Space Park Leicester

BPSC 2024 LEICESTER

Opening Plenary

Planetarium, National Space Centre

Wednesday 19th June 09:30 - 11:00

A New View of Mercury with MIXS

Emma Bunce (Institute for Space, University of Leicester, UK)

Co-authors: On behalf of the MIXS team

Key Points: The UK-designed and built Mercury Imaging X-ray Spectrometer MIXS on the ESA-JAXA BepiColombo mission will enable a new view of Mercury's formation and evolution.

Abstract: Mercury has a unique role in understanding the evolution of planets from precursor planetesimals types, magmatism, a potential era of carbon-rich magma oceans, and the processes associated with volatile element mobilisation, together with a new understanding of Mercury's unique magnetosphere. The challenge that planetary scientists have faced with existing Mercury datasets is a lack of both global and high-resolution data. These science questions will be addressed with MIXS, which goes into orbit at Mercury on the ESA-JAXA BepiColombo mission from early 2026 for a 2-year nominal mission. MIXS will provide both the first global compositional map of Mercury's surface, and using the 10 km spatial resolution in its telescope channel, give compositional analyses of volcanic events, lava flows, volatile-rich areas, impact craters, that hold the key to determining the origin and evolution of the planet. MIXS will also be sensitive to the interplay between Mercury's magnetic field, the solar wind, and species released from the surface.

Venus: what we don't know (but soon will)

Richard Ghail (Royal Holloway, UK)

Co-authors: On behalf of the EnVision, Davinci, Veritas and Shukrayaan teams, and the Venus science community

Key points: We thought we knew Venus, but it is proving to be a more complex and enigmatic world than we ever imagined. The fleet of missions scheduled for the end of the decade promises many answers, and more questions.

The last decade has transformed our understanding of Venus, both directly through evidence for volcanic activity, including during an 8-month period of the Magellan mission, and indirectly through improved modelling. These discoveries shed light on a new class of large, geologically complex and active planets, informing our understanding of the dozens of recently discovered Earth-sized exoplanets.
Recognising that complexity implies we know less about Venus than we previously thought. Classification schemes and mapping units developed after Magellan are misleading, implying a common formation mechanism for coronae, tesserae and other features. While some commonality of process likely exists, a range of serendipitous processes were also key to the nature of each feature. Chief amongst these, tesserae and crustal plateaus are not uniformly ancient, but constructed and restructured through multiple episodes of tectonic deformation, magmatism, erosion and sedimentation. Some parts are undoubtedly active today. Indeed, what the impact craters reveal is that there are no large areas of Venus that are young or old: rejuvenation is a much more localised process on Venus than Earth.
This lends hope that answers to key questions will be forthcoming in the fleet of future missions: how volcanically and seismically active is Venus? Did it once have oceans, perhaps even life? What processes drove the transition and when? However, given its Earth-like size and complexity, the wealth of data these missions will obtain will undoubtedly lead to more questions than answers, for generations to come.

The Mineralogy of Asteroid Bennu: First Impressions From a "Quick Look"

Ashley King (Natural History Museum, London)

Co-authors: Helena Bates (NHM), Pierre Haenecour (LPL-UoA), Catherine Harrison (NHM/UoM), Lindsay Keller (NASA-JSC), Loan Le (NASA-JSC), Tim McCoy (SI), Jens Najorka (NHM), Paul Schofield (NHM), Sara Russell (NHM), Kathie Thomas-Keprta (NASA-JSC), Michelle Thompson (Purdue), Valerie Tu (NASA-JSC), Tom Zega (LPL-UoA), Harold Connolly Jr (LPL-UoA/RU/AMNH), Dante Lauretta (LPL-UoA)

Key points: First results from the analysis of samples returned from asteroid Bennu by the OSIRIS-REx mission.

On 24 September 2023, NASA's Origins, Spectral Interpretation, Resource Identification, and Security Regolith Explorer (OSIRIS-REx) mission returned to Earth a sample of the carbonaceous rubble-pile asteroid Bennu [1]. Carbonaceous asteroids are thought to be chemically primitive, rich in volatiles, and likely played an important role in the formation of planetary systems.

Based on spacecraft observations, it was predicted that the Bennu sample would consist of abundant phyllosilicates plus carbonates, oxides, and carbon, similar to the composition of highly aqueously altered CI ("Ivuna-like") and CM ("Mighei-like") carbonaceous chondrite meteorites [e.g., 2, 3]. This hypothesis was initially tested during a "quick-look" analysis of the fine dust coating the avionics deck of the sample canister and the outside of the sample collector. Over three days, the mineralogy of a small fraction (~138 mg) of this dust was characterised using a combination of optical and electron microscopy, infrared (IR) spectroscopy, and X-ray diffraction (XRD).

Most Bennu particles are dark and have morphologies that range from angular to sub-rounded or hummocky. They typically consist of ~80 vol.% phyllosilicates, with <10 vol.% Fe-sulphides and magnetite, and <5 vol.% carbonates and anhydrous silicates. The Fe-sulphides are mainly pyrrhotite, carbonates are dolomite plus minor calcite and breunnerite, and magnetite occurs in a range of morphologies including framboids and plaquettes. Phosphates (Mg-Na- and Ca-rich) are also present as minor phases. This mineralogy is in good agreement with remote observations of Bennu's surface and is consistent with hydrothermal alteration on a parent body that accreted in the outer solar system.

[1] Lauretta et al. (2022) Science 377:285.
[2] Hamilton et al. (2019) Nat. Astron. 3:332.
[3] Lauretta et al. (2023) arXiv [astro-ph.EP] 2308.11794.

Parallel 1A: Chondrites and Bennu

Conference Room (with overflow in room 0.11 Swift) at Space Park Leicester

Wednesday 19th June 11:30 - 13:00

Bulk Oxygen Isotope Composition of Aggregate Samples from Asteroid Bennu Returned by OSIRIS-REx.

Ian Franchi (The Open University, UK)

Co-authors: Richard Greenwood (OU, UK), James Malley (OU, UK), Jessica Barnes (U.Arizona, USA), Ann Nguyen (NASA JSC, USA), Harold Connolly Jr

Key points: Bulk high precision oxygen isotopic composition of samples of samples returned by the NASA OSIRIS-REx mission

NASA's OSIRIS-REx mission delivered a sample of regolith from asteroid Bennu to Earth in September 2023. Remote sensing measurements indicated that the asteroid is rich in hydrated minerals and organics [e.g. 1,2], with several different boulder types identified [3].

Oxygen 3-isotope signatures reflect the materials from which parent asteroids accreted and the geological processes that operated during asteroidal evolution. Aggregate samples of particles (typically <500 um) are likely derived from many different larger stones and boulders, and their composition may therefore represent the average composition of Bennu. Evidence for the presence of multiple lithologies, including exogenous components, within the regolith may be provided from selected size fractions of the aggregate sample.

We determined the O isotope composition of several Bennu samples, separated into fines (<100 um) and intermediates (100–500 um), using the laser-assisted fluorination system at the Open University. The samples have a similar, but not identical, isotopic composition to some of the most chemically primitive chondritic materials known, such as the CI and CY chondrites and samples from asteroid Ryugu [4]. Isotopic variation observed between different particle size fractions of the aggregate samples indicate heterogeneity within Bennu's regolith that may be related to lithologies with different mechanical properties.

References: [1] Hamilton V.E. et al. (2019) Nat. Astron., 3, 332-240. [2] Simon A.A. (2020) Science 370, eabc3522. [3] DellaGiustina D.N. et al. (2020) Science 370, eabc3660. [4] Greenwood R.C. et al. (2023) Nat. Astron. 7, 29.

Space Park Leicester

BPSC 2024 LEICESTER

Anhydrous silicates from asteroid Bennu: Evidence for protoplanetary disc components

Sara Russell (Natural History Museum, London)

Co-authors: Ian Franchi (OU, UK), Xuchao Zhao (OU, UK), Rhian Jones (Manchester, UK), Ashley King (NHM, UK), Harold Connolly (Rowan), Tobias Salge (NHM, UK), Natasha Almeida (NHM, UK), Helena Bates (NHM, UK), Paul Schofield (NHM, UK), Catherine Harrison (NHM, UK), Phil Bland (Curtin), Trevor Ireland (Uni Queensland), Fred Jourdan (Curtin), Steve Reddy (Curtin), William Rickard (Curtin), Dave Saxey (Curtin), Nick Timms (Curtin), Tom Zega (U. Arizona), Tim McCoy (Smithsonian), Jess Barnes (U. Arizona), Ann Nyugen (NASA JSC), Dante Lauretta (Uni Arizona)

Key points: Although Bennu material is highly aqueously altered, it contains some olivine and pyroxene grains that formed before accretion. Their chemistry and isotopic composition can give clues to protoplanetary disc components from which Bennu's parent body was formed.

NASA's OSIRIS-REx mission delivered regolith from asteroid Bennu to Earth in September 2023 [1]. Remote sensing measurements indicated that the asteroid is rich in hydrated minerals [2,3], and this hypothesis [4] was confirmed by initial examination of the sample [1]. Bennu has experienced extensive interaction with an aqueous fluid producing phyllosilicates, carbonates, sulphides, phosphates and magnetite [e.g. 4,5; see talk by King et al. at this conference]. Our analyses also showed that Bennu contains olivine at levels of up to a few percent, as well as rarer pyroxene, consistent with predictions [4]. Olivine and pyroxene are typically up to 10 microns across (occasionally larger) and exist as isolated rounded to angular or irregularly shaped chemically homogeneous grains. Olivine compositions tend to be forsteritic, most commonly Fo95-99, with more fayalitic compositions present in much less abundance. Chromium, Mn and Ca are present in all olivines typically well above the detection limit. Orthopyroxene grains are typically enstatite-rich: En96-98 and Wo0-1. Oxygen isotope compositions analysed by NanoSIMS will be presented. These grains show that Bennu accreted from protoplanetary disc material, and their study provides clues to their provenance.

References: [1].[2] Lauretta D. S. et al. (2024) arXiv [astro-ph.EP] 2404.12536. [2] Hamilton V. E. et al. (2019) Nat. Astron., 3, 332–340. [3] Kaplan H. H. et al. (2020) Science, 370, eabc3557. [4] Lauretta D. S. et al. (2023) arXiv [astro-ph.EP] 2308.11794 [5] King A. J. et al. (2024) LPSC #1109. [5] Zega T. J. et al. (2024) LPSC #2348.

CM Carbonate-eous chondrites: phase heritage of tochilinite-cronstedtite intergrowths reveal a carbonate precursor.

Luke Daly (University of Glasgow, UK)

Co-authors: Martin D. Suttle, Martin R. Lee, John Bridges, Leon Hicks, Pierre-Etienne M. C. Martin, Cameron J. Floyd, Laura E. Jenkins, Tobias Salge, Ashley J. King, Natasha V. Almeida, Diane Johnson, Patrick W. Trimby, Haithem Mansour, Fabian B. Wadsworth, Gavyn Rollinson, Matthew J. Genge, James Darling, Paul A. J. Bagot, Lee F. White, Natasha R. Stephen, Jennifer T. Mitchell, Sammy Griffin, Francesca M. Willcocks, Rhian Jones, Sandra Piazolo, Joshua F. Einsle, Alice Macente, Lydia J. Hallis, Aine O'Brien, Paul F. Schofield, Sara S. Russell, Helena Bates, Caroline Smith, Ian Franchi, Lucy V. Forman, Phil A. Bland, David Westmoreland, Iain Anderson, Richard Taylor, Mark Montgomery, Mark Parsons, Jérémie Vasseur, Matthias van Ginneken, Penelope J. Wozniakiewicz, Mark J. Burchell, Daniel Hallatt, Luke S. Alesbrook, Vassilia Spathis, Richard Worden, Julie Behnsen, Kate Black

Key points: What were TCIs? Texture suggests carbonate. Where did carbon go?

Tochilinite-cronstedtite intergrowths (TCIs) are characteristic of CM carbonaceous chondrites [1-4]. TCIs are thought to form from an evolving fluid replacing metals, sulphides, anhydrous silicates or growing into voids [1-4] but the relative proportion of TCI precursors is unconstrained. Phase heritage states that during replacement reactions the morphology and crystal orientation of secondary phases are controlled by the precursor's mineralogy [6].
Here we use coordinated microanalysis and phase heritage to determine the precursor phase(s) of TCIs within the Winchcombe CM chondrite.
Our results show that care must be taken to identify true TCIs, as some morphologically similar objects have no cronstedtite [7]. In several locations TCIs partially replace carbonates including aragonite and calcite. Where primary carbonate is surviving within a TCI, TCIs adopt the morphology of the carbonate with Fe-S-rich tochilinite preserving the carbonate's sub-grain boundaries and 120° triple junctions. The dominant TCI textures within the matrix of Winchcombe have similar sub-grains with triple junction boundaries that are distinct from TCI textures that have replaced metal, sulphide or silicates. Our data suggest that matrix TCIs, representing 20-40 vol% of Winchcombe, may have originally been carbonates and thus CM chondrites may have been much more carbonate-rich than previously thought. Subsequent loss of carbonate from CMs requires open system alteration.

[1] Suttle et al., 2021, GCA. [2] Lee et al., 2014, GCA. [3] Vacher et al., 2017 GCA. [4] Pignatellit et al., 2016, MAPS. [5] Alexander et al., 2012, Science. [6] Timms et al., 2017, EPSL. [7] Topping et al, 2024 BPSC.

The aqueous history of Essebi (C2-ung)

Liza Riches (The Open University, UK)

Co-authors: Martin Suttle (The Open University), Ian Franchi (The Open University)

Key points: Analysis of carbonates in C2-ung sample Essebi reveal multiple stages of aqueous alteration which overlap with brecciation events. The carbonates present are petrographically distinct, but early-stage alteration calcites show similar isotopic trends to grains previously found in CM chondrites.

As a widespread product of aqueous alteration, carbonates are a valuable tool for investigating hydrous processes on early Carbonaceous Chondrites (Farsang et al., 2021). Multiple generations of carbonate grains can form as fluid conditions evolve during a protracted alteration sequence, tracking the different stages of aqueous alteration (Tyra et al., 2012). By analysing carbonates petrographically, chemically, and isotopically it is possible to infer changes in conditions throughout the alteration sequence, most notably changes in temperature and O-isotope fluid composition.

Essebi is a breccia with ~6 area% chondrules and fine-grained phyllosilicate matrix.

Multiple generations of carbonates were identified using an SEM, the oldest group is a collection of larger (or fragments of large grains), anhedral calcite grains with δ17O values between 18.3 ‰ and 23.4 ‰ and δ18O values between 33.6 and 42.0 ‰, the second group is composed of smaller, sub to euhedral calcite grains δ17O ranging between 10.3 ‰ and 16.2 ‰ and between 23.1 and 27.5 ‰ for δ18O. In addition, dolomites were found within a large clast and additional calcites were found both bordering this clast and within veins which suggest that some later carbonates formed after brecciation in later stages of aqueous alteration. This is different to typical CM observations where aqueous alteration predates brecciation. Whilst showing similar oxygen isotopic trends to CM groups, these calcites did not show the same petrographic observations of CMs. This shows that CM alteration processes may be similar to those on non-CM parent bodies.

Investigating Ca-Al-rich Inclusions (CAIs) and Compound-Chondrule-CAI (CCCAIs) Populations within CM Chondrites using Oxygen Isotopes

Pierre-Etienne Martin (University of Glasgow, UK)

Co-authors: Luke Daly (UofG, U. of Sydney, U. of Oxford), Johan Villeneuve (CRPG, France), Martin. R. Lee (UofG) and Yves Marrocchi (CRPG, France)

Key points: The existence of CCCAIs suggests that chondrules and CAIs interacted within high particle density environments in the protoplanetary disk prior to their incorporation into their CM parent bodies. Using oxygen isotope spectroscopy, we traced back the origin of the CCCAI components in regards to their regular counterparts.

Compound-Chondrule-Calcium-Aluminium-rich Inclusions (CCCAIs) are rare occurrences that have been sporadically reported within most major carbonaceous groups (CO, CV, and CH) and only described four times within aqueously altered CM (Mighei-like) chondrites.
CCCAIs have been described as CAIs enclosing chondrules or as chondrules enclosing CAIs. Their existence suggests that chondrules and CAIs interacted within high-particle density environments in the protoplanetary disk prior to incorporation into their mutual parent bodies. We investigated chondrule and CAI populations from two CMs: LAP 02239 (CM2.4-2.5) and Aguas Zarcas (two samples; CM2.2-2.3). Large-area SEM-EDS investigations revealed three confirmed CCCAIs amongst the samples. Oxygen isotope analysis (16O, 17O, and 18O) using Secondary Ion Mass Spectrometry (SIMS) was conducted to characterise the CAI and chondrule components of the CCCAIs and to compare them with CAI and chondrule populations within their host meteorites. Targeted mineral phases include spinel from CAIs and the CAI component of CCCAIs, and olivine and diopside for chondrules and the chondrule component of the CCCAIs.
Results show that the CAI and chondrule components of CCCAIs originate from the same O isotope reservoirs as their regular counterparts. No oxygen isotope variations were observed within the investigated CCCAIs. However, the chondrule component of one of the identified CCCAIs displays a very primitive O isotope composition similar to that of Amoeboid Olivine Aggregates, suggesting a near-solar formation environment. Future work will include a more in-depth investigation of the potential link between the CAI O-isotope signatures and the degree of aqueous alteration of their host CM lithologies.

Multi-technique analysis of sulphur-bearing serpentine in carbonaceous chondrites

Niamh Topping (University of Leicester, UK)

Co-authors: John Bridges (Uni of Leicester, UK), Leon Hicks (Uni of Leicester, UK), Chris Allen (ePSIC, DLS, UK)

Key points: Correlative electron microscopy and x-ray synchrotron analyses of phyllosilicate material in CM and CI chondrites to investigate the role of sulphur in sulphur-bearing serpentine minerals.

Carbonaceous chondrites (CCs) contain important history in their mineralogy about processes in the early Solar System. It is widely accepted that CM and CI chondrites have undergone extensive aqueous alteration on their parent bodies [Brearley 2006; Suttle, 2021], resulting in secondary mineral assemblages where the bulk volume is phyllosilicate-rich matrices and the dominant phase is serpentine [McSween, 1987], a sheet silicate with 0.70 nm repeating tetrahedral-octahedral layers. Sulphur in both terrestrial [Debret, 2017] and extra-terrestrial [Zega, 2004] materials has been previously studied, where both conclude that sulphur is incorporated into the serpentine structure, but differ in valence states. Debret (2017) suggest a valence state of S6+ in abyssal serpentines, whereas Zega (2004) investigated the Mighei CM-chondrite and suggest S2-, where sulphur replaces the O2- in the tetrahedral layer. We have adopted a multi-technique approach to study S-bearing serpentines in several CM and CI samples. Winchcombe and Aguas Zarcas (CM-type) and Ivuna, Orgueil and Ryugu (CI-type) were studied. SEM BSE imaging and EDS were conducted on an FEI Quanta 650 SEM, whilst high-resolution, aberration-corrected TEM measurements (HRTEM imaging for lattice spacings, high-resolution EDS, and 4DSTEM with correlative EDS mapping) were conducted at ePSIC, Diamond Light Source (DLS). S-K edge XANES measurements were taken on the I18 microfocus beamline at DLS. We have identified S-bearing serpentines in several CC specimens using EDS compositional information and HRTEM lattice spacing measurements. The dominant sulphur species appears to be S2- and we suggest that sulphur is likely incorporated into the mineralogical structure of serpentine.

Parallel 2A: Giant Planet Ionospheres, & Magnetospheres

Abbey Room (with overflow in the Exosat) at Space Park Leicester

Wednesday 19th June 11:30 - 13:05

Aspects of Magnetosphere-Ionosphere Coupling Across Worlds

Nick Achilleos (University College London, UK)

Key points: Magnetosphere-ionosphere coupling manifests in many different ways. Observable signatures of this process include planetary aurorae, atmospheric phenomena and response to solar wind conditions.

In this overview, we will consider some of the similarities and differences in how 'magnetosphere-ionosphere' coupling manifests at the planets Jupiter, Saturn and the Earth. Auroral emissions and their variability are a common thread in this comparison - however, the detailed nature of the plasma flow shears associated with auroral currents arise for different reasons at the different planets. This leads to distinct morphological properties for auroral emissions associated with a solar-wind origin, as opposed to an internal magnetospheric origin. Moreover, one of the biggest 'mysteries' associated with the observations at Saturn's magnetosphere by the Cassini spacecraft - the ubiquitous quasi-periodic modulations in field and plasma properties - seems to be consistent with a particular type of vortical flow perturbation in the upper atmosphere 'communicating' its presence to the magnetospheric environment.

Jupiter’s dawnside magnetodisc: the force-balance context to Juno observations

Gabrielle Provan (University of Leicester, UK)

Co-authors: J. D. Nichols (UoL, UK) and S. W. H. Cowley (UoL, UK)

Key points: It is the hot magnetospheric plasma which predominantly governs variations in the total azimuthal current in the magnetodisc.

We employ an iterative vector potential model of force balance in Jupiter’s dawnside magnetodisc in order to examine the physics behind variations in the total azimuthal current previously observed by Juno. Specifically, we vary three key parameters that govern the force balance: a hot plasma parameter (=pV), the iogenic plasma mass outflow rate, and the ionospheric conductivity. We consider data obtained by Juno on orbits 1-12 as the spacecraft travelled inbound towards Jupiter and crossed the Jovian magnetodisc in Jupiter's middle magnetosphere. We fit the model to the residual component of the magnetic field and the density of the plasma sheet ions, finding the best-fit parameters for each orbit. We find orbit-by-orbit variations in the best-fit parameters, demonstrating a dynamic plasma sheet. We find a relation between the total azimuthal current in the magnetodisc and the hot plasma parameter, demonstrating that it is the hot plasma which predominantly governs variations in the total azimuthal current in the magnetodisc.

Saturn's asymmetric magnetospheric flows

Tom Stallard (Northumbria University, UK)

Co-authors: K. Adams (Northumbria), Nahid Chowdhury (U. Leicester), Ruoyan Wang (U. Leicester)

Key points: We explore observations of Saturn's ionospheric winds, removing known axisymmetric and atmospheric flows, to attempt to unveil underlying magnetospheric flows

Saturn's magnetosphere is dominated by the strong interaction between the atmosphere and surrounding magnetospheric plasma. Like Jupiter, the coupling between the neutral atmosphere and ionosphere attempts to accelerate both the ionosphere, and through field-aligned currents, the magnetospheric plasma in to corotation. Unlike Jupiter, however, this attempt largely fails - the plasma almost immediately sub-corotates at Enceladus, as ions provide too much torque for the atmosphere to control. In addition, a twin-cell vortex within the neutral atmosphere also drives further flows within the ionosphere and out into the surrounding magnetosphere. At Jupiter, Wang et al., 2023 recently observed the neutral atmosphere flows, showing a huge atmospheric vortex aligned with the magnetic pole of the planet. This reduces breakdown in corotation currents in the upper ionosphere, but allows asymmetric currents to flow. Similar measurements of the neutral flows at Saturn would be ground-breaking, but the atmosphere is too cool to allow comparable measurements to be made.

Here, we use measurements of the ion winds by Stallard et al., (2019) and Chowdhury et al,. (2021) to emulate the predicted Saturnian thermospheric flows, assuming axisymmetry around the magnetic pole as with Jupiter. We further utilise Chowdhury's measurements of the changing ion flows with Saturn's planetary period phase changing to estimate how the thermosphere moves as the planet rotates. Using this, we then calculate the effective ion drift in the upper ionosphere as an averge over time, attempting to reveal any asymmetric magnetospheric flows in the process.

IRTF-iSHELL observations of Jupiter's aurora during the NASA-Juno mission

Rosie Johnson (Aberystwyth University, UK)

Co-authors: Tom Stallard (Northumbria University), Tom Knight (Aberystwyth University)

Key points: IRTF-iSHELL IR H3+ observations of Jupiter's southern aurora during PJ4. Discuss novel method to study the ionospheric and magnetospheric current system at Jupiter and how it is connected to the solar wind, nicknames 'Jupidarn'.

Our long-standing ideas surrounding the generation of Jupiter's aurora have been challenged by new results from the NASA Juno mission, which discovered a complex array of auroral currents that conflict with past theory. A global view of these currents is required to determine how they are generated; however, this can only be achieved through observations with ground-based telescopes since spacecraft can only provide information along the orbital path. Since 2016, IRTF-iSHELL observations have been used to provide ground-based support for the NASA-Juno mission, observing Jupiter's aurora while Juno takes in-situ measurements of the magnetosphere as well as observing the aurora. These ground-based measurements are critical as Juno-JIRAM lacks the spectral resolution to measure the Doppler shift of the H3+ spectra, from which the line-of-sight velocity can be derived and the ionospheric flows inferred.
We present the H3+ parameters measured in Jupiter's southern auroral region during PJ4. We discuss how these flows compare to past observations and how they relate to some of the Juno discoveries. Furthermore, we discuss our plans for the H3+ line-of-sight velocities and how they will be used to develop a novel method to study the ionospheric and magnetospheric current system at Jupiter and how it is connected to the solar wind, which we nickname 'Jupidarn'.

Ionospheric disturbances at Jupiter observed by JWST

Henrik Melin (University of Leicester, UK)

Co-authors: O'Donoghue, L. Moore, T. S. Stallard, L. N. Fletcher, M. Roman, J. Harkett, O. King, E. M. Thomas, R. Wang, P. I. Tiranti, K. Knowles, I. de Pater, T. Fouchet, P. Fry, M Wong, B. Holler, R. Hueso, M. K. James, G. S. Orton, A. Mura, A. Sanchez-Lavega, E. Lellouch, K. de Kleer, M. R. Showalter

Key points: JWST observes irregular shapes in Jupiter's upper atmosphere, suggestive of breaking of gravity waves.

The charged particle ionosphere of Jupiter, forming part of the upper atmosphere, is an important interface region between the atmosphere below, the magnetic field, and the space environment. It is formed via the ionisation by both auroral electron precipitation at the poles and by solar extreme ultraviolet (EUV) radiation across the sunlit disk. Since the incoming solar radiation is smooth across the disk of Jupiter, the expectation was that the ionosphere at low latitudes should be very smooth and feature-less in nature. Here, we present JWST NIRSpec IFU observation (ERS #1373) of the low-latitude ionosphere in the region of the Great Red Spot, showing surprising structures within the ionosphere. There are arcs, bands, and spots covering the entire field-of-view, showing variability of a factor of four, indicating that once produced by solar EUV, the structure of the low-altitude ionosphere is externally forced, altering its structure. The GRS is surrounded by fierce troposphere turbulence that can generate gravity waves which can propagate up in altitude and alter the structure of the observed ionosphere. We propose that these observations provide evidence of string coupling between the lower and upper atmosphere.

Jupiter's auroras from Hubble and Juno

Jonny Nichols (University of Leicester, UK)

Key points: Jupiter's auroras as observed from the Hubble Space Telescope and Juno

We present recent work in which we compare Hubble Space Telescope observations of Jupiter's FUV auroras with Juno observations of the magnetosphere. We show that Jupiter's equatorial magnetospheric radial current, which drives corotation in the magnetosphere, is strongly correlated with the dawn side auroral intensity. We go on to examine the cause of low latitude auroral patches by comparison with energetic particle data in the inner magnetosphere, and show that the patches are associated with magnetospheric injections and ongoing convection in the magnetosphere.

Parallel 1B: Small Bodies and Chondrites

Conference Room (with overflow in room 0.11 Swift) at Space Park Leicester

Wednesday 19th June 14:00 - 15:35

The ESA Comet Interceptor Mission

Colin Snodgrass (University of Edinburgh, UK)

Co-authors: The Comet Interceptor team

Key points: Comet Interceptor will launch in 2029 and wait in space until a suitable new comet is found, before performing a fast flyby mission and releasing two small probes. This will give us our first in situ investigation of a largely unaltered long period comet.

Comet Interceptor is a European Space Agency (ESA) mission in cooperation with the Japan Aerospace Exploration Agency (JAXA). It aims to characterise through a close flyby a long period comet, preferably dynamically new, or an interstellar object. The main spacecraft will be accompanied in its encounter with the target comet's nucleus by two small probes, one provided by Europe, and the other by Japan, providing multi-point measurements of the cometary coma during the flyby. The mission is planned for launch in 2029. It is unique in being designed and built before its target is known: in the era of next generation sky surveys (in particular the Vera C Rubin Observatory's Legacy Survey of Space and Time) it is expected that incoming long period comets will be discovered at relatively large distance, but still with too little time to plan and launch a mission following discovery. Instead, Comet Interceptor will launch to the Sun-Earth L2 point, sharing a launch with the ESA Ariel space telescope, and wait in space for a suitable target to be found. We will describe the mission and the preparations that are being made for science with it, including work towards identification of a suitable target.

The volatiles of giant and giant Oort cloud comet C/2014 UN271 sent with JWST

Bryce Bolin (NASA Goddard Space Flight Center)

Co-authors: Mike Brown, Mohi Saki, Dina Prialnik, Silvia Protopapa

Key points: We observed the largest known Oort Cloud comet with JWST. We detected cometary volatiles that may provide constrains on the origin of the Oort Cloud.

The physical properties of 140 km Oort cloud comet C/2014 UN271: Comets are pristine remnants of the original planetesimals that formed beyond the gas giants. The Oort Cloud comet C/2014 UN271, hereafter UN271, is ~140 km in diameter, large enough that it could be an intact example of a planetesimal that accreted in the protoplanetary disk. It is on its first inbound into the planetary region, providing the rare opportunity to study an original planetesimal's physical and volatile properties. We present Gemini S/GMOS-S and JWST/NIRSpec observations of UN271 taken in 2021 and 2022, covering 0.4-5.2 microns. Our observations provide constraints on the comet's dust and volatile contents (H_2O, CO_2, and CO), its activity-driving mechanism, and the planetesimals and Oort Cloud formation.

Constraining ion transport in the diamagnetic cavity of comet 67P

Zoe Lewis (Imperial College London, UK)

Co-authors: Arnaud Beth (Imperial, UK), Marina Galand (Imperial, UK), Pierre Henri (CNRS, France), Martin Rubin (Bern, CH), Peter Stephenson (Lunar and Planetary Laboratory, Arizona, USA)

Key points: A 1D ionospheric model that incorporates acceleration by an ambipolar electric field has been developed for comet 67P. The model is used to constrain the size of the electric field and bulk velocity of the plasma through comparison with electron density from the Rosetta instruments.

Comet 67P was the target of the ESA Rosetta mission, escorted by the spacecraft for two years. By perihelion in August 2015, the neutral and plasma data obtained by the spacecraft instruments showed that the comet had become a dynamic object with large scale plasma structures and a rich ion environment. One such structure is the diamagnetic cavity: a region surrounding the nucleus where mass loading by un-magnetised cometary ions prevents the solar wind from carrying the magnetic field to the surface. Within this region, unexpectedly high ion bulk velocities have been observed, thought to be caused by acceleration from an ambipolar electric field. The nature of this field is difficult to determine analytically.
In this study we use a 1D numerical model of the cometary ionosphere to constrain the impact of various electric field profiles on the ion density profile. In the model we include three ion species, H_2O^+, H_3O^+ and NH_4^+, and assess how their relative composition, as well as the total plasma density, vary with ambipolar electric field strength. By comparing simulated electron densities to Rosetta Plasma Consortium data sets, we find that to recreate the plasma densities measured inside the diamagnetic cavity near perihelion, the model requires an electric field proportional to r^{-1} of around 0.5–2 mV m^{-1} surface strength, leading to bulk ion speeds at Rosetta of 1.2–3.0 km s^{-1}.

Chips off differentiated asteroids revealed by ESA's Gaia

Marco Delbo (Observatoire de la Côte d'Azur, France)

Co-authors: Chrysa Avdellidou (UoL, UK), Marjorie Galinier (OCA, FR), Laurent Galluccio (OCA, FR)

Key points: Asteroid spectra obtained by ESA's Gaia space mission reveal an unexpected overabundance of asteroids with a spectral class that indicates an olivine-rich composition. These could be fragments of early generation asteroids that went through heating and differentiation.

Classification of asteroid reflectance spectra obtained by ESA's Gaia space mission reveals that asteroids with a spectral class that indicates an olivine-rich composition are overabundant of more than a factor of 10 compared to previous results.
We follow up several of these asteroids by obtaining near infrared spectra using the SpeX instrument at the NASA infrared telescope facility (IRTF). We then combined Gaia visible and IRTF near-infrared spectra to obtain a more compositionally diagnostic description of the reflectance of these asteroids than that offered by the Gaia data alone.
We present the findings of our observational survey and discuss their implications for the "missing mantle problem." This problem, a long-standing question in planetary science, refers to the observed scarcity of olivine-rich asteroids in the main belt. This scarcity appears inconsistent with the theories suggesting that differentiated asteroids, which contain substantial amounts of olivine, should have been abundant during the early stages of our solar system's formation. We show that the abundance of Gaia olivine-rich asteroid is dependent on the heliocentric distance, contrasting with previous findings. We also find olivine rich asteroids in collisional families, which are logical to be expected to form from the break-up of a differentiated parent body.

The Search for a Long-Lost Planetesimal

Ben Rider-Stokes (The Open University, UK)

Co-authors: Sam Jackson (OU), Thomas Burbine (Mount Holyoke College), Lee White (OU), Richard Greenwood (OU), Mahesh Anand (OU), Akira Yamaguchi (NIPR), Monica Grady (OU).

Key points: Using UV-Vis-NIR spectra to search for remnants of a long lost planetesimal.

Angrite meteorites are fragments of an ancient, long-lost body that once existed in our Solar System. While the size of the angrite parent body (APB) remains disputed, recent estimates point toward a Moon-to-Mars-sized object. Yet, curiously, unlike the howardite-eucrite-diogenites, which are thought to originate from a much smaller object in comparison, 4 Vesta, no known parent body has been spectrally matched to the angrites in the modern-day Solar System. In this study, we evaluate the spectral properties of ten unique angrites using a JASCO MSV-5700 UV-Vis-NIR microspectrophotometer (MSP) at the Open University and compare them with over 700 asteroids to evaluate the potential parent bodies of the angrites. Based on the analysis and subsequent asteroidal comparisons, a strong match between the angrites and the asteroid (354) Eleonora was identified. (354) Eleonora is the largest A-type asteroid, with a diameter of approximately 150 km, akin to the early estimates of the parent body size for angrites. The surface mineralogy consists of a fine-grained lithology with intermediately mixed olivine, resembling the petrology of the rapidly-cooled (quenched) angrites. Based on the proximity to the 5:2 mean-motion resonance, material from the surface of (354) Eleonora could be easily distributed to the inner Solar System, and hence delivered to Earth. We, therefore, conclude that (354) Eleonora provides the most likely candidate (in the currently known population of asteroids) for the angrite meteorites, demonstrating the second-only meteorite-parent match.

Understanding Aqueous Alteration in CM Chondrites using Infrared Spectroscopy and Thermogravimetric Analysis

Jodie Sutherland (University of St Andrews, UK)

Co-authors: Dr Ashley King (NHM, UK), Dr Helena Bates (NHM, UK)

Key points: Deciphering the IR spectra and TGA water content to further understand the degree of aqueous alteration and thermal alteration within CM chondrites.

C-type asteroids are primitive bodies that formed within the outer solar system and are likely to have played an important role in the formation and evolution of the terrestrial planets. Fragments of C-type asteroids known as carbonaceous chondrite meteorites are found on Earth and we can use these to constrain the geological history. CM chondrites record varying quantities of water-rock reactions and thermal metamorphism on C-type asteroids and in this study, I aim to characterise this using Infrared spectroscopy.

I took small aliquots of bulk CM chondrite powders previously characterised using XRD and TGA and mixed them with KBr to make pellets. The mineralogy and water content was characterised using transmission IR spectroscopy. Pellets were measured before and after heating to remove any water absorbed from the terrestrial atmosphere. Analysis of IR spectra focused on the 3µm and 10µm features. Most of the CM chondrites and Tarda showed strong 3 µm and 10 µm features and only a minor olivine feature at 11.2 µm, consistent with hydration and abundant phyllosilicates. The degree of alteration can be inferred from the intensity of the 3 µm feature and the 11.2 µm / 10 µm intensity ratio; the 3 µm feature increases and the 11.2 µm feature decreases as the level of hydration and aqueous alteration increases. Studying the IR spectra and TGA water content can decipher the degree of aqueous and thermal alteration within CM chondrites, which will be used to understand the sources of water to the early Earth.

Space Park Leicester

BPSC 2024 LEICESTER

Parallel 2B: Giant Planet Ionospheres, Magnetospheres & Astrobiology

Abbey Room (with overflow in the Exosat) at Space Park Leicester

Wednesday 19th June 14:00 - 15:30

The 30 year pursuit to unearth Uranus's infrared aurorae

Emma Thomas (Northumbria University, UK)

Co-authors: Henrik Melin (UoL, UK), Tom Stallard (NU, UK), Mohammad N. Chowdhury (UoL, UK), Ruoyan Wang (UoL, UK), Katie Knowles (NU, UK), Steve Miller (UCL, UK)

Key points: First detection of the infrared aurora at Uranus via H3+ spectroscopy since first investigations in 1992. We identify discrete auroral structures similar to the UV aurorae, with a possible auroral arc which has never observed before.

The Ice Giants stand as scientific gems within our own solar system. The first and only fly-by of the planet was Voyager II in 1986, where subsequent data created more questions than answers. One of the most unusual aspect of Uranus is it's magnetic field, off centered and tilted an extra 59˚ degrees from the planet's rotational axis (Ness et al., 1986), presenting a constantly changing magnetospheric system. Interactions between Uranus's magnetic field lines and ionosphere drive the aurorae, first observed by Voyager II (Herbert and Sandel, 1994) and redetected via HST in the 2010's (Lamy et al., 2012, 2017). Since the early 1990's (Trafton et al., 1993), we have continuously searched for the infrared aurora at this planet (e.g. Melin et al., 2011, 2013, 2019), analogous to the aurorae of Jupiter and Saturn but none have confirmed its existence. Here we present H3+ emission mappings across Uranus's ionosphere, along with ionospheric temperatures, H3+ column densities and H3+ total emission as observed by Keck-NIRSPEC close to Uranus's 2007 equinox.

We reveal discrete structures with segments closely resembling an auroral arc, of H3+ emission that aligns with the latitudinal positions of the UV northern aurora. Spectral analysis confirms these intensity features are not driven by a temperature increase, but instead occur at locations of increased H3+ column density, indicative of auroral precipitation via Magnetosphere-Ionosphere coupling. Hence after 30 years of investigation, we have confirmed the presence of the infrared aurora at Uranus.

Asymmetry in Uranus' high energy proton radiation belts

Matthew Acevski (Imperial College London, UK)

Co-authors: Adam Masters (ICL, UK), Sophia Zomerdijk-Russell (ICL, UK)

Key points: The asymmetric nature of Uranus' magnetic field can cause variations in radiation belt particle drift velocity which could tell us why the proton radiation belts at Uranus are so weak.

Uranus is one of the least explored planets in our solar system, it exhibits a unique magnetic field structure which was observed by NASA's Voyager 2 mission nearly 50 years ago. Notably, Uranus displays extreme magnetic field asymmetry, a feature exclusive to the icy giant planets. We use the Boris algorithm to investigate how high energy protons behave within this unusual magnetic field which is motivated by Voyager 2's observation of lower-than-expected high energy proton radiation belt intensities at Uranus. We simulated full drift motions of high energy protons around Uranus and found that the azimuthal drift velocity can vary by as much as ± 15% around the planet. This results in areas around Uranus where particles will be more depleted (faster drift) and other regions where there is a surplus of particles (slower drift). This could provide a partial explanation for the "weak" proton radiation belts observed by Voyager 2. Furthermore, for the innermost high-energy proton radiation belts, the asymmetry of the magnetic field can be shown to cause a significant drift motion in the radial direction which can cause particles to hit the planets' upper atmosphere when they otherwise would not have. These findings highlight the need for a future mission to Uranus so we can better our understanding of the effects of extreme magnetic field asymmetry on the planets' local plasma environment.

Microstructure controls longevity of exposed salt-rich ices on icy worlds

Hannah Chinnery (The Open University, UK)
Presented by: Mark Fox-Powell (The Open University, UK)

Key points: We investigated the sublimation dynamics of salty ices representative of cryovolcanic deposits on icy worlds. We propose that salt-ice microstructure, which is influenced by freezing rate and salt composition, controls the sublimation rate and hence long-term stability of such deposits, with implications for their detection by future missions.

Salt-rich water ice at the surfaces of icy worlds such as Europa, Enceladus and Ceres is of particular interest for Solar System exploration as it can record the chemistry and potential habitability of subsurface liquid water. Endogenic salts can originate by gradual freezing of fluids within outer ice layers, or through rapid emplacement of subsurface brines onto the surface via cryovolcanism. However, post-depositional evolution of ices exposed at the surfaces of these worlds is not understood, thus the long-term stability and detectability of salt-rich ice is rarely considered.

We investigated the sublimation dynamics of salt-rich ices under vacuum at sub-zero temperatures. Experimental ices were produced by freezing brines at contrasting rates which contained sodium salts detected at icy worlds including chlorides, carbonates and sulfates. We found that the presence of salts in general decreased the rate of ice sublimation. Furthermore, carbonate and sulfate ices formed through rapid 'flash' freezing, such as may occur during cyrovolcanism, exhibited slower ice loss rates than those formed through gradual freezing. Based on electron microscope imagery, we propose that differences in the salt-ice microstructure, which is strongly affected by freezing rate, influence the rate of sublimation by controlling the surface area of ice exposed to vacuum. Our findings demonstrate how the composition and formation history of salt-rich ices affects their post-depositional longevity at icy world surfaces, and reveal how microscale properties can influence macroscale behaviour. These findings are important for future missions that aim to detect and characterise deposits of endogenic salts at icy worlds.

The signature of rapid freezing recorded in the composition of experimental NaCl-rich cryovolcanic ice

Rachael Hamp (The Open University, UK)

Co-authors: M. G. Fox-Powell (OU), C. G. Salzmann (UCL), L. Pereira (Diamond), Z. Amato (OU/ISIS Neutron), H. Chinnery (OU), M. L. Beaumont (UCL), T. Headen (ISIS neutron)

Key points: New NaCl hydrate formed upon flash freezing of icy moon relevant cryovolcanic ice grains which would indicate regions on ice moons where fluids have been rapidly emplaced on the surface.

The interaction and exchange of material between the internal oceans and surfaces of icy moons could provide information on ocean chemistry and thus potential habitability. Areas of cryovolcanic activity could contain a record of recently exposed ocean material, and identifying such regions will be a major priority for upcoming missions. Salts such as NaCl that are identified on the surface of icy moons are considered endogenic, however the formation of salty ices under conditions relevant to cryovolcanic eruptions, and the implications for their remote detection, are not well understood. We investigated how the composition and microstructure of salt-rich ices in the Na-Cl-H2O system vary as a function of salt concentration and freezing rate, allowing us to explore the potential diversity of salty ices phases that form during cryovolcanism. We used x-ray and neutron diffraction, cryo-scanning electron microscopy and differential scanning calorimetry to study the phase composition and micro-structure in Na+/Cl--bearing ice created with varying concentrations and freezing rates. Diffraction showed the presence of a previously unknown crystalline hydrate in flash-frozen NaCl brines which does not form at slower cooling rates, meaning its presence on icy moons could indicate regions where fluids have been rapidly emplaced on the surface. We are currently carrying out structural refinement on this new NaCl hydrate. Our findings show that the structure and phase composition of Na+/Cl- bearing ice is dependent on freezing rate, indicating that properties of salt-rich ices can act as a record of thermal history that could be exploited by future missions.

Using synchrotron x-ray diffraction and tomography to study ocean world cryogeochemistry.

Liam Perera (Diamond Light Source)

Co-authors: Sarah Day (DLS), Stephen Thompson (DLS)

Key points: Using x-ray imaging and diffraction we reveal insights into the microtexture of Na-Cl-HCO3 ices frozen at different rates. We link these complex microtextures to transport processes within icy moon crusts.

The surface of Europa contains non-ice material thought to originate from aqueous processes occurring within the interior. It is believed that the interior is connected across a range of spatial and temporal scales from rapid eruption of cryovolcanic plumes to crustal convection and overturning on geological timescales. These transport processes will involve the freezing of multi-component fluids and the formation of inorganic salts. The sequence of precipitation of these salts will produce an assemblage of minerals that can be used to reconstruct the thermal and geochemical evolution of the system.
We use a combination of synchrotron powder x-ray diffraction (PXRD) and x-ray microtomography (µCT) at Diamond Light Source to study the low temperature phase behaviour of Na-Cl-HCO3 fluids.
Here we show the influence of carbonate chemistry on the sequence of cryogenic precipitation and the development of complex microstructures. These observations provide insights into crustal transport processes and will help in interpretation of observational data from upcoming Galilean missions.

Exploring Habitability in Martian Crater Lakes: Insights from Gale Crater and Simulation Experiments

Ben Tatton (The Open University, UK)

Co-authors: M. C. Macey (OU, UK), S. P. Schwenzer (OU, UK), S. Cogliati, (OU, UK), K. Olsson-Francis (OU, UK)

Key points: Gillespie lake member groundwater during diagenesis was habitable with nitrate dependent sulphur oxidation potentially being a viable metabolism.

Martian crater lakes, such as Gale Crater, were likely habitable during the Noachian-Hesperian transition, with the stratigraphy of rock members at Gale Crater recording a dynamic hydrological environment. The Curiosity Rover has detected evidence of wetting, drying, and rewetting cycles in Gale Crater before transitioning to more euxinic conditions. Studies of terrestrial analogue sites have shown that such environmental perturbations have an impact on the formation of biosignatures. The implications for biosignature formation can be further investigated via simulation experiments that replicate the geochemical environment of the extraterrestrial site of interest. A novel fluid and regolith simulant were produced based on results from CHIM-XPT modelling of water-rock reactions with the Gillespie Lake Member in Gale Crater and inoculated with an environmental culture from a high-altitude lake Mars analogue site. Sub-culturing and cell washing were conducted after inoculation every 14 days for 56 days. The impact of the simulated chemistry on the abundance and diversity of the community was assessed via cell counts and metagenome sequencing. Cell counts indicated consistent growth. Metagenome data showed that microbes from the genera Desulfovibrio, Humidesulfovibrio, and Sulfurospirillum dominated the community after 56 days, with sulphur oxidation and reduction, dissimilatory nitrate reduction to ammonium (DNRA), and denitrification being present in this endpoint community. These results indicate that the Gillespie Lake member would have been habitable during diagenesis for anaerobic dissimilatory metabolisms and highlight the plausibility of microbially mediated biogeochemical cycles.

Parallel 1C: Small Bodies & Modelling

Conference Room (with overflow in room 0.11 Swift) at Space Park Leicester

Wednesday 19th June 16:00 - 17:00

Dating the giant planet instability with meteorites

Chrysa Avdellidou (University of Leicester, UK)

Co-authors: Marco Delbo (OCA, FR), David Nesvorny (SwRI, USA), Kevin J. Walsh (SwRI, USA), Alessandro Morbidelli (OCA, FR)

Key points: The giant planet instability is now dated between 60 and 100 Myr after the formation of the solar system. We also propose that there is a casual relationship with the formation of our Moon.

The identification of meteorite parent bodies provides the context for understanding planetesimal formation and evolution as well as the key solar system dynamical events they have witnessed. We identified that the family of asteroid fragments whose largest member is asteroid (161) Athor is the unique source of the rare EL enstatite chondrite meteorites (Avdellidou et al. 2022), the closest meteorites to Earth in terms of their isotopic ratios. The Athor family was created by the collisional fragmentation of a parent body 3 Gyr ago in the inner main belt (Delbo et al. 2019), however the diameter of the Athor family progenitor was much smaller than the putative size of the EL original planetesimal (Triellof et a. 2022). Therefore, we deduced that the EL planetesimal that accreted in the terrestrial planet region underwent a first catastrophic collision in that region, and one of its fragments suffered a more recent catastrophic collision in the main belt, generating the current source of the EL meteorites.

We investigated the possible ways that could have brought the Athor family progenitor in its current position in the inner main belt. To do so, we used an interdisciplinary methodology where we combined laboratory meteorite thermochronometric data, thermal modelling, and dynamical simulations.

We showed that planetesimal fragments from the terrestrial zone must have been implanted into the main asteroid belt at least 60 Myr after the beginning of the solar system. We concluded that the giant planet instability is the only dynamical process that can enable such implantation so late in the solar system timeline.

Rewriting the Hierarchical Clustering Method as a Neural Network

Andrew Marshall-Lee (Armagh Observatory and Planetarium, UK)

Co-author: Apostolos Christou (AOP, UK)

Key points: We discuss the short comings of a well-used clustering algorithm for asteroid families. We then present how it can be reworked to be a trainable neural network.

The Hierarchical Clustering Method (HCM) is a mature and well-used technique to identify asteroids that have a similar origin, such as a collision and breakup of a larger body i.e. a family. However, with the ever-increasing amount of data that is arising from surveys like GAIA and the future LSST there are more edge cases in which the technique starts to lose efficacy in identifying family members. The HCM starts to falter in that it does not have a probabilistic result, an asteroid is either considered definitively part of a family or not, this means with ever- more data the edge cases start to more seriously interfere with the algorithm. This, ultimately, is a clustering problem and we have devised a novel method for extending the HCM's ability to identify asteroid families. We have successfully been able to rework the HCM to be in the form of the simplest neural network, known as a 'Perceptron'. We then trained this network to recognise the family members of Carbonaceous families in the inner Main Belt. This proof-of-concept demonstrates that, if a simple neural network is viable, it is possible to expand the network with a more advanced topography. Such as: The inclusion of additional input parameters, both orbital and physical together; and multi-layered networks.

A Numerical Study of Near-Earth Asteroid Family Orbital Dispersion

Alice Humpage (Armagh Observatory and Planetarium, UK)

Co-author: Apostolos Christou (AOP, UK)

Key points: We have studied the orbital evolution of near-Earth asteroid families and pairs, to find those places where they disperse the slowest after breakup. We present our results to aid future searches.

Despite extensive searches, there are very few confirmed positive identifications of near-Earth asteroid (NEA) families. As more NEAs are found, it will be important to focus the search for families in those places where they disperse the slowest after breakup.
We have studied the orbital evolution of NEA families and pairs, integrating a wide range of simulated clusters of NEAs where we varied the initial orbital inclination, ejection speed,

proximity to planetary orbits and to mean-motion resonances. We present our results to aid future searches. Our findings show that the dispersion of NEA families is slowest at higher inclinations, and further from the nearest planet. Cluster orbital dispersion is significantly affected by Kozai-Lidov oscillations that can bring the orbits of family members closer to their nearest planet, leading to stronger and more frequent encounters. In most cases, cluster dispersion is unaffected by breakup mechanisms, whether gentle (e.g. YORP or tidal), or more energetic (e.g. collisional). We have also found that mean-motion resonances will slow Kozai-Lidov oscillations, delaying interactions with planets, and therefore lowering the dispersion rate of families. However, those slower oscillations bring the orbits of the family and planet together for longer. This results in a larger increase in dispersion than if the cluster had been formed outside of the resonance.

Shape modelling NEA contact binary 2006 DP14 with optical and radar data

Richard Cannon (University of Edinburgh, UK)

Co-authors: Agata Rozek (UoE, UK), Colin Snodgrass (UoE, UK), Tanja Holc (UoE, UK)

Key points: We use optical and radar data to create a shape model of contact binary NEA 2006 DP14 in order to better understand how contact binary SSSOs form and originate.

Bilobed objects (contact binaries) appear across the solar system in both asteroid and comet populations. Radar imaging reveals that at least 15% of near-Earth asteroids (NEAs) are contact binaries - whereas spacecraft imaging suggests that bilobed objects make up the majority of comet nuclei. With the recently discovered moon of Dinkinesh, Selam, being a contact binary, there is a new focus on how contact binaries are formed, with the main contenders being reaccumulation of fragments after a catastrophic collision, or fragmentation from rotational instability of the asteroid. To date, less than 15 contact binaries from both asteroid and comet populations have detailed shape models leaving much to be understood. We aim to create a comprehensive shape and spin-state model of contact binary (388188) 2006 DP14. To create the model we shall use radar and optical images from 2014, supported by additional optical images from 2022 and 2023. Both the radar delay-Doppler images and optical lightcurves independently support that DP14 is a contact binary. Modelling these shape differences will allow better comparisons to theory based dynamical simulations to investigate likely origins, while an additional spin-state solution and shape model will give vital hints into not only the objects own formation history, but allow us to place the results in the wider context of other similarly shaped solar system objects.

Parallel 2C: Astrobiology

Abbey Room (with overflow in the Exosat) at Space Park Leicester

Wednesday 19th June 16:00 - 17:00

The IR characterisation of the Lake Salda hydromagnesites and clays

Connor Ballard (University College London, UK)

Co-authors: Louisa Preston (UCL); Lewis Dartnell (UOW); Catherine Regan (UCL); Andrew Coates (UCL)

Key points: We use FTIR spectroscopy to analyse microbialitic deposits from Lake Salda, a Jezero Crater analogue, to determine our ability to detect organics across the IR spectrum. We find that removing excess water through lyophilization enables us to better detect potential organic features.

Accurately identifying organic geochemical signatures is a prominent theme in Martian surface exploration and wider astrobiology. To improve our chances of detection and minimise false negative or positive signatures, we must continue to scrutinise techniques used in the search for life through terrestrial analogue investigations.

The hydromagnesite deposits of Lake Salda can provide insights into the nature of biosignature detection and preservation on Mars, since they are representative of Mg-carbonate deposits at Jezero Crater. At Lake Salda, hydromagnesite is predominantly deposited through cyanobacterial microbialite formation. These deposits dominate ancient and recent lake deposits, which are interspersed with Fe/Mg phyllosilicates.

This work employs FTIR spectroscopy as a reproducible and non-invasive technique to explore biosignature preservation in Mg-carbonate and Mg/Fe phyllosilicate deposits. We later correlate spectral features using VisNIR spectroscopy and remove excess hydration using lyophilization. FTIR spectroscopy reveals strong hydration absorptions alongside minor organic signatures, including deoxyribose C-O stretching (1044cm-1) and phosphate backbone (PO2-) stretching (1220 cm-1) in organic rich samples. VisNIR spectroscopy identifies the inclusion of metal-OH ions (Fe, Mg, Fe) in both hydromagnesite microbialites and the Salda phyllosilicate deposits, while chlorophyll a (443 nm), carotenoids (498 nm), phycocyanin (629 nm) and chlorophyll b (687 nm) are identified in the microbialites.

Lyophilization reduces interstitial H2O absorptions (2800cm-1 – 3600cm-1) present in most microbialites, which obscure regions of key biosignature absorptions, including aliphatic hydrocarbons. The reduction in H2O intensity increases our ability to detect a strong 2923cm-1 band, assigned to the aliphatic CH2 V3 stretching mode, in the most organic rich samples.

Biological Nitrogen Fixation within Mars Analogue Sites

Toni Galloway (University of St Andrews, UK)

Co-authors: Sophie Nixon (UoM, UK), Eva Stüeken (UoStA, UK), Jon Telling (UoN, UK), Christopher Stead (UoM, UK), Carla Greco (UoM, UK), Joanne Boden (UoStA, UK), Arola Moreras-Marti (UoAuck, NZ), Mark Fox-Powell (OU, UK), Claire Cousins (UoStA, UK)

Key points: This work confirms the direct impact of geochemical conditions on biological nitrogen fixation in Mars analogue sites, and links the presence of biological nitrogen pathways to complimentary isotopic biosignatures.

All life as we know it requires nitrogen for essential cellular structures including DNA. Within nitrogen-depleted environments such as hot springs, a small subset of microorganisms are forced to fix dinitrogen (N2) into bioavailable forms and this process acts as a bottleneck for productivity. Ancient Noachian-age (4.1-3.7Ga) terrestrial hot spring deposits and fixed nitrogen compounds have been discovered on the surface of Mars, suggesting that early Martian hot spring communities may have also required a source of fixed nitrogen. We aim to understand the geochemical controls on biological nitrogen fixation within analogue sites and link the presence of nitrogen-fixing genes to complimentary isotopic signatures which could be used as biosignatures in future Mars missions.
d15N values of biomass, sediment and rock samples taken from sample sites were compared to d15N values of dissolved N2 to calculate fractionation effects (D15N) and resulting fractionations were between 0 to -6‰. These ranges are concurrent with those produced by biological nitrogen fixation and ammonium uptake pathways. Metagenomic data agrees with this hypothesis, as the required genes for these pathways are present in all sites and show high relative gene abundances. These findings suggests that the main controls on the d15N of biomass and sediment in these systems are biological nitrogen fixation and uptake. This work provides evidence that these systems have the capability to preserve isotopic biosignatures produced by biological nitrogen cycling, making them valuable targets in future missions to Mars.

Characterisation and mechanochemical alteration of lunar and Martian analogue materials

Jon Tandy (University of Kent, UK)

Co-authors: Nadia Leila Butt (University of Kent, UK), Oliver Staples (University of Kent, UK)

Key points: A laboratory simulation of planetary weathering using ball milling techniques characterises physical and mechanochemical alterations of varied lunar and Martian regolith analogues. Multiple, complementary analyses find distinct variation in the behaviour and properties of regolith grains from the different analogue materials.

During the past few years a variety of naturally occurring and synthetic analogue materials relevant to both the moon and Mars have been broadly utilised to replicate several planetary processes and environments within the laboratory. It is therefore vital that both the physical and chemical properties of these simulants are well characterised to understand how well they replicate the surface material of the actual planetary body. Mechanical abrasion, saltation and other weathering processes also play an important role on the properties of planetary regolith. This presentation will provide an overview of recent research at Kent characterising various lunar and Martian analogue materials and examining how these materials respond to some of these weathering processes through the use of ball milling techniques. Observations from multiple, complementary analytical techniques including XRD, ATR-FTIR spectroscopy, SEM-EDX and TGA demonstrate clear differences in the physical and chemical properties of these simulants before and after milling and provide clues about the associated mechanochemical alteration mechanisms. Several variables including milling time, frequency and type (e.g. mixer mill versus planetary mill) were also shown to considerably affect the resulting properties of the mineral grains. These conclusions provide an indication of the appropriateness of certain materials for simulating planetary regolith under particular conditions and should inform the choice of specific analogues for future laboratory work replicating planetary processes.

How To Find Life on Mars: Investigating biological potential and putative biosignature formation

Arjun Patel (AstrobiologyOU, The Open University, UK)

Co-authors: Dr Susanne Schwenzer (Open University, UK), Dr Nisha Ramkissoon (Open University, UK), Professor Karen Olsson-Francis (Open University, UK)

Key points: Modelling of the water-rock interactions at Jezero will accommodate the determination of Gibbs energy change in the system, and provide the basis for experimental exploration of biosignature formation.

Jezero's high potential for habitability led it to be selected as the landing site of NASA's Mars2020 mission. The goal of this mission is the exploration of the crater whereby it discovered basaltic to basaltic-andesitic lava flows at the crater floor. The data collected from the PIXL instrument reveals a unique chemistry in the Rochette member, a rock from the Máaz formation, the uppermost igneous formation at the crater floor. Mars2020 also found variations in mineralogy including secondary phases. Our analysis of Mars2020's findings found Rochette's chemistry to show a lack of SiO_2, Al_2O_3 and MgO, and enrichment in FeO, Na_2O, SO_3, and Cl compared to other Martian basalts, and demonstrates clear evidence of aqueous alteration. This provides a unique a unique host rock composition that can be combined with a plausible fluid, which will be used as the input for geochemical modelling of Rochette, allowing the determination of the formation pathway of secondary minerals and of the Gibbs energy of the fluid-rock reactions at Jezero. Bulk-rock modelling has shown the precipitation of clays and iron-bearing minerals in the reaction between Rochette and a bespoke Martian fluid composition suggesting that aqueous reactions with the ability to produce potentially bioavailable free energy could occur at Jezero.

Plenary

Shuttle Suite, National Space Centre

Thursday 20th June 09:30 - 11:00

LSST and the Solar System

Meg Schwamb (Queen's University Belfast, UK)

Key points: Solar System science opportunities with the Vera C. Rubin Observatory and the Legacy Survey of Space and Time

The Vera C. Rubin Observatory is currently under construction in Chile. This international facility will radically transform our view of the changing night sky. Rubin Observatory will contain an 8.2-m telescope equipped with the world's largest optical imager, a 3.2-gigapixel camera capable of capturing a 10 square degree patch of the night sky (~40 times the size of the full Moon) in a single exposure. Starting in at the end of 2025/early 2026, the Rubin Observatory will carry out the widest and deepest optical survey to date, the Legacy Survey of Space and Time (LSST), scanning the entire visible sky approximately once every three nights for ten years.

In addition to discovering millions of various types of explosive transients per night, the LSST will provide an unprecedented dataset to explore the Solar System's small body inventory. LSST will enable the discovery and monitoring of over 5 million Main Belt asteroids, almost 300,000 Jupiter Trojans, over 100,000 Near Earth Objects (NEOs), more than 40,000 Kuiper belt objects (KBOS), tens of interstellar objects, and thousands of comets. Many of these objects will receive hundreds of observations in multiple bandpasses. In this talk, I will present the unique Solar System science opportunities that will be available in the LSST era. I will also provide updates on current and future activities within the LSST Solar System Science Collaboration and highlight avenues for future synergies within the planetary and astronomical communities focusing on opportunities for UK-based researchers.

The Extremely Large Telescope: Prospects for planetary science

Aprajita Verma (University of Oxford)

Co-authors: UK ELT team

Key points: I will review the status of the Extremely Large Telescope and discuss prospects for planetary science with the ELT.

With a primary mirror of 39.3m, ESO's Extremely Large Telescope will be the "World's Biggest Eye on the Sky" operating in the visible to infrared wavelength range. The ELT will collect 13 times more light than the largest visible-IR telescopes today and the telescope's fully adaptive design will deliver images 6 times sharper than the JWST. The sensitivity and spatial resolution afforded by the ELT will revolutionise our understanding of the Universe. The ELT is well into its construction phase with first-light at the end of this decade. I will review the status of the ELT project including an overview of the telescope, its innovative instruments and prospects for planetary science with the ELT.

4219: a Gale odyssey

Steve Banham (Imperial College London, UK)

Co-authors: Mars Science Laboratory Science Team

Key points: Curiosity has explored the northern margin of Mount Sharp for 4219 Martian sols. This presentation will showcase the changes recorded by the rover during its ascent of Mount Sharp, to understand how habitability was impacted by climate change.

The Mars Science Laboratory rover, Curiosity, has explored the northern margin of Mount Sharp for 4219 Martian sols. During this time, the scientists have gathered compelling evidence that shortly after crater formation, a habitable environment existed within its bounds. The lower part of the stratigraphic succession preserves a record of persistent lakes fed by fluvial systems originating from the crater rim. As the rivers entered the lake, they released plumes of sediment and assorted nutrients into the water column to be distributed across the lakebed – recorded as the Murray formation. Geochemical and mineralogical assessments indicate that environmental conditions preserved in the strata during this timeframe would have sustained life, if it were present.
On Sol 3047, Curiosity made a sharp right turn after crossing the phyllosilicate unit, to drive up into the orbitally-defined sulphate-bearing unit. From this point, Curiosity witnessed distinct changes in the stratigraphy, recording a progressive drying of the crater. The rover identified a gradual change from humid conditions containing a record of perennial lakes, to isolated ephemeral lakes, and onto desolate deserts. During this ascent, interstratification of aeolian strata became more common, including sand sheets, dune strata and deflation scours. However, despite this general aridification, the succession was occasionally punctuated by episodes of

abundant water: the Amapari ripple bed for example, records a brief shallow lake: a veritable oasis, free of ice.
This presentation will showcase the changes recorded by the rover during its ascent of Mount Sharp, to understand how habitability was impacted by climate change.

Parallel 1D: Mars: Ice, rivers and more

Shuttle Suite, National Space Centre

Thursday 20th June 11:30 - 13:05

Ice on Mars: Its importance for next generation missions, and the interdisciplinary science opportunities it brings.

Frances Butcher (University of Sheffield, UK)

Key points: This presentation will provide an overview of the pipeline of planned missions that will prepare for human exploration of Mars, and explore the diverse range of potential science opportunities from ice-access missions and their orbital and robotic precursors.

Ice affects more than one third of Mars' surface. It is a key component of Mars' climate system, and has had a major influence on the evolution of its surface, subsurface, and atmosphere over geologic time. Subsurface ice deposits in Mars' mid-latitudes are prime targets for next-generation orbital and robotic missions, which will prepare for the first human missions. Human missions will require some in situ water resources, which could be extracted from Mars' ice deposits along with high-value scientific samples such as ice cores and other contextual materials. Mars' ice deposits are also exciting targets in the search for microbial life; glaciers are an important component of Earth's biosphere, and can sustain habitable micro-scale meltwater environments at extremely cold temperatures.

This presentation will provide an overview of the pipeline of planned missions that will prepare for human exploration of Mars, and explore the diverse range of potential science opportunities from ice-access missions and their orbital precursors. It will also highlight near-term priorities for science and exploration activities towards ice-access missions, which are highly complementary to existing expertise in the UK's planetary science and wider research communities. This includes, but is not limited to, the realms of geology, atmospheric and climate science, astrobiology, cryosphere science, human health, and Mars exploration science.

Estimating the Age of Ice in a Martian Mid-Latitude Debris-Covered Glacier from Numerical Modelling and Particle Tracking

Neil Arnold (Scott Polar Research Institute, University of Cambridge, UK)

Co-author: Frances Butcher (Sheffield University, UK)

Key points: We have used numerical modelling and particle tracking to estimate the age of ice in a Martian debris-covered glacier. Results show estimated ice ages vary systematically across the ice surface, with the oldest ice nearest the ice margin, raising the possibility that shallow sampling could access old ice.

In a recent study we identified a small mid-latitude debris covered glacier in Nereidum Montes, Mars, which is incised by a gully. The gully exposes internal layers which become more inclined down-flow and connect to arcuate glacier-surface structures near the margin. Our flow modelling demonstrated that these structures could represent old ice layers (and potentially intervening dust/debris bands) that have been transported up to the surface from deep interior positions by ice flow. Here we extend our modelling experiments, using particle tracking to estimate the age of the ice in the glacier, both across the glacier surface and through the ice column. Average modelled ages of surface ice (from burial to re-emergence at the surface, assuming no surface debris layer) at the locations of three of the glacier surface structures were ~180, 100 and 69 Myr, with the oldest ice located closer to the ice margin. The older ice flows at deeper levels within the glacier before veering towards the surface. A vertical age/depth profile through three particle tracks produced ages of 20.5, 32.5, and 81.0 Myr through the ~50 m depth of the glacier. Our results suggest that glacier-surface crater retention ages may considerably underestimate the true age of the ice therein, and that ice flow dynamics could lead to systematic variations in ice age across glacier surfaces. They also raise the possibility that shallow sampling near glacier margins may allow access to older ice than may be possible with vertical ice coring through sub-horizontal ice layers.

Structure and Stratigraphy of the Margin Unit, Jezero Crater: Implications for Potential Formation Mechanisms.

Alex Jones (Imperial College London, UK)

Co-authors: S. Gupta (Imperial College London, UK), R. Barnes (Imperial College London, UK), B. Horgan (Purdue University, IN, USA), G. Paar (Joanneum Research, Austria), K. Stack (JPL, Pasadena, USA) , B. Garzcynski (Purdue University, IN, USA), R. Williams (Planetary Science Institute, AZ, USA), J. Bell (ASU, Tempe, USA), J. Maki (JPL, Pasadena, USA), S. Alwmark (Lund University, Lund, Sweden), E. Ravanis (Hawai'I Institute of Geophysics and Planetology, HI, USA), F. Calef (JPL, Pasadena, USA), L. Crumpler (New Mexico Museum of Natural History and Science, NM, USA), K. Williford (Blue Marble Space Institute of Science, WA, USA), A. Vaughan (Apogee Engineering, AZ, USA), J. I. Simon (NASA Johnson Space Centre, Houston, USA), S. Gwizd (JPL, Pasadena, USA), C. Tate (Cornell University, NY, USA), A. Annex (Caltech, Pasadena, USA), A. Klidaras (Purdue University, IN, USA), C. Bedford (Purdue University, IN, USA), K. Farley (Caltech, Pasadena, USA), N. Randazzo (University of Alberta, Canada), N. Schmitz (German Aerospace

Center (DLR), Germany), L. Kah (University of Tennessee, TN, USA), A. Brown (Plancius Research, MD, USA), G. Caravaca (IRAP, CNRS, CNES, Univ. Toulouse, France).

Key points: The carbonate-bearing Margin Unit of Jezero crater is astrobiologically compelling, but has an uncertain origin. Here, we report on Perseverance rover observations of the lithology, structure and stratigraphy of the unit to constrain how it may have formed.

The Perseverance rover is exploring the Margin Unit of Jezero crater, a carbonate- and olivine-rich geologic unit stratigraphically underlying the Jezero western fan and lining the inner margin of the western crater rim. Its strong orbital carbonate signature makes the Margin Unit astrobiologically compelling [1], however its origin is uncertain. Prior to exploration by Perseverance, hypotheses considered ranged from a lake shoreline deposit [1], part of a regionally extensive carbonated pyroclastic or igneous deposit [2], or alternatively, aeolian or fluviolacustrine.

We report on outcrop observations of the Margin Unit acquired by the Mastcam-Z camera between sols 910 – 1130, with the aim of characterising the unit's primary lithologies and constraining potential depositional or emplacement mechanism(s). We integrate these observations with 3D measurements taken using the modelling and visualisation software PRo3D [3] to create a structural-lithologic map and cross-section of the unit explored so far. Results indicate different emplacement mechanisms for the eastern and western Margin Unit. The Eastern Margin Unit comprises plane-parallel stratified sandstone beds, sub-horizontally or gently inclined either basinwards or rimwards. Potential cross stratification, truncation surfaces and convolute bedding are also observed. Conversely, the Western Margin Unit comprises apparently structureless outcrops with intervals of NE-inclined, dm-scale planar layers, lacking sedimentary structures. Our favoured hypothesis is that outcrops in the east may preserve a lake shore beach-bar deposit, overlying and potentially reworked from a different olivine-carbonate lithology exposed in the west.

[1] Horgan et al. 2020, Icarus
[2] Brown et al. 2020, JGR: Planets
[3] Paar et al. 2023, ESS

The Fluvial History of Noachis Terra

Adam Losekoot (The Open University, UK)

Co-authors: Matt Balme (The Open University, UK), Peter Fawdon (The Open University, UK), Angela Coe (The Open University, UK)

Key points: We have found a broad distribution of inverted fluvial channels across Noachis Terra. This shows that that previously unreported overland fluvial processes were active during the Noachian epoch in this region.

The detail of Mars' early climate is still poorly understood. Observations of fluvial networks and sedimentary rocks in the southern highlands suggest that liquid water must have been present on the surface for prolonged periods, but climate models (e.g. Wordsworth et al., JGR, 2015) suggest that the planet was too icy and cold during its early history for sustained surface water flow. They note that parts of Noachis Terra are poorly dissected by fluvial networks, invoking a mainly dry "icy highlands" model instead. This model suggests that late Noachian Mars had a cold and icy climate, and that ice-melt was the dominant control on valley formation (e.g. Hobbs et al., Geomorphology, 2016). Extensive sinuous ridges were identified in Arabia Terra (e.g. Davis et al., Geology 2016), another area thought to lack fluvial networks, and interpreted to be inverted fluvial channel belts. We have searched for Fluvial Sinuous Ridges (FSRs) in Noachis Terra, using a global 6 m/pixel CTX image mosaic. We have identified many FSRs, ranging from single segments less than a kilometre long to interconnected, branching networks tens to hundreds of kilometres in length. Four distinct morphologies have been identified. These FSRs indicate that the late Noachian must have been capable of sustaining liquid water flow and the formation of large, complex fluvial networks. The broad distribution of these FSRs points towards a distributed source of water, consistent with precipitation and overland flow.

Periodic Bedrock Ridges across the equatorial region of Mars: Insights from a global survey

Elena Favaro (ESA/ESTEC)

Co-authors: M.R. Balme (Open University, UK), J.D. McNeil (NHM, UK), P. Fawdon (Open University, UK), J. Davis (Imperial College London, UK), P.M. Grindrod (NHM, UK), S. Banham (Imperial College London, UK), S.R. Lewis (Open University, UK)

Key points: Periodic bedrock ridge distribution and morphology mapped globally for the first time.

Periodic bedrock ridges (PBRs) are meter- to decametre-scale wind-transverse repeating linear ridges observed on Mars [1-6]. To date, PBR identification and documentation has been largely opportunistic, drawing on high-resolution images and in situ observations from active NASA landing sites [2,3] and future ESA landing sites [3-5]. While their ubiquity across Mars is becoming clear, no large-scale study of PBRs has been undertaken. This precludes our ability to draw conclusions about the distribution and development of PBRs across varying spatial and temporal scales.

A recent study at Oxia Planum – the landing site of ESA's ExoMars Rosalind Franklin rover – and the wider circum-Chryse basin [3], noted that PBRs were often found on phyllosilicate- (clay) bearing terrain. Drawing on that work, this research investigates PRBs on phyllosilicate-bearing terrain across the Martian equatorial region (20°S to 20°N) detected by OMEGA (Observatoire pour la Mineralogie, l'Eau, les Glaces et l'Activit´e) and CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) instruments [7]. PBR morphometrics (i.e. crestline size and orientation, wavelength, etc.), coupled with a characterization of the geology and geomorphology of each site will be analysed to determine whether PBRs in phyllosilicate-bearing terrain share commonalities across Mars.

[1] Montgomery et al. (2012). J. Geophys. Res. Planets, 117(E3); [2] Stack et al. (2022). J. Geophys. Res. Planets, 127(6); [3] Bretzfelder et al. (2024). Icarus, 408; [4] Favaro et al. (2021). J. Geophys. Res. Planets, 126(4); [5] Favaro et al. (2024). EPSL, 626,118522; [6] Silvestro et al. (2021). Geophys. Res. Letters, 48(4); [7] Carter et al. (2023). Icarus, 389.

Magmatic and Crustal History of the Phosphate-rich Martian Poikilitic Shergottite, Northwest Africa 7937

Bianka Babrian (The Open University, UK)

Co-authors: John F. Pernet-Fisher (UoM, UK), Rhian H. Jones (UoM, UK)

Key points: Abundant (3 vol%) merrillite in the non-poikilitic domain of NWA 7937 is texturally associated with maskelynite enriched in potassium. Merrillite is partially replaced by chlorapatite, a texture commonly linked to secondary alteration by Cl-rich brines.

Shergottites are the most abundant and diverse group of Martian meteorites. Poikilitic shergottites have a characteristic bimodal texture that tracks magmatic evolution throughout the Martian crust. Northwest Africa (NWA) 7937 is an enriched poikilitic shergottite yet to be described in detail. Its paired stones (NWA 7387, NWA 7397, NWA 7755) are better studied and documented [1][2]. Here, we report on the petrology and mineral chemistry of NWA 7937 from SEM and EMPA analyses, as well as trace element abundances measured by LA-ICP-MS. NWA 7937 is texturally and chemically similar to its paired stones. Cumulate poikilitic domains consist of olivine chadacrysts and minor chromite, enclosed by large ovoid pyroxene oikocrysts with pigeonite cores and augite overgrowth rims. The non-poikilitic domain contains ~50 vol% olivine, ~30 vol% interstitial maskelynite, ~10 vol% pigeonite and minor augite, phosphates, Cr-Ti-spinel, ilmenite, and sulphides. The non-poikilitic domain has a notably high (3 vol%) abundance of phosphate minerals, mainly merrillite that is partially replaced by chlorapatite. Of particular note is the textural association between phosphate minerals and regions of potassium enrichment in maskelynite, which has been observed but not explained in paired stones. We are exploring the sources of P, K, and Cl in NWA 7937 to understand whether some or all of these elements are (i) derived from the magmatic mantle source, (ii) reflect crustal interactions, or (iii) were introduced during a secondary, potentially hydrothermal, alteration event.

[1] Howarth et al., 2014. MaPS 49, 1812-1830. [2] Wang et al., 2017. MaPS 52, 2437-2457.

Space Park Leicester

BPSC 2024 LEICESTER

Parallel 2D: Giant Planet Atmospheres

Conference Room (with overflow in the Abbey Room) at Space Park Leicester

Thursday 20th June 11:30 - 13:05

Aerosol layers, clouds, spots and the colours of Uranus and Neptune

Patrick Irwin (University of Oxford, UK)

Co-authors: Jack Dobinson (U. Oxford, UK), Nicholas Teanby (U. Bristol, UK), Leigh Fletcher (U. Leicester, UK), Michael Roman (U. Leicester, UK), Amy Simon (NASA-GSFC, USA), Michael Wong (U. California - Berkeley, USA), Glenn Orton (JPL, USA), Daniel Toledo (INTA, Spain), Santiago Perez-Hoyos (U. Basque Country, Spain)

Key points: Spectral imaging observations of Uranus and Neptune have given new insights into the aerosol structure of these planets and the distribution of condensible gases such as methane and hydrogen sulphide. In this presentation we will highlight recent discoveries.

In the last twenty years, spectroscopic imaging observations of Uranus and Neptune have revolutionised our understanding of these planetary atmospheres. In spectroscopic imaging observations, each pixel in the resolved image contains a continuous spectrum, from which we can retrieve gaseous abundances and the vertical distribution of scattering particles - something that filter imaging alone cannot achieve. Observations with the STIS instrument on Hubble Space Telescope have determined that the abundance of methane decreases with latitude from the equator to the poles by roughly a factor of two in both atmospheres. At longer wavelengths, observations with the NIFS instrument at Gemini-North have revealed not only the presence of hydrogen sulphide, but also hints of its latitudinal variation.

We highlight recent advances made with spectral imaging observations, using HST/STIS and also VLT/MUSE. On both planets we find a common aerosol structure comprised of: 1) a deep layer of aerosol/H_2S ice near the H_2S condensation level at $p > 5$ bar; 2) a middle layer of aerosol/CH_4-ice near the CH_4 condensation level at $p = 1 – 2$ bar; and 3) an upper layer of photochemical haze. Variation of properties of the middle aerosol layer is found to be responsible for the bulk difference in colour between these planets, and also for the seasonal cycle of Uranus's colour. Meanwhile, variations in the deep layer are found to be responsible for Neptune's dark spots. In addition, a new class of deep bright cloud has been identified in Neptune's atmosphere, which hints at deep, vigorous convection.

High-altitude winds over Jupiter's Equatorial Zone: Could disparate measurements be reconciled through the QQO?

John Rogers (British Astronomical Association)

Key points: High-level winds over the EZ, measured as ~0 m/s in 2020 & 2021 from amateur images and ~140 m/s in 2022 from JWST images, could represent different phases of a stratospheric oscillation.

From 2018 to 2022, Jupiter's Equatorial Zone exhibited a broad, visibly orange-tinted band, which was also very bright in methane absorption band images, indicating an unusually high altitude. Amateur methane-band images in 2020 and 2021 revealed large-scale waves and bright patches on this band which were almost stationary (Rogers & Go, 2021; Rogers & Mizumoto, 2021-23), unlike all other features of the EZ, which drift very rapidly eastwards. Conversely, Hueso et al.(2023) have tracked hazes using near-IR JWST images in 2022 July, revealing a very rapid eastward jet of ~140 m/s at the ~100-200 mbar level. These disparate measurements may cover similar altitude ranges. We suggest that they may represent opposite phases of Jupiter's equatorial stratospheric oscillation (JESO). This was first characterised as a quasi-quadrennial oscillation (QQO) of temperatures derived from thermal-IR measurements, which has now been found to be three-dimensional, with the temperature fluctuation descending over several years, maintaining a period of ~4-6 years (Cosentino et al., 2017; Giles et al., 2020; Antuñano et al., 2020). These oscillations are predicted to lead to alternating wind patterns which descend likewise, and range from ~140 m/s to 0 m/s at the ~3-30 mbar level (Cosentino et al., 2017; Giles et al., 2020). Although this is probably somewhat higher than the tracked hazes, it suggests that future work could use existing IR observations to constrain the altitude of the hazes and to model the QQO during these recent years, to establish whether it is consistent with the direct measurements.

Temperature Structure, Chemistry, and Clouds in the Atmosphere of Uranus and Neptune as Revealed by JWST

Michael Roman (The University of Leicester, UK)

Co-authors: Leigh Fletcher (Leicester, UK), Patrick Irwin (Oxford, UK), Heidi Hammel (AURA, USA), Henrik Melin (Leicester, UK), Naomi Rowe-Gurney (RAS, UK), Oliver King (Leicester,UK), Jake Harkett (Leicester, UK), Glenn Orton (JPL, USA), Julianne Moses (SSI, USA), Matthew Hedman (U.Idaho,USA), James Sinclair (JPL,USA), Imke de Pater (Berkeley, USA)

Key points: We observed Uranus and Neptune with JWST and analysed the results with a radiative transport model. From these data, we retrieve new constraints on the temperatures, chemsitry, and cloud structure as never before possible.

We present results from recent JWST observations of Uranus and Neptune. Spatially-resolved spectroscopy from JWST NIRSpec (1.6–5.2 µm) and MIRI (4.9–28.5 µm) were acquired in January and June 2023 and amount to the most significant new infrared observations of the ice giant's atmosphere since Voyager 2.
Owing to frigid atmospheric temperatures, Uranus' and Neptune's infrared spectra are extremely weak. Prior to JWST, much of these spectral regions had never been spatially resolved before, while other spectral regions had never been observed. From the ground, spatially resolved observations of the ice giant mid-infrared emission are limited to imaging targeting the brighter regions of the infrared spectrum (i.e. ~13 µm emission from stratospheric ethane and acetylene, and 17-25 µm from the H2 continuum [1]). From space, the Spitzer Space Telescope observed the planets' mid-infrared spectra between ~7 and 36 µm, but Spitzer lacked the spatial resolution necessary to resolve potential thermal and chemical structure across the disk [2]. Now, with its exceptional sensitivity and outstanding spatial and spectral resolution, JWST reveals Uranus' and Neptune's stratospheric temperature and chemistry with exquisite new detail, placing new constraints on hydrocarbon abundances, cloud properties, and temperature structure across the disk. In this talk, we introduce these new data along with results of our radiative transfer analysis.
With a projected lifetime of over a decade, JWST promises to continue providing exciting new insights into the atmospheric structure, composition, and variability of the ice giants for years to come.

Tropospheric Clouds of Jupiter; Reducing Degeneracy, Reducing Complexity

Charlotte Alexander (University of Oxford, UK)

Co-author: P.G.J.Irwin (Uni of Ox, UK)

Key points: Jupiter's cloud tropospheric cloud structure from visible/IR radiative transfer modelling.

Jupiter has a dynamic atmosphere, regular undergoing changes in its complex cloud top appearance. However, these visual changes extend beyond the cloud tops and to the tropospheric structure and processes driving this change. Current models of this cloud structure are often complex, with a huge number of variable parameters, in order to model the tropospheric cloud profile as it changes. Within this parameter space there is a huge amount of degeneracy, in which cloud properties play off each other in order to produce a model which is able to match the spectra of each observation. In this work we are reducing the number of parameters which are able to vary, whilst we model across the entire disc using the NEMESIS radiative transfer code (Irwin et al. 2008). Additionally, we increase the scrutiny of these spectral fits by simultaneously fitting two viewing angles, utilising the Minnaert fit outlined in Pérez-Hoyos, et al., (2020) and as for the Ice Giants in Irwin et al. (2022). Here we will present our work which show cloud models for the planet using observations taken with VLT/MUSE, and how they correspond to the changing visual appearance of Jupiter.

P.G.J.Irwin, et al., (2008), JQSRT, 109:1136–1150
S.Pérez-Hoyos, et al., (2020), Icarus, 352:114031
P.G.J.Irwin, et al., (2022), JGR:Planets, 127, e2022JE007189

The Thermal and Compositional Structure of Jupiter's Great Red Spot from JWST/MIRI Spectroscopy

Jake Harkett (University of Leicester, UK)

Co-authors: Jake Harkett, Leigh N. Fletcher, Oliver R.T. King, Michael T. Roman, Henrik Melin, Heidi B. Hammel, Ricardo Hueso, Agustín Sánchez-Lavega, Michael H. Wong, Stefanie N. Milam, Glenn S. Orton, Katherine de Kleer, Patrick G.J. Irwin, Imke de Pater, Thierry Fouchet, Pablo Rodríguez-Ovalle, Patrick M. Fry, Mark R. Showalter

Key points: Jupiter's Great Red Spot was observed by JWST/MIRI in 2022 to study the 3D structure of temperature, aerosols, gaseous species and the dynamics of the vortex.

Situated within the Southern Tropical Zone (STrZ), the Great Red Spot (GRS) dominates the morphology of the southern hemisphere. Despite the array of observations that have characterised this region, numerous unanswered questions remain regarding the composition, driving mechanism and longevity of the GRS. JWST/MIRI observed the GRS in July and August 2022 as part of a Guaranteed-Time programme (Cycle 1 – GTO 1246). The Medium Resolution Spectrometer (MRS) was used allowing the full 4.9 – 27.9 µm spectral region to be observed in the 6.9 by 7.9 arcsec field of view, including the first ever mapping of the 5.5 – 7.7 µm range. This enabled unprecedented probing of the low temperatures, elevated aerosols and gaseous abundances that persist within the vortex (Fletcher et al., doi: 10.1016/j.icarus.2010.01.005). The vertical aerosol and gaseous structure was derived throughout the 1-mbar (using 7-16 µm spectra) to 5-bar range (using 5-7 µm spectra), complementing the Juno investigation of the depth of the GRS at higher pressures (Bolton et al., doi: 10.1126/science.abf1015) as well as providing a better understanding of the coupling between the GRS and the stratosphere above.

The MIRI data were acquired alongside simultaneous Hubble, VLT/VISIR and JWST/NIRCam observations. This wider spatial context enabled dynamical observations of this anticyclone and its interaction with the surrounding STrZ. In this presentation we will: (i) present the inferred 3D temperature and chemical structure derived using JWST; (ii) describe the inferred deep tropospheric aerosol structure and dynamics of the GRS; and (iii) explore the interaction between the GRS and surrounding atmosphere.

Jupiter System Science with JWST/NIRSpec

Leigh Fletcher (University of Leicester, UK)

Co-authors: Oliver King (University of Leicester), Francesco Biagiotti (University of Rome La Sapienza), Michael Roman (University of Leicester), Henrik Melin (University of Leicester), Jake Harkett (University of Leicester), Imke de Pater (UC Berkeley), Thierry Fouchet (Observatoire de Paris, Meudon), Alessandro Mura (INAF – Istituto di Astrofisica e Planetologia Spaziali (INAF-IAPS)), Davide Grassi (INAF – Istituto di Astrofisica e Planetologia Spaziali (INAF-IAPS)).

Key points: JWST/NIRSpec (1-5.3 µm spectroscopy) has mapped Jupiter's atmosphere from the cloud-forming weather later into the ionosphere, and has provided new insights into the surface composition of the Galilean satellites.

During the first two years of scientific operations, JWST has provided new insights into the myriad environments of the Outer Solar System, from the planetary atmospheres, to their delicate rings, and plethora of satellites. We present an overview of results in the Jupiter system from the NIRSpec instrument, using integral-field spectroscopy to acquire spatially-resolved spectral maps across a 3x3 arcsecond field of view, with a spectral resolution of 2,700. The NIRSpec dataset comprises early-release science observations (ERS) acquired in 2022, alongside guest observer programmes in 2022-23. On Jupiter, mosaics of NIRSpec observations from 1.8-5.3 µm were acquired for (i) the Great Red Spot (GRS) and its surroundings; and (ii) the south polar domain of high-altitude aerosols and auroral emission. We map chemical composition and aerosol structure in these regions, revealing unprecedented internal structure within the GRS (a series of concentric ovals with increased reflectivity/altitude in the vortex centre), and wave patterns in the ionosphere above the GRS (Melin+2024). A combination of principle component analysis (PCA) and Gaussian Mixture Models (GMM) was used to cluster NIRSpec spectra for subsequent analysis via optimal estimation inversions, and we directly compared Juno/JIRAM spectra (at lower spectral/spatial resolution) of the same region in 2016 for comparison. NIRSpec cubes of Io (de Pater+2023), Europa (Villanueva+2023), Ganymede (Bockelee-Morvan+2023), and Callisto (Cartwright+2024) will also be presented, revealing the distributions of volcanic lava, water ices, acid hydrates, CO2 ices and potential organics on the satellite surfaces. Together, these showcase the rich capabilities of JWST/NIRSpec for giant planet system science.

Parallel 1E: Mars: ExoMars & Gale

Shuttle Suite, National Space Centre

Thursday 20th June 14:00 - 15:35

The Upper Gediz Vallis Ridge at Gale Crater: Sedimentary Rock Clasts Transported by a Late-Stage Debris Flow on Mars?

Joel Davis (Imperial College London, UK)

Co-authors: Rebecca Williams (PSI, USA), William Dietrich (UC Berkeley, USA), Claire Mondro (Caltech, USA), Sharon Wilson (Smithsonian, USA), , Gwénaël Caravaca (IRAP, France), Lucy Thompson (U. New Brunswick, Canada), Olivier Gasnault (IRAP, France), Gerhard Paar (Joanneum Research, Austria), Edwin Kite (U. Chicago, USA), Alex Bryk (UC Berkeley, USA), Steven Banham (Imperial College, UK), Sanjeev Gupta (Imperial College, UK), Amelie Roberts (Imperial College, UK), Emma Harris (Imperial College, UK), John Grotzinger (Caltech, USA).

Key points: We present a Curiosity rover investigation of Gediz Vallis ridge in Gale crater, a possible ancient debris flow deposit.

The Mars Science Laboratory (MSL) Curiosity rover continues to ascend Aeolis Mons in Gale crater, Mars, with the goal of characterising formerly habitable palaeoenvironments. Since September 2022, Curiosity has been traversing Gediz Vallis, a ~9-km long canyon incising into sulfate-bearing, sedimentary rocks on the northern margins of Aeolis Mons. Along the Gediz Vallis floor is the upper Gediz Vallis Ridge (uGVR), a quasi-sinuous, ~1.5 km long, ~80-100 m wide, ~5-30 m high, ridge. Upslope, uGVR is clearly set within an erosional channel, which disappears downslope. Near the Gediz Vallis outlet, uGVR transitions into the broader, lower GVR, recently interpreted by Bryk et al. (2023, AGU Fall Meeting) as a degraded alluvial fan. Since entering Gediz Vallis, Curiosity has undertaken an extensive long-distance imaging campaign of the eastern uGVR flank, acquiring multiple Mastcam and ChemCam Long Distance Remote Micro Imager (LD-RMI) mosaics. Additionally, in August 2023, Curiosity approached the ridge margins and conducted an in-situ investigation (“Bouboukas”). A major objective of Curiosity’s uGVR campaign is to determine the primary depositional conditions and palaeoenvironment of the ridge, which may record evidence for late-stage surface water flow in Gale. Here, we will present observations from Curiosity’s uGVR campaign, which suggest that the remnant deposit may record evidence for late-stage debris flows, which transported material downslope from further up Aeolis Mons.

A Habitable Oasis in a Martian Desert? A Record of Groundwater and Changing Winds in Gale Crater

Amy Dean (Imperial College London, UK)

Co-authors: Steven Banham (ICL, UK), Gerhard Paar (JR, Gratz)

Key points: (1) Identification of three orders of bounding surface in the compound cross-bedding at the Siccar Point outcrop; their orientation unique to previous Stimson outcrops along the eastern Greenheugh Pediment. These records of palaeocurrent refine our understanding of ancient atmospheric circulation within Gale crater. (2) Soft sediment deformation seen superimposing and deforming the cross-bedding, to the result of fluidisation. Therefore, introducing fluids to the arid erg is necessary and groundwater within these dunes could provide a habitable environment within Gale.

The Siccar Point outcrop is part of the eastern Greenheugh Pediment, Gale crater. It is formed of Stimson formation: an aeolian sandstone comprised of erosion-resistant cross-bedding. Stimson formation records variations in wind strength and direction, as they influence aeolian dune morphology and orientation, which refines our understanding of ancient atmospheric circulation. Additionally, groundwater deformation structures are identified here, providing opportunity to understand early environmental change and habitability.

From Sol 3215 to 3315, Mars Science Laboratory rover, Curiosity, imaged Siccar Point using Mastcam; the photomosaics were used to interpret the sedimentary structures and architecture. Soft sediment deformation was identified, superimposing and deforming the cross-bedding, to the result of fluidisation. Therefore, the introduction of fluids into the arid erg is necessary. Compound cross-bedding, with three orders of bounding surface, was also identified, relating to superimposed dunes and wind reversal. First-order surfaces are laterally extensive (>50 m) and truncate second-order surfaces (< 2 m). Further outcrop interrogation used VRvis Pro3D to measure palaeocurrents for quantitative comparison with previous Stimson outcrops. Cross-bed dip-azimuths trend to the south-east, which contrasts with the north-easterly trend elsewhere in the Stimson; this variation is accredited to a local change in dominant wind direction. Spatial and temporal variations in airflow dictate the morphology of aeolian bedforms, which is recorded in the orientation of their lee slope. Siccar Point records an evolving and altering atmospheric circulation, with seasonal variations in wind, which interacted with the ancient dunefield in Gale. Groundwater within these dunes could provide a habitable environment within Gale.

Secondary Impact Craters in the ExoMars Landing Site at Oxia Planum

Peter Grindrod (Natural History Museum, London)

Co-authors: J.M. Davis (Imperial College London, UK), E. Harris (Natural History Museum, UK), G. Magnarini (Natural History Museum, UK), P. Fawdon (Open University , UK), E.A. Favaro (ESA - ESTEC, NL), M.R. Balme (Open University , UK), L.L. Tornabene (Western University CA), and G.S. Collins (Imperial College London, UK)

Key points: Extensive secondary impact craters are identified in the ExoMars Landing Site at Oxia Planum. Most secondary craters likely originate from the Mojave impact crater-forming event ~10 Ma.

The ESA ExoMars Rosalind Franklin (EMRF) rover is scheduled to launch in 2028, and will land in the Oxia Planum region of Mars. In this study we have investigated extensive secondary craters within the EMRF landing ellipse, to place absolute age markers in the stratigraphic framework of Oxia Planum, and to identify the likely primary source crater(s). We manually refined the recent Mars catalogue of small impact craters [1] in the Oxia Planum region, before distinguishing between primary and secondary craters [2]. Of the impact craters in our study region, 38,793 (10.2%) were classified as primary craters, with 342,791 (89.8%) classified as secondary craters. We identified at least 19 separate clusters of craters that occur in cone shapes, typically up to 40 km long and 20 km wide at the distal ends. These cones appear to show a distinctive size distribution of craters, with larger craters limited to the proximal (apex) region, and a gradual transition to smaller craters in the distal region. The direction of small crater clusters strongly suggests that the majority of craters identified as secondaries are sourced from the Mojave impact crater, although larger, older secondary craters from other sources are also present. Given that the Mojave impact is ~10 Ma [2], these secondaries can be used as absolute stratigraphic markers throughout Oxia Planum, particularly in quantifying the rate of recent and active surface processes.

[1] Lagain A. et al. (2021) Nature Comms. 12, 6352. [2] Lagain A. et al. (2021) Earth Space Sci. 8, e2020EA001598.

Fluvial and Lacustrine Processes on Mars and their relevance to exploring Mars' Habitability

Nisha Gor (The Open University, UK)

Co-authors: Peter Fawdon (The Open University, UK), Matt Balme (The Open University, UK)

Key points: Here we investigate a chain of four intersecting craters interpreted to be a series of ancient paleolakes in western Arabia Terra. We present a reconstruction of the geological history of these lakes and consider the fluvial and lacustrine history of the region including the implications for Oxia Planum and the ExoMars rover mission.

Ancient lake basins provide valuable insights about the environment of Mars. These locations are important because they record the environment in which they were formed possibly including evidence for early prebiotic processes that may have occurred in Mars' ancient past. Here we investigate a chain of four intersecting craters interpreted to be a series of ancient paleolakes named Abu, Varahamihira, Aarna and Kyara (the AVAK lake system). Located in western Arabia Terra S.E. of the ExoMars Rover landing site in Oxia Planum, the timing and persistence of this lacustrine activity would have been governed by the regional hydrology possibly driven by groundwater fluctuations. Our ongoing mapping has identified a variety of tectonic, fluvial and lacustrine processes that occurred in the study region and operated at several phases in time. Examples of key observations include a channel flowing out from Abu crater interpreted be an outlet that breached the rim when the water level reached a spillway point during one or more phases of fluvial or lake activity. Sediment fans with different morphologies are also observed within different craters. They show the direction of transport between the different lakes formed by overspilling. We present a reconstruction of the geological history of the AVAK lake system. Our studies constrain the depth of water in the craters when lakes formed and evaluate what AVAK can tell us about the fluvial and lacustrine history of the region including the implications for Oxia Planum and the ExoMars rover mission.

The rich meteorological dataset of the InSight Mars mission.

Claire Newman (Aeolis Research)

Co-authors: Stephen R. Lewis (OU, UK) Aymeric Spiga (Sorbonne and LMD, France), Francois Forget (LMD, France), Jorge Pla Garcia (CAB, Spain), Maria Ruiz (CAB, Spain), Orkun Temel (KU Leuven and ROB, Belgium), Ozgur

Key points: The InSight lander measured pressure, wind speed and direction, air and surface temperature at the surface of Mars for over one Mars year, as well as monitoring vortices, turbulence, sand motion and dust lifting. This dataset is hugely valuable to Mars atmospheric scientists, including modelers using it to improve understanding and predictions of Mars's near-surface meteorology and aeolian activity.

While its primary objectives were to study the interior of Mars and its present-day seismic activity, the InSight lander also carried several meteorological sensors (primarily needed to differentiate true seismic signals from those produced by wind or passing vortices, or as part of a heat flow experiment) as well as cameras which could be used to monitor atmospheric and surface changes. Although power became increasingly limited due to dust build-up on the lander's solar panels, InSight's Pressure Sensor measured nearly continuously at up to 20Hz for ~1.25 Mars years, giving the highest frequency pressure dataset yet obtained on Mars. The Temperature and Winds for InSight (TWINS) instrument consisted of two booms pointing in opposite directions (such that at least one sensor would measure winds from a given direction with minimal influence from lander hardware). Each boom measured air temperature and winds at 1Hz nearly continuously for over one Mars year. Finally, the Heat Flow and Physical Properties Package (HP3) regularly measured the diurnal variation of surface temperature. We will provide an overview of InSight's meteorological and aeolian datasets, and show how we are using them to validate the predictions of four global and four mesoscale atmospheric models of InSight's landing site in Elysium Planitia. Such work is important not only for Mars science - for example, attempting to explain why InSight saw many strong vortices but no dust devils - but also for reducing uncertainty in meteorological predictions for future landing sites, needed for planning Entry-Descent-Landing and surface operations.

Surface and atmospheric discoveries from the ExoMars Trace Gas Orbiter mission

James Holmes (The Open University, UK)

Co-authors: the TGO team

Key points: Latest science results from the ExoMars Trace Gas Orbiter mission

The ESA ExoMars Trace Gas Orbiter (TGO) is the first component of the ExoMars programme. TGO started science observations of the martian atmosphere and surface from a 400 km altitude orbit in late April 2018 and continues to this day. The scientific payload on the orbiter consists of four instruments; the Nadir and Occultation for Mars Discovery (NOMAD) and Atmospheric Chemistry Suite (ACS) spectrometer suites, the Colour and Stereo Surface Imaging System (CaSSIS) and the Fine-Resolution Epithermal Neutron Detector (FREND). NOMAD and ACS map the composition and distribution of Mars' atmospheric trace gases (including water vapour, ozone, hydrogen chloride, carbon monoxide and many others) in unprecedented detail across a wide wavelength range utilising both solar occultation and nadir modes of observation. The spectrometer suites are also sensitive to and providing mapping of isotopologues, aerosols and the thermal structure of the atmosphere. CaSSIS has produced over 42,000 high-resolution colour images and over 2,200 successful stereo pairs that can be converted into digital terrain models of the martian surface. FREND is creating the most detailed map ever produced of hydrated minerals in the shallow subsurface of Mars.

This talk will give a brief description of the TGO mission and overview of the instruments, followed by details of the exciting new science results and discoveries related to the surface and atmosphere of Mars.

Parallel 2E: Mars: Outer Planet Moons

Conference Room (with overflow in the Abbey Room) at Space Park Leicester

Thursday 20th June 14:00 - 15:30

PlanetMapper: a Python package for visualising, navigating and mapping Solar System observations

Oliver King (University of Leicester, UK)

Co-author: Leigh Fletcher (Leicester, UK)

Key points: PlanetMapper is a Python software package that simplifies the complex process of navigating, mapping and visualising observations of Solar System targets

PlanetMapper is an open-source Python package to visualise, process and understand astronomical observations of Solar System objects, such as planets, moons and rings. Astronomers can use PlanetMapper to 'navigate' observations by calculating coordinate values (such as latitude and longitude) for each pixel in an observed image and can map observations by projecting the observed data onto a map of the target body. Calculated values are exportable and directly accessible through a well-documented API, allowing PlanetMapper to be used for custom analysis and processing. PlanetMapper can be used to help generate publication quality figures and has a Graphical User Interface to significantly simplify the processing of astronomical data. PlanetMapper can be applied to a wide range of datasets, including both amateur and professional ground-based observations, data from space telescopes like Hubble and JWST and data from spacecraft exploring the Solar System.
PlanetMapper is described by King et al., 2023 (https://doi.org/10.21105/joss.05728) and the source is available on GitHub (https://github.com/ortk95/planetmapper). PlanetMapper is published on PyPi and can easily be installed with `pip install planetmapper`.

Titan in Late Northern Summer from JWST and Keck

Conor Nixon (NASA Goddard Space Flight Center)

Co-authors: JWST Titan Science Team, Keck Titan Science Team.

Key points: We report on observations of Titan during 2022 and 2023 that reveal changes in its atmosphere in the approach to northern fall equinox. JWST and Keck spectroscopy and imaging are revealing new information about cloud and gas distributions, which we compare to models.

Titan is an object of fascination for scientists researching the solar system, as a 'terrestrial-like' world with active meteorology and fluvial and lacustrine formations based on methane chemistry and condensation. The Cassini-Huygens mission explored Titan extensively from 2004 to 2017, but since that time further observation of its slow seasonal cycle has been possible only via telescopes positioned on or close to the Earth. Titan's unique characteristics led to a concerted post-Cassini observational campaign, with many of the most powerful telescopes available to astronomy. In this work we report on observations from 2022 & 2023 with three instruments on the James Webb Space Telescope (JWST), NIRCam, NIRSpec and MIRI, also in coordination with imaging from Keck II. In November 2022 and July 2023, Titan was the subject of multi-spectral filter imaging with JWST NIRCam and Keck II NIRC2, revealing tropospheric clouds at mid-northern latitudes, in line with climate modeling predictions for this season (late northern summer). In filters sensitive to the upper troposphere, we observed clouds growing and apparently ascending in altitude during a Titan day. JWST NIRSpec spectroscopy yielded for the first time a high resolution (R=2700) spectrum of Titan across the entire near-infrared (1-5 microns) unobscured by telluric absorption. This, among other things, enabled measuring the detailed structure of the CO 4.7 um non-LTE emission, including the fundamental, the first two overtone bands and two isotopic bands. It is also the first time that CO2 emission has been resolved in the NIR and the first time it has been seen on Titan's dayside. Finally, very sensitive spectroscopy with JWST MIRI in the mid infrared (5-28 microns) confirmed the many stratospheric gases seen by Cassini CIRS, but also added a new detection of methyl (CH3) in the middle atmosphere, a product of methane photochemistry that was expected but not previously seen. We modeled parts of the spectra to find a global mean temperature profile and profiles of minor gases. Soon we hope to extract yet more results from the NIRSpec and MIRI spectra as our understanding of the calibration and modeling progresses. In this presentation we summarize our results to date and describe planned future observations of Titan with JWST and Keck cycles.

X-ray optics development for studying the Jovian system and Galilean moons

Natasha Carr (University of Leicester, UK)

Co-authors: C. H. Feldman (UOL, UK), S. T. Lindsay (UOL, UK), A. Martindale (UOL, UK), G. D. Berland (JHU APL, USA), G. B. Clark (JHU APL, USA), W. R. Dunn (UCL, UK), B. Parry (UCL, UK)

Key points: The Jovian system is host to a unique magnetic environment which generates X-rays through several processes, and understanding these emissions allows us to uniquely address a wide range of science questions. We present an X-ray instrument concept for a Jupiter mission; a concept drawing on the extensive history and heritage of lobster eye telescopes developed at the University of Leicester.

The Jovian system is host to a unique magnetic environment which generates X-rays through several processes, and understanding these emissions allows us to uniquely address a wide range of science questions. X-ray images can distinguish the ion and electron aurorae, characterising magnetosphere-ionosphere coupling and plasma populations. Relativistic particles in Jupiter's radiation belts produce X-rays, and global X-ray imaging can track variability of the production processes, providing understanding of extreme particle acceleration in the Universe. X-rays can image charge exchange processes that are key for mass transportation in Io's torus. Giant planets couple to the solar wind but these interactions are not well understood – X-rays could image the cusp of Jupiter. Particle precipitation to the surfaces of moons produces fluorescent line emission and thick-target bremsstrahlung X-rays, which provide elemental compositional maps of the moons - breaking IR molecular degeneracies - and characterise the precipitating population. The development of Micro Pore Optics has enabled the creation of smaller, lighter X-ray telescopes using lobster eye arrangements to allow wider fields-of-view. This permits an instrument similar to BepiColombo MIXS or SMILE SXI to perform in-situ X-ray observations of the systems of the outer planets – a recent, transformational development allowing science that would not have been possible with the high mass of traditional X-ray telescopes. We present an X-ray instrument concept for a Jupiter mission, with applications on missions to other outer planetary bodies. This concept draws on the extensive history and heritage of lobster eye telescopes developed at the University of Leicester.

Thermal microphysical modelling of Enceladus' surface

Georgina Miles (Southwest Research Institute, USA)

Co-authors: Carly Howett (U. Oxford, UK; PSI, USA), John Spencer (SwRI Bulder, USA)

Key points: Ice microphysical models of the surface of icy moons reveal a temperature dependence of thermal inertia. Modelling suggests significant changes to porosity, ice phase and contact quality would be required to produce thermal inertia anomalies on Enceladus.

Quantifying the endogenic heat being released from the surface of Enceladus is key to understanding its heat balance and evolution. Multiple studies have aimed at constraining Enceladus active south polar terrain (SPT) emission, but this the first to constrain non-SPT emission.

Thermal observations and surface temperature models are used to identify departures from expected surface temperatures. Uncertainties in the surface thermal properties make characterising endogenic heat sources challenging, but they can be used to establish upper limits for expected heat loss. Without further information, sources of endogenic heat need to be distinguished from unexpected thermal inertia anomalies.
To test whether physical changes to surface ice properties could increase localized thermal inertia we have developed a thermal microphysical model. We quantify the sensitivity of thermal inertia of icy moons to phase, porosity and grain size, with a particular focus on the emissivity and temperature dependency of the thermal inertia. Our results show to increase Enceladus' global thermal inertia greater than the range of uncertainty (3 - 50 J m-2 K-1 s-1/2) would require any amorphous ice to become crystalline, for porosity of the surface to be greater than 0.8 and for the ice to have tight contacts. We also find that the temperature dependence of bulk thermal inertia becomes stronger with increasing grainsize, suggesting it should be a consideration in surface temperature modeling at grainsizes over 0.01 m for all porosity and phases of ice.

A Geochemical Model of Europa's Ocean and Seafloor

Lewis Sym (The Open University, UK)

Co-authors: Nisha Ramkissoon (OU, UK), Mark Fox-Powell (OU, UK), Victoria Pearson (OU, UK), Mohit Melwani Daswani (JPL, USA)

Key points: Europa's subsurface ocean could potentially be habitable, but little is known about the ocean or seafloor compositions. Here, a geochemical model of Europa is developed which will be used to investigate water-rock reactions and energy available to life.

Europa is proposed to host a global liquid water ocean that is in contact with a silicate interior. Understanding the composition of this ocean and the underlying rock is crucial for evaluating the habitability of Europa. However, the presence of an ice shell impedes direct observation or analysis of the ocean and seafloor rock, leaving their compositions largely unknown. In this study, possible compositions were explored using computer modelling to simulate the thermal evolution of Europa's interior over its ~4.5 Gyr lifetime and assess the volatiles released from the interior as it is heated.
Using a CM chondrite composition as an analogue for the material that accreted to form Europa, the model revealed a scenario for the evolution of Europa's ocean and seafloor compositions from post-accretion to the current day. The composition and structure of the current-day Europa model shows good agreement with observations, bolstering the credibility of this method. An

important result of the model is that the seafloor retains its primordial hydration up to the current-day, which has implications for the water-rock reactions that could be occurring there.

Given these new constraints on possible Europan ocean and seafloor compositions, and how they would have varied over time, further work is needed to evaluate Europa's habitability. An experimental Europa simulant is being developed, based on the model output, to investigate the potential water-rock reactions occurring at Europa's seafloor, and this will inform calculations regarding the energy available to support life.

Interaction of microbial biomass with cryogenic mineral phases during freezing of Europa-relevant brines

Alvaro del Moral (AstrobiologyOU, The Open University, UK)

Co-authors: Victoria K. Pearson, Karen Olsson-Francis and Mark G. Fox-Powell (AstrobiologyOU, The Open University, UK)

Key points: Microbial survival during freezing

Europa, one of Jupiter's moons, has regions beneath its icy surface that may harbour life. Salt minerals on Europa's surface likely originated from the ocean, suggesting that if life existed in the sub-surface, it could have become trapped within the ice along with ocean-derived brines[1,2], leading to close associations between microbial biomass and salts.

In previous work, we obtained a microbial community capable of growing under simulated sub-surface European ocean conditions[3]. Salt solutions based on models of Europa's ocean[4] were seeded with cells of our analogue community and a strain isolated from an analogue environment, and frozen at three different rates, allowing us to explore the implications of a range of cryovolcanic and exhumation processes at Europa. Electron microscopy was used to analyse sublimated ice-templated salt structures and microbial cells. The identity and abundance of mineral phases were determined using X-ray diffraction and spacecraft-relevant techniques such as Raman and near-infrared spectroscopy.

Results demonstrate that freezing decreases the number of intact cells, but the proportion of intact vs. damaged cells showed opposite correlations with the freezing rate for our community vs. the pure strain. While the spatial distribution of salts was controlled primarily by the freezing rate, we observed a close association between cryogenic salt phases and microbial biomass. We also found that the occurrence of specific cryogenic mineral phases depended on the presence of cells, indicating that biomass can influence salt precipitation during freezing. These mineralogical differences were detectable using mission-relevant techniques such as Raman spectroscopy.

References: [1] Buffo, J. J. et al. (2022) Astrobiology 19; [2] Santibáñez, P. A. et al. (2019) JGR Biogeosci. 124; [3] Del Moral, et al. (2022), Europlanet Science Congress, Granada, Spain; [4] Melwani Daswani, M., et al., (2021) Geophys. Res. Lett. 48.

Parallel 1F: Mars Magnetosphere, Ionosphere & Atmosphere

Shuttle Suite, National Space Centre

Thursday 20th June 16:00 - 17:00

New Measurement Technique for the Martian Ionosphere: First Results of Mars Express - ExoMars Trace Gas Orbiter Mutual Radio Occultation

Jacob Parrott (Imperial College London, UK)

Co-authors: Håkan Svedhem (TU Delft, NL), Olivier Witasse (ESA, NL), Colin Wilson (ESS, NL), Ingo Müller-Wodarg (Imperial College London, UK)

Key points: -102 vertical electron density profiles extracted from equipment that was originally designed for comms, mutual radio occultation allows you to measure relatively upsampled regions of mars.

Spacecraft-to-spacecraft radio occultations experiments are being conducted at Mars between Mars Express (MEX) and Trace Gas Orbiter (TGO), the first ever extensive inter-spacecraft occultations at a planet other than Earth. Due to the UHF frequency, this measurement technique is adept at sensing ionospheres and this unique spacecraft configuration allows for measurements around noon and into the deep-night. This presentation shall show the first 102 such occultations. Of these, 63 observations have to-date resulted in the extraction of vertical electron density profiles. These observations are the successful results of a major feasibility study conducted by the European Space Agency to use pre-existing relay communication equipment for radio science purposes.

The M-MATISSE mission: Mars Magnetosphere ATmosphere Ionosphere and Space weather SciencEAn ESA Medium class (M7) candidate

Beatriz Sanchez-Cano (University of Leicester, UK)

Co-authors: the M-MATISSE team

Key points: The M-MATISSE mission is an ESA Medium class (M7) candidate currently in Phase dedicated to unravel the complex and dynamic couplings of the Martian magnetosphere, ionosphere and thermosphere (MIT coupling) with relation to the Solar Wind and the lower

atmosphere. It will provide the first global characterisation of the dynamics of the Martian system at all altitudes, to understand how the atmosphere dissipates the incoming energy from the solar wind, including radiation, and Space Weather activity.

The "Mars Magnetosphere ATmosphere Ionosphere and Space-weather SciencE (M-MATISSE)" mission is an ESA Medium class (M7) candidate currently in Phase A study by ESA. M-MATISSE's main scientific goal is to unravel the complex and dynamic couplings of the Martian magnetosphere, ionosphere and thermosphere (MIT coupling) with relation to the Solar Wind (i.e. space weather) and the lower atmosphere. It will provide the first global characterisation of the dynamics of the Martian system at all altitudes, to understand how the atmosphere dissipates the incoming energy from the solar wind, including radiation, as well as how different surface processes are affected by Space Weather activity.
M-MATISSE consists of two orbiters with focused, tailored, high-heritage payloads to observe the plasma environment from the surface to space through coordinated simultaneous observations. It will utilize a unique 3-vantage point observational perspective, with the combination of in-situ measurements by both orbiters and remote observations of the lower atmosphere and ionosphere by radio crosstalk between them.
M-MATISSE is the product of a large organized and experienced international consortium. It has the unique capability to track solar perturbations from the Solar Wind down to the surface, being the first mission fully dedicated to understand planetary space weather at Mars. It will revolutionize our understanding and ability to forecast potential global hazard situations at Mars, an essential precursor to any future robotic & human exploration.

Atmospheric science with the M2020 Perseverance rover: key results and future objectives

Alexander Stott (ISAE-SUPAERO, Université de Toulouse, France)

Co-authors: German Martinez (LPI, USA), Claire Newman (Aeolis research, UK/USA), Michael Wolff (SSI, USA), Manuel de la Torre Juarez (JPL, USA), Jose Antonio Rodriguez-Manfredi (CAB CSIC-INTA, Spain) and the M2020 atmospheric working group

Key points: The Perseverance rover has a wide array of instruments to characterise the Martian atmosphere. We will show how these measurements yield insights into the ongoing dynamic activity in the location for which samples are being collected for the return to Earth.

The NASA Perseverance rover has been exploring Jezero crater for almost 2 Mars years. In doing so, the rover has experienced a variety of conditions over the seasons, including dust storms. During this time the rover has travelled from the crater floor up to the rim and so observing how

the conditions vary over terrain. Throughout this exploration, several instruments have acquired new data sets to characterise the Martian atmosphere. This includes MEDA (Mars Environmental Monitoring Station), Mastcam-Z, SuperCam, the navigation cameras, EDL (Entry descent and Landing) cameras and MOXIE. These measurements contribute to the mission goal of helping to prepare for future human exploration on Mars. This is achieved by (1) validating global atmospheric models of the Martian environment with in-situ surface weather measurements, and (2) characterising dust size and morphology to understand its diurnal and seasonal properties and possible effects on the operation of landed missions.
The variety of terrain, types of measurements and the increasing length of the dataset yields a vital source of information on the Martian climate. We will provide an overview of the main results and the future goals of the atmospheric working group on the Perseverance mission.

The role of magnetic topology and plasma pressure on the ionopause formation at Mars

Katerina Stergiopoulou (University of Leicester, UK)

Co-authors: Beatriz Sánchez-Cano (UoL, UK), Mark Lester (UoL, UK), Chris M Fowler (WVU, WV, USA), David J Andrews (IRF, SWE), Shaosui Xu (SSL, CA, USA), Niklas J T Edberg (IRF, SWE), Simon Joyce (UoL, UK), Dikshita Meggi (UoL, UK), Anna K Turner (WVU, WV, USA)

Key points: We identify ionopause-like boundaries using an automated routine that we developed and we find that the ionopause formation is correlated to changes in magnetic topology and plasma pressure balance

At planets with no intrinsic dipolar magnetic field such as Mars, an ionopause is often formed, a boundary that separates the planetary plasma from the solar wind. The ionopause boundary and its formation drivers in the upper dayside ionosphere of Mars is yet to be fully characterised. In this study, we use observations from NASA's MAVEN mission to probe the Martian upper dayside ionosphere and describe the physics of the ionopause boundary as well as its variability drivers. We developed an automated method to identify the ionopause as the location of sharp gradients in electron density and temperature. We focus on the 8th MAVEN deep dip campaign (DD8) from October 2017 that consists of 50 consecutive orbits. The trajectories of the DD8 orbits are similar to each other and thus, the impact of the changing upstream conditions on the Martian ionosphere can be studied. We utilise and compare data from several instruments on board MAVEN, namely the LPW, SWEA, STATIC, SWIA and MAG, in order to investigate in detail the factors controlling the ionopause. We find that the ionopause formation is correlated to changes in magnetic topology, and more specifically an ionopause in most cases is formed where there is

a change from closed to either open or draped magnetic field lines, and to thermal pressure balance between the ionosphere and the magnetosheath.

Parallel 2F: Mercury

Conference Room (with overflow in the Abbey Room) at Space Park Leicester

Thursday 20th June 16:00 - 17:00

Volatiles in Mercury's crust – what do we need BepiColombo to find out?

David Rothery (The Open University, UK)

Key points: We need to learn more about Mercury's surprising volatiles actually are. BepiColombo should help a lot, and peak-ring basins are a good place to look.

The first evidence that Mercury's surface is rich in volatiles came when MESSENGER gamma ray spectroscopy revealed a high (Mars-like) K/Th ratio and X-ray spectroscopy shows 2-4% sulfur and elevated Na and Cl. Visual evidence of volatiles shaping Mercury's landscape comes most obviously from: volcanic vents at the centres of explosively distributed volcanic deposits (evidencing violent expansion of gases) continuing into maybe the most recent few 100 Ma; and 'hollows' where the upper 10-20m of ground is being passively lost to space, almost certainly via some kind of volatilization mechanism which is a slow ongoing process even today. MESSENGER data gave us very little insight into the mineralogy of the volatiles involved in these processes. The biggest explosive volcanic deposit has been shown to be low in S (so S was lost in a gas phase?), whereas sulfides and or chlorides are leading contenders for the hollow-forming volatiles. BepiColombo is better equipped for both elemental and mineralogical analysis, and will work at finer spatial resolution.

Mercury's 56 peak-ring craters are venues hosting both explosive volcanism and hollows: there are hollows in about 23 and explosive volcanic vents in about 11. Both types of feature occur either on the peak-ring, or in a place where the peak ring has been either destroyed, or buried by lava flows. Praxiteles and Scarlatti are the only two peak-rings hosting clear examples of explosive vents as well as hollows. I will discuss the pre- and post-impact depths where the volatiles are likely to occur.

Investigating the Origin of Flows Around Craters on Mercury and the Moon

Alistair Blance (The Open University, UK)

Co-authors: David Rothery (OU, UK), Matt Balme (OU, UK), Jack Wright (ESA), Valentina Galluzzi (IAPS, Italy), Susan Conway (CNRS, France)

Key points: Similar frequency of flow features around craters on Mercury and the Moon, many appearing to result from down-slope collapse of proximal ejecta or transient crater rim material into an adjacent crater. Mercury additionally has two ejecta flows on flat ground.

Flow features occur around impact craters across the Solar System. Their layered morphologies, steep margins, and lobate shapes contrast with ballistically emplaced crater ejecta deposits, which thin gradually away from the crater rim. Some are interpreted as ground-hugging flows of ejecta during an impact event, e.g. on Mars, where volatiles may fluidise ejecta material. In contrast, some flows around craters are probably landslides, especially on bodies with minimal volatiles such as the Moon. Mercury provides an interesting point of comparison: an intermediary step between volatile abundant Mars and volatile depleted Moon. We globally surveyed Mercury and the Moon for flow features around craters, finding that both bodies have a similar number of features (Mercury 97, Moon 92). Mercury is larger, but the Moon has a higher crater density, so abundances per crater are comparable. Most features identified extend downslope into adjacent craters, with the majority having failure scarps at their source. Morphological evidence indicates syn-impact formation, collapse of proximal ejecta or the transient crater rim into the adjacent crater being a likely origin. The similar frequency of these features around craters on Mercury and the Moon indicates they are a fundamental feature of impact cratering on uneven topography, with volatiles not required to explain their existence. However, Mercury, unlike the Moon, does have two examples of crater-related flows on flat ground, interpreted here as ejecta flows. Additionally, Mercury has more flows that lack a source failure scarp and seem to emanate directly from a crater rim.

Investigating the Surface Composition of Mercury through X-Ray Fluorescence Experiments on Meteorite, Terrestrial and Synthesised Material.

Julia Cartwright (Institute for Space, University of Leicester, UK)

Co-authors: S. T. Lindsay (P&A, UoL, UK), T. L. Barry (GGE, UoL, UK), G. Hall (P&A, UoL, UK), A. Martindale (P&A, UoL, UK), and E. J. Bunce (IfS P&A, UoL, UK)

Key points: We are performing ground-truth in-lab experiments on Mercury analogues using GREF to build a spectral library to interpret forthcoming data from MIXS on BepiColombo.

As the smallest and least explored rocky planet in the Solar System, Mercury's surface composition is not well characterised, while its complex history is of great importance for understanding planet formation and planetary migration models. NASA's MESSENGER mission (2011-2015) revealed unexpected surface compositional variability, with evidence for distinct

terranes, volatiles and clues to reducing formation conditions. The ESA/JAXA BepiColombo Mission, on-course to reach Mercury in 2025, has the potential to obtain improved compositional data for the surface. Specifically, the Mercury Imaging X-ray Spectrometer (MIXS) has the capability to acquire higher resolution surface elemental composition (max. achievable resolution ~ 10 km vs. ~ 200 km non-imaging field of view for for MESSENGER) through detecting X-Ray Fluorescence (XRF), generated by interaction of solar-coronal X-rays and charged particles with the Mercurian regolith. By ground-truthing the spectra gathered by MIXS, we will obtain the best interpretation for lithologies located on the Mercurian surface.
Here, we are using the MIXS Ground Reference Facility (GREF), which is equipped with flight-like MIXS instrumentation, and is based at the University of Leicester (Space Park). With GREF, we are performing X-ray spectroscopy on Mercurian analogues: meteorites, terrestrial samples and synthesised material that share properties with Mercury, to establish a sample library to allow for direct comparison with real-time mission data. We will present our first results for a suite of terrestrial and meteoritic samples, compare with modelled spectral data for expected compositions, and discuss our plans to further investigate compositional and textural features on Mercury.

Preparations for the Mercury Imaging X-ray Spectrometer's observations of Mercury's Low Reflectance Material

Adam Fox (University of Leicester, UK)

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Key points: The nature of the darkening agent in Mercury's Low Reflectance Material is a key science question for the upcoming BepiColombo mission. We present an investigation into an indirect method of identifying carbon (the leading candidate darkening agent) enrichments using scattered X-ray observations with the Mercury Imaging X-ray Spectrometer (MIXS).

Mercury is an understudied world retaining many mysteries, including those responsible for its heterogeneous surface. One area of considerable interest is the Low Reflectance Material (LRM), these anomalously dark patches on Mercury's surface are proposed to be correlated with enhancements of a 'darkening agent'. Currently, the leading candidate is graphite (carbon) in abundances greatly exceeding those observed on other terrestrial planets (wt %s).

The BepiColombo mission, due to arrive in December 2025, carries the Mercury Imaging X-ray

Spectrometer (MIXS), which measures elemental abundances in the upper tens of microns of Mercury's surface from orbit. MIXS uses X-ray fluorescence from major rock-forming elements through sodium to nickel to derive compositions. However, with XRF, MIXS cannot quantitatively detect carbon directly, nor will BepiColombo's other instruments.

This work presents an indirect analysis method for detecting carbon enrichments using the scattered X-ray background. Low atomic number materials are known to have large scattering cross-sections for soft X-rays, however they are very weakly interacting. We observed a range of terrestrial reference materials and graphite-spiked samples in laboratory-based studies with the MIXS qualification model detector. Agreement was found between the relative scatter intensities and behaviour of these samples with modelled values. This verifies the model which we then use to predict observations at Mercury, importantly under a range of different solar conditions. From this, the plausibility of two proposed statistical methods that would provide support for/against carbon enrichment in weight percent levels being the dominant darkening agent in the LRM are explored.

Parallel 1G: Moon and Phobos

Conference Room (with overflow in room 0.11 Swift) at Space Park Leicester

Friday 21st June 09:00 - 10:30

The Canadian Lunar Rover Mission: Journey to the Moon's South Pole

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Key points: The flagship of the Canadian Space Agency's Lunar Exploration Accelerator Program (LEAP) is the Canadian Lunar Rover - the first ever Canadian-led planetary exploration endeavour.

The flagship of the Canadian Space Agency's Lunar Exploration Accelerator Program (LEAP) is the Canadian Lunar Rover - the first ever Canadian-led planetary exploration endeavour. Canadensys Aerospace Corporation will land a 35 kg rover in the south polar region of the Moon no earlier than 2026. It will carry Canadian and U.S. payloads as part of NASA's Commercial Lunar Payload Services (CLPS) initiative. The rover will be able to operate inside of permanently shadowed regions (PSRs) for up to one hour and survive multiple lunar days/nights.

There are 3 high-level objectives for the Lunar Rover Mission: (1) Demonstrate and characterize Canadian technology on the surface of the Moon; (2) Perform meaningful science; and (3) Increase the Canadian Space Sector's readiness for future lunar missions. In addition, there are 3 overarching science objectives: (1) Lunar polar geology and mineral resources; (2) Lunar polar shadow, cold-traps, and volatiles; (3) Environmental monitoring for engineering to ensure the future presence astronaut(s) health.

To date, six instruments will be carried by the rover including stereocameras, a multispectral imager (MSI), a Lyman-Alpha Imager (LAI), a Lunar Hydrogen Autonomous Neutron Spectrometer (LHANS), a radiation micro-dosimeter and the U.S. Lunar Advanced Filter Observing Radiometer for Geologic Exploration (LAFORGE) which includes state-of-the-art infrared filters provided by the University of Oxford. All instruments are designed to geologically, chemically and environmentally characterise the landing site and identify areas that would be promising for the detection of water ice.

Unravelling the complex geological history of Taurus-Littrow Valley, Apollo 17 landing site.

Giulia Magnarini (Natural History Museum, London)

Co-authors: Peter Grindrod (NHM, UK), Thomas Mitchell (UCL, UK)

Key points: 1) Recent tectonism, coupled with long-lasting influence of the subsurface geometry of Taurus-Littrow Valley, has caused continuous slope deformation. 2) 3D clast-size analysis and clast fabric investigation of core sample 73002 reveal evidence of granular flow dynamics during the Light Mantle emplacement.

Taurus-Littrow Valley, the Apollo 17 landing site, is a location of complex geology on the Moon, where ancient tectonic structures have given origin to mountains and valleys; young tectonic structures have formed; and a recent, unique, hypermobile landslide developed. Over the past years, we have focused on two scientific questions regarding two recent geological features in Taurus-Littrow Valley, the Lee-Lincoln fault and the Light Mantle landslide deposit: 1) Is the seismic activity associated with the Lee-Lincoln fault responsible for the formation of the Light Mantle landslide? 2) What is the origin of the hypermobility of the Light Mantle? In this presentation, I will summarise our findings from the studies we conducted in the attempt to address these questions. This will include our works on evidence of slope deformation associated with recent tectonic activity of the Lee-Lincoln fault; and on the investigation of distinctive clast fabrics related to the emplacement of the Light Mantle within the Apollo 17 core sample collected from the landslide, as part of our involvement with the NASA Apollo Next Generation Sample Analysis (ANGSA) programme.

Using a hypervelocity light gas gun and iSALE numerical modelling to investigate impact-driven transport of biosignatures from Mars to Phobos

Zoe Emerland (The Open University, UK)

Co-authors: Victoria Pearson (OU, UK), Manish Patel (OU, UK), Simon Green (OU, UK), Nisha Ramkissoon (OU, UK), Samuel Halim (Birkbeck, UK)

Key points: Phobos could be a repository for impact-ejected material that may contain evidence of ancient martian life.

Phobos, the larger and closer of Mars' two moons, is not considered a location where extant or extinct life may exist. However, its close proximity to Mars means it could be a repository for impact-ejected material that may contain evidence of ancient martian life. This work investigated the delivery of possible martian biosignatures to Phobos and their subsequent detection within the Phobos regolith.

Bespoke Mars-relevant basaltic projectiles were designed and doped with the potential organic biosignature glycine. These were fired using the All-Axis Light Gas Gun (AALGG) at the Open University into two Phobos regolith simulants at a range of relevant velocities. Analysis with optimised GC-FID indicated no resolvable difference in glycine survival between the compositional and physical Phobos regolith simulant targets, and that there was a general reduction in survival with impact velocity. However, the proportion of glycine that survived at similar impact velocities varied significantly. To explore this, the results were compared with iSALE-2D hydrocode simulations that revealed that the survival of glycine could be fit by logistic function sigmoid curves with impact velocity.

This study highlights the stochastic nature of impact delivery and provides a baseline from which more complex molecular biosignature survival and modification could be investigated. It supports the potential presence of martian material, including biosignatures, within Phobos' regolith, which is significant for interpreting data from samples returned from Phobos by JAXA's Martian Moons eXploration mission.

Investigating the Origin of Mars' Moon Phobos: A Ground-Truthing Approach through Laboratory Analysis of Meteorites

Emelia Branagan-Harris (Natural History Museum, University of Oxford, UK)

Co-authors: Sara Russell (NHM), Neil Bowles (University of Oxford), Ashley King (NHM), Katherine Shirley (University of Oxford), Helena Bates (NHM)

Key points: To determine the origin of Mars' moon Phobos, JAXA's Martian Moons eXploration (MMX) mission is set to visit Phobos and retrieve samples to Earth. To ground-truth MMX's remote observations of Phobos, we have used XRD and FTIR to characterise the bulk mineralogy and IR spectral properties of carbonaceous chondrites and shocked darkened ordinary chondrites.

The origin of Mars' moon Phobos is unknown. Two theories prevail: Phobos is a by-product of a high-energy collision between an asteroid and Mars, which resulted in ejected orbiting material forming Phobos. Alternatively, Phobos is a captured asteroid from the volatile-rich outer Solar System. JAXA's Martian Moons eXploration (MMX) mission is set to visit Phobos and then return samples from the surface to Earth in 2031. The characterisation of these samples will determine the origin of Phobos.
To ground-truth remote observations of Phobos, we have used XRD and FTIR to characterise the bulk mineralogy and IR spectral properties of carbonaceous chondrites, the composition of which could be indicative of a captured asteroid, and shocked darkened ordinary chondrites that could represent a collisional formation. By acquiring XRD and IR data from the same material, mineral abundances can be directly correlated with features in reflectance spectra. We find that carbonaceous chondrites show spectral features consistent with their phyllosilicate- and carbonate-rich mineralogy (identified from XRD), while the ordinary chondrites contain spectral features related to abundant olivine and pyroxene. When MMX reaches Phobos, its remote spectral measurements can be compared to the FTIR measurements taken in this project, which are correlated with the mineralogy and water content determined from XRD.

Toward Multiview-Multispectral Sensing from the Martian Moons eXploration Spacecraft: Imaging Ryugu Samples with the Laboratory OROCHI Simulator

Roger Stabbins (Rikkyo University; Institute of Space and Astronautical Science, JAXA, Japan)

Co-authors: Shingo Kameda (Rikkyo University, Japan; ISAS/JAXA, Japan), Fumiya Nishio (Rikkyo University, Japan), Kentaro Hatakeda (ISAS/JAXA, Japan), Ryota Fukai (ISAS/JAXA, Japan), and the TENGOO & OROCHI Camera Team))

Key points: As part of preparations for imaging Phobos with the JAXA Martian Moons eXploration spacecraft multiview-multispectral imager (OROCHI), we present an imaging campaign of grains of asteroid Ryugu at multiple phase-angles and multiple visible-to-near-infrared wavelengths (400 – 950 nm), with a laboratory simulatory simulator of the OROCHI flight model.

The JAXA Martian Moons eXploration (MMX) mission will address the question of the origin of Phobos and Deimos by launching a spacecraft to the Mars system in 2026, performing dedicated surveys of the moons, and by collecting a sample from the surface of Phobos and returning it to Earth in 2031. OROCHI is a wide-angle visible-to-near-infrared (VNIR) 8-channel 8-camera multispectral imaging system for MMX, with a key objective of characterising the surface spectral diversity of the moons from orbit, during descent, and once landed on the surface of Phobos.

Operating a new imaging system in a new environment requires preparation, but the development timelines and protections required of spaceflight hardware rarely allow for extensive ground-based operation trials to be performed with the final Flight Model of an instrument. In preparation for multiview and multispectral imaging with the MMX spacecraft from the surface of Phobos, we have developed a laboratory simulator of the MMX OROCHI multispectral imager (LOROS), and have used it to image pristine grains of asteroid Ryugu collected in aggregate as an analogue of the surface scattering properties of Phobos, at the JAXA Extraterrestrial Sample Curation Centre (ISO-6 Cleanroom). We describe LOROS and demonstrate equivalent performance to OROCHI, and present the results of multi-phase multispectral imaging of the Ryugu C9003 aggregate sample. We discuss the implications of the surface bidirectional-reflectance distribution function on near-field imaging with the unique 8-camera 8-channel configuration of OROCHI, in the context of resolving the subtle VNIR features expected of Phobos.

NASA's Lunar Trailblazer mission - a small satellite to explore the Moon's water

Neil Bowles (University of Oxford, UK)

Co-authors: Bethany Ehlmann (Clatech, USA), Rachel Klima (JHU/APL, USA), Calina Seybold (JPL, USA), Andy Klesh (JPL, USA),Simon Calcutt (Univ. Oxford, UK) Keith Nowicki (Univ. Oxford, UK), Tristram Warren (Univ. Oxford, UK), Katherine Shirley (Univ. Oxford, UK), Henry Eshbaugh (Univ. Oxford, UK), Rory Evans (Univ. Oxford, UK), Bharvi Chikani (Univ. Oxford, UK), Kerri Donaldson Hanna (UCF, USA), Cyril Bourgenot (Univ. Durham, UK) Chris Howe (STFC RAL Space, UK) and the Lunar Trailblazer team.

Key points: A description of NASA's Lunar Trailblazer Mission that includes a UK built instrument, the Lunar Thermal Mapper

Lunar Trailblazer is a NASA SIMPLEx small satellite science mission for understanding the Moon's water and water cycle. Selected in June 2019, Lunar Trailblazer is in storage and on track to launch as a secondary payload on the Intuitive Machines IM-2 lander launch with SpaceX, scheduled for late 2024. Identifying water, determining its form and abundance, and mapping the distribution of water ice and geologic units at <100m spatial scales relevant to robotic and human exploration provide critical knowledge for future lunar surface exploration. Trailblazer simultaneously measures composition, temperature, and thermophysical properties from a lunar polar orbit at high spatial and spectral resolution over select areas of the Moon. The objectives are to detect and map water on the Moon at key targets to (1) determine its form (OH, H2O or ice), abundance, and local distribution as a function of latitude, soil maturity, and lithology on the sunlit Moon; (2) assess possible time-variation in lunar water on sunlit surfaces; (3) use terrain-scattered light to determine the form, abundance, and distribution of exposed water in permanently shadowed regions; and (4) collect thermal data to understand how local albedo and surface temperature gradients affect ice and OH/H2O concentration, including the potential identification of new cold traps. Trailblazer will perform the highest-to-date spatial resolution compositional and thermophysical properties mapping at the Moon and conduct reconnaissance of potential future landing sites. Lunar Trailblazer's international team is led by Caltech and managed by JPL. A Lockheed Martin-built and integrated ~200 kg smallsat carries two instruments: (1) JPL's High-resolution Volatiles and Minerals Moon Mapper SWIR imaging spectrometer (<70 m/pixel, 0.6-3.6 µm, 10 nm spectral resolution) and (2) the UK-contributed, University of Oxford-built Lunar Thermal Mapper multispectral thermal imager (<50 m/pixel, 4 broadband thermal channels 6-100 µm, 11 compositional channels 7-10 µm).

Parallel 2G: Venus & Mercury

Abbey Room (with overflow in the Exosat) at Space Park Leicester

Friday 21st June 09:00 - 10:35

Source of Mercury's Hollow-Forming Materials: Preliminary Results from Geological Mapping, Spectra, and Impact Simulations

Jack Wright (European Space Agency, ESAC, Spain)

Co-authors: Emma Caminiti (LESIA, Paris Observatory, PSL, France), Auriol S. P. Rae (University of Cambridge, UK), Sebastien Besse (European Space Agency, ESAC, Spain)

Key points: We combine geological mapping, reflectance spectroscopy and numerical impact simulations to constrain the subsurface distribution of Mercury's hollow-forming material. Our results show it can come from the whole thickness of the crust, deeper than previously known.

Mercury has a large core, but paradoxically the surface is also volatile rich. Most core-enlarging scenarios envisaged for Mercury would have heated the silicates and preferentially driven-off these volatiles. Mercury's hollows, flat floored, rimless depressions tens of metres deep and up to tens of kilometres across, appear to have formed by the loss of some volatile material to space upon its exposure at the surface, often by impact craters. Hollows lack superposing craters, indicating that they may be undergoing active formation today. The subsurface distribution of Mercury's hollow-forming material is not known. If confined to the upper few kilometres of Mercury's crust, sampled by the craters up to a few hundred kilometres in diameter in which most hollows are found, then perhaps it was accreted as a late veneer after the core-enlarging event. Alternatively, if the hollow-forming material is present throughout a greater thickness of Mercury's silicate portion then the timing of any high-temperature core-enlarging event must have taken place very early in the planet's history to allow time for a volatile-rich silicate fraction to reaccrete. Here, we study the Caloris basin: Mercury's largest, well-preserved impact structure. We employed a combination of geological mapping, reflectance spectroscopy, and numerical impact simulations to map the present-day distribution of the hollow-forming material in Caloris ejecta, preserved as hummocky plains hosting km-scale knobs, back to its pre-Caloris, subsurface distribution. Our results suggest that Mercury's hollow forming material comes from the whole thickness of the crust, a deeper constraint than previous studies.

Occurrences of very smooth patches across Mercury's global: implications for effusive volcanism

Annie Lennox (The Open University, UK)

Co-authors: Chris Malliband (OU, UK), David Rothery (OU, UK), Matt Balme (OU, UK), Jack Wright (ESA, ESAC, Spain), Susan Conway (Université de Nantes)

Key points: We conducted a global survey for patches of very smooth material across Mercury. These patches are commonly associated with craters and/or tectonic features. Patches with evidence of being volcanically emplaced may represent a protracted phase of waning effusive volcanism on Mercury.

Large scale effusive volcanism, responsible for most of Mercury's 'smooth plains', is accepted to have ended by ca. 3.5 Ga [1]. The present study is a survey of local occurrences of very smooth surfaces, often with the evidence for being topographically ponded. These patches are seldom larger than a few 10s of km across and are characterised by little to no texture and a paucity of superposing impact craters. We have identified over 3000 patches, including some previously reported occurrences [2,3,4], which we have classified based on their degree of freshness/smoothness. Patches exist in every quadrangle and can be categorised into four geological settings: hosted within crater interiors, external to craters, catenae-hosted, and isolated deposits (the majority of which are bounded on one side by a lobate scarp). We will explore the association between these patches and tectonic features, impact craters and volatiles. Emplacement scenarios being considered include impact-related (either as impact melt or fluidized impact ejecta) or small-volume effusive volcanism. For those with favourable evidence indicating a volcanic origin, these may represent a protracted phase of waning effusive volcanism post-3.5 Ga, advancing our understanding of Mercury's thermal evolution and possibly extending the duration of effusive volcanism towards the era when the youngest explosive eruptions occurred.

References: [1] Byrne P. K., et al., (2016). Geophys. Res. Letters. [2] Strom et al., (1990). USGS Astrogeol. Sci. Centre [3] Malliband C., et al. (2020). PhD Thesis. [4] Wang et al., (2021). Geophys. Res. Letters.

Modelling the Time-Dependent Magnetic Fields That BepiColombo Could Use to Probe Down Into Mercury's Mantle

Sophia Zomerdijk-Russell (Imperial College London, UK)

Co-authors: Adam Masters (ICL, UK), Haje Korth (APL, USA) & Daniel Heyner (TU Braunschweig)

Key points: Inductive processes due to forcing of Mercury's magnetosphere by the solar wind could be used by BepiColombo to probe the planet's interior. Frequencies in derived inducing field spectra could be used to obtain an electrical conductivity profile through to Mercury's mantle.

Due to Mercury’s proximity to the Sun and its small size, the planet’s magnetosphere is a unique and dynamic system. The interplay between the solar wind and embedded Interplanetary Magnetic Field (IMF) and the dayside Hermean magnetosphere drive an electric current on the system’s magnetopause boundary. Variability in the external solar wind leads to motion of the magnetopause and changes to this boundary’s current structure. By exploiting the inductive processes that result from these solar wind-driven magnetospheric changes, the interior structure of magnetised planets can be better understood. To prepare for the BepiColombo spacecraft’s arrival at Mercury, we asses solar wind forcing in this planet’s environment, through analysis of data acquired by the MESSENGER and Helios spacecraft, and the resulting influence on the magnetopause’s inducing field. The results suggest that BepiColombo will encounter highly unpredictable solar wind conditions and that the inducing field of the magnetopause that is generated in response to variable solar wind ram pressure is non-uniform across Mercury’s surface. It was also found that IMF variability has some effect on Mercury’s magnetopause current and the resulting inducing magnetic field. With frequencies ranging from ~5.5×10^-5–1.5×10^-2 Hz, the inducing magnetic field spectrum inferred for solar wind ram pressure driven magnetospheric variability suggests that transfer functions derived from the two BepiColombo spacecraft could enable us to obtain a profile of conductivity through Mercury’s crust and down into the mantle.

Constraining Tessera Evolution in Phoebe Regio

Connor Hoad (Royal Holloway, University of London, UK)

Co-authors: Christina Manning (RHUL, UK), Philippa Mason (ICL, UK), Richard Ghail (RHUL, UK)

Key points: Unpicking the structural records of complex, highly tectonised tessera terrains is paramount for constraining Venus' regional geologic histories.

Venusian Tesserae are enigmatic, chaotic planetary terrains characterised by high radar returns from their rough, blocky surfaces, and the presence of two or more intersecting suites of tectonic lineations. These terrains occupy~8% of Venus' surface, with a preferential distribution amongst isostatically compensated topographic rises. Tesserae often record multiple episodes of variable

tectonic regimes, and are widely accepted to represent the oldest crustal remnants of Venus' deep geologic history.
Phoebe Regio, a topographic rise situated along the eastern margin of Venus’ Beta-Atla-Themis region, is distinct from more typical tessera-dominated rises. Gravity data suggests that Phoebe is dynamically compensated by mantle upwelling, with surface features indicative of plume activity. Ongoing research aims to better constrain the geologic history of Phoebe Regio through detailed remote sensing using 75m/pixel Magellan SAR imagery. Mapping is undertaken with a core focus on constraining the structural evolution of the constituent subclasses of tessera terrains, to facilitate a more nuanced investigation into the region’s tectonic evolution

Unravelling compositional differences of venusian surface basalts

Julia Semprich (Astrobiology OU, The Open University, UK)

Key points: Petrological models are used to explore the origins of compositional difference of venusian basalts allowing for an interpretation of their formation conditions.

Venusian basalts record compositional differences because of various melting depths, differences in source regions, and volatile content. Linking basalt compositions to melting depth and reservoir is hence crucial to further constrain Venus’ geological evolution and will significantly contribute to the interpretation of data obtained by future Venus missions. Here, I use petrological modelling to determine the compositions of partial mantle melts for a range of protolith compositions, thermal gradients, and varying water contents, allowing for a comparison to surface observations and the prediction of potential formation conditions.
The modelled melt compositions depend strongly on thermal gradients and the amount of melt for peridotitic and basaltic protoliths. Deep mantle melts on low thermal gradients (5-10 °C/km) are the most silica-depleted and contain the highest FeO. Partial melts on higher thermal gradients (20-25 °C/km) can contain higher SiO_2 and lower FeO. The addition of water shifts melting to shallower depths although the initial amount of melt is very low. While large uncertainties in surface data make the derivation of conclusive formation conditions difficult, my results show that melts with high FeO content, comparable to those derived for Venera 9, likely originated in the deep mantle indicative for a mantle plume. The Venera 13 composition could have formed by partial melting in the deeper mantle, possibly from a fluid-enriched source. The Venera 14 composition likely formed by shallow melting of the mantle, although melting of a metamorphosed basaltic protolith may also be possible and would be indicative of a more tectonically active past.

Investigation of $FeCl_3$ and OSSO as candidates for the Venusian unknown UV absorber

Joanna Egan (University of Leeds, UK)

Co-authors: Wuhu Feng (NCAS, University of Leeds), Alexander James (School of Chemistry, University of Leeds), James Manners (Met Office), Daniel Marsh (Schools of Chemistry and Physics and Astronomy, University of Leeds), John Plane (School of Chemistry, University of Leeds)

Key points: We investigate ferric chloride and cis- and trans-OSSO as potential causes of the inhomogeneous UV absorption observed in the upper clouds of Venus. We present laboratory absorbance spectra of FeCl3 in sulphuric acid, and estimate atmospheric concentration and spectral intensity of absorption from the two potential candidates compared to observations.

Understanding the composition and distribution of the unknown UV absorber in the Venusian atmosphere has been an open question in planetary science for close to 100 years, with instruments on both past and future missions dedicated to its study. Many candidates for the cause of the absorber have been proposed over the years. We present investigations of two of them: ferric chloride (FeCl3) and the cis- and trans-forms of the SO dimer (OSSO). We have measured the absorption spectrum of FeCl3 in sulphuric acid, and show that it is much more similar in shape to the observed spectrum of the unknown absorber than prior FeCl3 spectra available in the literature. We have also added sulphur chemistry and iron chemistry into the global Planetary Climate Model for Venus (PCM-Venus), in order to predict the abundance of OSSO produced from the recombination of two SO molecules, and of FeCl3 by the reaction of gas phase HCl with iron from ablated cosmic dust particles. Using the laboratory-measured FeCl3 absorption spectrum in varying quantities in the different cloud modes of the Venusian clouds, and gas phase OSSO in the abundances calculated using the PCM-Venus model results, we perform 1D radiative transfer modelling to estimate the observable absorption from the two species and a mixture of both, compared to the spectrum measured by MESSENGER/MASCS during its June 2007 Venus flyby. We conclude that both candidates show some merit as the unknown absorber.

Community Session

Conference Room (with overflow in the Abbey Room) at Space Park Leicester

Friday 21st June 11:00 – 13:00

The European Space Agency Research Fellowship Programme

Jack Wright (European Space Agency, ESAC)

Key points: The ESA Research Fellowship is an important postdoctoral opportunity open to British early career planetary scientists. I will explain the programme from my perspective as a current Research Fellow.

The European Space Agency Research Fellowship is an independent postdoctoral fellowship open to ESA Member State nationals in the early stages of their scientific careers. The next call for applications will open in late August, with a deadline in mid-September. In this presentation, I will provide an overview of the programme, anecdotes of my first-hand experience as a final-year ESA Research Fellow, and clarification of the application process. I will be very happy to answer questions on this subject for an extended period of time if the schedule will allow it.

Status and Overview of the ExoMars/Rosalind Franklin Mission and Mars Sample Return Campaign

Elliot Sefton-Nash (European Space Agency, ESTEC, the Netherlands)

Co-authors: E. Sefton-Nash, J. L. Vago, G. Kminek (ESA/ESTEC, Netherlands)

Key points: The Rosalind Franklin Mission is re-established with contributions from NASA and is on schedule for launch in 2028. Meanwhile, preparations for Mars Sample Return continue.

Finding signs of life elsewhere is one of the most important scientific objectives of our time. ExoMars was conceived to answer one question: Was there ever life on Mars? All project design decisions have focused and continue to centre on the achievement of this one scientific goal. This is particularly the case for the Rosalind Franklin rover. Putting the science team in the best possible condition to search for physical and chemical biosignatures has led to: 1. the need for a 2-m depth drill; 2. the choice of payload instruments; 3. the landing site requirements that led to selection of the Oxia Planum landing site, and; 4. the surface exploration strategy that guides how the Rover and instruments are used together to achieve the mission objectives. The Rosalind Franklin Mission is re-established with contributions from NASA and is on schedule for launch in 2028.

Meanwhile, preparations for Mars Sample Return continue: Following completion of the 'Three Forks Depot' containing a set of 10 carefully selected samples, Mars 2020 further pursues collection of diverse samples from Jezero crater with astounding science potential. While re-architecture of the flight segment by MSR Campaign partners NASA and ESA is underway, research and development activities on the ground continue at a sustainable level in order to build capabilities and experience for future sample receiving and analysis, and to provide further opportunities for scientific engagement.