17th UKPF Early Career Researcher Meeting

Information and Programme booklet

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[Click here to skip to the programme]

Foreword

Greetings,

We look forward to welcoming you to Imperial College London on 15th January 2024 for the 17th UKPF early career researcher meeting! The overwhelming response to our call for abstracts and registrations is a testament to the vibrant and growing planetary science community in the UK. Our aim is to foster a supportive and engaging atmosphere where early career researchers can confidently present their work, be it through talks or posters, to their peers.

We would like to thank the Earth Science and Engineering department for administrative support and for allowing us to use the venue, and a huge thank you to anonymous academics who reviewed an enormous number of abstracts. We would like to extend special thanks to Peter Fawdon at OU who was extremely helpful in helping us create an engaging and inclusive programme. We also thank The UK Space Agency for providing funding for the event, who's support has allowed us to provide travel grants, free food, and put on an event to accommodate the enthusiasm of a thriving early career researcher community.

Contained within this booklet is everything you need for a fulfilling experience at the UKPF Early Career Researcher Meeting, including detailed programme schedules, abstracts, and travel guidelines.

If you have any questions about the meeting, please contact earlycareermeeting@ukpf2024.co.uk or chat to one of the organising committee on the day.

Warm regards,

UKPF Early Career Researcher Meeting Organising Committee
(Jordan Stone, Zoe Lewis, Isabelle Mattia, Amelie Roberts, & Kosuke Ikeya)

Acting on behalf of the UK Planetary Forum

THANK YOU TO THE UK SPACE AGENCY EXPLORATION TEAM FOR SPONSORING THE MEETING!

Thanks to funding from the UK Space Agency, we've been able to provide travel grants to maximise participation from ECR planetary scientists across the UK!

The British Planetary Science Conference (BPSC) is taking place between 19th – 21st June 2024 at Space Park Leicester!

BPSC is the largest gathering of planetary scientists in the UK, and is a great opportunity to meet the wider community.

To register for and submit abstracts to BPSC, visit: bpsc2024.le.ac.uk

Contents

Important information

Travel to the Royal School of Mines

The meeting venue is G41, a lecture room in the Royal School of Mines. You can find an unannotated map of the South Kensington Campus here (there is an annotated map below and that's most likely all you need to look at in this section). Here is the address:

Royal School of Mines,
Imperial College London,
South Kensington Campus,
London
SW7 2AZ

We recommend using public transport. South Kensington is the closest underground station, but Knightsbridge and Lancaster Gate also work well. From South Kensington station, it's about a 10-minute walk past the Natural History Museum and the Science Museum. If you find yourself alone, walking in the green fields with the sun on your face, be troubled, for you are in Hyde Park and have gone too far.

If you are driving, you may book a parking space on the South Kensington Campus by emailing car.park@imperial.ac.uk.

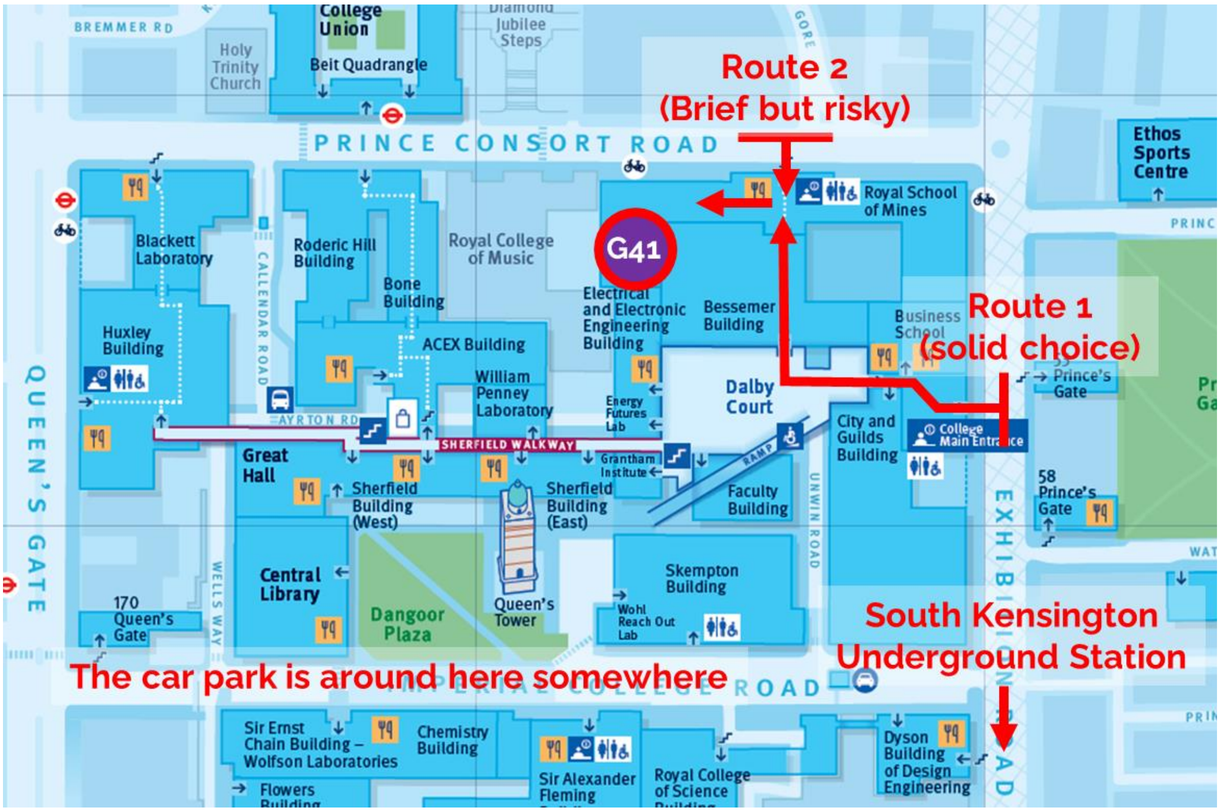
Finding and Accessing G41

If you are a wheelchair user, please contact earlycareermeeting@ukpf2024.co.uk as soon as possible and we will send you instructions directly.

There are two potential on-foot routes to the meeting venue (G41) (see map below):

Route 1: We recommend entering the university through the **City and Guilds Building** (the main campus entrance and reception), passing through the building, and entering the outdoor **Dalby Court**. From there, turn right and walk up the stairs into the **Bessemer building** (easily recognised by its hot pink entranceway oo la la). Go though the hallway and enter the main reception for the **Royal School of Mines** (see, figure 1, route 1). There should be some volunteers to help direct you to G41, or you can follow signs (start by turning left). This route avoids doors that require swipe-card access.

Route 2: You can also enter the Royal School of Mines through the main entrance (see figure 1, route 2) if the door is open, or by using a swipe-card. From there, you just turn right and follow the signs to the meeting down the long corridors.



Food and Social

Lunch will be provided courtesy of the UK Space Agency. All food will be vegan or vegetarian, and we have noted the dietary requirements you submitted in the registration form. Tea and coffee, as well as biscuits, will be provided during the breaks.

There will be a social event after the meeting for those of you who are able to stick around. We will provide you with all the information about that on the day, and we plan to book a table for dinner after the social.

Virtual Attendance

Here is a zoom link to join the meeting:

https://imperial-ac-uk.zoom.us/j/97659322896?pwd=NDZ2V1Eyc3NEUlV2M3J0N1VYaWlKZz09

Meeting ID: 976 5932 2896

Passcode: b8gX$j

We will open the zoom call at 9am on 15th January and share the slides and a view of the speaker. You will be able to ask questions in the chat box during the talks.

The lighting talks relating to the posters will be viewable live as with the rest of the talks, and the abstracts for each poster are available in this booklet if you'd like to find out more about the research. However, the poster session will not be recorded. We encourage you to contact presenters if you have any questions about their research.

If you have any questions about virtual attendance, please email earlycareermeeting@ukpf2024.co.uk

Information for Presenters

Talk format

Talks will be 7 minutes long and we will be keeping tight on the timings as we are excited to hear from all of you. You will then be able to sit on a Q&A panel with 3-5 other speakers from your talk theme for an up to 10 minute Q&A session. The 5 talk themes are:

- **Planetary Environments and Habitability** – encompassing astrobiology and investigations into all types of environments on other planets like fluvial and lacustrine systems, oceans, geysers, and volcanoes.
- **Exploration and Instrumentation** – encompassing planetary science missions, instrument and methods development, and the use of and development of data from planetary science missions.
- **Small Bodies & Impacts** – encompassing the study of asteroids, comets, meteorites, and impacts.
- **Planetary Geology and Geochemistry** – encompassing the study of the composition, structure, processes, and geochemistry of planets, with a focus on seismology, regolith properties, and surface processes.
- **Atmospheres and Magnetospheres** – encompassing anything related to the atmospheres or magnetospheres of planets and moons.

No need to send your slides in advance, we will be uploading them to the computer during the day. So please bring a laptop or a memory stick so we can transfer the slides during a break or at the start of the day. If you are not able to do this, please email your slides to earlycareermeeting@ukpf2024.co.uk

In your abstract decision email, we gave you the option to receive feedback on your talk from your peers. For those of you who have asked for this, we will distribute feedback forms before your talk and collect them after each session. There will be no grading or competition, just an opportunity for people to provide anonymous constructive feedback. If you would like to receive feedback on your talk and haven't already asked, please email earlycareermeeting@ukpf2024.co.uk or chat to us on the day.

Lightning talk and poster format

Lightning talks will be 2 minutes long each.

Please have a look through these lightning talk presenters lists and find your name:

Lightning Talk List Session 1

Lightning Talk List Session 2

When your lightning talk session begins, please join all other presenters in your session in a scramble to form a line in the correct order according to that list.

We hope to organise posters by themes on the day to make it easier for people to find posters in their field. Please hand your poster over to a member of the organising committee in the morning, so we can have everything ready for the poster session in time - we will probably be wearing UKPF t-shirts to help you identify us. Lunch will be provided during the poster session, so please don't feel like you have to stand by your poster throughout the whole session. Please eat your lunch first!

Programme

9:00 – 09:20	Arrival and registration
09:20 – 09:25	Opening remarks

Session 1: Small bodies and Impacts

09:25	Matthew Dobson The Discovery and Evolution of a New Epoch of Cometary Activity on Chiron
09:33	Onur Celik The coefficient of restitution estimations in granular small body surfaces
09:41	Bre Tilley Insights on the lunar provenance of Calcalong Creek meteorite from dating of granophyre clasts
09:49	Mark Boyd* Spherules from the K-Pg Boundary Layer: Preservation and Evidence of Impacts
09:57	Jodie Sutherland Understanding Aqueous Alteration in CM Chondrites using Infrared Spectroscopy and Thermogravimetric Analysis
10:05	Session 1 Q&A panel

Session 2: Exploration and Instrumentation

10:13	Robert Platt* Denoising CRISM Hyperspectral Images of Mars with Machine Learning
10:21	Daniel Le Corre Searching for Intact Lava Tubes on the Moon with Deep Learning
10:29	Adam Fox* Preparations for the Mercury Imaging X-ray Spectrometer's observations of Mercury's Low Reflectance Material
10:37	Session 2 Q&A panel

10:45 – 11:00	Coffee break

11:00 – 11:20	Keynote: Prof. Marina Galand

Session 3: Lighting talk session

11:20 – 12:05	15 x 2-minute lightning talks
12:05 – 12:15	Break
12:15 – 13:00	15 x 2-minute lightning talks

13:00 - 14:15	Lunch (courtesy of UKSA) and poster session

14:15 – 14:35	Keynote: Prof. Sanjeev Gupta

Session 4: Atmospheres and Magnetospheres

14:35	Mark Sharman* Magnetosphere-surface interactions at Mercury
14:43	Catherine Regan* The Effects of Dust Storms on Mars' Induced Magnetosphere
14:51	Katie Knowles* Traces of Magnetic Field in Jupiter's Equatorial Ionosphere
14:59	Sophia Zomerdijk-Russell How Can BepiColombo Use Solar Wind Variability to Probe Mercury's Interior?
15:07	Joshua Ford Retrieval of temperature and gas abundances of Titan's atmosphere using Minnaert limb-darkening analysis
15:15	Session 4 Q&A panel

15:15 – 15:30	Coffee break

Session 5: Planetary Geology and Geochemistry

15:30	Giulia Magnarini* Recent and Active Surface Processes on the Moon
15:38	Kat Dapré* Global seismology in a three-dimensional Enceladus
15:46	Emily Bamber How Do Rivers Traverse Impact Crater Topography?

15:54	Michael McKee An Experimental Investigation of the Effects of Planetary Regolith Properties on X-ray Fluorescence Data
16:02	Session 5 Q&A panel

16:10 – 16:20	Break

Session 6: Planetary environments and habitability

16:20	Alex Jones* Investigating biomarker preservation on Mars using Earth analogues: Implications for Mars Sample Return.
16:28	Angus Aldis Bubbles are rockets for microbes; predicting microbial dispersion in Enceladus's plumes based on bubbling in Iceland's geothermal springs
16:36	Toni Galloway Isotopic and genomic evidence of biological nitrogen cycling within Mars analogue hot springs
16:44	Lewis Sym* Composition and Habitability of Europa's Ocean Over Time
16:52	Session 6 Q&A panel

17:00	Closing remarks

17:15 onwards	Social event: G35

*Speakers with stars have requested peer feedback on their talk

Lightning Talk List Session 1

1. **Pratibha Gautum** | Bioavailability of Organics in the Solar System
2. **Amelie Roberts** | Observations of aeolian palaeo-scours in the stratigraphy of Aeolis Mons, Gale crater
3. **Solomon Hirsch** | Formation of carbon-sulphur biomorphs in lab-simulated early Martian environments - consequences for morphological biosignatures and the origin of life
4. **Arjun Patel** | How to Find Life on Mars: Investigating Biological Potential and Putative Biosignature Formation
5. **Nisha Gor** | Fluvial And Lacustrine Processes on Mars, and Their Relevance to Exploring Mars' Habitability
6. **Emma Harris** | Sedimentology and stratigraphy of the Texoli butte: MSL Curiosity rover analysis of the upper-sulphate bearing unit in Gale crater, Mars
7. **Jonathan Adams** | Application of medium and very high-resolution satellite imagery to detect silica-rich rock for cosmogenic exposure dating in Antarctica.
8. **Gerard Gallardo i Peres** | Challenges and opportunities of inter-mission SAR change detection in the context of the future VERITAS & EnVision radar missions to Venus
9. **Jessica Hogan** | Salt-Ice Grain Formation in the Enceladus Plume: A Combined Experimental and Remote Sensing Approach
10. **Henry Eshbaugh** | Operations Overview of the LTM Instrument Aboard Lunar Trailblazer
11. **Duncan Lyster** | Optimising Thermal Mapping Instrument Filters to Unveil Enceladus' Subsurface Secrets
12. **Natasha Carr** | X-ray optics development for studying the Jovian system and Galilean moons
13. **Charlotte Bays** | Exploring the evolution of organic matter in post-aqueously heated carbonaceous chondrites
14. **Carys Bill** | Constraining Impact Parameters for the South Pole-Aitken Basin Formation

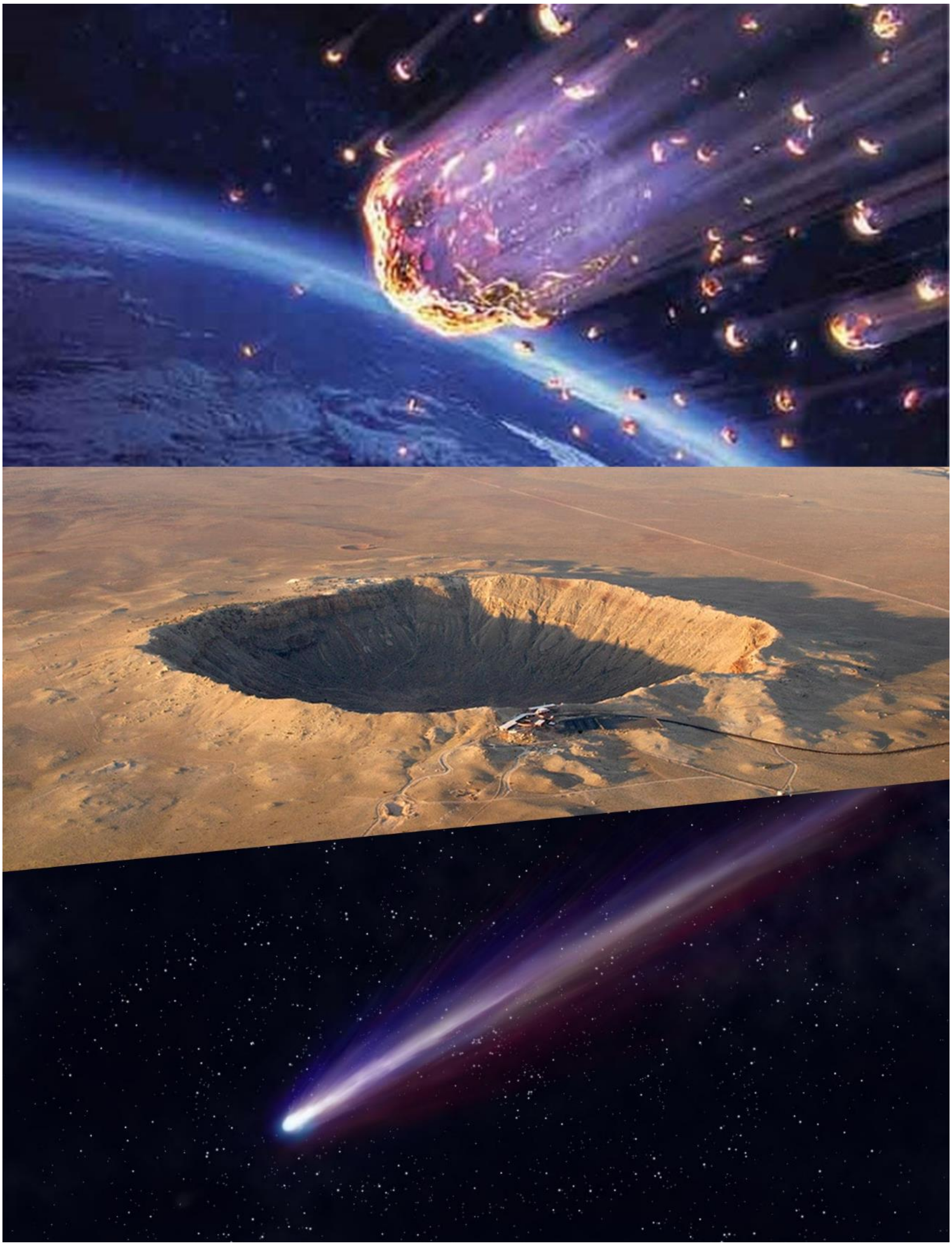
Lightning Talk List Session 2

1. **Isabelle Mattia** | The Effect of Early Diagenetic Processes on the Quantification of Fossil Micrometeorite Flux in the Geological Record
2. **Liza Riches** | Aqueous alteration history from carbonates in Essebi (C2-ung)
3. **Joshua Hollowood** | Impact-Induced Halogen Fractionation in Chondritic Meteorites: Implications for the Development of Earth's Halogen Signature
4. **Bianka Babrian** | Low Temperature Geochemistry on Water-rich Asteroids, Explored Through Hydrothermal Alteration Experiments
5. **Tom Barrett** | The Source of Hydrogen in Enstatite Chondrites
6. **Ben Rider-Stokes** | The Volatile Content of Early-Formed Crusts in the Inner Solar System
7. **Arty Goodwin** | Discerning the Likely Source of Geochemical Anomalies within Altered Impact Glasses from the Stac Fada Member Impactite, NW Scotland
8. **Stephanie Halwa** | Investigating the Apollo 16 Regolith Record
9. **Annie Lennox** | Geological Mapping of the Bach Quadrangle (H15) of Mercury
10. **Moni Konkona Boruah** | Probing the origin(s) of volatiles in the Moon and their Resource Potential
11. **Vinayak Shastri** | Water ice clouds on Mars

12. **Matthew Acevski** | Investigating the Unusual Radiation Belts of the Icy Giant Planets

Abstracts

Small Bodies and Impacts



The Discovery and Evolution of a New Epoch of Cometary Activity on Chiron

Presenting Author: Matthew Dobson, QU Belfast

Matthew M. Dobson[1], Megan E. Schwamb[1], Charles Schambeau[2], Alan Fitzsimmons[1], Larry Denneau[3], Nicolas Erasmus[4], A. N. Heinze[5], Luke J. Shingles[6,1], Robert J. Siverd[3], Ken W. Smith[1], John L. Tonry[3], Henry Weiland[3], David. R. Young[1], Michael S. P. Kelley[7], Tim Lister[8], Pedro H. Bernardinelli[9], Marin Ferrais[10], Emmanuel Jehin[11], Grigori Fedorets[12,1], Susan D. Benecchi[13], Anne J. Verbiscer[14]
[1]Queen's University Belfast; [2]University of Central Florida; [3]University of Hawaii; [4]South African Astronomical Observatory; [5]University of Washington; [6]GSI Helmholtzzentrum für Schwerionenforschung; [7]University of Maryland; [8]Las Cumbres Observatory; [9]University of Pennsylvania; [10]Arecibo Observatory, University of Central Florida; [11]University of Liège; [12]University of Helsinki; [13]Planetary Science Institute, USA; [14]University of Virginia.
Applicant E-mail: mdobson04@qub.ac.uk

The Centaurs are small Solar System objects located on chaotic orbits between the giant planets. They are thought to have originated in the Kuiper belt and are likely precursors of short-period comets. Centaurs are known to exhibit cometary activity, however, unlike comets, this activity is decoupled from heliocentric distance. The mechanism responsible for Centaur activity is currently not well-understood, with newly exposed pockets of volatile ices [1] and the amorphous-to-crystalline transition of subsurface ice [2] being proposed to explain this elusive phenomenon. As Centaurs form an intermediate transitionary stage between the primordial Kuiper belt and more physically evolved short period comets, understanding the cause of Centaur activity is a key step in understanding cometary evolution in the Solar System.

One of the largest members of the known Centaur population is (2060) Chiron, which has a well-established history of cometary activity [3][4][5][6] and is also one of the few small Solar System objects to have a system of debris rings [7][8]. In 2021, Chiron suddenly and unexpectedly brightened, behaviour highly indicative of a cometary outburst [9][10]. The large dataset of serendipitous observations from the Asteroid Terrestrial-impact Last Alert System (ATLAS) survey [11] allowed us to detect this brightening from Chiron's phase curve, shown in Figure 1, which measures the object's distance-corrected brightness as a function of viewing angle, highly analogous to the phases of the Moon. Figure 1 illustrates that Chiron became much brighter in 2021 than the previous 6 years of ATLAS observations, increasing in brightness far beyond its rotational lightcurve amplitude.

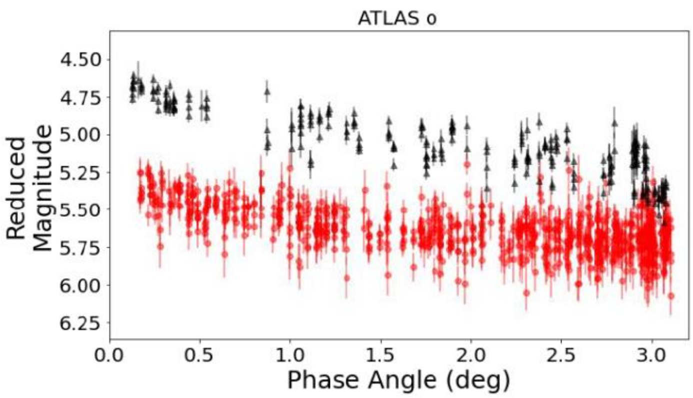


Figure 1: ATLAS o filter phase curve of (2060) Chiron. Data from the 2021 outburst (black triangles) show the increase in Chiron's brightness compared to previous observing seasons (red circles).

We present the results of our analysis of this 2021 brightening event, using multi-filter serendipitous observations from ATLAS, the Zwicky Transient Facility, the Dark Energy Survey, and Gaia, and follow-up observations from the Gemini North telescope, Las Cumbres Observatory telescope network, and TRAPPIST-South. We show that current models of Chiron's ring system [7] cannot explain the observed brightening. We propose that the most likely cause of Chiron's observed brightening 2021 is an epoch of new or increased cometary activity. We also demonstrate that high-cadence, long-baseline observations will improve the detection and analysis of cometary outbursts across populations of small Solar System objects by future surveys, such as the Legacy Survey of Space and Time by the Vera C. Rubin Observatory [12].

References:
[1] Prialnik (1992) ApJ, v.388, p.196; [2] Jewitt (2009) ApJ, 137, 5, pp. 4296-4312; [3] Meech and Belton (1989) IAU Circ., 4770, 1 (1989); [4] West (1991) IAU Circ., 4970, 1 (1990); [5] Bus et al. (2001) Icarus, 150, 1, pp.94-103; [6] Belskaya et al. (2010) Icarus, 210, 1, p.472-479; [7] Ortiz et al. (2015) A&A, 576, id.A18, 12pp; [8] Sickafoose et al. (2020) MNRAS, 491, 3, p.3643-3654; [9] Dobson et al. (2021) *RNAAS,* 5, 9, 221; [10] Dobson et al. (2023) PSJ, 4, 5, id.75, 34pp.; [11] Tonry J. L. et al. (2018) *PASP*, 130, 988, 064505; [12] LSST SSSC eprint arXiv:0912.0201;

The coefficient of restitution estimations in granular small body surfaces

Presenting Author: Onur Celik, University of Glasgow

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Introduction: Particle ejection events observed by the OSIRIS-REx in asteroid Bennu [1] and subsequent particle rebound from the surface [2] suggest that low-speed impact events may be more common than previously thought. Events such as those may only be observable to close observations but would result in an incessant evolution of small body surfaces rather than disruptive high-energy impacts. On the other hand, these low-energy impacts may be likened to the ballistic landings of small landers (such as MASCOT-2 on Hayabusa2 mission [3]) in which low-speed impact with the surface absorbs some of the impact energy. However, often landers bounce of small body surfaces, just as the rebounding particle of Bennu. It is then of interest how the coefficient of restitution may be calculated in granular small-body surfaces, such that these rebound events, and more broadly, these impacts can be explained. These two low-energy impact events may be considered a form of impact cratering. The crater scaling relationships allow estimating crater size, ejection speed and ejected mass as a function of macro parameters of surface, impact and impactor [4]. We have previously shown with discrete element method (DEM) impact simulations that the crater-scaling relationships of high-energy impacts are also applicable to these low-speed impacts [5].

The coefficient of restitution can then be defined as the ratio between outgoing and incoming impactor energy, in which the energy sinks could be identified to estimate final remaining energy (if any). In this paper these are considered to be the energy spent to eject particles, the energy that turn into particle and impactor rotation. The energy spent on particle ejection can be analytically derived from the scaling of ejecta speed and ejected mass. The DEM impact simulations, on the other hand, provide the history of particle rotation and impactor motion, which may be used derive empirical relationships to calculate the impact energy lost to these processes.

In this study, a set of DEM simulations presented in Refs [5] are analysed to estimate the coefficient of restitution obtained in the simulations semi-analytically. The simulations are performed at the level of Bennu gravity and at impact speeds of 5-50 cm/s impact speeds in line with Bennu's particle ejection events [4]. The semi-analytical analysis is then performed to estimate the remaining energy, which is then compared to the simulation results. The results show that the energy sinks considered constitute the majority of the energy absorbed upon impact and the coefficient of restitution estimations are in good agreement with the simulations.

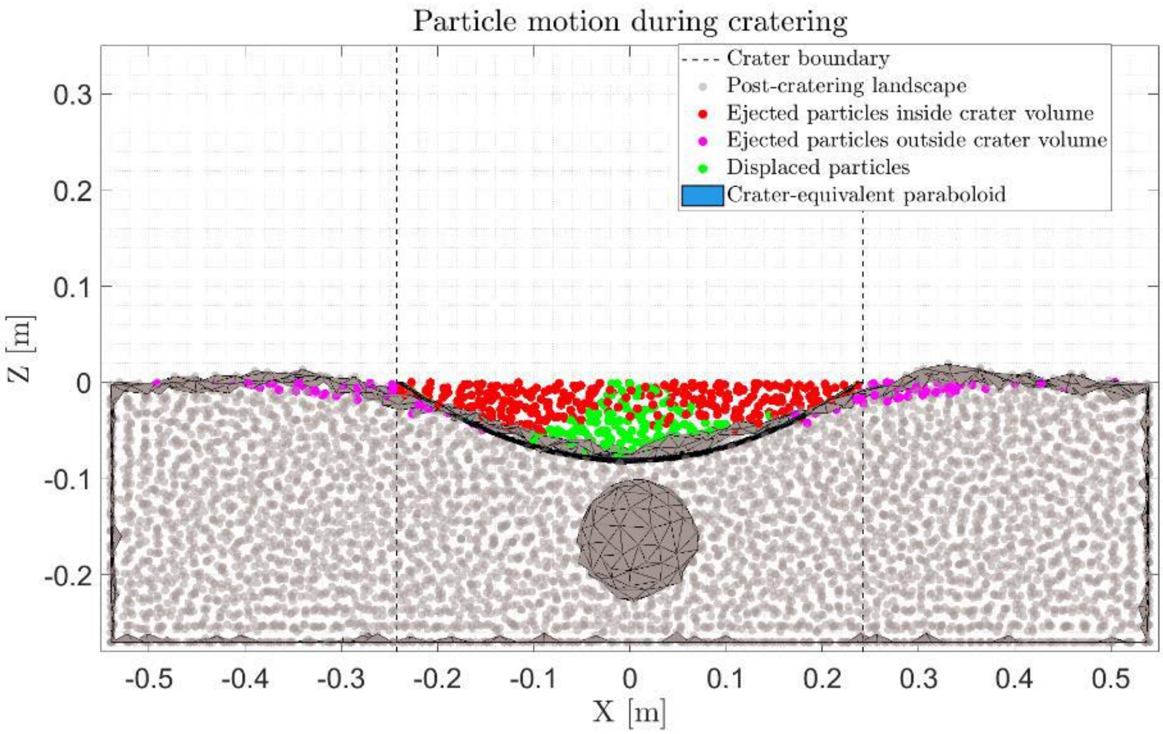

Fig 1. Partitioning of particle motion in low-speed cratering

References: [1] Lauretta, D. et al. (2019) *Science, 366*, 6470. [2] Chesley, S. et al. (2020) *JGR Planets, 125,* 9. [3] Lange, C. et al. (2018) *Acta Astronautica, 149*, 25–34. [4] Holsapple. K. A. (1993) *Annual review of earth and planetary sciences,* 21(1), pp.333-373. [5]ÇelikO. et al. (2022) *Icarus*, 114882.

Insights on the lunar provenance of Calcalong Creek meteorite from dating of granophyre clasts

Presenting Author: Bre Tilley, University of Manchester

B. H. Tilley[1], K. H. Joy[1], J. F. Snape[1], R. Tartèse[1], J. F. Pernet-Fisher[1]
[1]The University of Manchester
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Introduction: Calcalong Creek is a single stone lunar meteorite (~19 g) that was reputedly discovered in Western Australia by a First Nations meteorite hunter sometime during the 1960s [1-2]. It was not classified as having a lunar origin until later, when bulk geochemical analyses showed that it has a distinctly lunar KREEP-rich (where KREEP stands for K, REE, and P) incompatible element signature [2]. The sample is a regolith breccia, with µm- to mm-sized clasts set in a glassy and highly vesicular matrix [2-3]. These clasts sample a diverse array of lithologies, including granophyres, mare basalts, highland materials, impact products, and single mineral fragments. Compared to other lunar meteorites, Calcalong Creek is enriched in incompatible elements, leading to the suggestion that it originates from either the Procellarum KREEP Terrane (PKT) [3-5] or the South Pole-Aitken (SPA) basin [3-4,6].

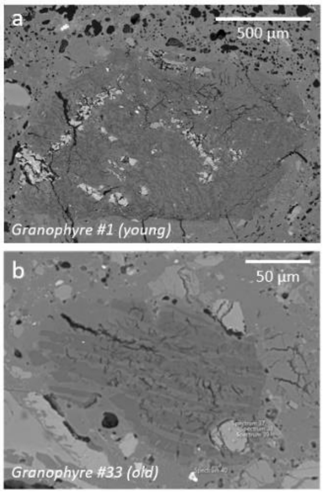

Fig. 1. Scanning electron microscope (SEM) back scatter electron (BSE) images of two distinct granophyre clasts in Calcalong Creek.

Granophyre Clasts: In Calcalong Creek, granophyre clasts (see **Fig. 1**) range in size from 100 to 500 µm and are primarily distinguished by their intergrowths of quartz with K-feldspar (An2-11Ab25-37Or54-73) and/or plagioclase (An34-73Ab33-55Or1-11). In addition to the intergrowths, these clasts also contain variable amounts of Fe-rich olivine (Fo15-18), apatite, merrillite, zircon, baddeleyite, and/or ilmenite.

Radiometric Age Dating: We carried out Pb-Pb and U-Pb dating via secondary ion mass spectrometry (SIMS), and Rb-Sr dating via laser ablation inductively coupled mass spectrometry (LA-ICP-MS). The results show two distinct age populations for the granophyre clasts in Calcalong Creek, one at ~4.25 Ga and another at ~3.92 Ga. These two age populations are like those that have been reported in other lunar granophyres [7].

Younger Population. The younger granophyre clast (see **Fig. 1a**) has a Pb-Pb isochron date of 3927 ± 12 Ma (see **Fig. 2a**), which is consistent with a Rb-Sr isochron date of 3831 ± 112 Ma. Analyses of U-Pb systematics in two zircon grains reveal highly discordant behaviour, potentially indicative of more recent disturbance. Quartz in this clast shows a fractured texture, which could be the result of brittle deformation from shock (< 3-4 GPa) or a volume change effect caused by transition from a high temperature silica polymorph (e.g., cristobalite, tridymite). Thus, it is suggested that this may represent an impact reset age.

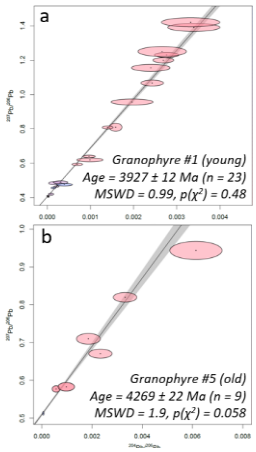

Fig 2. 207Pb/206Pb vs. 204Pb/206Pb isochrons of two distinct granophyre clasts in Calcalong Creek. Errors are reported to 2σ.

Older Population. The older granophyre clasts (see **Fig. 1b**) have Pb-Pb isochron dates ranging from 4269 ± 22 Ma (see **Fig. 2b**) to 4341 ± 114 Ma. One of the clasts yielded a Rb-Sr isochron date of 4364 ± 259 Ma. The U-Pb systematics of Ca-phosphates in the clasts indicate some degree of resetting at 4114 ± 80 Ma. Compared to the younger clast, quartz in these older granophyres generally show less fracturing, suggesting that they largely preserve their original minimum crystallization ages.

Conclusions: The evolved clasts in Calcalong Creek are similar in texture, mineralogy, geochemistry, and ages to Apollo high-alkali suite granophyres [7-8]. The younger 3927 ± 12 Ma dates of our clasts align well with that proposed for the 3922 ± 12 Ma timing of the Imbrium impact [8] and the older 4.2 Ga dates are similar to the age proposed for the Serenitatis impact [9]. We suggest that Calcalong Creek was likely sourced from a regolith surrounding the PKT [3-5], and the meteorite is likely not from the potentially older (> 4.3 Ga?) SPA basin as has previously been suggested [3-4,6].

References: [1] Wlotzka F. (1991) *Meteoritics, 26,* 255-262. [2] Hill D. H. et al. (1991) *Nature, 352,* 614-617. [3] Hill D. H. & Boynton W. V. (2003) *Met. & Planet. Sci., 38,* 595-626. [4] Calzada-Diaz A. et al. (2015) *Met. & Planet. Sci., 50,* 214-228. [5] Korotev R. L. (2009) *Met. & Planet. Sci., 44,* 1287-1322. [6] Corrigan C. M. et al. (2009) *72nd Annual Meteoritical Society Meeting,* 5375. [7] Meyer C. et al. (1996) *Met. & Planet. Sci., 31,* 370-387. [8] Nemchin A. A. (2021) *Geochemistry, 81,* 125683. [9] Černok A. et al. (2021) *Commun. Earth Environ., 2* 120.

Spherules from the K-Pg Boundary Layer: Preservation and Evidence of Impacts

Presenting Author: Mark Boyd, Imperial College London

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[1]Department of Earth Science and Engineering, Royal School of Mines, Imperial College London, SW7 2AZ, UK; [2]Science and Solutions for a Changing Planet DTP, Grantham Institute, Imperial College London, SW7 2AZ, UK.
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Introduction: Microspherules occur in trace amounts throughout the geologic record and result from high-temperature planetary and environmental processes, such as the atmospheric entry of cosmic dust or impacts. It is well-established that impacts of planetary bodies generate spherules [e.g., 1], which are typically most abundant in distal deposits [2]. Spherules may form as condensation products from a plume of vaporised target rock and impactor, or as ballistically ejected quenched droplets [3]. The occurrence of impact spherules can be used to reconstruct Earth's impact history [4] and thus may contextualise environmental change resulting from such events.

Methods: Grey clay was collected from a Cretaceous-Palaeogene (K-Pg) succession [e.g., 5] in Climax Canyon, 0.5 km west of Raton, CO, USA. The clay layer, 15 mm thick, is overlain by a 2 mm rusty-coloured horizon and is stratigraphically bound by poorly consolidated brown mudstones. In places, the rusty horizon is interlaminated with the clay. The clay was separated into two fractions using a 500 µm sieve, and spherules were picked from the < 500 µm fraction under a binocular microscope. Textural and compositional analyses of particle exteriors were performed using a Hitachi TM4000Plus scanning electron microscope at Imperial College London, with energy-dispersive spectroscopy (EDS).

Results: A preliminary recovery rate of spherules from Climax Canyon clay is 8 g-1. The spherules are 100-300 µm in diameter and are sub-spherical to spherical in shape. Most particles are covered in 2 µm, circular depressions on their surfaces, obscuring other textures. ClimaxC_010 and ClimaxC014 are not completely covered in depressions, revealing hummocky and smooth surfaces, respectively. The particles are friable and have cracks on the exterior surfaces. Matrix clay is affixed to the surface of some spherules and is composed of ~2 µm-sized spherules in a polygonal framework, with a tight size distribution. In some picked spherules, this material has partially infilled their interiors.
Spherules are dominated by Al-silicates (Al < 13 wt.%), with some showing localised concentrations of Ti (< 23 wt.%). ClimaxC_004 is bound within a grain of clay, with only one hemisphere preserved. The spherule is an Al-rich silicate, similar in composition to the surrounding clay, though with elevated Mg abundances. ClimaxC_004 shows a Ti enrichment localised to a backscatter-bright region, 60 µm in size. Fe and Mg contents are low (< 1 wt.%), though Mg positively correlates with Al abundance.

Discussion: Al-silicate geochemistry is consistent with alteration to clay assemblages, such as kaolinite or a smectite, seen in other K-Pg spherules [6]. Given compositional similarities with previously identified impact spherules and abundance within the K-Pg boundary layer, the Climax Canyon spherules are interpreted as impact spherules. Since the layer was deposited within a few days [7], it is unlikely that other natural sources contributed to the Climax Canyon collection. Clays likely originated from glassy precursors, possibly via a palagonite intermediate, as observed in impact spherules [6] and V-type micrometeorites [8]. Palagonite, formed by glass hydration, may have caused cracks via expansion, which in places are infilled by secondary products. The microspherulitic texture of the clay is consistent with kaolinite alteration [5,6], with Ti enrichments due to Ti mobility during diagenesis [5].

Implications: Mapping spherule alteration pathways is key to determining microspherule formation mechanisms, which in turn indicate planetary processes and environmental conditions in the geologic record. Understanding spherule preservation will improve identification of ancient impacts and aid models of environmental responses to such events. Classifying spherules and attributing a formation mechanism will minimise the misidentification of micrometeorites, improving cosmic dust flux estimates.

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

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Introduction: CM chondrites are a sub group of carbonaceous chondrites. These meteorites record water-rock reactions in the early Solar System and might be the main source of water to Earth [1]. However, CM chondrites have experienced a wide range of aqueous alteration, from being hydrated and very highly altered with a high concentration of phyllosilicates and a small quantity of anhydrous silicates, to mild alteration, where a larger fraction of the anhydrous silicates have survived and there are fewer phyllosilicates present [2]. The cause of this variation in CM chondrites is not well understood, but could be related to differences in temperature, water/rock ratio, or timescales of alteration. Here, we have used infrared (IR) spectroscopy and thermogravimetric analysis (TGA) to investigate the extent of aqueous alteration in CM chondrites.

Samples and Methods: Meteorite chips (~50 mg) were powdered using a mortar and pestle. Approximately 3mg of powdered meteorite sample was then mixed with 300mg of KBr powder. The mix of sample and KBr was homogenized and put into a dye, which was then put into a presser at ~10 tons, producing a disc shaped pellet. The pellets were analysed using transmission IR spectroscopy, with spectra acquired from 2.5cm to 25cm, with a spectral resolution of 2 cm-1 To minimise the influence of adsorbed terrestrial water, the pellets were then heated in an oven at 200°C for 2 hours and immediately re-analysed. In addition, ~10 mg of each meteorite powder was analysed using TGA, where the mass loss was recorded as the sample was heated in a nitrogen atmosphere from room temperature to 1000°C. The mass loss from ~200 – 800°C was used to estimate the abundance of water in the samples.

Results and Discussion: In total we analysed 30 meteorites, 28 CM chondrites recovered from Antarctica, the CM fall Winchcombe, and the C2ung fall Tarda. Analysis of the transmission IR spectra focused on the 3µm and 10µm features. The 3µm feature is caused by -OH/H_2O bonds and shows the amount of hydration in a sample. The 10µm feature is related to the abundance of silicate minerals in a sample, either phyllosilicates (~10 µm) formed by aqueous alteration or olivine (~11.2 µm) that survived hydration. 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. The IR spectral features also correlates with the estimated water content of the samples. Three of the CM chondrites differed from the others in having weak 3 µm features, very strong 11.2 µm features, and low water abundances. These meteorites likely experienced thermal metamorphism at >500°C that dehydrated and recrystallized the phyllosilicates [3]. Studying the IR spectra and TGA water content can be used to 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.

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Exploration and Instrumentation

Denoising CRISM Hyperspectral Images of Mars with Machine Learning

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Introduction: The Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) has produced the most detailed and comprehensive dataset to date regarding the mineralogical composition of Mars' surface. Throughout its operational lifespan, CRISM has unveiled the presence of numerous minerals, marking their first-time identification on Mars (1). However, as the operational duration of CRISM extended, a noticeable decline in the signal-to-noise ratio (SNR) of the images ensued. This diminishing SNR is attributed to successive failures of the cryocooling systems onboard the instrument (2). Consequently, discerning minerals with highly similar spectral signatures has become progressively more challenging in recent observations made by CRISM. To address this issue, we propose a novel signal denoising technique inspired by the Noise2Noise image reconstruction methodology rooted in Deep Learning (3).

Method: Our approach leveraged a dataset sourced from a series of meticulously characterized CRISM images and pixels possessing high SNR (4). Synthetic noise is then introduced to this dataset, using a Gaussian distribution with an additional randomly scaled uniform factor.

Results and Discussion: The model's performance is quantitively assessed using synthetic as well as real data, extending the evaluation to encompass downstream classification tasks. Comparative analysis against alternative CRISM signal reconstruction techniques substantiates that our proposed model excels in the accurate reconstruction of spectra. This is especially notable in the case of narrow absorption features that are prevalent in hydrated mineral groups and phyllosilicates, resulting in a 30% increase in downstream classification performance compared to prior methods. Finally the model is tested on unseen whole images (Figure 1). Our model allows for analysis and confident mineral identification in CRISM observations which have previously been unusable. This opens avenues for characterization of mineralogy in as yet unstudied areas of the Martian surface.

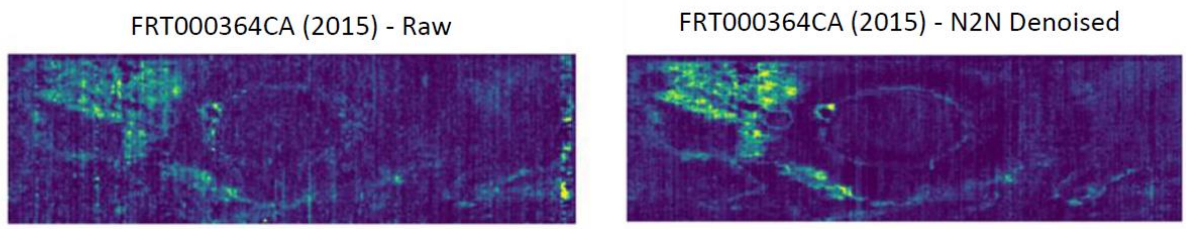

Figure 1: FRT000364CA image acquired recently (2015), in raw form (left) and denoised by our proposed method(right). Image is of the Hydrated Fe/Mg Clay summary parameter detailed in (5).

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Searching for Intact Lava Tubes on the Moon with Deep Learning

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Introduction: Sub-surface cavities are likely to play a crucial role in future robotic and human space exploration [1]. Lava tubes are examples of such cavities which have been explored on Earth [2] and remotely observed on other Solar System surfaces [3]. Lava tubes are underground conduits which have been formed by currently or previously flowing lava [4]. They are revealed to the surface when the roofs of evacuated lava tubes become unstable and collapse, often creating sinuous chains of collapse pits along the path of the tube (as shown in Fig. 1). These pit chains may allow access to entire cave systems, which would provide natural shelter from harmful radiation and micrometeorite impacts on the Moon [5].

Searching for Intact Lunar Lava Tubes: The high resolution of the Narrow Angle Camera on-board NASA's Lunar Reconnaissance Orbiter (LRO) can reveal pits with great detail, although the issue is knowing where to look. A current catalogue of Lunar pits has only ~280 features (most of which are impact melt pits) across the entire surface of the Moon [6]. Therefore, automated techniques will be incredibly advantageous in surveying larger regions for the smaller lava tubes which may be more readily explored by spacecraft or humans. We will present preliminary results of a Mask RCNN Deep Learning model trained to detect individual pits on the Moon. These detections are then assessed on a number of factors to determine if they signify the presence of lava tubes. The scales of the intact sections of any predicted lava tubes will then be inferred by estimating the volumes of the collapses with the Pit Topography from Shadows (PITS) tool [7].

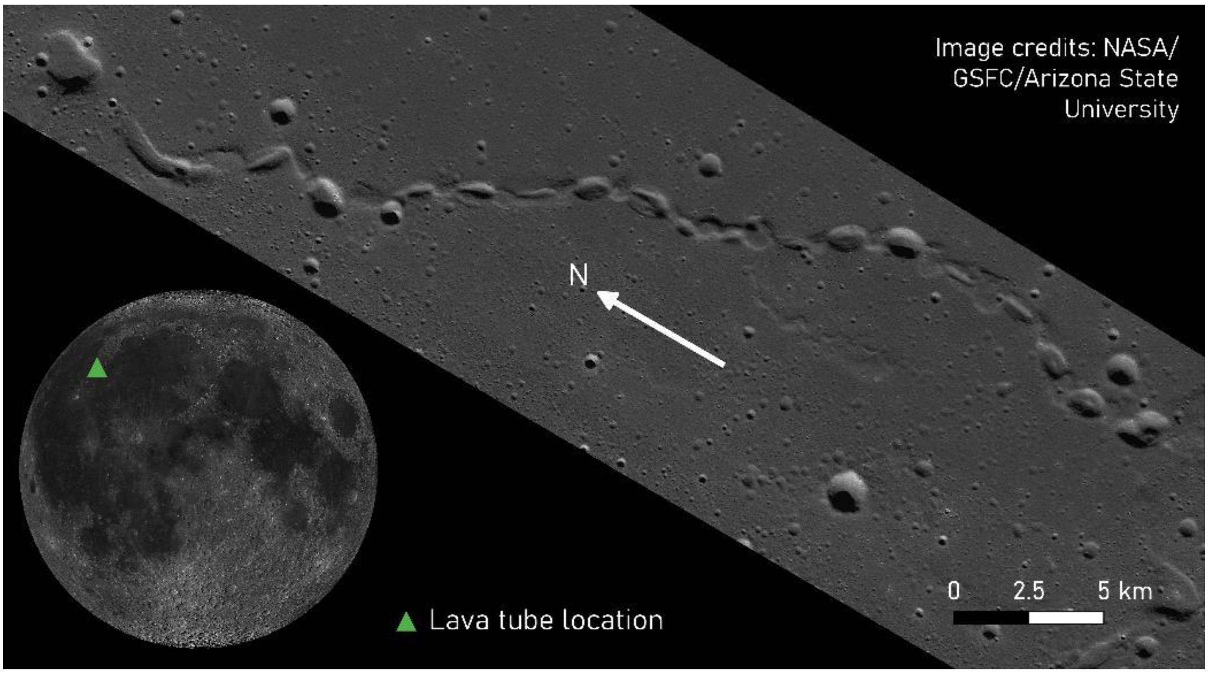

Figure 1: Mosaic of LRO Narrow Angle Camera (NAC) images showing the proposed Gruithuisen lava tube [3].

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

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Introduction: The Mercury Imaging X-ray Spectrometer MIXS [1] is a key instrument onboard the BepiColombo mission to Mercury [2]. MIXS will perform orbital X-ray fluorescence analysis, utilising solar coronal X-rays as an illumination source to infer elemental abundances in the upper tens of microns of Mercury's surface. With science operation commencing in early 2026, preparations are underway to fully exploit the science capabilities of MIXS data. The MIXS Ground Reference Facility (GReF) allows testing of a MIXS qualification model detector in a controlled environment; here, we have observed a large catalogue of international reference materials under X-ray illumination, along with additional samples of Mercury-like compositions.
Mercury's low reflectance material (LRM) has been proposed to be composed of carbon in the form of graphite [3,4]. NASA's MESSENGER spacecraft provided the most in-depth observations of Mercury to date and was able to estimate the abundance of carbon within the LRM [5], concluding an enrichment of up to 3.1 wt% over an average northern hemisphere abundance of ~1 wt% [6]. Low Z material is extremely challenging to detect with X-ray fluorescence, with direct detection of the carbon fluorescence line not possible with MESSENGER's XRS, nor likely with MIXS in a quantitative manner. MESSENGER's other instruments, including GRNS, which was responsible for the above estimates, also suffer from difficulties in directly and unambiguously detecting carbon. BepiColombo's instrument suite will also be insensitive to carbon directly and therefore indirect methods to support the presence of carbon in the LRM are being investigated, including the method described below.

Methodology: Scattered X-rays provide an insight into the presence of low Z material. Preliminary testing showed that the addition of carbon changes the overall gradient of the scattered bremsstrahlung continuum from the laboratory X-ray source. To quantify this, the ratio of the average intensity between a region of high- and a region of low-energy continuum ($I2$ and $I1$ respectively) is inspected (Fig 1). The average atomic number ($\bar{Z}$) was determined for a catalogue of samples using published abundances and is utilised as a proxy for the abundance of low Z material. All samples were observed under standardised conditions in the GReF and $I2/I1$ found for each.

Results and Discussion: Figure 1 shows $I2/I1$ as a function of average atomic number. The catalogue of reference materials fits well to either a power law or an exponential. However, a further series of samples which were doped with graphite in varying wt %, thus lowering their average atomic number, produces a similar but shallower curve. These lab-based measurements are being used to determine whether this method can provide sensitivity to enrichments in low Z material and, by inference, support (or refute) the presence of carbon as the darkening agent in Mercury's LRM through orbital observations by the BepiColombo spacecraft from 2026.

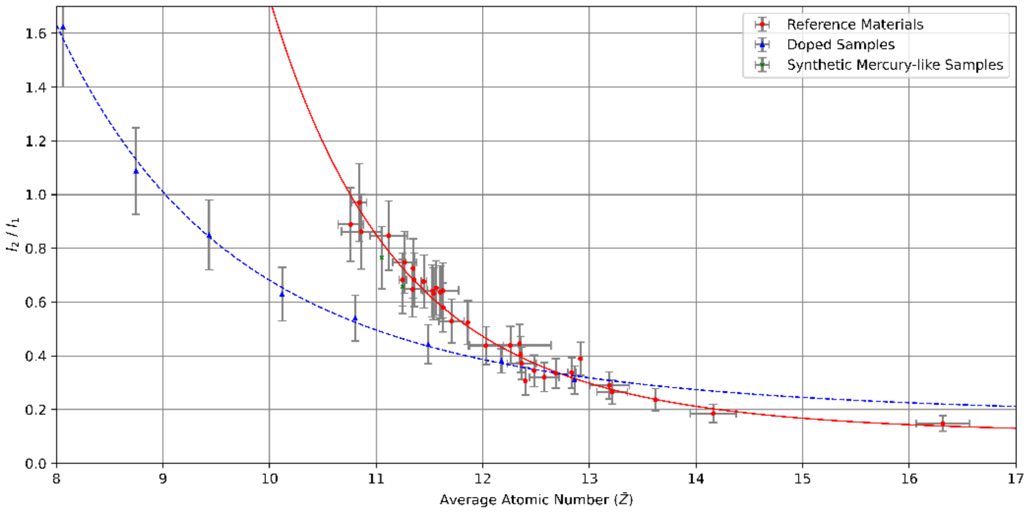
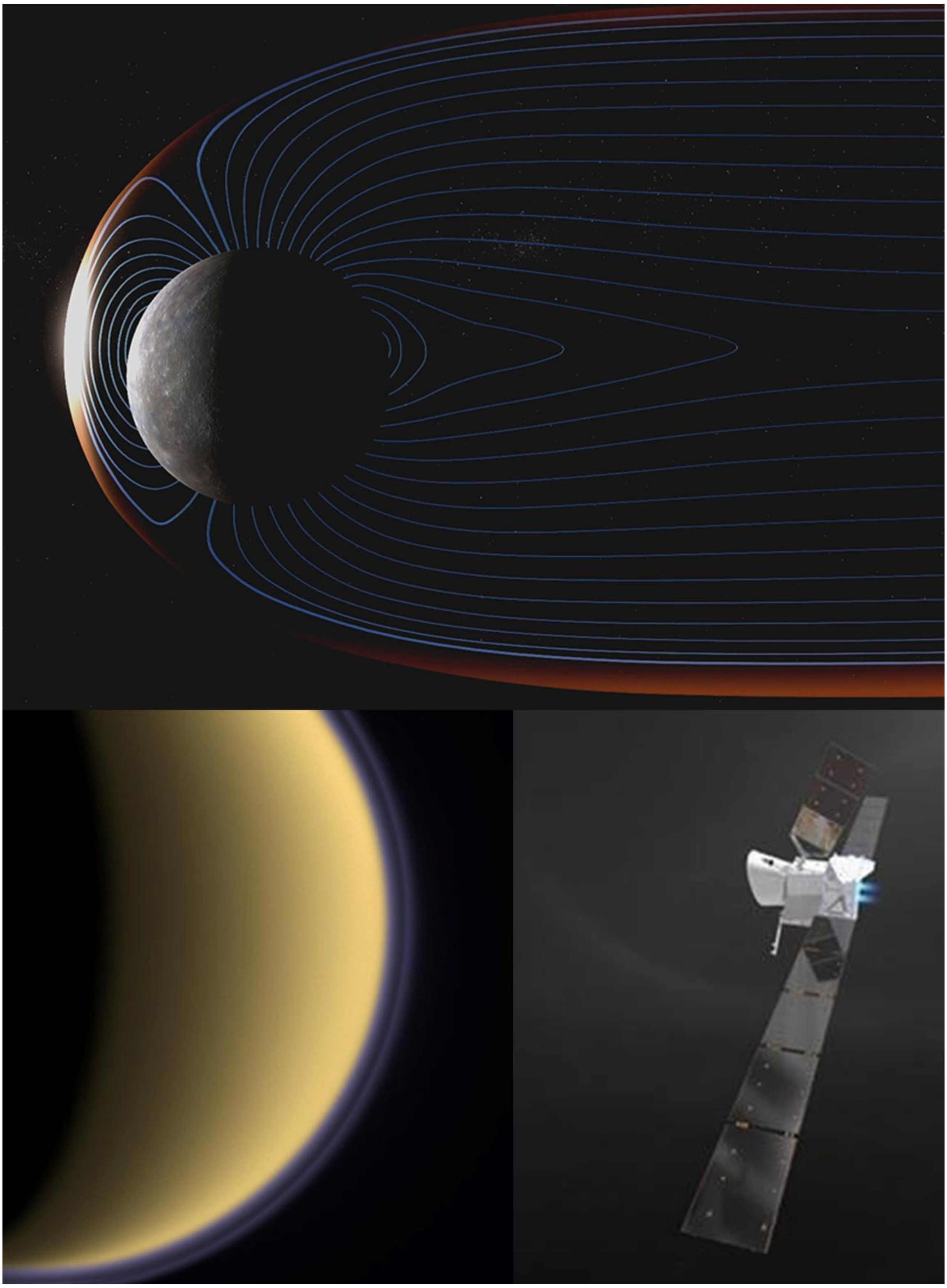


Figure 1: Ratio of high energy to low energy scattered continuum X-rays as a function of sample average atomic number. Showing power law fits to reference materials (solid red) and doped samples (dashed blue).

References: [1] Bunce et. al. (2020) *Space Sci. Rev., 216:126(8)*. [2] Benkhoff et al. (2021) *Space Sci. Rev., 217:90(8)*. [3] Vander Kaaden and McCubbin (2015) *J. Geophys. Res. Planets, 120, 195-209.* [4] Murchie et al. (2015) *Icarus, 254, 287-305.* [5] Peplowski et al. (2015) *Planetary and Space Sci., 108, 98-107.* [6] Peplowski et al. (2016) *Nat. Geosci., 9(4), 273-276.*

Atmospheres and Magnetospheres



Magnetosphere-surface interactions at Mercury

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Introduction: The NASA MESSENGER mission in 2011-2015[1] revolutionised our understanding of Mercury's magnetosphere and showed it to be a small but highly dynamic system dominated by intense solar wind conditions. The X-ray Spectrometer (XRS) [2] was used to map the elemental composition of Mercury's surface by measuring fluorescence X-rays generated at the surface by its interaction with solar X-rays. A similar process was also detected by XRS on the nightside of the planet [3] (see Figure 1), caused by energetic electrons injected from the magnetosphere in a process similar to the generation of Earth's aurorae.
The aim of this project is to use data from the MESSENGER mission and future ESA/JAXA BepiColombo mission to further characterise this interaction and use it to study the dynamics of the magnetosphere, and the populations of particles that exist within it.

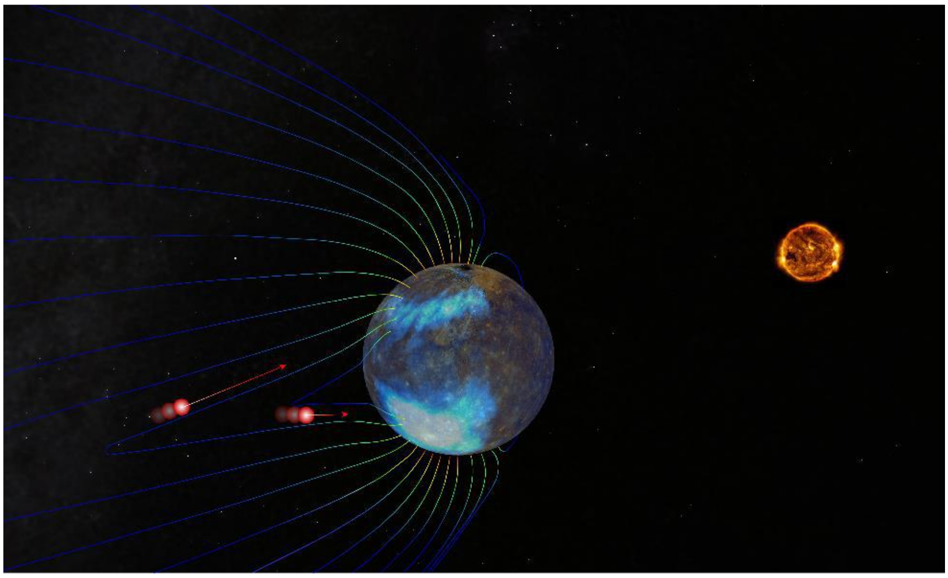

Figure 1: Image showing regions of X-ray fluorescence from Mercury's nightside and modelled magnetic field lines. Figure courtesy of S. Lindsay.

BepiColombo and MIXS: BepiColombo [4] is the next mission to Mercury and is a collaboration between the European Space Agency (ESA) and Japanese Aerospace Exploration Agency (JAXA). It comprises the Mercury Planetary Orbiter (MPO) from ESA, and Mio from JAXA, and both will arrive at Mercury in late 2025 after a seven-year cruise. Onboard MPO is the Mercury Imaging X-ray Spectrometer (MIXS) [5] which was designed and built at the University of Leicester. This instrument will build on the discoveries made by MESSENGER XRS with superior energy and temporal resolution and the ability to spatially resolve surface features in X-rays for the first time.

Current Work: Previous work has catalogued and mapped x-ray fluorescence events on the nightside, and showed their distribution is related to boundaries in the magnetosphere such as the magnetic equator [3]. Building on this work, we have reanalysed these data using a new projection and begun investigating their distribution with respect to the open/closed field line boundary. We are also investigating a high-latitude population of events that appear distinct from the rest of the dataset. We aim to characterise these populations and the different processes causing them.

Future Work: This project will combine observations from XRS with data from MESSENGER's magnetic field and particle instruments to gain a better understanding of the particle populations that cause nightside x-ray fluorescence, and their context in Mercury's magnetic environment and the processes within it. Following the start of the BepiColombo science mission in early 2026, we will also analyse the first data returned by MIXS and exploit the improved capabilities of this new instrument. Combining this with the rest of MPO's suite of instruments and the Mio spacecraft, we will be able to perform coordinated observations of the magnetosphere for the first time and explore magnetosphere-surface interactions in greater detail than ever before.

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The Effects of Dust Storms on Mars' Induced Magnetosphere

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Mars's magnetosphere is a sensitive system that varies due to external and internal factors, such as the solar wind conditions, and crustal magnetic fields. A signature of this influence can be seen in the position of two magnetic boundaries; the bow shock and induced magnetospheric boundary (IMB, or magnetic pile-up boundary). The bow shock moves closer to Mars during times of high solar activity and the bow shock and IMB bulges away from Mars over crustal magnetic fields in the southern hemisphere. This study investigates whether large-scale atmospheric events at Mars have any signature in these two magnetic boundaries by investigating the 2007 and 2018 dust storm.

The 2007 global storm lasted for several months, and increased atmospheric temperatures and densities of both water vapour and carbon dioxide in the atmosphere, leading to an increase in atmospheric escape. Using Mars Express, we identified boundary locations before, during and after the event and compared these to modelled boundary locations and areographical locations on Mars. We find that whilst it is unclear whether there is an impact on the bow shock position by the dust storm, the IMB does change significantly, with a depression occurring over the southern hemispheric crustal fields. This is the opposite of what has been seen in previous studies of the IMB over crustal fields. A proposed explanation of this feature can be seen in Figure 1.

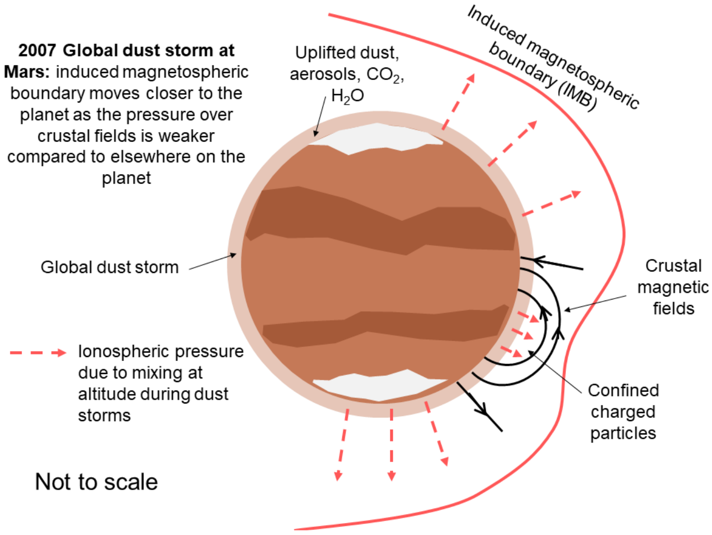

Fig. 1. *: Possible cause of the depression in the induced magnetospheric boundary over crustal magnetic fields during the 2007 global scale dust storm at Mars*

The 2018 global dust storm was stronger than 2007, having multiple growth phases and a 'storm within a storm' occurring during its lifespan. In addition to identifying boundaries with Mars Express, we also used NASA's MAVEN satellite to catalogue bow shock and IMB crossings. Both the bow shock and IMB increase in altitude due to the occurrence of the 2018 storm by a few thousand kilometres, but positions don't return to pre-storm values after the end of the global dust storm. This suggests that although surface conditions have returned back to normal, the effect on the magnetosphere may be longer lasting.

Traces of Magnetic Field in Jupiter's Equatorial Ionosphere

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Introduction: Planetary ionospheres are the critical transition region between the magnetosphere and the underlying atmosphere, as these vast systems couple through this thin boundary layer at the top of the atmosphere. While there is relatively significant understanding of how these systems couple at Earth, the interactions at the Giant Planets are much more poorly understood.

Spectral analysis of near-infrared (NIR) emissions from the major upper-atmospheric ion, H_{3+}, give us a unique window into this coupling at the Giant Planets. However, while we have detailed measurements of the thermospheric temperatures and ionospheric density within the auroral regions, mid-to-low latitudes have remained largely unexplored due to NIR emissions from these regions being much weaker and spectrally entangled with bright neutral species. Therefore, the interplay between the ionosphere and magnetic fields away from the poles remains enigmatic.

Previous Investigations: Previous long-term H_{3+} observations of Jupiter's equatorial region, averaged over many nights, revealed large-scale features within the low-latitude ionosphere, originating from localised ionosphere-magnetosphere interactions [1]. More recently, NASA's Juno spacecraft has revealed great complexities in the Jovian magnetic field, with significant small-scale anomalies in sub-auroral regions, which appear to coincide with the complex structures detected in NIR ionospheric emissions [2] [3].

Recent Observations: We investigate the leading potential sources for the dark sinusoidal 'ribbon' of weakened H_{3+} emission in the vicinity of the jovigraphic equator, which has been shown to be an ionospheric signature of Jupiter's magnetic equator [1]. Here, based on ground-based observations using the 10-meter Keck telescope in 2022, we present preliminary mid-to-low latitude maps of Jovian column-averaged H_{3+} temperatures, densities and radiance, capturing the previously identified dark ribbon. Early indications from these observations show how brightness variations are driven by column density at Jupiter, as opposed to temperature, which suggests differences in ion population due to some not yet understood process, driven by direct ionosphere-magnetosphere coupling.

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How Can BepiColombo Use Solar Wind Variability to Probe Mercury's Interior?

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The magnetosphere of Mercury is a unique, dynamic system due to the planet's small size, proximity to the Sun, and its weak internally generated magnetic field. Interactions between the dayside Hermean magnetosphere and the solar wind, with the embedded interplanetary magnetic field (IMF), drive an electric current on the system's magnetopause boundary. Changes in the external solar wind can lead to motion of the magnetopause boundary and perturbations to the boundary's current structure. By utilizing the inductive processes that arise from these magnetospheric changes driven by the solar wind, a better understanding of the interior structure of magnetised planets can be gained. In preparation for the BepiColombo mission's arrival at Mercury, we assess different contributors of solar wind forcing at Mercury and their impacts on the magnetopause's inducing field, through analytical modelling and analysis of data acquired by the MESSENGER and Helios spacecraft. Helios measurements suggest that the solar wind encountered by BepiColombo will be highly unpredictable and that the inducing field of the magnetopause that is generated in response to variable solar wind ram pressure is nonuniform across Mercury's surface. IMF variability was also found to influence Mercury's magnetopause current and the resulting inducing magnetic field. The frequency range of the example inducing field spectrum generated from the Helios solar wind dynamic pressure data suggests transfer functions determined by the dual spacecraft of BepiColombo could allow us to obtain a profile of conductivity through Mercury's crust and into the mantle.

Retrieval of temperature and gas abundances of Titan's atmosphere using Minnaert limb-darkening analysis

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In 2017 the Cassini spacecraft finished its 13-year mission completing 127 close flybys of Saturn's largest moon, Titan. During this time, the Composite Infrared Spectrometer (CIRS) on-board the spacecraft captured 8.4 million spectra in the thermal infrared (7 - 1000 μm) [1], allowing the temperature and gas abundances of Titan's atmosphere to be determined. With its thick and dense atmosphere comprising ~98% nitrogen, ~2% methane and rich C-N-H photochemistry [2], the moon provides the perfect environment to explore hydrocarbon-based planets similar to prebiotic Earth [3].

Six years after the mission finished, new discoveries are still being made through bettering retrieval methods, signal-to-noise (SNR) and computation. Here we present an investigation into a new retrieval analysis that aims to increase the SNR of captured spectra, and thus produce more detailed and clearer results. The Minnaert limb-darkening analysis originated from a paper in 1941 that built upon Helmholtz' reciprocity principle to study the photometric properties and surface features of the moon [4]. This idea has been expanded upon to study the reflectivity of large planetary atmospheres such as Uranus and Neptune and has been proven to be more computational efficient and accurate than simple averaging methods [5,6]. In this study, we investigate the potential use of Minnaert limb-darkening analysis on Cassini CIRS thermal infrared data taken from Titan's atmosphere. By measuring the observed thermal emission in the planet's atmosphere over a wide range of emission angles, a parameterised emission function can be retrieved for each wavelength. This allows re-construction of the spectra accounting for geometrical variations, suppressing noise and improving quality of fits in the modelling. We use this analysis alongside the NEMESIS radiative transfer and retrieval tool [7] to model temperature and gas abundances.

To our knowledge, this analysis has not been used for thermal infrared data. This poses a challenge as infrared signals are much weaker and consequently conventional methods may not be suitable for CIRS data. While still in its infancy, we present the current approach and challenges of this new method and analyse its accuracy, benefits and future potential. The hope is that we will be able to better study and understand minor gas abundances by increasing the signal to noise of weak emission features.

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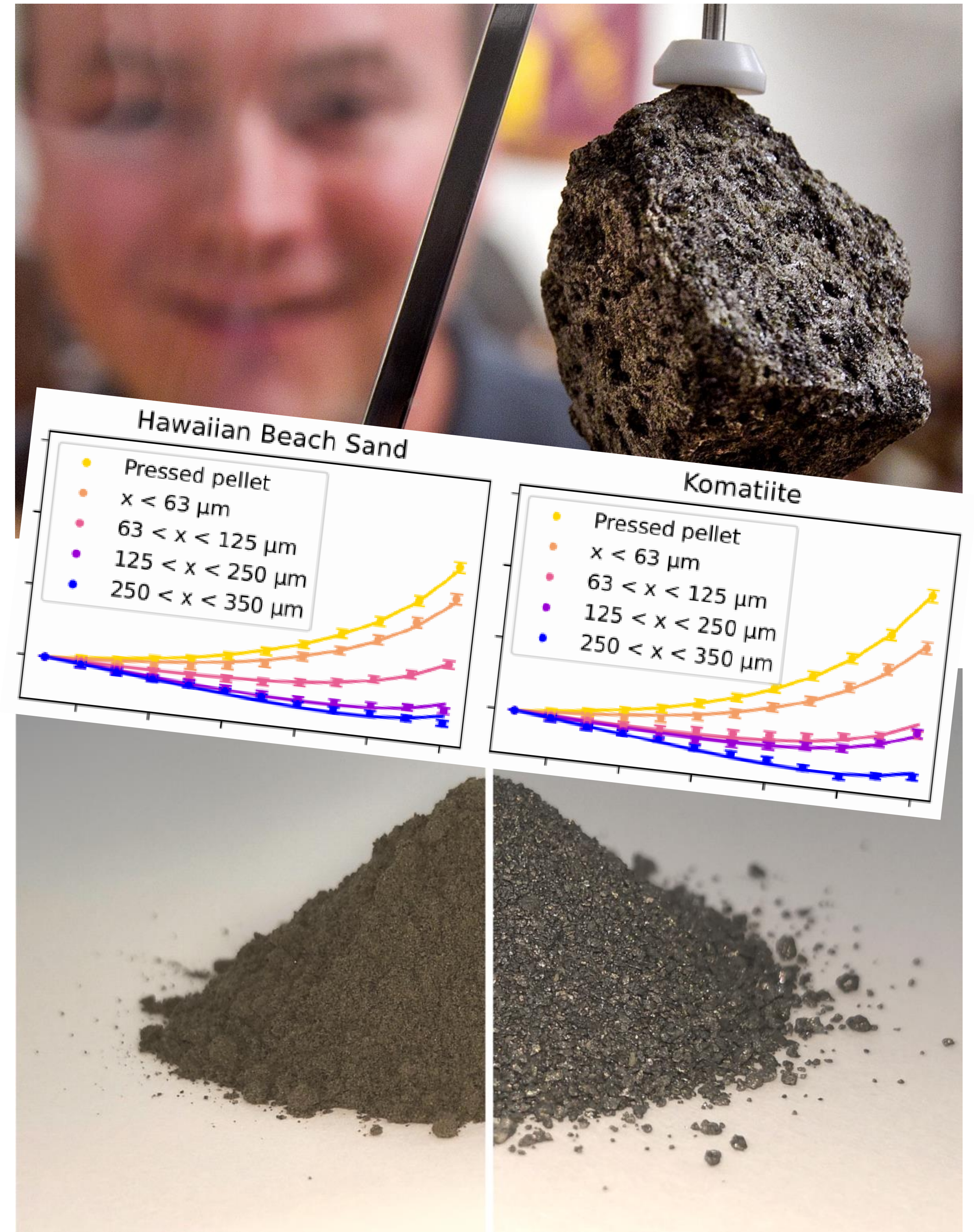
Planetary Geology and Geochemistry



Recent and Active Surface Processes on the Moon

Presenting Author: Giulia Magnarini, Natural History Museum

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Introduction: In this presentation I will provide an overview of my current research as a postdoctoral researcher at the NHM, which consists in detecting and quantifying a range of active surface processes at the Apollo 17 landing site and also globally on the Moon. The objectives of the projects are: (1) determine the validity of using indirect events in deriving crater chronology functions; (2) reveal the present-day seismic activity of the Apollo 17 landing site from orbital data; (3) quantify the rate of active surface processes on the Moon on a global scale. The project is split into three Work Package.

Understanding the Origin and Dynamics of the Light Mantle: The Light Mantle is a unique case of a 5-km-long, hypermobile landslide on the Moon [1]. Different weakening mechanisms have been proposed to explain how the landslide slid for several kilometers away from the headscarp; however, no consensus is reached.
Friction Experiments on Lunar Analogue Anorthosite-bearing material. We conducted friction experiments under vacuum to investigate the viability of dynamic friction weakening. Our results show that localized dynamic friction weakening does not occur in this material at loading conditions where, instead, weakening is observed in other materials on Earth. Therefore, possibly other fluidization-related mechanisms contributed to the initiation of the Light Mantle [2].
Investigation of the Light Mantle core samples 73001/73002. This work is part of out involvement with the NASA Apollo Next Generation Sample Analysis (ANGSA) program. This study aims to investigate the presence of clast fabrics, morphologies, distribution related to the emplacement of the Light Mantle. The recognition of the microstructures of the rock and mineral clasts within the core sample will be a critical step towards interpreting the mechanical behaviour of the Light Mantle landslide [3].

Present-Day Activity of the Lee-Lincoln Fault Scarp: The Lee-Lincoln thrust fault is a young tectonic structure on the Moon, which cut across Taurus-Littrow Valley, Apollo 17 landing site area [4][5]. It is suggested that the seismic shaking associated with the Lee-Lincoln fault may have been an important factor in triggering surface changes and mass-wasting events in the area [1][4][5]. Also, it is suggested that the fault may potentially be still active [5].
Slope Deformation Associated with Recent Tectonism in Taurus-Littrow Valley. In this work, we identified a variety of features and structures on the slope of the South Massif that postdate the emplacement of the Light Mantle landslide. Such evidence of recent slope deformation processes includes boulders with associated boulder tracks, regolith disturbance, breaks in slope, crestal graben, and other linear slope structures. The extensive presence of slope deformation evidence suggests that this location has been affected by repetitive processes that have effectively modified the slope of the South Massif. We suggest that the efficiency of these processes is the product of continuous, and perhaps ongoing, effects of recent tectonism in Taurus-Littrow Valley associated with the Lee-Lincoln fault, coupled with the influence of the subsurface geometry of the valley inherited from the impact basin formation [6].

Global Change Detection and Active Processes: This ongoing part of the project includes three sub-projects.
42 Years of Impact Cratering at the Apollo 15 Landing Site. We carried out a pilot study of long-term imaging to test whether new impact features are identifiable between Apollo-era (Apollo Panoramic Camera) and present-day data (LROC Narrow Angle Camera). We identified 320 new impact features over a study region of 30 km2. Only the largest feature (15.9 m diameter) had a discernible crater at the center of the dark feature [7].
Identifying Secondary Craters from the Tycho Impact Event. Ejecta from the Tycho impact event, located ~2200 km from the Apollo 17 landing site, has long been supposed to be the event that triggered the landslide that formed the Light Mantle in Taurus-Littrow Valley ~110Ma [8]. We are currently refining existing crater database to smaller diameter (80 m) within a 250-km-wide swath that extends from Tycho crater to beyond Taurus-Littrow Valley (~2500 km). We are implementing Machine Learning crater identification. We will apply Automatic Secondary Crater Identification [9] to our mapped craters.
Quantifying Secondary Impact Features. We focus on some of the largest new impact events identified by using LROC NAC images [10, 11, 12 and other unpublished record]. One of our objectives is to compare ejecta and secondary impact features on different targets (e.g., mare vs highlands).

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Global seismology in a three-dimensional Enceladus

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Background: Single-station seismology on the Moon and Mars has paved the way for significant improvements in our understanding of the terrestrial bodies [1]. The icy ocean worlds present a new type of target for planetary seismology, which has the potential to collect data sampling any depth within a body and can therefore provide crucial constraints on interior structure. Mission proposals including Titan's Dragonfly [2], Europa Lander [3], and Enceladus's Orbilander [4] feature landed seismometers as part of their payloads; we model results for potential seismic experiments on Saturn's icy moon Enceladus in order to improve and support future mission design that can account for and take advantage of the unique seismic responses of icy ocean worlds.
Enceladus has high predicted levels of in-built seismicity to serve as sources, including venting from the south pole, fault reactivation at the Tiger Stripe Fractures, impactors, and tidal 'creaking' [5]. Seismology on Enceladus is also likely to avoid sources of incoherent noise known to have affected previous single-station seismic missions, as it lacks a significant atmosphere and has a low diurnal temperature range [6].

Methodology: We investigate the effects of a fully-3D ice shell on the potential to observe key phases identified from our one-dimensional simulations, particularly for body wave propagation. Enceladus is characterised by its heterogeneous ice shell thickness which varies most strongly with latitude and is much thinner at the poles, particularly at the south pole (~5 km), than at the equator (~30 km). We generate full-wavefield simulations using AxiSEM3D [7] for two three-dimensional ice shell thickness models based on the same topographic model [8,9,10], and incorporate a latitude-dependent surface temperature profile [11,12] to capture the effects of temperature-dependent seismic attenuation in the ice.

Results & Conclusions: One-dimensional modelling has revealed the importance of ice thickness, attenuation, and epicentral distance in affecting the phases that can be observed by a single landed seismometer, and shown that a station within a reasonable epicentral distance from a south polar source can potentially observe phases that are transmitted through the entire depth of Enceladus [13]. For our three-dimensional ice shell models, we find that the source at the warm and highly attenuating south pole removes energy from ice-transmitted phases with shallow take-off angles compared to other source locations. We show that placement of a landed seismometer at specific longitudes can selectively mitigate receiver-side ice shell effects due to thickness to improve the signal-to-noise ratio of collected data. We further find that the location of the assumed seismic source and receiver at constant epicentral distance has a significant impact on the amplitudes, and therefore detectability, of various phase arrivals key for one-dimensional structural inversion, highlighting the need for modelling work to investigate potential landing sites.

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How Do Rivers Traverse Impact Crater Topography?

Presenting Author: Emily Bamber, University of Texas

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Introduction: The topography of Mars is dominated by impact craters. Fresh impact craters are circular depressions with tens to hundreds of meters of *crater rim relief*, which divides Mars' surface into separate intra- and inter-crater basin. To have achieved the observed long, integrated martian valley systems and transformed crater interiors into lakes (with high potential for habitability), past martian surface water must have traversed these crater rim topographic obstacles.

Geomorphic Analysis of Crater-Inlet Valleys: In traversing crater rims, water erosion eventually formed *crater-inlet valleys*, observed on the surface of Mars today. Our geomorphological analysis of martian crater-inlets and adjacent areas has revealed that the elimination of crater rim relief primed crater basins for crater-inlet valley formation and integration into larger regional valley systems (i.e., the martian Valley Networks) [1]. This is consistent with the suggestion that early Mars' surface was characterized by widespread landscape *degradation* (i.e., erosion) by various processes [2].
If early, widespread erosion eliminated uplifted crater rim relief, and promoted crater-inlet valley formation: Why do all degraded craters on Mars not have an inlet valley? Comparison of the morphology and terrain associated with breached (with inlet) and non-breached (without inlet) craters suggests that basin hydrology has more of a controlling influence on inlet formation than basin topography [3]. That is, crater-inlet valley formation was promoted for craters that are highly-inset within the catchment (i.e., craters deeper within regional depressions), with high surrounding drainage density, and with a greater potential contributing area. We suggest that the importance of basin hydrology-related factors over topographic factors is the result of hydrologic factors less frequently surpassing inlet incision thresholds than the latter.

Modeling the Competition Between Impact Crater Topography and Fluvial Characteristics: It's interesting to note that the position of a crater within a wider catchment area appears to be a first-order control on the amount of water that was available for fluvial incision (i.e., craters deeper within regional depressions receive more water) [3]. On a crater-dominated landscape, this essentially means that the position of smaller craters within larger crater basins, or larger basins bounded by craters, influences where rivers will flow and where lakes will form. To investigate the ways crater-dominated terrain influences the characteristics of rivers and watersheds, we employ a fluvial erosion model on simulated cratered terrain (Figure 1), modifying crater attributes and model parameters for fluvial erosion. Different crater rim heights (analogous to different degrees of crater degradation) result in qualitatively different configurations of valleys and their watersheds (Figure 1), which are currently being investigated quantitatively.

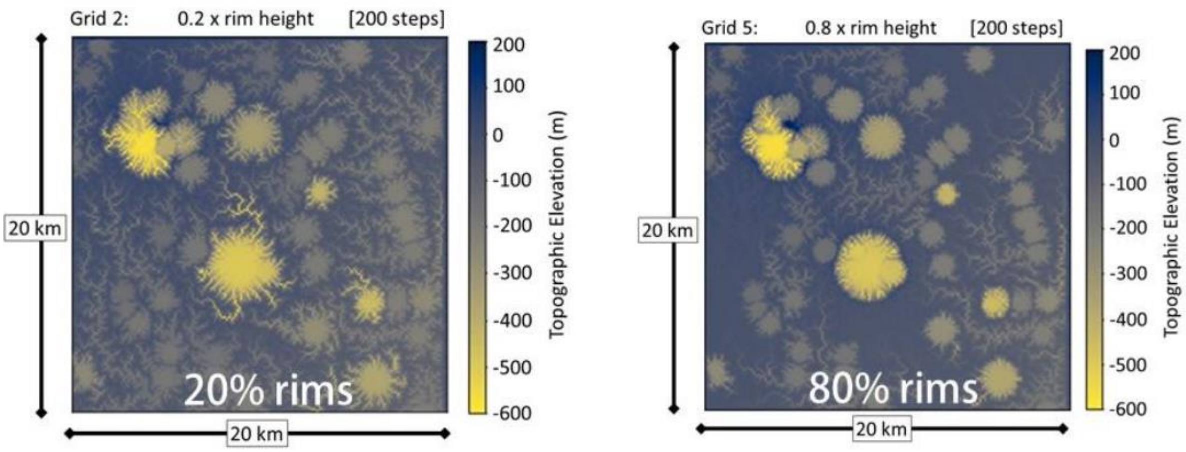

Figure 1: Model topography for different fractional rim heights, after 200 model steps. The starting model grid has an overall slope of 0.003 (from the top left corner towards the bottom right), roughness of 50 m, and craters between 1 – 4 km in diameter. In the fluvial stream power model, K = 0.001, m = 0.5, and n = 0.5.

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An Experimental Investigation of the Effects of Planetary Regolith Properties on X-ray Fluorescence Data

Presenting Author: Michael McKee, University of Leicester

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Introduction: The uppermost surface layer of airless planetary bodies in our Solar System are composed of regolith, particulate material produced from the constant bombardment of solar wind and micrometeoroids over billions of years. X-ray fluorescence (XRF) spectroscopy is used to assess the chemical composition from orbit [1,2], but the accuracy of theoretical predictions via the 'fundamental parameters' method varies depending on the properties of the regolith particles [3, 4, 5]. These effects are collectively called 'regolith effects'. We have conducted experimental work using the MIXS Ground Reference Facility (GReF) on an extensive suite of samples from glasses to basaltic ashes, all with an array of grain size distributions to investigate the magnitude of these regolith effects.

Results and Discussion: In order to account for the regolith effects in our data, we apply an additional attenuation term (accounting for the increased path length of the fluorescing X-ray) to the fundamental parameters equation for the primary X-ray fluorescence intensity which can be found I in [6]. The intensity of $f$the fluorescing X-ray reaching the detector then reduces to $I\delta$:

$$I_\delta = I_f e^{-\mu\rho\delta sec\,\psi} \quad (1) \qquad\qquad \delta = A(cos\psi - cos\theta) \quad (2)$$

where μ is the mass attenuation coefficient for the fluorescing X-ray for a given sample composition, ρ is the bulk density of the sample, A is a free parameter to be evaluated in a curve-fitting routine, θ is the incidence angle of the X-ray source, and ψ is the emergence angle of the fluorescing X-rays. δ is a physical parameter which is governed by the surface roughness of the sample and is angular-dependent. The probability of an incident X-ray entering the medium through a pore or roughness feature increases with incidence angle, which increases the depth of the site of fluorescence. Using equation 1 we have applied a curve-fitting routine to determine a magnitude for A and applied it to experimental data (Figure 1). The accuracy of the fit is remarkable after applying this correction factor to the fundamental parameters equation. We are working towards creating a robust and universal empirically derived correction method that can be applied to future planetary missions that utilise XRF to produce more accurate elemental abundance maps of the surface terrain, providing an experimental verification for the methods employed by [7].

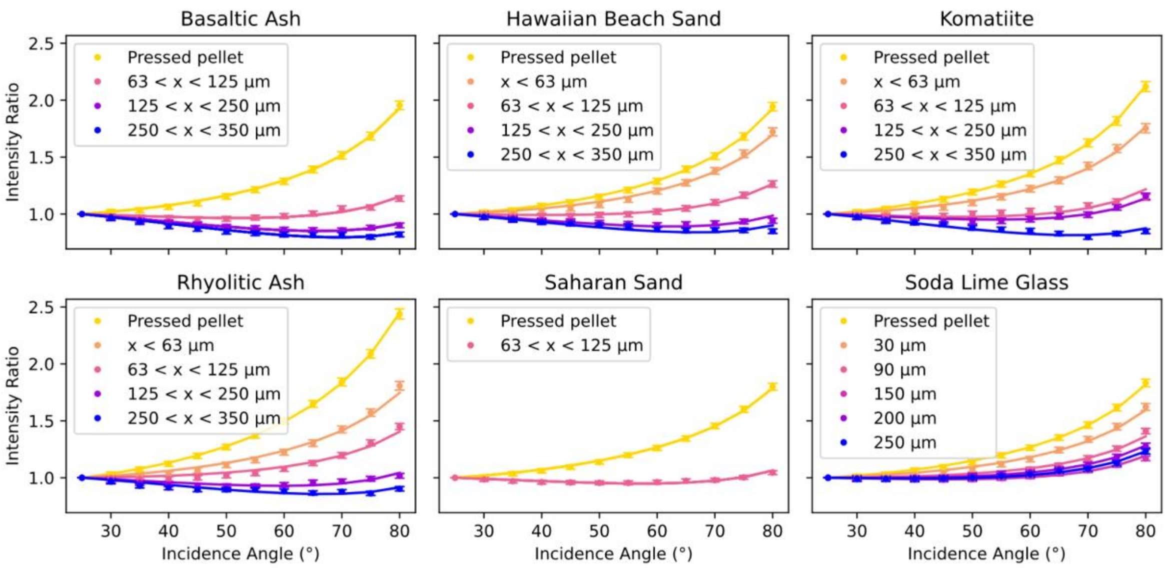

Figure 1: Silicon Kα intensity ratio to 25° for all sample grain sizes and incidence angles. Dots are data points and solid lines are the curve-fitted values using equation 1.

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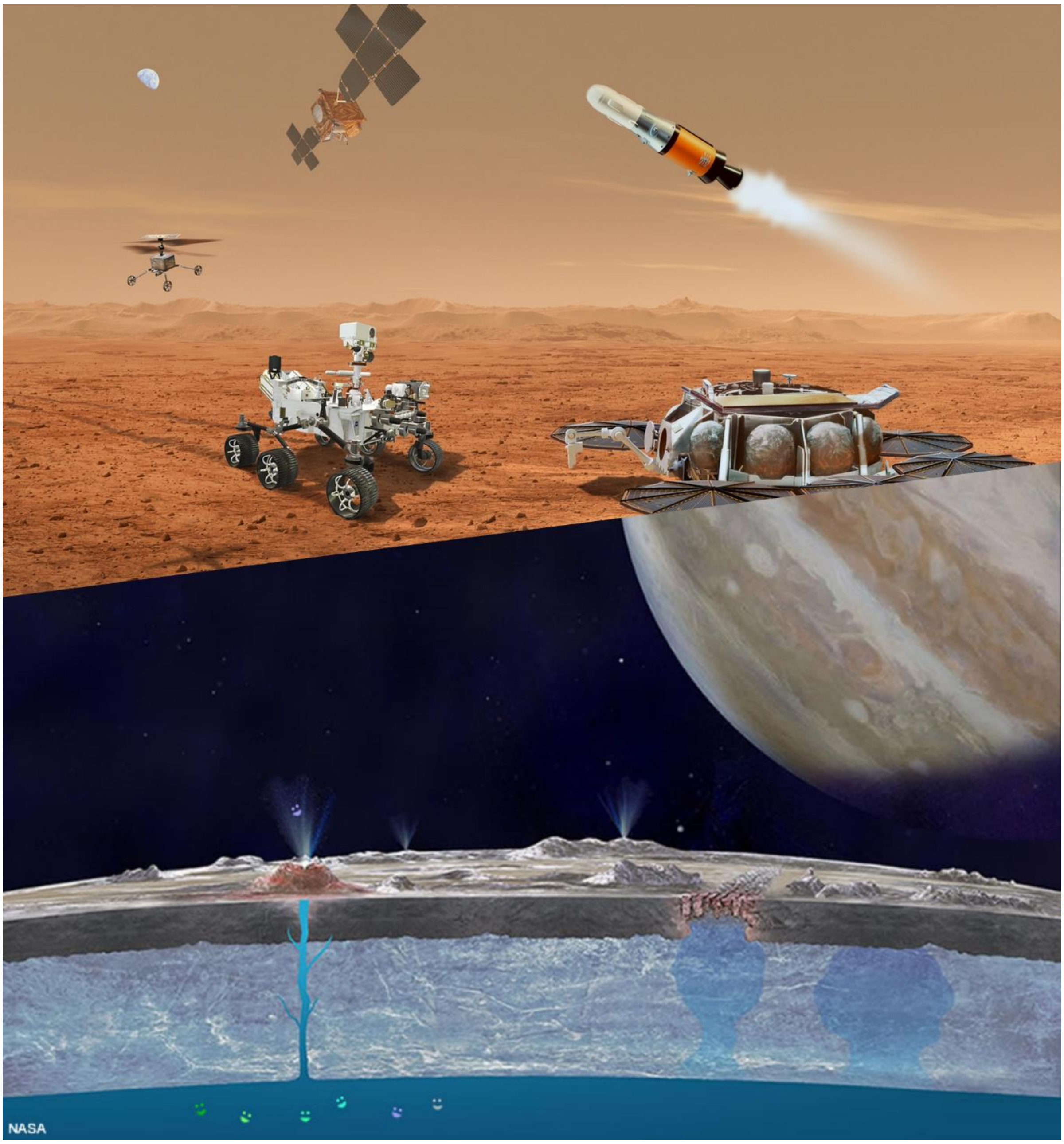
Planetary Environments and Habitability



Investigating biomarker preservation on Mars using Earth analogues: Implications for Mars Sample Return

Presenting Author: Alex Jones, Imperial College London

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Introduction: If life ever existed on Mars, it will have produced organic signatures which may be preserved in the rock record. To be detected at the present day, organic matter must survive billions of years of diagenesis, and avoid being degraded by oxidising minerals, processes and extraction techniques. This study investigated the detectability of macromolecular organic matter (MOM) in circumneutral iron deposits by pyrolysis-Gas-Chromatography-Mass-Spectrometry (py-GC-MS). These deposits provide an analogue for the late Noachian and early Hesperian periods of Mars' history, where geologic evidence supports the presence of abundant surface water and more habitable conditions [1,2]. MOM has recently been detected alongside iron oxides in mudstones of the Glen Torridon region of Gale Crater [3,4], the site of the MSL Curiosity rover mission (Fig. 1A). Iron oxides are known to act as a *"double-edged sword"*, both capable of aiding the preservation of organics, but also hampering their detection via thermal extraction methods due to their propensity for oxidising reactions [5,6]. Therefore, improving our understanding of such organic-inorganic interactions is essential when selecting samples for future Earth return.

Methods: Prior to this study, Mars-analogue samples were collected from a bacteria-hosting, circumneutral iron bog at Imperial College's Silwood Park campus (Fig. 1B). Samples were subject to simulated diagenesis via hydrous pyrolysis, and subsequently solvent extracted to leave insoluble organic residues. This study treated half of these residues with a strong acid to remove iron oxides. Treated and untreated samples were then subject to py-GC-MS to investigate the effects of iron oxides on organic preservation and detection.

Results & Discussion: While a range of organic compounds survived simulated diagenesis and solvent extraction, in the untreated samples none of the detected py-GC-MS products were diagnostic of biology. By removing iron oxides via an additional acid leaching stage, a greater diversity and abundance of organic compounds were revealed, including several which were unambiguously biogenic. However, the acid leaching stage was only found to improve organic detection in one of six attempts, suggesting considerably more work is needed to establish repeatability of the methods used. Nonetheless, this highlights the importance of sample return missions in the search for signs of past life on Mars, since sample pre-processing steps such as acid leaching are not possible via *in-situ* rover methods.

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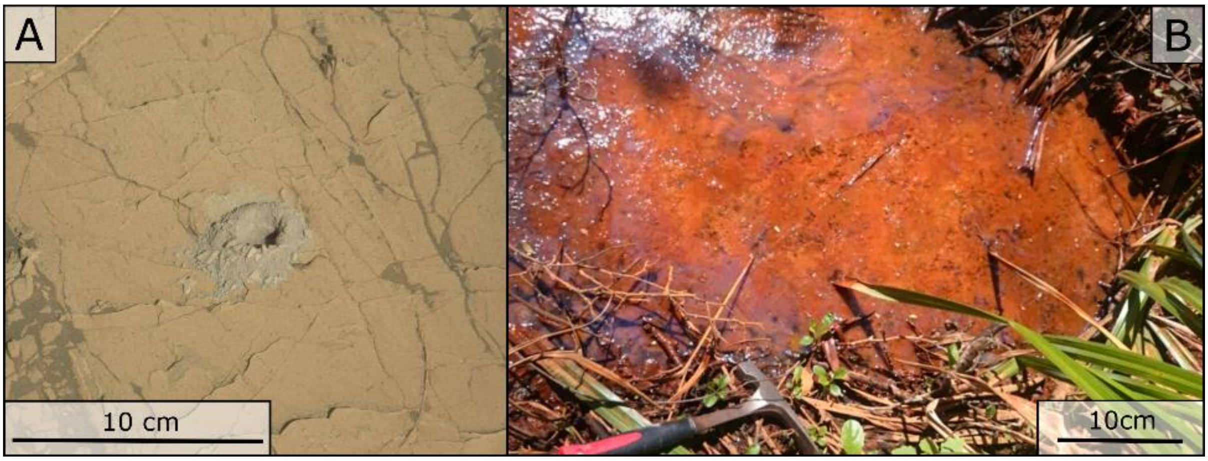

Figure 1: (a) Mastcam image taken by the Curiosity rover of the Nontron drill site, Glen Torridon, showing an ironoxide bearing mudstone found to contain MOM (Credit: NASA/JPL-Caltech) and **(b)** Photograph of the Silwood Park sample site showing a possible modern terrestrial analogue for the Glen Torridon mudstones.

Bubbles are rockets for microbes; predicting microbial dispersion in Enceladus's plumes based on bubbling in Iceland's geothermal springs

Presenting Author: Angus Aldis, The Open University

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The Cassini Mission confirmed Enceladus, a moon of Saturn, has a sub-surface ocean that is hydrothermally active and contains the ingredients for life1. The moon also produces supersonic plumes that eject aerosolised droplets of ocean water into space, likely formed by vigorous bubbling of hydrothermal gases2. Dependent on these bubbling mechanics, if life is present in the ocean, long distance microbial dispersion may occur via the plumes allowing for sample by spacecraft3,4. Despite this theory, it is unknown what evidence of microbial life might be transferred into the plumes by this bubbling. This presentation discusses preliminary results of a field campaign that used Iceland's geothermal springs as analogue sites for Enceladus plume formation. Iceland was selected as its geothermal springs and Enceladus's ocean share aerosolisation driven by bubbling of hydrothermal gases and both host niches for chemotrophic microbial communities5,6. *In situ* sampling and aerosol monitoring was undertaken at Ölkelduháls, within the Hengill volcanic massif, at bubbling hot springs of varying temperatures (65oC – 86oC), pH (2.5 – 6.5) and size. Total aerosol particle count decreased with downwind distance from the springs. Despite this, particle size distribution was dominated by larger particles (≤ 10 µm in diameter) at all distances from the aerosol source. This observation is likely due to present bubbling mechanisms, as background samples contained proportionally fewer particles ≤ 10 µm in diameter. Future analysis will quantify aerosol microbial abundance and size distributions using Flow Cytometry. Microbial community structure in the aerosol will also be investigated using DNA sequence analysis techniques. Combined, these analyses will provide detailed information regarding whether the captured aerosol microbes represent the entire spring's community, or just a snapshot. Overall, this work can make predictions about microbial dispersion dynamics in the plumes of Enceladus if life is present on the icy moon. This work may help inform future missions that seek evidence of life by capturing plume material.

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Isotopic and Genomic Evidence of Biological Nitrogen Cycling within Mars Analogue Hot Springs

Presenting Author: Toni Galloway, University of St Andrews

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Introduction:
Ancient Noachian terrestrial hot spring deposits have been discovered on Mars [1,2,3], evidencing potentially once-habitable environments. One key nutrient for life is nitrogen. While fixed nitrogen compounds have been discovered on Mars [4]; the Martian nitrogen cycle (past and present) in hot spring environments is poorly understood, including how it implicates life and any resulting biosignatures. On Earth's surface, nitrogen is cycled almost exclusively by biological processes. We examine the biological nitrogen cycling within Mars analogue geothermal systems in Iceland and investigate how this is impacted by the geochemical constraints imparted by their geological inputs, with the aim of identifying biosignatures for future missions.

Results:

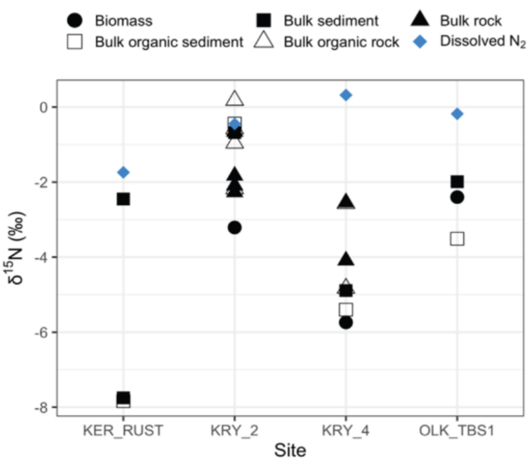

Figure 1: d15N values of total and organic nitrogen of bulk biomass, sediment, rock and dissolved N_2 from hot spring sites.

d15N values of organic nitrogen within biomass, sediment and rock samples are between 0 to -7.75‰ for all sites, with most samples falling between -2 and -5‰ (Figure 1). When considering the d15N values of dissolved N2 within these sites as the metabolic substrate, these fractionations are consistent with the effects produced by biological nitrogen fixation and ammonium uptake pathways [5,6]. Corresponding metagenomic data agrees with this interpretation as these pathways showing some of the highest abundances in all sites (Figure 2). Functional denitrification pathways are also found in all sites; however, dissolved nitrate concentrations are below the detection limit, suggesting this pathway does not impact the d15N of bulk biomass. It is also possible that these enzymes are being used to reduce vanadate instead of nitrate [7]. Overall, we find these environments to be extremely nitrogen-limited which is consistent with increased expression of nitrogen-fixing genes. The activity of specific nitrogenase enzymes is influenced by the availability of dissolved metals in the fluid. One example of this is in the KER_RUST site where sulfide concentrations were high enough (800ppb) to scavenge molybdenum (used in

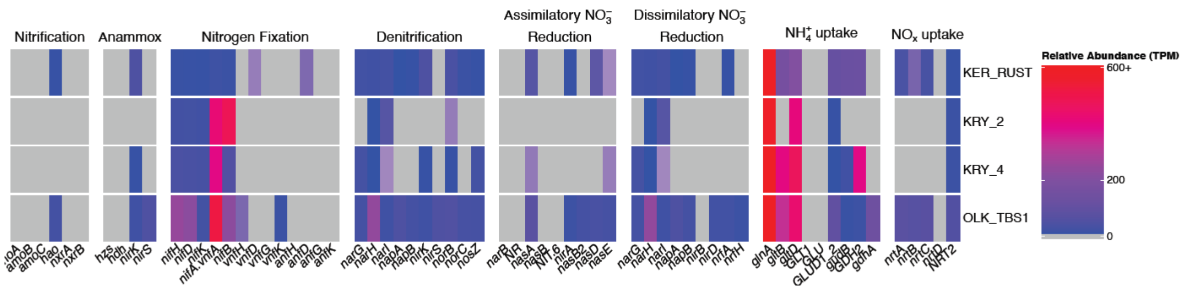

Figure 2: Relative gene abundances of nitrogen-cycling pathways from metagenomic data extracted from hot spring microbial communities.

conventional nitrogen fixation) from the water, explaining the preference for alternative nitrogenase genes detected in this site along with corresponding light d15N values. In conclusion, our results demonstrate that the geochemical environment exerts strong controls on microbial metabolisms in hot spring environments which lead to diagnostic biosignatures in the sedimentary rock record.

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Composition and Habitability of Europa's Ocean Over Time

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Introduction: Europa is proposed to host a global liquid water ocean that is in contact with a silicate interior [1]. 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 rock, leaving their compositions largely unknown. Previous modelling work has shown that, if Europa accreted entirely from CI or CM chondritic material, sufficient volatiles could be released during prograde metamorphism to account for the current size of the hydrosphere [2]. However, thermal models predict that temperatures in Europa's interior would gradually increase over billions of years [*e.g.* 3], where the progressive release of volatiles would change the ocean composition over time. In this study, possible ocean 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 starting material as it is heated.

Methods: The composition of Murchison (a CM chondrite) was chosen to represent the silicate material that accreted to form Europa because the CMs: formed close to early Jupiter (unlike the CIs [4]), contain sufficient water (largely held within hydrated silicates [5]), and can produce fluid compositions consistent with salts observed on Europa's surface [2, 6]. A 1-dimensional thermal evolution code was used to model the temperatures achieved within Europa's interior [3]. Temperature-depth profiles were then extracted at two points in time to reflect the formation of the proto-ocean (*i.e.* ~1600 Myr since the calcium-aluminium-rich inclusions (CAIs)) and the current-day ocean (~4568 Myr since the CAIs). Rcrust [7] and Perple_X [8] were used to predict the electrolytic fluid speciation from the starting material when heated to the temperatures predicted by the first temperature-depth profile (Stage 1; 4 – ~1600 Myr) and then the second (Stage 2; ~1600 – ~4568 Myr). Pyrrhotite was extracted from the starting material past the Fe-FeS eutectic temperature (which was also calculated using Rcrust and Perple_X) to approximate core formation. The volatiles forming the proto-ocean (*i.e.* those released in Stage 1) were then equilibrated using CHIM-XPT [9], where supersaturated gases were exsolved and minerals precipitated. The further volatiles (*i.e.* those released in Stage 2) were then added to the proto-ocean in CHIM-XPT, forming the current-day ocean.

Results and Discussion: Released volatiles for the proto-ocean are predicted to form a ~77.9 km deep layer around Europa. With the addition of the further volatiles, the current-day ocean would be ~84.8 km deep. The extraction of pyrrhotite, which occurs after proto-ocean formation, would form a metallic core of ~271.5 km radius by the current day. The current-day ocean depth and core radius predicted here agree with those inferred for current-day Europa based on observations [3]. The model predicts that both the proto- and current-day oceans would be rich in Na+, Cl-, and CO32-, which may explain the recent observation of NaCl and CO2 in geologically-disrupted regions of Europa's surface [10, 11]. Large concentrations of NH3 and NH4+ are predicted for both the proto- and current-day oceans, despite the lack of any clear detection of nitrogen species on the surface. However, this abundance may be explained by the absence of thermodynamic data for solid nitrogen-bearing phases in the model resulting in an overestimation of nitrogen release during metamorphism (mainly as NH3). A key difference between the proto- and current-day oceans is their HS- concentration, where the current-day ocean has only ~0.2% that of the proto-ocean. This is due to the addition of the iron-rich Stage 2 volatiles to the proto-ocean causing the precipitation of pyrite (removing HS- from solution).

Conclusion: We find that Europa's ocean composition would have varied over time as a result of continued prograde metamorphism, with particular changes in HS- concentration. The significant decrease in HS- content could affect the potential for energy generation by sulfide-oxidising microbes in the current-day ocean and, thus, would have implications for Europa's continuous habitability.

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Poster & Lightning Talk Abstracts

Here is a link to a folder containing all the abstracts relating to the posters and lightning talks:

https://1drv.ms/f/s!AiUM3-d5M4dClDo0CN9AvsIME2eK?e=DCnDsc

List of attendees

Adam Fox, PhD student at the University of Leicester
Adam Losekoot, PhD student at the open university
Aimee Farrant, Curation Analyst NHM
Alex Jones, PhD student at Imperial College London
Alistair Balance, PhD student at The Open University
Ally Wong, MSci student at Imperial College London (recently graduated)
Amelie Roberts, PhD student at Imperial College London
Angus Aldis, Astrobiology PhD Student at The Open University
Annie Lennox, PhD student with the Open University
Arjun Patel, PhD student at The Open University
Arty Goodwin, PhD student at the University of Manchester
Ashley King, Research Fellow at the Natural History Museum
Ben Rider-Stokes, Post Doctoral Researcher at Open University
Benjamin Man, PhD Student at the Open University
Bianka Babrian, PhD student at The Open University
Bram de Winter, PhD student at University of Oxford
Bre Tilley, PhD student at the University of Manchester
Carys Bill, PhD student at Imperial College London
Catherine Baulamon, MSc astrobiology, Birkbeck
Catherine Harrison, PhD student at NHM
Catherine Regan, PhD student at MSSL – University College London
Charlotte Bays, PhD candidate at Royal Holloway, University of London, and the NHM
Connor Ballard, PhD Student
Daniel Le Corre, PhD student at the University of Kent and ACRI-ST
Daval Amratlal, MSc Student at UCL
Divyareshmi Thottungal Ravy, PhD student at University of Manchester
Duncan Lyster, University of Oxford
Ekta Aggarwal, PhD at Imperial College London
Emery Grahill-Bland, MSc at UCL
Emily Bamber, PhD Student at The University of Texas at Austin
Emma Harris, PhD student at Imperial College London
Gemma Lenthall, PhD student at University of Manchester
Gerard Gallardo I Peres, PhD student at Imperial College London
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Hayley Lowe, 1st year PhD student at the University of Manchester
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Ilankuzhali Elavarasan, Incoming Master's student at University of Texas
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Isabelle Mattia, PhD student at Imperial College London
Jake Hanlon, PhD Student at MSSL (UCL)
James Salmon, MSc student at University College London
Jessica Hogan, PhD student at The Open University
Jessica Wills, 2nd year PhD student at University of Kent

Jodie Sutherland, 4th year MGeol student at University of St Andrews
Joe McNeil, Postdoc, Natural History Museum
Joe Williams, PhD student at University of Exeter
Joel Davis, Lecturer at Imperial College
Jonathan Adams, PhD Student at Imperial College London
Jordan Stone, PhD student at Imperial College London
Joshua Ford, PhD student at Bristol University
Joshua Hollowood, PhD Student at Imperial College London
Karen Anne Devoil, UCL Centre for Planetary Science
Kat Dapré, PhD student at the University of Bristol
Katherine Shirley, Postdoc at University of Oxford
Katie Knowles, 2nd Year PhD Student at Northumbria University
Kit-Hung Mark Lee, MSc student at University College London
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Lewis Sym, PhD student at The Open University
Liza Riches, PhD student at the Open University
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