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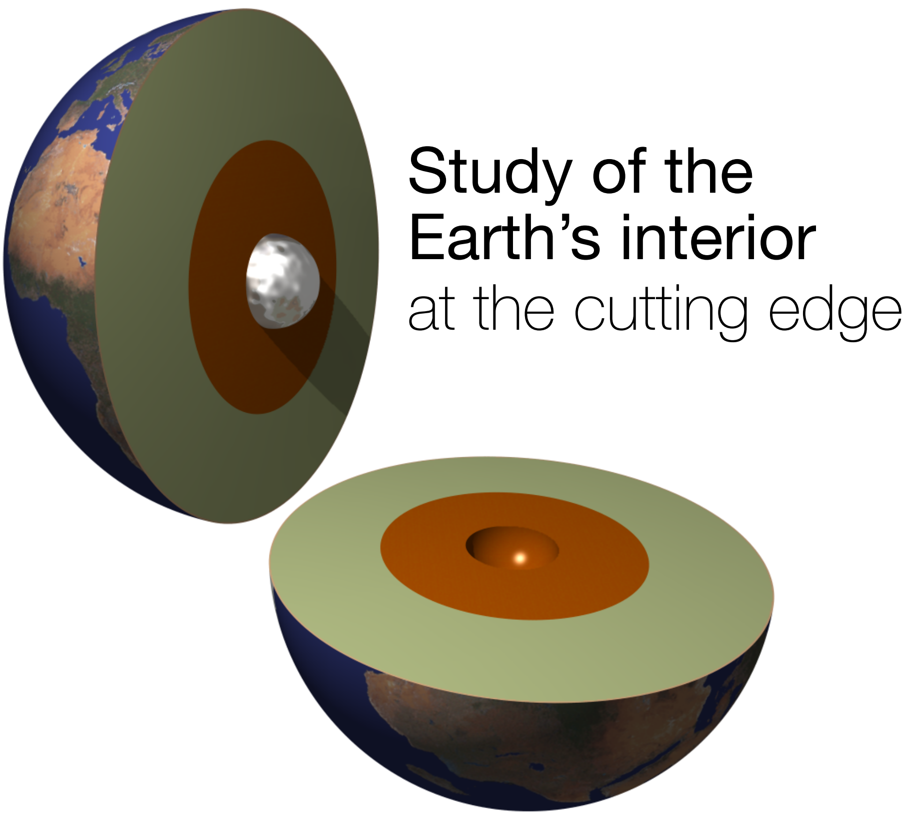

Schedule

Friday 12 May

10:00 – 10:30	Tea and posters
10:30 – 11:00	**Invited:** Matt Jackson (University of California Santa Barbara): *Sampling primordial reservoirs with hot plumes*
11:00 – 11:15	Jennifer Jenkins (University of Cambridge): *Mid-mantle seismic structure beneath Europe and Iceland: Implications for the nature of the Iceland mantle plume*
11:15 – 11:30	Simon Hunt (UCL): *Deformation of bridgmanite + ferropericlase under lower-mantle conditions*
11:30 – 11:45	Lotta Kemppinen (University of Bristol): *First identification of molybdenite in diamond-hosted sulphide inclusions and possible implications for Re–Os dating of diamonds*
11:45 – 12:00	Paula Koelemeijer (University of Oxford): *Large-scale topography of the core–mantle boundary*
12:00 – 12:15	Lars Stixrude (UCL): *Electrical conductivity of silicate liquids at extreme conditions and planetary dynamos*
12:15 – 12:30	Martha G. Pamato (UCL): *Pre melting in fcc and hcp metals*
12:30 – 13:30	*Lunch and posters*
13:30 – 14:00	**Invited:** Alex Fournier (Institut de Physique du Globe de Paris): *Power-based scaling laws for planetary dynamos: An updated database and a reassessment*
14:00 – 14:15	Oliver Bardsley (University of Cambridge): *The evolution of magnetic-Coriolis waves in the Earth's outer core*
14:15 – 14:30	Avishek Ranjan (University of Cambridge): *Columnar structure formation in the Earth's core by internally-driven inertial waves*
14:30 – 14:45	Vernon F. Cormier (University of Connecticut): *Earth's inner core and its boundary from seismic body waves*
14:45 – 15:00	Yunguo Li (UCL): *Carbon in the Earth's inner core*
15:00 – 15:15	Amy Edginton (UCL): *The Implications of Fe–S–Si on Mercury's core evolution*
15:15 – 15:30	Andy Biggin (University of Liverpool): *Did average geomagnetic field strength increase 1–1.5 billion years ago and, if so, why?*
15:30 – 16:00	*Posters*
16:00 – 17:00	*For RAS fellows only: RAS AGM*
17:00 – 18:00	*RAS Ordinary Meeting; all welcome*

Oral presentations

Sampling primordial reservoirs with hot plumes

***Matt Jackson**, University of California Santa Barbara, Santa Barbara, CA, 93106-9630, USA* (jackson@geol.ucsb.edu)
J.G. Konter, University of Hawaii
T. Becker, University of Texas

Ocean island lavas erupted at volcanic hotspots are thought be sourced by buoyantly upwelling mantle plumes. Such plumes convey material from the deep Earth's mantle. Thus, the geochemistry of hotspot lavas erupted at the Earth's surface provide information about the distribution of geochemical reservoirs in the Earth's deep interior. However, it is difficult to employ the geochemistry of ocean lavas to infer the depth of domains sampled by these lavas. An important question is whether the the geochemistry of lavas erupted at the Earth's surface relate to geophysical observables that allow us to infer the location and origin of geochemical reservoirs in the Earth's interior. Of particular interest is the location of primordial domains in the deep Earth, as recent work has shown that lavas with primitive (high) $^{4}He/^{3}He$ ratios can host $^{129}Xe/^{130}Xe$ signatures [1] and ^{182}W anomalies [2] that are consistent with early Hadean formation of the high $^{4}He/^{3}He$ mantle domain.

Konter and Becker (2012) [3] provided a comparison of Sr-Nd-Pb isotopic geochemistry hotspot lavas with a variety of geophysical parameters. They demonstrated that the proportion of the C componentpresumed to host high $^{4}He/^{3}He$in hotspot lavas exhibits an inverse relationship with seismic shear-wave velocity anomalies in the shallow mantle (200 km) beneath each hotspot. Hotspots with a larger fraction of the C component overlie shallow mantle lower seismic shear-wave velocity anomalies (interpreted to relate to hotter mantle temperatures) than hotspots with a smaller fraction of the C component. To further evaluate this observation, Konter and Becker (2012) proposed "that correlations should be made based on helium isotopes."

Thus, we compare maximum $^{4}He/^{3}He$ with seismic shear-wave velocity anomalies in the shallow mantle, and we use the same depth interval (200 km) for extraction of shear-wave velocity anomalies that Konter and Becker employed [4]. Our results confirm Konter and Beckers (2012) observation, and show that plume-fed hotspots with the highest maximum $^{4}He/^{3}He$ (i.e., which host a higher proportion of the C component) overlie regions of low seismic shear-wave velocity anomalies at 200 km than hotspots that host only low $^{4}He/^{3}He$. This result is consitent with recent work that shows an inverse relationship between maximum $^{4}He/^{3}He$ and seismic shear-wave velocity anomalies in the mantle beneath the western United States [5]. Additionally, we find that hotspots with the highest maximum $^{4}He/^{3}He$ are associated with higher hotspot buoyancy fluxes than hotspots that host only low $^{4}He/^{3}He$ [2]. The relationship between $^{4}He/^{3}He$, shallow mantle seismic shear-wave velocity anomalies, and buoyancy flux is most easily explained by a model where hotter plumes (inferred from low seismic shear-wave velocity anomalies) are more buoyant and entrain more of a deep high $^{4}He/^{3}He$ reservoir than cooler plumes that underlie low $^{4}He/^{3}He$ hotspots. If the high $^{4}He/^{3}He$ domain is denser than low $^{4}He/^{3}He$ mantle components, then this domain will be entrained only by the hottest, most buoyant plumes. A deep, dense reservoir will be resistant to being entrained in the convecting model and is thus ideally suited for preserving early-formed Hadean domains that are sampled by modern hotspot lavas sourced by the hottest plumes.

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Mid-mantle seismic structure beneath Europe and Iceland: Implications for the nature of the Iceland mantle plume

Jennifer Jenkins, *University of Cambridge, Bullard Laboratories, Madingly Rise, Madingly Road, CB3 0EZ* (jj405@cam.ac.uk)
Arwen Deuss, Urecht University
Sanne Cottaar, University of Cambridge

Until recently, most of the lower mantle was considered to be well-mixed with strong heterogeneity restricted to the lowermost several hundred kilometers above the core-mantle boundary, also known as the D" layer. However, several recent studies have started to hint at a potential change in earth structure at mid-mantle depths, with evidence from both seismic tomography (Fukao and Obayashi 2013, French and Romanowichz, 2015) and global viscosity structure (Rudolph et al., 2015).

We present a continental-wide search for mid-mantle P to S wave converted phases and find most observations come from approximately 1000 km depth beneath Iceland and Western Europe. Conversions are identified using a data set of 50,000 high quality receiver functions which are systematically searched for robust signals from the mid-mantle. Potential P to s conversions are analysed in terms of slowness to determine whether they are true observations from depth or simply surface multiples arriving at similar times. We find broad regions with robust signals from approximately 1000 km depth in several locations; beneath Iceland and across Western Europe, beneath Ireland, Scotland and Eifel.

Similar observations have previously been observed mainly in subduction zone settings, and have been hypothesised to be caused by down-going oceanic crustal material. Here we present observations which correlate with slow seismic velocities in recent tomographic models. These low velocities appear to be a channel deviating from the broad mantle plume beneath Iceland at mid-mantle depths. We hypothesise that the mid-mantle seismic signals we observe are caused by either a phase transition occurring with plume material or by small-scale chemical heterogeneities swept along with upwelling material and ponding around 1000 km. Either interpretation suggests a thermo-chemical plume structure is required to explain our observations.

Deformation of bridgmanite + ferropericlase under lower-mantle conditions

Simon Hunt, *Department of Earth Sciences, University College London, Gower Street, London, WC1E 6BT* (`simon.hunt@ucl.ac.uk`)
Fang Xu, Okayama University
David Dobson, University College London

The Earth's lower mantle is composed of ∼70% bridgmanite [(Mg,Fe)SiO_3] and ∼20% ferropericlase [(Mg,Fe)O] and minor percentages of other phases including Calcium perovskite. The rheological properties of these phases are critical to understanding the fate of subducting slabs and mantle convection.

Bridgmanite is only stable above ∼23 GPa making experiments of its rheology and other transport properties extremely challenging. The earliest studies of bridgmanite rheology were performed in diamond anvil cells (DAC) but at low-temperatures and at uncontrolled strain-rates (e.g. Merkel et al., 2003). More recently Girard et al. (2016) used a Rotational Drickamer to deformed post-spinel bridgmanite + ferropericlase at high temperature and pressures greater than 24 GPa but they did not report any LPO or textures from their experiments. Tsujino et al. (2016) deformed bridgmanite in the multi-anvil and reported the dominant deformation system in bridgmanite is slip on the (100) plane. However these experiments were to only low strains.

Here we report results of experiments performed in the DT-Cup (Hunt et al., 2014) in which we deform bridgmanite and 'post-spinel' bridgmanite + ferropericlase, at 25 GPa and 1500°C, to high strains and measured their relative strengths and LPO development. The DT-Cup is a development of the 6-8 Kawai style multi-anvil which allows deformation experiments under lower mantle conditions to high strain.

We find that the strength of bridgmanite and bridgmanite + ferropericlase is similar to ∼20% strain and that the rate of M-index development is also very similar. The textures we generate are consistent with those of Tsujino et al. (2016).

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First identification of molybdenite in diamond-hosted sulphide inclusions and possible implications for Re-Os dating of diamonds

Lotta Kemppinen, *Department of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Rd, BS8 1RJ* (lk15127@bristol.ac.uk)
Simon C. Kohn, Ian J. Parkinson, Galina P. Bulanova, Daniel H. Howell and Chris B. Smith (University of Bristol)

Inclusions in natural diamonds provide a direct insight into the chemistry and mineralogy of the Earth's mantle. Owing to its strength, diamond can carry to the surface materials, including sulphides that were captured within it at depth during its growth. Due to their highly-siderophile element contents, sulphide inclusions in diamonds can be dated using the Re-Os isotopic system, thereby offering a unique window into the recycling of volatile elements through the Earth's interior over time.

Sulphide inclusions are the most commonly-encountered mineral inclusion in diamonds, despite relatively low normal mantle sulphur compositions (~200 ppm), implying that sulphides may play an important role in the formation of certain diamonds. Sulphides can act as reducing agents on an oxidised slab component for example to promote diamond formation [1, 2]. It has also been shown that sulphide melts could host significant amounts of carbon at depth [3], and even act as a direct medium for diamond growth [4, 5].

Sulphides typically exist as Fe-Ni-Cu sulphide melts in the upper mantle diamond stability field. Inclusions trapped in diamond in molten form, have unmixed into assemblages of sulphides (pyrrhotite pentlandite chalcopyrite) upon cooling during the diamond's ascent by kimberlite eruption. Many inclusions have also developed characteristic rosette-shaped or disc-shaped fractures lined with sulphides due to the differences in thermal expansion properties of the encapsulated sulphides and host diamond. The bulk composition of diamond-hosted sulphide inclusions can be reconstructed using a variety of analytical techniques and is essential, namely for accurate Re/Os isotopic measurements, which commonly require the extraction and chemical purification of the sulphides prior to N-TIMS analysis [6, 7].

A discreet molybdenite (MoS_2) phase has been identified for the first time by Raman spectroscopy in syngenetic sulphide inclusions in several eclogitic diamonds from the Mir kimberlite (Yakutia, Russia). Our observations suggest the molybdenite has unmixed from an original sulphide melt, and it occurs as sub-µm sized disseminations at the chalcopyrite rims of the inclusions and sometimes, in their decompression cracks. Molybdenite also occurs in sulphide inclusions from eclogitic diamonds from Argyle (NW Australia), and peridotitic diamond-hosted inclusions from Udachnaya (Sakha Republic, Russia) and Murowa (Zimbabwe).

Molybdenite is the principal carrier of rhenium (Re) on Earth, and therefore, we have used mass balance calculations to estimate the potential effects of its presence on the partitioning of Re within sulphide inclusions in diamonds. Although we will re-apply the Re-Os technique to previously dated Mir diamonds, the results of our model show that not recovering the molybdenite phase in the Re/Os dating procedure could lead to a significant misinterpretation of the Re/Os isochron ages of diamonds (of the order of several hundred million years).

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Large-scale topography of the core-mantle boundary

Paula Koelemeijer, *Department of Earth Sciences, University of Oxford, OX1 3AN, Oxford* (paula.koelemeijer@univ.ox.ac.uk)
Arwen Deuss, Utrecht University
Jeroen Ritsema, University of Michigan

The core-mantle boundary (CMB) marks the largest change in physical properties and temperature within the Earth, separating the slowly convecting rocky mantle and rapidly flowing iron outer core. The interplay of such dynamic processes at the CMB produces a range of structures at scales from tens to thousands of kilometres. In particular, accurate estimates of density variations are required to model mantle flow and to distinguish between a thermal or compositional origin of mantle heterogeneity. Topography on the CMB itself also plays a critical role in the coupling between the outer core and mantle. By studying these features through seismic observations, we gain important insights into core and mantle dynamics, leading ultimately to better constraints on the history of our planet.

Here, we review recent normal mode studies focused on the imaging of large-scale CMB structure. Normal modes are key for probing Earth's deep interior since they have the potential to resolve density variations, as well as velocity and topography structure. Particularly, Stoneley modes that are confined to the liquid-solid interface of the CMB provide an invaluable tool for determining CMB topography and lower mantle density structure. We present the results of a straightforward model space search, in which we determine the probability of different density and CMB topography models while incorporating our data uncertainties (Koelemeijer et al., 2017). We discuss the implications of our results in light of different geodynamic scenarios.

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Electrical conductivity of silicate liquids at extreme conditions and planetary dynamos

Lars Stixrude, *University College London* (l.stixrude@ucl.ac.uk)
Roberto Scipioni, University College London
Michael P. Desjarlais, Sandia National Laboratory

Are silicate dynamos possible? So far, planetary dynamos seated in silicate material are unknown. Several lines of evidence motivate the consideration of a silicate dynamo in the early Earth and in super-Earth exo-planets: 1) paleomagnetic evidence of a very early dynamo-generated field 2) models of the eartly thermal state of Earth in which the mantle is too hot to permit a core-generated field, and 3) the possibility of a deep, thick and long-lived basal magma ocean. The key requirement is that the electrical conductivity, of silicate liquids be sufficiently large at the relevant high pressure-temperature conditions ($\sigma > 1000$ S/m). Despite its importance, σ of silicate liquids is unknown above a few GPa in pressure, where measured values are far too small to support dynamo activity. However, observations of reflectivity from oxide liquids in shock wave experiments suggest a different mechanism of conductivity at high pressure (electrons rather than ions). We have used ab initio molecular dynamics simulations to compute from first principles the value of σ at extreme conditions in systems with compositions that are simple (SiO_2) and rich ($MgO–FeO–CaO–Al_2O_3–Na_2O–SiO_2$). We use DFT+U with and without spin polarization combined with the Kubo-Greenwood formula. We find that the value of σ exceeds the minimum requirements and that a silicate dynamo seated in a basal magma ocean is viable. We also find that the electrical conductivity shows a remarkable non-monotonic dependence on pressure that reveals connections to the underlying atomic structure, and highlights broken charge ordering as a novel compression mechanism.

Pre-melting in fcc and hcp metals

Martha G. Pamato, *Department of Earth Sciences, University College London, London WC1E 6BT, United Kingdom* (m.pamato@ucl.ac.uk)
Ian G. Wood, University College London
David P. Dobson, University College London
Simon A. Hunt, University College London
Lidunka Vočadlo, University College London

Although the Earth's core is believed to be made of an iron-nickel alloy with a few percent of light elements, its precise structure and composition still remain an unknown. Seismological and mineralogical models in the Earth's inner core do not agree, with mineralogical models resulting from ab initio calculations predicting shear-wave velocities up to 30% greater than observed values. Recent computer calculations revealed that this difference may be explained by a dramatic, non-linear, softening of the elastic constants of Fe just before melting.

To date, computer simulations are the only result on pre-melting of direct applicability to the Earth's core and it is crucial to investigate such phenomena at inner core conditions. Measuring the pressure dependence of pre-melting effects at such extreme pressures and temperatures to the required precision is exceedingly challenging. However, pre-melting effects have been observed or suggested to occur in other materials at lower pressures, particularly noble metals, which exhibit large departures from linearity (modulus defects) at elevated temperatures.

Here we investigate to what extent pre-melting behaviour occurs in the physical properties of other metals at more experimentally tractable conditions. In particular, we measured the unit-cell volumes and thermal expansion coefficients of gold (Au) and zinc (Zn) up to their melting point. Au is an ideal test material as it crystallises in a simple monatomic face-centred cubic structure while Zn adopts the hexagonal close-packed structure thought to be stable in pure Fe at inner core conditions. Both metals have a relatively low melting temperature making them ideal material to study in a laboratory. Precise measurements of unit cell lattice parameters were performed using a PANalytical X'Pert Pro powder diffractometer, equipped with an incident beam monochromator (giving very high resolution diffraction patterns) and with environmental stages covering the range from 40 K to 1373 K, with a readily achievable temperature resolution of 1 K.

We will discuss the conditions under which pre-melting occurs, the effect of structure and defects in the solid, and the consequences for pre-melting in the Earth's core.

Power-based scaling laws for planetary dynamos: An updated database and a reassessment

Alexandre Fournier, *Institut de Physique du Globe de Paris, 1 rue Jussieu, 75238, Paris cedex 05, France* (fournier@ipgp.fr)
Thomas Gastine, IPGP
Julien Aubert, IPGP

Numerical dynamo models notoriously do not operate in the adequate region of parameter space, since the stiffness of the problem at hand makes it mandatory to resort to enhanced values of transport properties for a solution to be within reach. Accordingly, the application of scaling laws derived from numerical simulations to planetary interiors implicitly assumes that simulations operate in the adequate dynamical regime. Christensen and Aubert (2006, CA06 henceforth) proposed along these lines power-based, diffusivity-free scaling laws for magnetic field strength and flow speed, based on the analysis of an ensemble of such simulations.The CA06 laws were subsequently applied to a large number of bodies in the solar system, including Earth. They have received some criticism in the past few years, in particular with regard to a residual effect of diffusivites on the properties deduced from the CA06 dataset. In view of providing a refreshing look at this issue, and noting that simulation have improved since 2006, we complement the CA06 dataset with simulations performed during the last decade. This amounts to doubling the size of the dataset (from $\mathcal{O}(100)$ to $\mathcal{O}(200)$ members), while enabling a broader sampling of parameter space. Physics-based selection criteria (most notably the magnetic energy to kinetic energy ratio) further allow us to select those dynamos which we think are indeed in the appropriate dynamical regime. This reduced dataset (comprising $\mathcal{O}(50)$ members) convincingly reveals power-based, diffusion-free scalings for magnetic field strength and flow speed.

The evolution of magnetic-Coriolis waves in the Earth's outer core

***Oliver Bardsley**, University of Cambridge* (ob275@cam.ac.uk)
Peter Davidson

It is thought that helical waves influenced by the background rotation and magnetic field may play an important role in the Earth's fluid dynamo. We concern ourselves with the dispersion of such waves from a localised source, for example a small buoyant anomaly, in a large-scale background magnetic field. When this mean field is uniform, the primary rays emitted by the source are hybrid inertial-Alfvén waves, which propagate rapidly along the rotation axis (like inertial waves) as well as along field lines (like Alfvén waves) [Bardsley & Davidson 2016, *J. Fluid Mech.*,**805**]. However, the mean magnetic field in the Earth's outer core is inevitably spatially non-uniform, a complication which we address by employing ray-tracing techniques to track the evolution of the principal wave packets as the field gradually varies; we consider a purely horizontal field which is antisymmetric about the equator, as a zero-order approximation to the azimuthal field in the Earth's core. The ultimate fate of the wave packets is heavily dependent on their launch location, but in general the inhomogeneity forces the inertial-Alfvén waves to mutate into a more generic class of magnetic-Coriolis waves. We describe this process and the diverse zoo of waves which emerge.

Columnar structure formation in the Earth's core by internally-driven inertial waves

Avishek Ranjan, *Department of Engineering, University of Cambridge, Cambridge CB21PZ* (ar606@cam.ac.uk)
Peter Davidson, U R Christensen, J Wicht

Columnar flow structures vertically spanning much of the core are a robust feature of many geodynamo simulations with rapid rotation. These are often interpreted in terms of columnar eigenmodes of convection, steady solutions of a boundary-value problem (BVP) in a sphere. However, the turbulent convection dynamics in the core is likely to be unsteady and the assumptions in the BVP are hardly justified for the core. We identify internally-driven inertial waves in a geodynamo simulation at high Rayleigh number (42 times supercritical) and low Ekman number $E = 3 \times 10^{-5}$. We use the MagIC code which solves the Navier-Stokes equations, coupled with the induction and temperature equations, in the Boussinesq approximation for a rotating, electrically-conducting fluid in spherical shell representative of Earth's geometry. Using cylindrical co-ordinates, we study the time-series of (a) azimuthal temperature gradient and (b) a time-derivative of vertical velocity ($\mathrm{d}w/\mathrm{d}t$). In these results, we find internally-driven inertial waves triggered by buoyant anomalies near the equator. These are low-frequency inertial waves which propagate vertically upwards (downwards) north (south) of the equator on a fast time-scale. We find that the slopes observed in the time-series of $\mathrm{d}w/\mathrm{d}t$ match closely with those expected from the group speed of low-frequency inertial waves. Moreover, the spectrum of $\mathrm{d}w/\mathrm{d}t$ lies in the inertial wave frequency range. Our results suggest that the columnar flow in the rotation-dominated core, an important ingredient for the maintenance of the dipolar magnetic field, is driven and maintained on a fast-time scale by low-frequency, internally-driven inertial waves.

Earth's inner core and its boundary from seismic body waves

Vernon F. Cormier, *Physics Department, University of Connecticut, Storrs, CT 06269-3046 USA* (vernon.cormier@uconn.edu)

Probing the inner core with seismic body waves can constrain its boundary topography and elastic impedance, the volumetric heterogeneity, texture, and rheology of the underling solid inner core, and the chemistry of the overlying outer core. After accounting for the focusing and defocusing of mantle heterogeneity, the amplitudes and travel times of P waves reflected from the inner core boundary at incidence angles from pre-critical to diffraction are consistent with an upper bound to topography of 1–2 km height in the 10–20 km wavelength range. This upper bound can assist in establishing estimates of viscosity in the uppermost inner core, imposing constraints on the mechanisms of differential rotation, its anisotropy, and possible convective flow. Large-scale, low-order harmonic order, elastic and anelastic structure of the inner core is now well documented in the uppermost 10–100 km of the inner core. These large-scale variations include regions of PKIKP multipathing and regions having anomalously large underside PKIIKP reflections, consistent with textural complexity and strong gradients in shear velocity near a solidifying or melting boundary. A number of observations, however, have yet to be well understood. These include the origin of time dependent travel times and amplitudes of PKIKP waves from earthquake doublets, the origin of occasional pulse-like signals in the coda between PKIKP and PKP-Cdiff, the relative contributions of inner core scattering and viscoelasticity to the attenuation of PKIKP and the coda of PKiKP, the mechanisms of lateral and depth dependent elastic anisotropy in the inner core, and the origin of an apparent structural transition half-way to the center of the inner core inferred from PKIKP attenuation and travel times.

Carbon in the Earth's inner core

***Yunguo Li**, Department of Earth Sciences, University College London. WC1E 6BT, London* (yunguo.li@ucl.ac.uk)
Lidunka Voadlo, University College London
John Brodholt, University College London.

Geophysical and cosmochemical models constrain the inner core to be composed mainly of iron and few percent light elements including Si, S, C, and H. However, mineral physics results do not agree with the seismological observations of both density and sound wave velocities in the inner core (Vovcadlo, 2007; Vovcadlo *et al*, 2009; Belonoshko *et al.*, 2007; Martorell *et al.*, 2013). Recent studies suggest a candidate for the inner core could be hcp iron alloyed with light elements (Li. *et al.*, 2001; Antonangeli, *et al.*, 2010; Hirose, *et al.*, 2013). Using *ab initio* molecular dynamics calculations, we have studied the structure and elastic properties of *hcp*-Fe alloys at 360 GPa up to the melting temperature. A ternary *hcp*-$Fe_{30}Si_1C_1$ alloy was found to match both the inner-core density and sound velocities. We also found other possible ternary and quaternary candidates based on a solid solution model, where carbon is always a necessary component to be in agreement with the seismic observations. These Fe-C-X compositions provide a new understanding of the Earth's core with important geodynamic implications.

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The implications of Fe–S–Si on Mercury's core evolution

Amy Edgington, *University College London (UCL)* (a.edgington.12@ucl.ac.uk)
Lidunka Vocadlo, UCL
Lars Stixrude, UCL
Ian G. Wood, UCL
David Dobson, UCL
Eero Holmstrom, Aalto University

The regime that governs the evolution of Mercury's core is fundamental to the origin and dynamics of the planet's magnetic field. Here we have used first principles methods to calculate the properties of Fe-S-Si, which, in combination with the melting behaviour of Fe-S-Si, reveal a top-down crystallisation of Mercury's core. Using a combination of ab initio molecular dynamics simulations, thermodynamic integration and free-energy minimisation, we additionally find that Fe, within the Fe-S-Si alloy, undergoes a gradual spin crossover extending far beyond the conditions of Mercury's interior. The properties of liquid Fe-S-Si and a top-down core crystallisation regime may have significant implications for the generation and strength of Mercury's magnetic field.

Did average geomagnetic field strength increase 1–1.5 billion years ago and, if so, why?

Andy Biggin, *Geomagnetism Laboratory, Dept. Earth Ocean and Ecological Sciences, University of Liverpool, L69 7ZE* (biggin@liverpool.ac.uk)

Knowing the timing of the first freezing of iron at the centre of Earth would provide a fundamental constraint on our planet's thermal evolution. It has recently been argued that palaeomagnetic intensity measurements support a substantial increase in the strength of the time-averaged field approximately 1.3 billion years ago and claimed that this could indicate a Mesoproterozoic age of inner core nucleation. Nevertheless, a more recent study by another group rejected this claim on the basis of rock magnetic and statistical arguments. This presentation will outline this controversy, the arguments on both sides, and what is being done to resolve it. It will also address the state-of-the-art in the documentation of long term palaeomagnetic variations and what they might signify in terms of our planetary thermal history.

Posters

Might a heavy rotating inner planetary core be a 'driver' for subduction?
Marjorie Allworth, *Fellow of the Geological Society of London* (marjorie.allworth@ntlworld.com)

Modelling geomagnetic variations in the satellite era
William Brown, *British Geological Survey* (wb@bgs.ac.uk)

Updated outer core reference model from a Bayesian inversion of normal mode eigenfrequencies
Sanne Cottaar, *University of Cambridge* (sc845@cam.ac.uk)
Jessica Irving, University of Princeton
Vedran Lekić, University of Maryland

Geomagnetic spikes on the core–mantle boundary
Chris Davies, *University of Leeds, Leeds, LS2 9JT, UK* (c.davies@leeds.ac.uk)
Catherine Constable, Scripps Institution of Oceanography, University of California San Diego, La Jolla, CA, USA

A study of geomagnetic jerks based on Chinese observatory records
Yan Feng, *The College of Mathematics and Statistics, Nanjing University of Information Science & Technology, Nanjing, 210044.* (frank_feng8848@163.com)
Richard Holme, University of Liverpool
Grace Cox, University of Liverpool
Yi Jiang, Nanjing University of Information Science & Technology.

Seismic investigations into the multi-scale lowermost mantle
Harriet Godwin, *Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN* (harriet.godwin@seh.ox.ac.uk)
Kuangdai Leng, University of Oxford
Paula Koelemeijer, University of Oxford
Karin Sigloch, University of Oxford
Tarje Nissen-Meyer, University of Oxford

Regional core-mantle boundary topography variations from body-wave differential traveltimes
Judit Gonzalez Santana, *Department of Earth Sciences, University of Oxford, OX1 3AN, Oxford* (judit.gonzalezsantana@seh.ox.ac.uk)
Paula Koelemeijer, University of Oxford
Tarje Nissen-Meyer, University of Oxford

Prototyping a new high-temperature, SQUID magnetometer system
J. Michael Grappone, *School of Environmental Sciences, University of Liverpool, Liv-*

erpool, Merseyside, L7 7BD (grappone@liverpool.ac.uk)
John Shaw, Magnetic Measurements
Andy Biggin, University of Liverpool

Implications of a weak geomagnetic field ∼370 million years ago for the effects of whole-mantle convection on long-term geomagnetic variation

***Louise Hawkins**, School of Environmental Science, University of Liverpool, Liverpool, U.K., L69 7ZE* (l.hawkins@liv.ac.uk)
Taslima Anwar, University of Alberta
Valentina Shcherbakova, Borok Geophysical Institute
Andy Biggin, University of Liverpool
Vadim Kravchinsky, University of Alberta
Andrey Shatsillo, Russian Academy of Science
Vladimir Pavlov, Russian Academy of Science

Investigation of crustal field in China using Swarm satellite data

***Yi Jiang**, Institute of Space Weather, Nanjing University of Information Science and Technology, Nanjing, 210044, China* (jsdjy1991@163.com)
Richard Holme, University of Liverpool Yan Feng, Nanjing University of Information Science and Technology

A high-latitude jet in Earth's core

***Phil Livermore**, School of Earth and the Environment, University of Leeds, LS2 9JT* (p.w.livermore@leeds.ac.uk)
Chris Finlay, DTU (Denmark)
Rainer Hollerbach, University of Leeds

Radial anisotropy at the top of Earth's inner core and implications for inner core dynamics

***Karen Lythgoe**, BP* (karen.lythgoe@uk.bp.com)
Arwen Deuss, Utrecht University

The reversed- and normal-flux contributions to axial dipole decay for 1880–2015

***Maurits Metman**, Institute of Geophysics and Tectonics, University of Leeds, Leeds, West Yorkshire, LS2 9JT* (eemcm@leeds.ac.uk)
Phil Livermore, University of Leeds
Jon Mound, University of Leeds

Modelling the deep Earth water cycle using mantle convection models

***Matthew Price**, Cardiff University* (pricemg@cardiff.ac.uk)
James Panton, Cardiff University
J. Huw Davies, Cardiff University
Tim Elliott, University of Bristol
Don Porcelli, University of Oxford

Water in inclusions in diamonds: A window into the mantle

Nuzhat Tabassum, *School of Earth Sciences, University of Bristol, Wills Memorial Building, Queens Road, Bristol BS8 1RJ, United Kingdom* (nuzhat.tabassum@bristol.ac.uk)
Simon Kohn, University of Bristol
Galina Bulanova, University of Bristol
Christopher Smith, University of Bristol

Flow and deformation in the sub-slab mantle

Jack Walpole, *University of Bristol* (jack.walpole@bristol.ac.uk)
James Wookey, University of Bristol
J.-Michael Kendall, University of Bristol
Guy Masters, Scripps Intitute of Oceanography, University of California San Diege

Thermochemical solution properties of silicate liquids at extreme conditions and implications for the magma ocean

Fred Wilson, *Earth Sciences, University College London, Gower Street, London, WC1E 6BT* (alfred.wilson.11@ucl.ac.uk)
Lars Stixrude, UCL

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