Centre for Planetary Sciences

10th Summer Meeting

Thursday 11 June 2020

Programme and Abstracts

Welcome

The Centre for Planetary Sciences at UCL/Birkbeck is delighted to welcome you to our Tenth Summer Meeting, on Thursday 11 June 2020, which this year will be a virtual event.

In these challenging times of remote working and social distancing, it is important to stay connected and we hope that we can bring a useful, constructive, lively Summer Meeting, strengthening our sense of community by sharing our research, and initiating further discussion and collaboration.

We hope this new format can also be seen as a fresh opportunity to share our research with a wider audience, so please feel free to forward the meeting link and this document to non-CPS colleagues who you think may be interested in attending.

Further updates about the meeting will be added to the meeting webpage.

The Microsoft Teams meeting platform and the virtual format are new for the organisers, so this will definitely be a learning experience for us and we thank you in advance for your understanding and patience on the day. To help the event run smoothly, please review the following section for joining instructions and best practice on the day.

Contents:

Accessing the meeting on Microsoft Teams

You will need:

- A device with microphone and speakers, or headset, to present audio and hear other participants.
- Preferably, the Microsoft Teams App installed on your device, or a supported web browser:

UCL attendees: Please click here to access the UCL Teams Support Centre. You will probably want to refer to "For non-Desktop@UCL devices (including devices at home)". Once installed, sign in to the Teams App using your UCL credentials.

External attendees (e.g. those without a UCL login): If you already use Teams, sign in to the Teams App using the credentials issued by your host university, business or other provider. If you do not have the Teams App installed, or are not currently using Teams, please click here to install the Teams App.

You do NOT need to possess an Office 365 or 'Teams Licence' to attend this event. If you do not currently use Teams, you do not need to attempt to 'Sign In' to the App.

All participants should click the meeting link to join the meeting at the time of the event, and choose to 'open it in the App' (if installed).

If you are unable to install the Teams App, you **must** use Microsoft Edge (Chromium-based) or Google Chrome. **Other web browsers are not supported for this event**.

Please note that the session may be recorded and retained as per UCL's retention schedule. The Chat function within the meeting will be retained as per UCL's retention schedule.

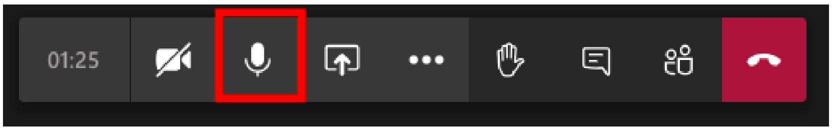
Please note we are unable to offer technical support to participants external to UCL.

Best practice on the day

Remaining on mute

The organiser will mute all participants, apart from the speaker, at the start of the meeting. If you join the meeting late, please remember to mute your microphone. Please remain on mute while presenters are delivering their talks and posters. See separate guidance below for asking questions after talks or at the end of each poster session.

You are able to toggle your mute status on and off by clicking the microphone icon on the Meeting Bar in the centre of the Teams meeting screen:



Teams Meeting Bar with microphone icon (mute button) highlighted.

Pinning the Presenter

To ensure that the presenter’s screen stays in the main section of your display, you should pin the presenter in Teams. Each participant will need to do this individually; this cannot be performed as a ‘global setting’ by the meeting organiser:

- Open the People pane, by clicking the ‘Show participants’ icon in the Meeting Bar.
- Check that the Presenter’s section is expanded and names are visible; if they are not, click the small ‘down arrow’ to the left of ‘Presenters’.
- Identify the presenter who is speaking and click the ellipses menu (...) next to their name. On the menu that appears, click ‘Pin’.

Blur background

‘Blur background’ enables your web cam to focus on you, and blur your background.

- During the meeting, click the ellipses (...) menu on the meeting bar, then click ‘Show background effects’.
- Select the blurred background (top right) from the selection pane that opens, then click ‘Apply’.

Blur background is only available in the Teams App, and not when accessing Teams via the Web.

Questions for the speakers

There should be a few minutes for one or two questions from the audience after each talk, and 5-10 minutes is reserved for questions at the end of each poster session.

- If you would like to ask a question to the presenter please click the hand icon on the Meeting Bar to 'raise your hand'.

The session chair should be able to view the list of participants in the order hands were raised and unmute the relevant person to ask their question. Please remember to re-mute yourself using the microphone icon in the Meeting Bar after you have spoken.

We have a tight schedule, so apologies if not all questions can be asked on the day or if discussions are cut short. Please feel free to contact the speaker after the meeting if you wish to follow up on that topic.

Leaving the meeting

At the end of the meeting, all participants should leave the meeting by clicking the red ‘hang up’ button on the meeting bar.

If you need to leave the meeting for a short while (for example, during the lunch break) you can re-join the meeting using the original link you were sent. Please remember to keep your microphone on mute when you re-join.

Further help

Please consult the UCL Teams Support Centre for further Teams support. The resource can be accessed via the ‘UCL Support’ icon on the left menu within Teams or via the UCL Teams Support Centre page.

These help resources are available only to UCL users and are not suitable for external participants. External participants should refer to the publicly accessible Microsoft Teams Help & Learning Centre.

The Centre for Planetary Sciences at UCL / Birkbeck Virtual Summer Meeting 2020

Thursday 11 June

Programme

Morning Talks		
10:00	Dr Dominic Papineau	Welcome
10:15	Divya Persaud *Mullard Space Science Laboratory*	Access-centered virtual conferencing for planetary science and beyond: reflections from Space Science in Context 2020
10:30	Richard Haythornthwaite *Mullard Space Science Laboratory*	Investigating heavy (above 200 u/q) positive ion composition in Titan's ionosphere from Cassini Plasma Spectrometer IBS observations
10:45	Prof Adrian Jones *UCL Earth Sciences*	Extraordinary multiple-shock history of the Chelyabinsk fireball chondritic meteorite as recorded in impact melts, pseudotachylites and ?ringwoodite. Was it a comet?
11:00	Affelia Wibisono *Mullard Space Science Laboratory*	Temporal and spectral analyses of Jupiter's X-ray aurorae
11:15	Flavien Hardy *UCL Physics and Astronomy*	Seasonal variations and compressibility of the magnetopause at Saturn
11:30	Prof Geraint Jones *Mullard Space Science Laboratory*	Crossing tails: Solar wind measurements downstream of active comets
Poster Session 1		
11:45	Giulia Magnarini *UCL Earth Sciences*	Longitudinal ridges in two lunar long runout landslides, the Apollo 17 light mantle avalanche and the Tsiolkovskiy Crater landslide: Linking morphological features to landslide dynamics
11:50	Zach Dickeson *NHM / Birkbeck EPS / OU / Imperial*	Topographic and morphological study of potential palaeolakes in the Oxia Planum drainage catchment
11:55	Qasim Afghan *Mullard Space Science Laboratory*	Comet dust tail analysis using the Finson-Probstein model
12:00	Questions	

LUNCH BREAK

Afternoon Talks

14:00	Dr Dominic Papineau *UCL Earth Sciences*	Macroscopic fossils of microbial communities in Eoarchean-Hadean jasper from the Nuvvuagittuq Supracrustal Belt
14:15	Sam Halim *Birkbeck Earth & Planetary Sciences*	Biomarker survival in terrestrial material impacting the lunar surface
14:30	Prof Andrew Coates *Mullard Space Science Laboratory*	PanCam: the ‘science eyes’ of the Rosalind Franklin (ExoMars 2022) rover
14:45	Prof Jonathan Tennyson *UCL Physics and Astronomy*	ExoMolHD: Precision spectroscopic data for studies of exoplanets and other hot atmospheres
15:00	Prof Graziella Brandaurdi-Raymont *Mullard Space Science Laboratory*	Soft X-ray imaging of geospace with SMILE
15:15	Gordon Yip *UCL Physics and Astronomy*	Peeking inside the black box: Interpreting deep learning models for exoplanet atmospheric retrievals

Poster Session 2

15:30	Prof Hilary Downes *Birkbeck Earth & Planetary Sciences*	Petrology and oxygen isotopes in new Enstatite Chondrite fragments from the Almahata Sitta Fall: Implications for the Nature of "Theia"?
15:35	Krishan Bhanot *Birkbeck Earth & Planetary Sciences*	Different types of spinel symplectites in lunar dunite 72415 and 72417
15:40	Sam Wright *UCL Physics and Astronomy*	Exploring non-LTE effects in Exoplanet atmospheres
15:45	Eleni Bohacek *Mullard Space Science Laboratory*	Enhancing the 3-D capability of science and engineering cameras on the ExoMars rover
15:50	Mukesh Bhatt *Birkbeck, School of Law*	Artemis and Actaeon: transforming a Moon treaty into international accords
15:55	Questions	

MEETING CLOSE

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ORAL ABSTRACTS

Morning session

Access-centred virtual conferencing for planetary science and beyond: reflections from Space Science in Context 2020

Divya M. Persaud[1], Eleanor S. Armstrong[2]

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There is a pressing need for climate-friendly conferences that are accessible to different people and which can still connect scholars meaningfully. The pressure on virtual conferencing technology in a COVID-19 era, as well as the many years of disabled activism around remote access and virtual meetings, make this an even more important issue. Furthermore, the need for dynamic intersection and collaborative work between the spheres of science and technology studies (STS), environmental and other justice-based activism, and the space sciences around issues of space ethics, governance, and human rights grows more urgent.

We will discuss Space Science in Context (14th May, 2020), an experimental virtual conference aiming to bring together space scientists, activists, and STS scholars, funded through the UCL Researcher-Led Initiative Award. The conference used a flipped-classroom model for 12 invited talk videos and ~30 multimedia e-posters across three primary sessions and two e-poster sessions, and engaged ~400 attendees worldwide. Invited talks were provided with full transcripts and closed captioning by Academic Audio Transcription, a company committed to the fair employment of disabled people. On the day of the conference, the five sessions were hosted at different times in video-chat hybrid formats. We reflect on the different access-centred aspects of this experimental format and their efficacy in facilitating cross-disciplinary conversations.

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Investigating heavy (above 200 u/q) positive ion composition Titan's ionosphere from Cassini Plasma Spectrometer IBS observations

Richard Haythornthwaite

Mullard Space Science Laboratory, UCL, Surrey, UK

Titan's ionosphere contains a plethora of hydrocarbons and nitrile cations and anions. Data from the Cassini Plasma Ion Beam Spectrometer (CAPS IBS) sensor have been examined for 5 close encounters of Titan during 2009 and due to the high relative velocity of Cassini to the cold ions in Titan's ionosphere, CAPS IBS can be used as a mass spectrometer. With this method mass groups are identified in the 200-300 u/q range with a 12-14 u/q spacing between groups. The three most significant peaks at 203 ± 2, 229 ± 3 and 266 ±4 u/q are investigated in further detail. These peaks are likely associated with ions with 16, 18 and 21 heavy (carbon/nitrogen) molecular ions and are also consistent with polyaromatic hydrocarbon (PAH) and nitrogen bearing PAH explanations. The proposed ions in this study are some of the heaviest ion identified so far utilizing using in-situ ion data at Titan. Our identifications could provide the link between previously identified low mass ions (under 200 u/q) and the high mass negative ions, as well as with aerosol and tholin formation in Titan's atmosphere.

Extraordinary multiple-shock history of the Chleyabinsk fireball chondritic meteorite as recorded in impact melts, pseudotachylites and ?ringwoodite. Was it a comet?

Clara Matthews-Torres[1], Paul Guyett[2] and **Adrian Jones[1]**

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[2]iCRAG, Trinity College Dublin

The petrographic study of two primitive (~4.56 Ga) meteorite samples from the Chelyabinsk impact shows relics of coarse-grained peridotitic minerals, olivine, orthopyroxene, some with geometric “hourglass” zoning and potassic glass, clinopyroxene, jadeite and Cr-spinel. These are intermingled with partially re-melted and cemented matrix chondritic breccias, cross-cut by multiple silicate glass veins with immiscible metallic droplets, and shock-veined pseudotachylites from previous shock events. Multiple young open fractures cut all the previous textures and document the final violent arrival and partial breakup of the ~20 m sized object at Chelyabinsk on February 15th 2013 at 09.22 am.

The presence of ringwoodite within cataclastic fine-grained regions of shocked olivine is inferred by characteristic blue-to-purple colours - a new observation, although high pressure jadeite has been used to calculate shock pressures of 3-12 GPa for >70 ms. (Ozawa et al, 2014 Sci Reports). The problem is that there are multiple shock events in this meteorite, and they may represent 8 different and variously combined collisions, as attributed to separate age-events from isotopic geochemical analysis (Trieloff et al 2017 MAPS).

The Chelyabinsk meteorite also contains unique metal-organic compounds including the first occurrence of dihydroxymagnesium carboxylate (Ruf et al 2017 PNAS). It may even have travelled for a long part of its history in a comet, explaining hydrous alteration to the crust before arrival at Earth, and the water observed in its trail through Earth’s atmosphere; perhaps one or more of the shock events were caused by comet capture and explosive degassing in space (Nakamura et al 2019, PNAS).

Temporal and Spectral Analyses of Jupiter's X-ray Aurorae

A.D. Wibisono[1,2], G. Branduardi-Raymont[1,2], A. J. Coates[1,2], W.R. Dunn[1,2]

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[2]The Centre for Planetary Sciences at UCL/Birkbeck, UK

It is now more than 40 years since it was discovered that Jupiter produces bright X-ray aurorae. There are two constituents to these emissions. Hard X-rays with energies above 2 keV are produced by precipitating electrons via bremsstrahlung radiation. Soft X-rays have lower energies and are due to charge exchange processes between precipitating ions and neutrals in Jupiter's atmosphere. The source of these ions is not very well understood but evidence from observational and theoretical studies seem to favour an iogenic origin rather than one from the solar wind.

Quasi-periodic pulsations in the auroral X-ray emissions have often been detected to have periods of tens of minutes and the two poles do not always beat in sync with each other. It is currently unclear as to why Jupiter's X-ray aurorae should behave in this way, but evidence suggests that wave-particle interactions may play a role.

Juno's arrival at Jupiter in 2016 means that in-situ measurements of the jovian magnetosphere can be used to complement remote sensing data obtained by Earth-orbiting observatories such as XMM-Newton. Juno revealed that Jupiter's magnetosphere was compressed during XMM-Newton's June 2017 observation of the giant planet's X-ray aurorae. We created solar wind and iogenic plasma models to fit XMM-Newton's spectra of the aurorae and showed that for this observation, the iogenic model gave the best fit meaning that the precipitation ions are from Io's volcanoes. We also ran discrete wavelet and fast Fourier transforms on the lightcurve of the aurorae from XMM-Newton to reveal that the northern and southern aurorae were pulsating at the same time with the same period of ~23 minutes for 12.5 hours which may hint that the X-ray aurorae at both poles share the same driver.

Seasonal Variations and Compressibility of the Magnetopause at Saturn

Flavien Hardy

Department of Physics and Astronomy, UCL, UK

A planet's magnetosphere is a surrounding region which forms when charged particles from the Sun encounter the planet's magnetic field. The boundary of this region, known as the *magnetopause*, moves in response to both external drivers (e.g. flux of solar wind particles) and internal drivers (e.g. planetary field, magnetospheric plasma populations fed by moon ejecta, etc.).

We are developing a physics-based model of the magnetopause at Saturn and using it alongside data from the *Cassini* spacecraft to illustrate the following points:

- The extent to which the magnetopause boundary at Saturn is able to be compressed (or expanded) is highly dependent on the size of the system.
- When the magnetosphere is in a plasma-depleted regime, the boundary is pushed closer to the planet and is shown to behave similarly to that of the Earth. In a plasma-loaded regime, the magnetopause is pushed further out and behaves more closely to that of Jupiter.
- The size, position and structure of the magnetopause boundary exhibit seasonal variations; a comparison of these variations will be drawn for various magnetic configurations.

Crossing tails: Solar wind measurements downstream of active comets

Geraint Jones

Mullard Space Science Laboratory, UCL, Surrey, UK

It's not only dedicated comet missions such as Rosetta that have encountered comets or their tails. We by now know of several comet tail crossings that have taken place entirely by chance, where cometary ions, carried by the solar wind, have swept across spacecraft travelling in interplanetary space. With the exception of Comet Siding Spring passing close to Mars in 2014, all of these events have been found after the event, usually appearing as unusual features in solar wind data. I'll provide a brief overview of these comet tail crossings, and what has been learnt from them so far. I'll then describe the effort being put into both finding comet tail crossings that unknowingly took place in the past, and predicting future tail traversals, such as the crossing by Solar Orbiter of Comet C/2019 Y4 (ATLAS)'s tail in early June 2020.

POSTER ABSTRACTS

Morning session

Longitudinal ridges in two lunar long runout landslides, the Apollo 17 light mantle avalanche and the Tsiolkovskiy Crater landslide: Linking morphological features to landslide dynamics

Giulia Magnarini[1], Thomas Mitchell[1], Peter Grindrod[2]

[1]Department of Earth Sciences, University College London, [2]NHM, London

On the Moon, mass wasting processes are mainly reported on the inner steep slopes of impact craters [1]. These events involve dry granular material, from regolith size to boulder size, and they occur in vacuum and in the absence of liquid water. However, since the early orbital observations of the Moon from the Lunar Orbiter mission and during the Apollo programme, two unusually long runout landslides have been also observed: the Light Mantle avalanche in the Taurus-Littrow Valley [2] and the Tsiolkovskiy crater landslide, on the far side[2][3]. These are the only cases of long runout landslides known on the Moon. Their uniqueness has intrigued researchers, for the origin of the reduction of friction required to explain their mobility remains unknown on a dry, airless body.

Their different morphological aspects bear differences in their formation processes, which include preparatory and triggering factors, and modality of transport. However, both landslide deposits are marked by longitudinal linear pattern. These distinctive structures are common in large-scale mass movements across the Solar System and their presence has always been intuitively associated with high-speed flows [4] and tentatively to the presence of a basal icy surface [5].

Alternatively, the finding of a scaling relationship between the wavelength of the longitudinal ridges and the thickness of the deposit for a martian long runout landslide [6] support the hypothesis that mechanical instabilities within the rapid moving slide are responsible for the formation of longitudinal ridges [7], regardless of environmental conditions.

Following recent work by [6], we decided to conduct morphological analysis of the Apollo 17 Light Mantle avalanche deposit and the Tsiolkovskiy crater landslide deposit in order to assess whether the same scaling relationship between the wavelength of longitudinal ridges and the thickness of the deposit is recurring in lunar long runout landslides. We here present the initial results from such morphometric analysis and discuss their possible implications.

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Topographic and morphological study of potential palaeolakes in the Oxia Planum drainage catchment

Z. I. Dickeson[1,2], P. M. Grindrod[1], M. R. Balme[3], S. Gupta[4], J. M. Davis[1], P. Fawdon[3]

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Introduction: The ExoMars rover is to land at Oxia Planum, and a key mission objective is to sample and analyse deposits with a prolonged aqueous history for the presence of biosignatures [1]. The area of the landing site meets these criteria as it (1) exhibits extensive outcrops of phyllosilicate mineralogy, and (2) is situated in the lowlands adjacent to a sedimentary fan and the termination of a highland valley network at the planetary dichotomy. However, clay bearing units in the landing ellipse may represent allochthonous and/or autochthonous deposits [2], and a better understanding of possible sediment sources in the drainage catchment area will be crucial to understanding Oxia Planum.

Numerous studies in western Arabia Terra have identified fluvial and palaeolake systems near the dichotomy [3, 4, 5], and others indicate the dichotomy in this region as the site of past groundwater upwelling [6, 7] or the palaeoshoreline of an ocean [8]. Possible palaeolakes have been identified in the Oxia Planum catchment, and noted as particularly relevant to the detection of biosignatures as ancient lacustrine environments could have hosted habitable conditions and contributed biological material to sediment sinks at the landing site [9, 10]. This work expands on previous studies characterising the Oxia Planum catchment area [9, 10], and will (1) surveying the area for further palaeolakes, (2) conduct a detailed analysis of multi-crater palaeolake system (Fig.1), and (3) examine a potential shallow inter crater lake outside of the catchment area.

Observations: Geomorphological features were mapped using CTX, HiRISE, and THEMIS images in ArcMap. Topographic data aided feature mapping and has been mosaicked from 465 m/pixel MOLA and 50-200 m/pixel HRSC digital elevation models (DEM), with a number of 20 m/pixel CTX DEMs derived from ISIS and SOCET SET.

Fluvial valleys and sedimentary fans were mapped across the study area. Valley segments beginning within closed basins or those that breached the downslope edge of basins were interpreted as being outlet valleys of open-basin palaeolakes, and the extents of these palaeolakes were then estimated based on the elevation required for spillover through the outflow valley (Fig.1). In addition, a number of basins with only inlet valleys were identified as possible closed-basin palaeolakes. Some examples of open-basin palaeolakes show evidence of multiple fill levels and basin breaching events, as well as fine sedimentary structures within their floors.

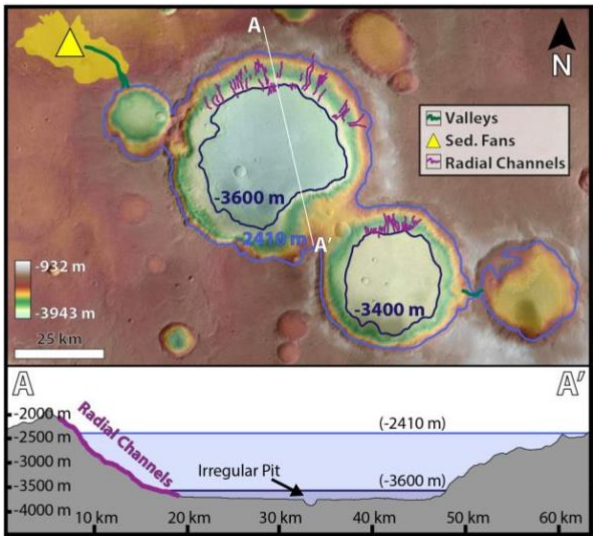

***Figure 1** – Detail of an open-basin palaeolake within the Oxia Planum drainage catchment showing: sedimentary fans (yellow triangles), incised valleys (green lines), radial channels (purple lines) and possible palaeolake extents (blue areas). (CTX, HRSC, MOLA DEM over CTX images)*

Discussion: Preliminary results indicate some new intra-crater open-basin palaeolakes which are not identified in previous studies and catalogues. These palaeolakes are shallow and hosted in intra-crater basins. Some are situated within the Oxia Planum catchment and are therefore possible sources of material ultimately deposited at the landing site in the lowlands. However, one example falls outside the catchment area defined on the current topography, and more high resolution DEMs will be produced to determine the hydrological relationship of this palaeolake to the catchment area.

A complex system of palaeolakes (Fig.1) also identified in previous works [9, 10] will be the focus of a further detailed mineralogical and sedimentary study to determine the history of filling and spillover events.

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Comet dust tail analysis using the Finson-Probstein model

Qasim Afghan

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Using a novel analysis method, the fine-structure detail of comet dust tails is analysed from amateur and professional comet images. Given the date and time of the image taken, the comet's position in the sky is calculated using an open source algorithm [1] and the comet's dust tail is simulated for that position and time using the Finson-Probstein model. This modeled dust tail structure is then projected and overlaid onto the comet image to directly compare the theoretical and real structure of several comet's dust tails, with the aim of identifying similarities and discrepancies between the model and the image.

This is a continuation of the work done previously on Comet McNaught, which ultimately led to the discovery of new fine-scale structure features in the comet's dust tail [2]. This model is now applied to several other comets, including Comet C/2004 F4 Bradfield, to find similar fine-scale structures and to highlight this model's utility in comet dust analysis.

Finally, this work will be put into context as the first step in the development of an automated analysis method for analysing cometary dust and ion tails. This automated analysis method is in preparation for the upcoming opening of the Vera Reuben Observatory (formerly known as 'LSST'), and aims to automatically identify comet tail structures from the Observatory's stream of comet images.

[1] https://doi.org/10.1088/0004-6256/139/5/1782

[2] https://doi.org/10.1016/j.icarus.2018.09.013

ORAL ABSTRACTS

Afternoon session

Macroscopic fossils of microbial communities in Eoarchean-Hadean jasper from the Nuvvuagittuq Supracrustal Belt

Dominic Papineau[1,2,3,4], Zhenbing She[4], Matthew S. Dodd[,3,4], Francesco Iacoviello[5], Zhongwu Lan[6], Erik Hauri[7*], Paul Shearing[5], Crispin T.S. Little[8]

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The oldest known microbial fossils occur as microscopic haematite filaments and tubes in a jasper-carbonate concretion from the banded iron formation (BIF) in the more than 3.75 Ga, and possibly up to 4.28 Ga, Nuvvuagittuq Supracrustal Belt in Canada. However, the microfossil complexity, community organisation, and possible metabolism remain to be documented. Newly observed haematitic microfossil specimens from a nodule in this BIF occur as centimetre-sized pectinate-branching and parallel-aligned filaments. Optical images further reveal that some of these have a twisted morphology and are enclosed inside haematite tubes. Inside the pectinate structure, there are also granules of coarse quartz that contain dozens of haematitic coccoidal-shaped microfossils. X-ray-based imaging reveals filaments inside the dense and opaque Fe-oxides, as well as millimetre-long twisted filaments.

Associated accessory minerals have geochemical compositions also consistent with a biological origin. For instance, filaments often contain ferrous iron in haematite and graphitic carbon, consistent with diagenetic experiments of the thermal alteration of Fe-oxidising microbial filaments. Associated calcite rosettes have ^{13}C-depletions around -11%, which points to the oxidation of biomass during diagenesis. Millimeter-size chalcopyrite crystals contain inclusions of apatite-galena, which demonstrate the ancestry of the apatite and Pb-loss during metamorphism. Sulphides in the jasper-carbonate BIF also have ^{33}S- and ^{34}S-enrichments consistent with an anoxic atmosphere and with microbial sulfur disproportionation. Collectively, the new observations suggest the Nuvvuagittuq microbial communities included photoferrotrophic and S-metabolizing microorganisms. This fossil microbial ecosystem is the oldest known on Earth, could be common on other planets with hydrothermal activity, and, by its ancestry, increases the probability for a more widespread existence of extra-terrestrial life than previously thought.

Biomarker survival in terrestrial material impacting the lunar surface

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The history of organic and biological markers (biomarkers) on the Earth is effectively non-existent in the geological record >3.8 Ga ago. Here, we investigate the potential for ejected terrestrial material (i.e., terrestrial meteorites) to survive impact with the lunar surface, modelled using the iSALE hydrocode. Previous modelling has relied heavily upon the assumption that peak-shock pressures can be used as a proxy for gauging survival of projectiles and their possible biomarker constituents. However, we show the importance of considering both pressure and temperature within the projectile, and the inclusion of both shock and shear heating during simulations. Shear heating provides an additional, underappreciated source of heat within the projectile material at the impact velocities considered for terrestrial meteorites impacting the Moon (i.e., between 2.5 and 5 km s^{-1}). Using a modified version of the Arrenhius equation, we estimate the survival of particular amino acids and the organic molecule lignin by calculating the extent of thermal degradation undergone by the respective biomarkers, post-impact. In spite of temperatures higher than predicted by previous modelling, we show that some biomarkers within terrestrial meteorites are likely to survive after impact with the Moon, especially at the lower end of the range of impact velocities considered. The timescales over which fragments of the impacting projectile cool are shown to be critically important for the long-term survival of biomarkers. Comparing sandstone and limestone projectiles shows similar temperature and pressure profiles for the same impact velocities, with limestone providing slightly more favourable conditions for biomarker survival.

PanCam: the ‘science eyes’ of the Rosalind Franklin (ExoMars 2022) rover

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The scientific objectives of the ExoMars Rosalind Franklin rover [1] are designed to answer several key questions in the search for life on Mars. In particular, the unique subsurface drill will address some of these questions for the first time, such as the possible existence and stability of sub-surface organics. PanCam [2] will establish the surface geological and morphological context for the mission, working in collaboration with other context instruments. Here, we give an update on this exciting mission, and describe the PanCam scientific objectives in geology, atmospheric science and 3D vision. We discuss the design of PanCam, which includes a stereo pair of Wide Angle Cameras (WACs), each of which has an 11 position filter wheel, and a High Resolution Camera (HRC) for high resolution investigations of rock texture at a distance. The cameras and electronics are housed in an optical bench that provides the mechanical interface to the rover mast and a planetary protection barrier. The electronic interface is via the PanCam Interface Unit (PIU), and power conditioning is via a DC-DC converter. PanCam also includes a calibration target mounted on the rover deck for radiometric calibration, fiducial markers for geometric calibration and a rover inspection mirror. Recent simulations [3] show the view from PanCam, the ‘science eyes’ of the Rosalind Franklin rover.

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ExoMolHD: Precision spectroscopic data for studies of exoplanets and other hot atmospheres

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The discovery of extrasolar planets is one of the major scientific advances of the last decades. Thousands of planets have now been detected and astronomers are beginning to characterise their composition and physical characteristics. To do this requires a huge quantity of spectroscopic data most of which is not available from laboratory studies. The ExoMol project (Tennyson & Yurchenko 2012, Tennyson et al. 2016) was established to give a comprehensive solution to this problem by providing spectroscopic data on all the molecular transitions of importance in the atmospheres of exoplanets. These data are widely applicable to other problems including studies of cool stars, brown dwarfs and circumstellar environments as well as many terrestrial applications. The ExoMol database (www.exomol.com) contains extensive data for about 80 molecules generated using mixture of first principles and empirically-tuned quantum mechanical methods to compute comprehensive and very large rotation-vibration and rotation-vibration-electronic (rovibronic) line lists. Many of these lists are huge (up to 150 billion individual lines).

Starting from September 2020 a new ERC-funded project, ExoMolHD will start. ExoMolHD will build on the ExoMol project by providing high accuracy spectroscopic data for high resolution studies of exoplanetary atmospheres. This will be done by re-factoring ExoMol line lists using high resolution laboratory measurements. Novel theoretical techniques will be used to provide similar high accuracy line lists for isotopically substituted species. The effects of pressure on the line shapes and positions will be considered. Finally, given the extreme conditions experienced by most observable exoplanets, namely high temperatures and huge levels of insolation, photodissociation is a major process chemical pro- cess. This has been well studied for cold molecules but photodissociation rates for hot species, which are likely to be 50 to 100 faster, remain unknown. New methods will be developed to compute these rates.

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Soft X-ray imaging of geospace with SMILE

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It is a relatively recent discovery that charge exchange soft X-ray emission is produced in the interaction of solar wind high charge ions with neutrals in the Earth's exosphere; this has led to the realization that imaging this emission will provide us with a global and novel way to study solar-terrestrial interactions.

In particular X-ray imaging will provide us with the means of establishing the location of the magnetopause and the morphology of the magnetospheric cusps. Variations of the magnetopause standoff distance indicate global magnetospheric compressions and expansions, both in response to solar wind variations and internal magnetospheric processes.

Soft X-ray imaging is one of the main objectives of SMILE (Solar wind Magnetosphere Ionosphere Link Explorer), a joint space mission by ESA and the Chinese Academy of Sciences, which is under development and is due for launch in 2023. This presentation will introduce the scientific aims of SMILE, show simulations of the expected images to be returned by SMILE's Soft X-ray Imager for given solar wind conditions, and will discuss some of the techniques that will be applied in order to extract the positions of the Earth's magnetic boundaries, such as the magnetopause standoff distance and the edges of the magnetospheric cusps.

Peeking inside the black box: Interpreting deep learning models for exoplanet atmospheric retrievals

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Deep learning algorithms are growing in popularity in the field of exoplanetary science due to their ability to model highly non-linear relations and solve interesting problems in a data-driven manner. For example, several works have attempted to perform fast retrieval of atmospheric parameters with the use of deep neural networks (DNNs). Yet, despite their high predictive power, DNNs are also infamous for being `black boxes'. It is their apparent lack of explainability that makes the astrophysics community reluctant to adopt them. What are their predictions based on? How confident should we be in them? When are they wrong and how wrong can they be? In this work, we present a number of general evaluation methodologies that can be applied to any trained model and answer questions like these. In particular, we train 3 different popular DNN architectures to solve the problem of retrieving atmospheric parameters from exoplanet spectra and show that all 3 achieve good predictive performance. We then present an extensive analysis of the predictions of DNNs, which can inform us —among other things — of the detection limit for atmospheric parameters for a given instrument and model. Finally, we perform a sensitivity analysis to identify to which features of the spectrum the outcome of the retrieval is most sensitive. We conclude that for different molecules, the wavelength ranges to which the DNN's predictions are most sensitive, indeed coincide with their absorption regions. The methodologies presented in this work help to improve the evaluation of DNNs and to grant interpretability to their predictions.

POSTER ABSTRACTS

Afternoon session

Petrology and oxygen isotopes in new enstatite chondrite fragments from the Almahata Sitta fall: Implications for the nature of “Theia”?

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Introduction: Enstatite chondrites are important varieties of meteorites because they have identical isotopic compositions to those of the Earth and Moon. The possibility that the Moon-forming Giant Impactor “Theia” has been discussed in several recent studies. The fall of Asteroid 2008 TC3 in Sudan in 2008 gives an opportunity to investigate very fresh (unweathered) extraterrestrial material. Most of the meteorite fragments found in the strewn field resulting from the fall were ureilites but a high proportion (20-30%) are other varieties of meteorites, including many enstatite chondrites. We have investigated 5 new enstatite chondrite fragments from the fall (known as the Almahata Sitta meteorite) for texture, mineralogy, mineral compositions, and oxygen isotopes. These pristine samples enable us to constrain the range of oxygen isotopes shown by the enstatite chondrite parent body/ies.

Petrography and Mineralogy: All of the samples are fractured but nearly unweathered (although oldhamite CaS shows evidence of weathering because it is unstable in the oxygen- and water-rich atmosphere of the Earth). All contain enstatite-dominated chondrules, in a matrix of abundant enstatite, albite feldspar, metal and sulfides. Some fragments contain more metal than the other samples. Some contain very diffuse chondrules, whereas others contain well defined and large chondrules. Mg-rich olivine (Fo99) is occasionally present in some chondrules. Both high-Fe (EH) and low-Fe (EL) types of enstatite chondrite are present in the studied fragments, as well as a wide range of recrystallisation states (petrographic types 3-6). One of the fragments appears to be an impact melt rock, a common occurrence among enstatite chondrites.

In all samples, enstatite (Mg2Si2O6) is the dominant mineral. Rarer feldspars are almost pure albite (NaAlSi3O8) and are commonly associated with enstatite and a silica (SiO2) phase. The silica phase contains impurities including 0.5 wt% Al2O3 and 0.5 wt% FeO, which is in agreement with its identification as cristobalite (a high temperature polymorph of the mineral quartz). The samples contain ubiquitous metals and sulfides which are distributed evenly through the sections, except for one sample in which they are concentrated in a metal-rich vein with sulfides, and are less abundant in a region of finer-grained metal-poor material that is rich in oldhamite. Si is found in the metal in all samples, indicating that the meteorites were formed in an extremely reducing environment. Samples contain a variety of sulfides including troilite (FeS), oldhamite (CaS), niningerite (Fe,MgS) and keilite (MgS). This also supports the very reduced state of enstatite chondrite formation, as these elements (Mg, Ca) are normally lithophile (oxygen-loving) rather than chalcophile (sulfur-loving). Graphite laths are also found sporadically throughout the samples.

Oxygen isotopes: Oxygen isotopes were obtained at the Open University using an infrared laser fluorination system. Four of the samples lies exactly on the Terrestrial Fractionation Line with Δ17O values in the range -0.005 to 0.029 ‰. These results are typical of enstatite chondrites and the Earth-Moon system. One sample has a Δ17O value of -0.29 ‰ which is lower than the others but still plots within the envelope of data from enstatite chondrites. This outlier confirms that the halo of isotopic data on either side of the Terrestrial Fractionation Line is a genuine feature, and that (unlike the Earth) the parent body/ies of enstatite chondrites was/were isotopically slightly heteroge-neous.

Discussion: Can this study shed any light on the theory that “Theia” was an enstatite chondrite? This theory assumes only one single parent body for all enstatite chondrites, whereas recent detailed mineralogical studies of enstatite chondrites show that there are at least 4 types of enstatite chondrite meteorites in our collections on Earth. The same four enstatite chondrite types have been found among the fragments found in the Almahata Sitta fall. So both the parent asteroid of Almahata Sitta and the Earth-Moon system have been showered by fragments from four separate enstatite chondrite parent bodies. Could “Theia” have been a series of impacts by closely related but separate enstatite chondrite planetesimals?

Different types of spinel symplectites in lunar dunite 72415 and 72417

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Symplectites are intergrowths of two or more minerals that occur because of a change in temperature and/or pressure. Therefore, they can tell us about the history of a rock sample from any planetary body. Spinel symplectites have been reported in lunar dunites from the Apollo 17 mission to the Taurus–Littrow valley. Samples 72415 to 72418 were taken from a 10 cm size clast from boulder 3, station 2. Sample 72417 yielded an age of 4.55 ± 0.1 Ga. Hand specimens are brecciated and composed of pale-green, translucent olivine grains up to 10 mm in size, set in a fine-grained matrix. We have investigated Apollo 17 samples 72415,4 and 72417,9003 by electron microprobe analysis (TS 72415,53) and micro-CT.

Electron microprobe results: The sample shows a brecciated texture of angular to sub-angular fragments of olivine Fo_{86-89} in a matrix of smaller angular fragments, with rare diopside, anorthite, spinel and Fe-Ni metal. Olivine grains show shock features with undulose extinction and mosaicism. Fractures crossing olivine crystals are common. We have found three types of symplectite with different compositions of spinel. One symplectite (spinel Type 1a) is between spinel (sp) + diopside (cpx) ± enstatite (opx); another is between spinel + anorthite (an) (spinel Type 1b) and is closely associated with olivine (ol). Spinel in Type 1a intergrowths have Mg# = 48 and Cr# = 67, whilst spinel in Type 1b intergrowths have Mg# = 60 and Cr# = 49. A third type of symplectite (spinel type 1c) is much smaller (<30 μm in size), very abundant, only found inside single olivine clasts and is composed of spinel + diopside ± enstatite. Type 1c spinel is intermediate in composition between Types 1a and 1b.

Micro-CT results: Micro-CT analysis of lunar dunites confirms that spinel forms complex structures of varying size, shape and texture. Spinel type-1a forms randomly orientated elliptical (<0.6 mm) structures with a highly vermicular texture in which spinel is wholly contained within a single grain. Individual spinel branches are in contact with each other and form a single crystal. Individual spinel structures have rounded edges but also include angular edges indicating fracturing. Spinel type-1b forms smaller structures which are elongate and flat, and formed around adjacent grains and thus is interstitial. Spinel type-1c cannot be imaged because of its small size. A completely new large unfractured high density structure with many individual elongate branches is seen to form linear channel-like features. These features often terminate at plate-like structures. Such structures have only been seen in the CT scans. We interpret this as a melt texture (here termed Type 2) but this requires further investigation to confirm that it is spinel or possibly troilite.

Based on texture and mineral chemistry of the spinels, we propose that Type 1a, b and c have different origins. The large sp + cpx symplectites (sp Type 1a) are formed from decompression of garnet, and the garnet was brought up from ~420 km depth by convective overturn. Type 1b have a shallower origin with interaction of ol and decompression melts forming ol + an + sp sympletitic textures. Type 1c have an exsolution origin, possibly as decompressed melt inclusions that cooled slowly and crystallised. Type 2 textures show no signs of fracturing and thus make this texture younger than all Type 1 spinel textures and most likely related to shock melting.

Exploring non-LTE effects in Exoplanet atmospheres

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Great advances have been made over the last few decades in probing the atmospheres of extra-solar planets, enabling us to further constrain the conditions that exist on these worlds. When modelling these atmospheres however, the work done to date has assumed that the species present are in local thermodynamic equilibrium (LTE). It is known, for instance on Earth, that non-LTE effects are present in the atmosphere and give rise to varying spectra; work already conducted by the community has expanded the remote sensing of non-LTE to other planets within our solar system. This poster presents a preliminary exploration into non-LTE effects in exoplanet atmospheres, showing the differences that arise in some notable molecular spectra due to these effects. An initial evaluation of the detectability of these differences by next generation space telescopes is presented, along with some indicative forward models and initial retrievals. Further work will involve further exploring atmospheric retrieval of non-LTE effects and instrument simulations.

Enhancing the 3-D capability of science and engineering cameras on the ExoMars rover

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The stereo camera systems on the ExoMars Rover are PanCam, a scientific instrument designed by MSSL/UCL, and the NavCams and LocCams, designed by Airbus for navigation. Both will provide 3-D imagery of the terrain around the rover for their respective communities. I developed emulators of these instruments from a static three-camera system to a full-sized rover, in order to collect representative data of the landing in 2023. We simulated a rover traverse at the Airbus “Mars Yard” and produced 3-D models using data from both instruments for the first time and compared these with corresponding LIDAR measurements.

Artemis and Actaeon: transforming a Moon treaty into international accords

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Continuing proposals for permanent present on or near the Moon after the Apollo landings raise questions of legitimacy, a discussion that itself has continued for over 50 years. National and geopolitical interests play a large part in adherence to and compliance with the Outer Space Treaty and its adjunct, the Moon Treaty. Apart from ratification and entry into force, new questions have arisen: the ethics of inhabiting a celestial body that has influenced cultures on Earth, the necessity of retaining pristine environments off-Earth, and the economic viability of settlements and mineral resources. Added are issues of said legitimacy for these activities, of covert militarisation, and of seeding a sterile environment with life, whether as ark or as biosphere. What is clear is the international community has differing approaches in deciding its answers. This paper will examine new and various mechanisms that allow resolution to these conundrums, by providing an overview of historical development of space law in short form, followed by the major considerations that may allow such conventions and agreements to be circumvented whilst remaining within the spirit of international law paradigm.

Keywords: Moon treaty, space law, legal mechanisms, ethics, law