating a system replete with refraction. We investigate the system using a combination of numerical simulations and semi-analytical WKB solutions, finding strong agreement between the two. The results show a notable difference depending on the height of the null point, with significant unexpected behaviour, including the presence of cusps in the wavefront, which we analyse using the WKB solution to demonstrate that these cusps form at caustics, and we contextualise these results in the theoretical understanding of magnetoacoustic-gravity waves.

References

Photospheric Magnetic Topology and Energy Injection: Key Precursors for a Real-Time Solar Flare Forecasting Framework

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Abstract

We present a large-scale investigation of photospheric magnetic field topology in solar active regions (ARs), with the aim of identifying physically meaningful precursors to flare activity and establishing a framework for operational flare forecasting that can be refined over time. Using the ARTop pipeline[1] applied to HMI/JSOC vector magnetograms for 625 ARs spanning approximately 16 years (2010 May – 2026 January), we compute six time-integrated parameters at the photospheric boundary for each AR over its full disk passage (E60° to W60°): the accumulated total field line winding (Wind), the accumulated delta winding (dL — the non-potential excess of total over potential winding, capturing current-carrying topological complexity), the accumulated magnetic helicity flux (helicity), the instantaneous Poynting flux ($\mathrm{d}E/\mathrm{d}t$) derived from DAVE4VM photospheric velocity estimates, its time integral E representing accumulated magnetic energy input through the photospheric surface (E), and the time-integrated unsigned vertical flux (int-mod-B). Flare labels are drawn from the Heliophysics Event Knowledgebase (HEK) via a Total Flare Index computed over a $\sim$ 20-day window per AR.

Superposed Epoch Analysis applied to a training set of 500 ARs, under three distinct windowing schemes (fixed 24 hr windows from AR emergence, sliding 24 hr windows across the full disk passage, and event-centred windows in the 24 hr prior to each recorded flare), yields parameter-specific threshold values grouped by flare class and total flaring activity. These thresholds are tested against 125 held-out ARs to examine when each parameter crosses its threshold, how long it remains above it, and whether such behaviour aligns with or precedes significant flare events — particularly X- and M-class flares.

A key feature of this approach is that the thresholds are designed as *living values*: once derived from 625 ARs, they can be recalculated using the full AR population for this period ($\sim$3300 regions) and updated periodically — for instance every two years — as new ARs are

included. This makes the framework inherently self-improving, with thresholds becoming progressively more robust as the observational baseline grows, and accessible to the broader community for operational use.

Note: This abstract is submitted to the UKMHD 2026. A full paper describing the methodology and results in detail is in preparation. The ARTop code is publicly available at GitHub[1].

References

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[1] `https://github.com/DavidMacT/ARTop`

Multistability and Pattern Formation in Liquid Metal Magnetoconvection

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4th & 5th June 2026

Abstract

Magnetoconvection (MC) refers to thermally driven flow of a conducting fluid under the influence of a magnetic field, such as in the Earth's core or the Sun's convection zone. It also occurs in engineering applications, including liquid-metal batteries, induction heating, casting, or cooling blankets for nuclear fusion reactors. MC simulations are of key importance for the understanding of the dynamics thereof and have practical applications in the design of fusion reactors. In an infinitely wide and long domain, the transition to turbulence is initiated through a linear instability of the base state in the bulk .[1] Insulating sidewalls result in another linear instability producing localised motion close to the side walls, so-called wall modes, beneath the onset of bulk convection, attributed to a suppression of the Lorentz force near the sidewalls .[2] However, for a given magnetic field strength, in cubic domains stable nonlinear wall-mode solutions of the equations of motion exist below the critical Rayleigh number at which the conducting state becomes linearly unstable, with solutions found on the super- and subcritical branches having different symmetries. Moreover, the transition to chaos and eventually to convective turbulence follows a sequence of bifurcations along the upper subcritical branch according to the Ruelle-Takens-Newhouse scenario, and the resulting turbulent flow retains properties of the equilibria on the subcritical branch and not of the linear wall-mode instability of the conducting state .[3,4] That is, unlike previously thought, the transition to turbulence in MC can be subcritical, bypassing the linear stability threshold, with relevance to the large-scale structure of the turbulent flow. While these results have been obtained in a cubic geometry, we explore if a similar scenario applies to – experimentally more common – cylindrical domains, as co-existing patterns have been found in MC experiments in cylindrical geometry of aspect ratio 1 .[5]

References

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