# Australian Planetary Science Meeting 2024 Conference Abstracts

## The Binar Prospector mission: Magnetometry of the Moon at ultimate resolution

[1]The Binar Prospector Team, presentation by Phil Bland*

[1]p.a.bland@curtin.edu.au, Curtin University, Australia

In-Situ Resource Utilisation (ISRU) is a critical strategic roadmap element in NASAs Artemis Program, and the principal differentiator between Artemis and Apollo. But the resources that can enable Artemis are located in permanently shadowed regions (PSRs) at the lunar poles, at temperatures down to 30K. Binar Propector is an Australian lunar resource prospecting mission, focused on expanding ISRU opportunities in the lunar environment. Using a pair of 12U CubeSat orbiters, flying at extreme low altitude, the goal of the Binar Prospector mission is to deliver a magnetic survey of the Moon at ultimate resolution, and identify mineralization and phases containing water ice outside of PSRs, allowing ISRU to occur within the capabilities of current space technology, and so enable human space exploration. Binar Prospector will take advantage of the new opportunity for rideshare to the Moon, and leverage the real potential of CubeSats for interplanetary missions: doing one job well in an environment that is not optimal for larger spacecraft.

## Can we detect planets around extremely active young Suns?

[1,2]Brown, E.L., [1]*Marsden, S.C., [3]Jeffers, S.V., [1,4]Heitzmann, A., [5] Barnes, J.R., & [6]Folsom, C.P.

*lead presenter

[1] Stephen.Marsden@unisq.edu.au, University of Southern Queensland, Australia

[2] Central Queensland University, Australia

[3] Max Planck Institut for Solar System Research, Germany
[4] University of Geneva, Switzerland
[5] The Open University, United Kingdom
[6] University of Tartu, Estonia

Young solar analogues make interesting targets in the search for exoplanets, with the potential to constrain theories of planetary formation and early evolution. However, they are rarely targeted for this purpose due to their extreme magnetic activity, which can mask or even mimic the presence of planets. We have used the young solar analogue V889 Her as a test case to determine realistic limits for the radial velocity (RV) detection of exoplanets around the most active young solar analogues. We found that the significant differential rotation and strong polar spots that are ubiquitous among these stars make it particularly difficult to model and filter stellar activity-induced RVs using a data-driven approach. By using the physically-motivated technique of Doppler Imaging to model the stellar surface spots and filter activity-induced RVs, we estimate that we could detect hot Jupiters around extremely active young Suns.

# In-Situ Meteorite Fission-Track Thermochronology with Application to Mesosiderites and Pallasites

[1]*Burke, T., [2]Glorie, S. & 2Hand, M.

[1]Thomas.Burke@adelaide.edu.au, University of Adelaide, Australia

[2] University of Adelaide, Australia

Although fission-track analysis is not a new tool for low temperature thermochronology, conventional fission-track applications account only for fossil track production from the spontaneous fission of 238U. Meanwhile meteorites have additional track sources from the spontaneous fission of extinct, short-lived 244Pu, galactic cosmic rays of heavy nuclei and the induced fission of U and Th from cosmic rays. Conventional fission-track methods additionally assume application to apatite, whilst the dominant meteorite reservoir of fossil track bearing minerals is merrillite (a Ca-Phosphate found only in meteorites). Historical attempts to account for these additional track sources and mineralogy make large assumptions, such as the initial Pu/U ratio of the solar system which has inconsistent and widely variable literature values. Additionally, they rely on indirect U concentration analysis via irradiating at a nuclear facility which introduces inherent risk of inducing fission from additional elements such as Th.

This study presents a refined approach for meteorite fission-track application by direct U concentration calculation from in-situ LA-ICP-MS analysis in conjunction with a merrillite mineral specific initial Pu/U ratio to calculate the low temperature model age of the Springwater Pallasite and the Mesosiderites Pinnaroo and EET87500.

## An Atlas of Apatite and Merrillite in Martian Meteorites: Insights into Classification and REE Geochemistry

Burke, T.F. [1]*, Tomkins, A.G.[2], Langendam, A.D.[3], Pinter, Z.[4] & Miller, L.[5]

*lead presenter

[1]Tahnee.burke@monash.edu, Monash University, Australia

[2] Monash University, Australia

[3]Australian Synchrotron, Australia

[4]CSIRO, Australia

[5]Australain National University, Australia

The phosphates, apatite and merrillite, are accessory phases in all martian meteorites. Although apatite is commonly used to assess volatile content and speciation in martian meteorites, merrillite is at least twice as abundant in most samples, but poorly understood. Given that shergottites are divided into enriched, intermediate and depleted subgroups based on bulk differences in LREE abundance, an understanding of phosphate mineral behaviour is essential to deciphering the petrogenetic differences between these groups because they are the main REE-bearing phases. This study examines variations in phosphate mineralogy and geochemistry of 26 martian meteorites, spanning all subtypes: shergottites, nakhlites, chassignites, ALH 84001 and two pairs of NWA 7034. Twelve of the shergottite samples were previously classified into enriched, intermediate and depleted subgroups based on bulk rock REE trends and La/Yb ratios. All samples were elementally mapped using the XFM beamline at the Australian Synchrotron, providing the relative abundance of merrillite, apatite and K-feldspar within each sample. We show that it is possible to classify shergottites using apatite (abundance x 10) to merrillite ratios ($A^{10}/M$). Enriched shergottites typically have $A^{10}/M$ of 1.15 to 9.25, intermediate shergottites range from 10.4 to 19.94 and depleted shergottites range from 24.02 to 39.19. Calculating the apatite to merrillite ratio provides a quick and straight-forward method of chemically classifying shergottites that avoids the need to destroy samples for bulk rock REE analysis.

## Planetary Science at the University of Southern Queensland

[1]*Carter, B.D., [1]Wright, D., [1]Horner, J.

[1]Brad.Carter@unisq.edu.au, University of Southern Queensland, Australia

Planetary science research at UniSQ aims to connect exoplanet astronomy with Solar system research as part of an overall strategy of studying the shared evolution of stars and their planetary systems. Our research is pursued using observational and computational projects done in collaboration with Australian and international partners. Mt Kent Observatory west of Brisbane is operated by UniSQ on behalf of our partners to perform optical surveys for stellar astronomy and planetary systems projects including follow-up observations for the NASA Transiting Exoplanet Survey Satellite.

# Global Significance of the Australian Impact Record

[1]*Cavosie, A.J., [1]Cousins, V.K., [1]Cox, M.A., [1]Timms, N.E., & [2]Quintero, R.R.

*lead presenter

[1]Space Science and Technology Centre, School of Earth and Planetary Science, Curtin University, Perth WA, Australia. Email: aaron.cavosie@curtin.edu.au.

[2] Department of Geology, University of Puerto Rico Mayagüez, Mayagüez Puerto Rico, USA

The record of terrestrial impact cratering includes ~200 structures that have been confirmed as having an impact origin, 32 (16%) of which are in Australia. A resurgence in the study of Australian impact structures over the last decade has revealed the global importance of many of these sites to the planetary science community. Five significant aspects of the Australian impact cratering record are reviewed here: (1) The oldest known terrestrial impact structure is now recognized as the ~70 km diameter 2.23 Gyr old Yarrabubba structure in Western Australia [1]. (2) Seven new Australian impact structures have been confirmed over the last 15 years, including four with diameters >10 km [1,2]. (3) Reidite, the first high-pressure mineral found in Australia, has now been documented at the Woodleigh and Gosses Bluff impact structures [3,4]. The oldest known impact ejecta horizon was discovered in the 3.48 Ga Dresser Fm. in the Pilbara craton [5]. Further exploration of the Australian cratering record will continue to yield new exciting discoveries.

References

[1] Quintero et al. 2021 GSA Special Pap. [2] Quintero et al. 2023 MAPS. [3] Cox et al. 2018 Geol. [4] Cousins et al. 2022 Met Soc. [5] Dobson et al. 2023 LPSC.

# First results from the ALMA planet hunting campaign: the exoALMA Large Program

[1,*]Christophe Pinte, and the exoALMA collaboration

[1] christophe.pinte@monash.edu, Monash University, Australia

ALMA has unequivocally demonstrated that protoplanetary disks are highly structured objects, exhibiting stunning gaps, rings and spirals. Young, still-forming exoplanets are an exciting possibility for the cause of these structures, however direct detection of these exoplanets remains a challenge. With the development of new analysis techniques, it is now possible to measure extremely subtle variations of the gas velocity structure due to embedded planets within these disks, providing a new tool in our planet hunting repertoire. The exoALMA Large Program was designed to capitalize on this new technique to conduct the first sub-mm planet hunting campaign. In this talk I will present the first results from the exoALMA program, spanning from the detection of embedded planets to studies of the turbulent state of stellar accretion disks.

## Trace elements reveal marine, subaerial, and hydrothermal controls on an early life habitat: The c. 3.48 Ga Dresser Formation, Pilbara Craton

[1,2]Djokic, T.,* 3Bolhar, R., [4]Brengman, L.A., [5,6]Havig, J.R., [2,7]Van Kranendonk, M.K.,

*lead presenter

[1]tara.djokic@australian.mueum Australian Museum Research Institute, Sydney, New South Wales, Australia

[2]Australian Centre for Astrobiology, School of Biological Earth and Environmental Sciences, University of New South Wales, New South Wales 2052, Australia

[3]School of Geosciences, University of the Witwatersrand, Johannesburg 2000, South Africa

[4]Department of Earth and Environmental Sciences, University of Minnesota - Duluth, Duluth, MN 55812, USA

[5]Department of Plant and Microbial Biology, University of Minnesota – Twin Cities, Saint Paul, MN 55108, USA

[6]Department of Earth and Environmental Sciences, University of Minnesota – Twin Cities, Minneapolis, MN 55455, USA

[7]Big Questions Institute, University of New South Wales Australia, Kensington, New South Wales, Australia

The c. 3.48 Ga Dresser Formation in the Pilbara Craton, Western Australia, harbors some of the earliest evidence of life on Earth. Although evidence points to a dynamic volcanic-hydrothermal caldera setting for the Dresser Formation, ongoing discussion continues surrounding the specific conditions that hosted stromatolites. Lithostratigraphic and geochemical evidence has been used to suggest hydrothermally-influenced marine and/or subaerial conditions facilitated life.

Previous workers identified three distinct fluid compositions (marine, hydrothermal, and subaerial) using trace and rare earth elements, but these analyses have been limited to isolated rock units (studies), offering only snapshots of specific depositional time intervals.

We undertook comprehensive trace and rare earth element analyses of 31 whole-rock samples from 10 lithofacies across the entire stratigraphic sequence.

Samples include a range of bedded cherts, hot spring geyserite, sinter terracettes, jaspilitic chert, and silicified volcaniclastic siltstone. By linking trace element and REE data with units from four lithostratigraphically-defined assemblages (A1-A4), our data highlights a complex evolution from marine to shallow water and subaerial conditions where stromatolites thrived, followed by a return to deep marine environments. Our trace and rare earth element data refine the existing volcanic-hydrothermal model, shedding further light on the geological processes influencing early life in the Dresser Formation.

This study contributes to reconstructing Earth's early life habitats, informing astrobiological research.

# Origin of Ishtar Terra from a craton formation mechanism on Venus

[1] Fabio A. Capitanio*, [2] Madeleine Kerr, [2] Dave R. Stegman, [3] Suzanne E. Smrekar

[1]School of Earth, Atmosphere and Environment, Monash University, Clayton, 3800 Victoria, Australia

[2] Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, San Diego, CA, USA

[3] Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109, USA

*lead presenter

e-mail Fabio.capitanio@monash.edu

The Ishtar Terra highlands on Venus consist of Lakshmi Planum, an Australia- sized crustal plateau with an average elevation of ~4 km, comparable to that of the Tibetan Plateau, surrounded by elongated mountain belts of ~10 km, taller than the Himalayas, floored by thick crust, comparable to that of cratons on Earth. While on Earth these features result from the collision of tectonic plates, the origin of Ishtar Terra remains enigmatic because Venus lacks Earth-like plate tectonics. Here, we use three-dimensional thermo-chemo-mechanical computational simulations of Venus-like convection, to show how magmatism and tectonics emerge from mantle dynamics. The models show that convective thinning of a weak lithosphere enhances decompression melting, favouring the emplacement of a thick magmatic crust on top of a deep residual depleted mantle. The stiffer residue deflects mantle tractions outwards, where fold belts form around the buoyant lithosphere, consequently uplifting into a plateau, yielding topography, crustal thicknesses and gravity remarkably consistent with that of Ishtar Terra. The plateau rigid root resists deformation and contribute to its preservation, suggesting that the mechanisms of plateau formation on Venus are comparable to that forming cratons in the early Earth.

## Aeolian Sediment pathways on Mars

[1]*Gunn, A., [2]Rubanenko, L., [3]Lapôtre. M., [4]Ewing, R., [5]Jerolmack, D., [6]Chojnacki, M., [7]Fenton, L., [1]Bintliff, N., [8]Pérez-López, S., [9]Soto, A. & [6]Smith, I.

[1]a.gunn@monash.edu, Monash University, Australia

[2]Technion, Israel

[3]Stanford University, Unites States

[4]Texas A&M University, Unites States

[5]University of Pennsylvania, Unites States

[6]Planetary Science Institute, Unites States

[7]SETI Institute, Unites States

[8]Brown University, Unites States

[9]Southwest Research Institute, Unites States

Owing to a lack of recycling through tectonic processes, large sedimentary systems accumulate on Mars' surface. Throughout its history, cratering has produced large amounts of sedimentary material. In past climates, fluvial processes carved canyons and laid down deltas. Today, active surface processes are largely gravity-driven, cryospheric, and aeolian. Despite a tenuous atmosphere, and frost covering sand for large periods of the year in high latitudes, aeolian activity on Mars is commonplace today. Here we discuss our recent progress in understanding how aeolian sediments are distributed and moved on Mars' surface. We will contextualize and highlight our studies on aeolian sediments in craters, around the north pole, and more broadly across the globe. These studies inherently make use of remotely sensed data; we employ a broad range of instruments onboard NASA spacecraft including HiRISE, CTX, SHARAD, and MOLA. These data are interwoven with theory, painstaking manual and automatic mapping of geologic and geomorphological features, and compared to global climate model and mesoscale simulations of Mars' atmosphere. Together, these studies help us understand climate history, the atmospheric dynamics that contribute to geomorphic work, and the long-term evolution of sedimentary systems and how they are connected.

# Late Archaean microbial life recorded in the 2.63 Ga Carawine Formation: implications for habitability on Early Earth

[1]*Hoogland, V., [1]*Flannery, D.T.,

*lead presenter

[1] v.hoogland@qut.edu.au, Queensland University of Technology, Brisbane, Queensland, Australia.

Large bolide impact events and changing ocean water chemistries of Archean paleoenvironments preserved in Western Australia (Pilbara Craton) and South-Africa (Kaapvaal Craton) provide opportunities to investigate important forces governing the habitability of Earth's early environments, and by extension those that may have influenced the habitability of other rocky planets.

This research aims to investigate the microbial communities responsible for constructing the world's oldest preserved carbonate platform, in the Neoarchean Carawine Formation (Hamersley Basin, Western Australia), and the environmental effects of a substantial impact event that is recorded within the stratigraphy of that basin. Through field and laboratory investigations, we are building a detailed lithostratigraphic framework and a high-density chemostratigraphic dataset including stable C and O isotopes, and trace element analyses. Microbialite morphology, sedimentology, and the geochemistry of (bio)chemical sediments will provide insights into late Archaean microbial communities, sea water chemistries, and responses to changing depositional environments including impact-related perturbations. A possible paleogeographic connection to the Kaapvaal Craton will also be examined through investigation of litho/chemostratigraphic correlations with the better-known Campbellrand-Malmani Platform (Transvaal Basin, South Africa.)

# Which ExoEarths Should We Search For Life? Or… Why Exoplanetary Science Needs To Talk About The Solar System!

[1*]Horner, J.

[1]jonti.horner@unisq.edu.au, University of Southern Queensland, Australia

Over the past three decades, humanity has entered the Exoplanet Era. Where once we wondered whether the Solar system was unique, we know now that planets are ubiquitous. In the coming decades, a major focus of exoplanetary science will be the search for life on these myriad alien worlds. But where should we look?

By the time we can look for clear signs of life beyond the Solar system, that search will have vast numbers of potential targets. But the required observations will be among the most challenging ever attempted. How will we filter the candidates to choose the most promising targets?

The keys to that conundrum lie in the one planetary system that we can study in exquisite detail – our own home. Here, I present examples of how we can use our own Solar system as a template to better understand the factors that can influence planetary habitability. By working together, planetary and exoplanetary scientists will one day answer the ultimate question: Are We Alone?

# Metal isotope insights into volatilisation during meteorite impact: A Cu isotope study of tektites

[1]*Jolly, J.C., [1]McGee, L.E.,

*lead presenter

[1]jake.jolly@student.adelaide.edu.au, University of Adelaide, Australia

The enigmatic behaviour of high-temperature element mobility within the solar system and on Earth remains a perplexing scientific phenomenon. Tektites provide an insight into these processes of metal transport and vaporisation of volatile elements under high temperature conditions. This study uses microscopy, bulk rock compositions, in-situ micro-chemistry, and Cu isotopes for a plethora of tektite shapes and locales to identify, quantify, and chemically assess the distribution of elements within tektites. Furthermore, this study attempts to investigate the chemical heterogeneity of flow banding and shaping for the first time. Examination of tektites through microscopy revealed flow banding of roughly 30 µm thicknesses but vary significantly within each sample. In-situ analysis of these bands indicates favoured extraction and diffusion of moderately volatile elements, such as Cu, Zn, and K, across individual samples on a micron scale. Cu isotope data supports the high temperature fractionation of elements during tektite formation with $\delta^{65}$Cu values (‰) generally increasing with decreasing Cu concentration (ppm). $\delta^{65}$Cu varies across a range of highly fractionated values of 1 to 7‰ and follow Rayleigh fractionation models. This geochemical, and extensive micro chemical analysis presents the first investigation into the composition of flow banding of tektites and heterogeneity between tektite shapes.

## Clues to past habitable environments on Mars? Formation of sulfur-rich amorphous materials

[1,*]King, P.L., [1,2]Renggli, C.J., [1]Oborski, E. M. & [1]Hunt, T.

1. Research School of Earth Sciences, Australian National University, Canberra ACT 2601, Australia.

2. Institut für Mineralogie, Westfälische Wilhelms-Universität Münster, Münster, 48149 Germany.

Mars is a sulfur-rich planet covered in dust with ~5 wt.% $SO_3$ and veins with ~40 wt. % $SO_3$. To evaluate habitable environments on Mars, it is critical to understand how sulfur phases form because they provide insight into the past environmental conditions.

Amorphous materials contribute significant sulfur to rocks in Gale crater (<10 wt.% $SO_3$) with the remainder locked in sulfates, and minor sulfides. Meteorite studies show that amorphous glasses – formed by volcanism or shock (>900 °C) – contain <1.3 wt.% $SO_3$. Thus, glass is not a significant sulfur sink in Gale crater. Instead, sulfur-rich amorphous phases are proposed to form at low temperatures aqueous/glacial and diagenetic processes in sediment requiring copious water.

We propose that volcanic and impact processes may also form sulfur-rich amorphous materials at moderate temperatures (~300-1000 °C). These events – that occurred extensively in Mars's early history – may have produced sulfur-rich amorphous material through gas/fluid condensation or gas-solid reactions. In volcanic events, S-rich gas condensed tiny, amorphous sulfur minerals or reacted with primary minerals/glass to form sulfates. Impact processes produced $SO_2$-rich plumes that recycled sulfur in amorphous (impact-damaged) materials. Studies of samples returned from Mars will provide a unique view of these materials and their formation processes.

## Ordinary chondrites, IIE iron meteorites and the theorised HH chondrite group: a statistical investigation of the groups and genetic relationships

[1]Kirby, R.K.

[1] rachel.kirby@monash.edu, Monash University, Australia

IIE iron meteorites formed through impact events on an ordinary chondrite (OC) parent body, however the nature of that parent body is debated in the literature. Some authors propose that they formed on the H chondrite parent body, whereas others suggest that they are derived from a theoretical HH chondrite parent – a group that is further reduced and higher in iron than H chondrites. A statistical evaluation of OCs and IIE iron meteorites demonstrate no clear evidence for a HH chondrite group. Furthermore, statistically IIE irons are indistinguishable from H chondrites in O isotopes, metal chemistry, olivine and pyroxene composition, and chondrule size. Mo, Ru, Cr and Ge isotopic compositions for IIE irons overlap with OC values. These results are consistent with the formation of IIE iron meteorites through impact event/s on a H chondrite parent body, accumulating metal at the surface/near-surface environment of an asteroid. These processes could account for the metal-rich spectra of asteroids such as 16 Psyche which has an overall density that is closer to H chondrites than iron meteorites.

# The Role of Layered Ejecta Craters In Our Understanding of Mars

[1]* Jones, E.

*lead presenter

[1] Curtin University

Layered ejecta craters are a unique morphology of impact crater which are observed to form on planetary bodies with water or other volatile reservoirs, such as Mars, Ganymede, Enceladus. Their occurrence on Mars is widely interpreted to indicate the past presence of volatiles, as a cryosphere, in the subsurface. This makes them important tracers of water resources, subsurface geology, and the habitability histroy of the planet. In this talk I will present some of my past research, the current state of understanding and remaining questions into layered ejecta crater on Mars

## The compressive strength of lunar regolith simulant geopolymer blocks

[1]Clint McNally

[1]Clint.mcnally@csiro.au, CSIRO Mineral Resources, Pullenvale Australia

In-situ resource utilization (ISRU) relies on the ability to make use of materials present in the lunar environment. The abundant presence of aluminosilicates on the lunar surface, and calcium plagioclase being a large constituent of the mare and highland regoliths, present an opportunity to use geopolymerization techniques to fabricate construction materials in-situ on the lunar surface. Building on CSIRO experience in geopolymer techniques, two feed materials were chosen: an Off Planet Research (OPR) highlands regolith simulant, and local southeast Queensland basalt quarry material that is geochemically similar to lunar mare. Using techniques from previous work, formulation of starting materials were created and set in standard 50mm cube moulds for compressive testing. Curing occurred in a sealed environment and then were opened to room temperature and pressure.

Compressive testing occurred at 17 days for the local quarry material and 21 days for the OPR material and compressive strengths were measured of 7MPa and 11.5MPa, respectively. The geopolymer was not fully set at that stage and displayed plastic deformation. Further curing occurred at room temperature and pressure from the previous compressive test point. Compressive testing occurred again at 38 and 42 days for each sample. Compressive strengths were 15.16MPa and 19.04MPa, respectively. The geopolymers fractured during compression testing suggesting curing had progressed to a point of completion, thus creating stronger bonds that require more energy to fracture. This study provides a starting point for strong ISRU construction material and lays the path forward for evaluating this method of construction in the lunar environment.

**Numerical impact modelling applied to understanding the structure and resource potential of lunar and planetary surfaces**

*Miljkovic, K., H. C. Branco, A. Sierszputowska, J. E. Hedgepeth, J. Maughan, E. G. Jones.

katarina.miljkovic@curtin.edu.au, Curtin University, School of Earth and Planetary Science, Space Science and Technology Centre, Perth, Western Australia

Impact cratering is a geological process common for all planetary bodies. The mechanics of impacts and associated shock physics can be simulated to high fidelity. When validated against observation, these simulations can provide answers to fundamental questions about the structure and evolution of planetary surfaces. Here, we offer a brief update on the research progress made by our impact modelling group. We discuss various numerical techniques applied to a range of impact conditions on the Moon, Earth, and Mars. The largest and oldest impact craters provide evidence into the earliest crustal structure and evolution in the inner solar system. Mid-range complex impact craters are sufficiently to significantly alter the structure of planetary crusts. Our work has investigated subsurface water reservoirs and hydrothermal mineralization on Mars and Earth. While small simple craters only affect shallow crustal layers, they are sufficient to expose subsurface ice deposits on Mars and contribute to the overall understanding of ice reservoir on Mars. Impact mechanics also assists in connecting lunar and planetary samples with their source craters, further contributing to the understanding of the geochemical structure and evolution of planetary surfaces. This work is funded under the ARC Future Fellowship.

# Crystalline imaging with the Planetary Instrument for X-ray Lithochemistry

[1,2*]Orenstein, B.J., [1,2]Flannery, D.T., [2,3,4]Jones, M. W. M., [5]Wright, A.P., [6]Davidoff, S., [7]Tice, M. M., [1,2]Nothdurft, L., [6]Allwood, A.C.

[1] brendanjozef.orenstein@hdr.qut.edu.au School of Earth and Atmospheric Sciences, Queensland University of Technology, Brisbane, QLD 4000, Australia.

[2] Centre for Planetary Surface Exploration, Queensland University of Technology, Australia

[3] Central Analytical Research Facility, Queensland University of Technology, Brisbane, QLD 4000, Australia.

[4] School of Chemistry and Physics, Queensland University of Technology, Brisbane, QLD 4000, Australia.

[5] School of Computational Science and Engineering, Georgia Institute of Technology, Atlanta, GA 30332, USA.

[6] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109, USA.

[7] Department of Geology and Geophysics, Texas A&M University, College Station, TX 77843, USA.

The Planetary Instrument for X-ray Lithochemistry (PIXL) is an energy-dispersive micro-x-ray fluorescence spectrometer on NASA's Mars 2020 mission *Perseverance* Rover, designed to create in-situ elemental maps of geological targets and high-accuracy elemental abundance data for key rock components [1]. As the instrument scans a target, PIXL's x-ray beam can be incident onto crystal lattices, resulting in the detection of diffraction [2-4].

Partitioning individual diffraction peaks according to peak energies reveals the spatial extents of crystals exposed in abrasion patches created by the rover [5]. We present a new method that uses PIXL's instrumental geometry and the energy-dispersive Bragg equation to partition individual peaks. Our method avoids grouping diffraction peaks of different energies, and the noisy partitions associated with previously-employed techniques [6]. Visualisation of the sizes and orientation of crystals has enabled important insights into rock formation, including the discovery of an igneous cumulate in the floor of Jezero Crater [5], and will eventually result in a higher-quality database of elemental abundances for minerals examined by the rover.

1. Allwood, A. C. *et al.* PIXL: Planetary Instrument for X-Ray Lithochemistry. *Space Sci Rev* **216**, 134 (2020).

2. Schofield, R. E. *et al.* Using Diffraction Peaks in X-Ray Fluorescence Spectra from the Mars 2020 PIXL Instrument for Mineral Phase Identification. *48th Lunar and Planetary Science Conference* **Abstract #2955**, (2017).

3. Orenstein, B. J. *et al.* A statistical approach to removing diffraction from X-ray fluorescence spectra. *Spectrochimica Acta Part B: Atomic Spectroscopy* **200**, 106603 (2023).

4. Wright, A. P., Nemere, P., Galvin, A., Chau, D. H. & Davidoff, S. Lessons from the Development of an Anomaly Detection Interface on the Mars Perseverance Rover using the ISHMAP Framework. in *Proceedings of the 28th International Conference on Intelligent User Interfaces* 91–105 (2023). doi:10.1145/3581641.3584036.

5. Liu, Y. *et al.* An olivine cumulate outcrop on the floor of Jezero crater, Mars. *Science* **377**, 1513–1519 (2022).

6. Tice, M. M. *et al.* Alteration history of Séítah formation rocks inferred by PIXL x-ray fluorescence, x-ray diffraction, and multispectral imaging on Mars. *Science Advances* **8**, eabp9084 (2022).

**What have we learnt about the formation of our solar system from observing protoplanetary discs?**

[1]*Price, Daniel J., [2]Pinte, C., [2]Borchert, E. & [3]Cuello, N.

*lead presenter

[1]daniel.price@monash.edu, Monash University, Vic 3800, Australia

[2] Monash University, Vic 3800, Australia

[2] IPAG, Univ. Grenoble-Alpes, France

I will try to place the formation of our solar system into the typical context of star and planet formation seen elsewhere in our Galaxy. Star formation is chaotic, with nearly all stars forming in clusters from turbulent molecular clouds. By observing protoplanetary discs around young stars we now have very direct evidence that planet formation occurs during this early, chaotic period. Applying this understanding to the solar system may shed fresh light on difficult problems, such as the truncation of the Kuiper Belt, possible origin of Chondrules and CAIs, the NC/CC dichotomy and the solar obliquity. I will explain how a coherent picture might emerge by combining the best of both astronomy and planetary science.

## Maximising the information from precious material: insights from the analysis of asteroid Itokawa particles

Rickard, W.D.A.[1]*, Timms, N. [2], Jourdan. F[2], Saxey, D.W. [1], S. M. Reddy[2], Bland, P.A.[2] & Nakamura, T.[3]

*lead presenter

[1] w.rickard@curtin.edu.au, John de Laeter Centre, Curtin University, Perth, GPO Box U1987, WA, Australia

[2] School of Earth and Planetary Sciences, Curtin University, Perth, GPO Box U1987, WA, Australia

[3]Tohoku University, Aoba, Sendai, Miyagi 980-8578, Japan

Particles brought back from asteroid Itokawa provide a rare opportunity to study unaltered extra-terrestrial material. Best practice involves analytical workflows that maximise the information extracted from the sample whilst minimising material consumption or alteration. This involves utilising state-of-the-art instrumentation and methods as well as planning the analyses so that they are conducted from non-destructive to minimally destructive. Here we present data from a correlated characterisation of particles from asteroid Itokawa using time of flight secondary ion mass spectrometry (ToF-SIMS), electron backscatter diffraction (EBSD), transmission electron microscopy (TEM), energy dispersive spectroscopy (EDS), $^{40}Ar/^{39}Ar$ geochronology, and Atom Probe Tomography (APT). By combining high resolution chemical, microstructural and isotopic information we were able to determine the formation and alteration history of the asteroid. The detailed characterisation of several Itokawa grains has resulted in publications on space weathering processes, proto-planetary disk processing as well as parent body formation and resetting events.

# Using comparative planetology techniques to determine the requirements of a preliminary in-situ robotic mission investigating the suitability of a lunar skylight for human exploration

[1]*Rose, E., [2]Hargrave, C. & [2]Shaw, M.

*lead presenter

[1] 103916142@student.swin.edu.au, Swinburne University of Technology & CSIRO, Australia

[2] CSIRO, Australia

A future lunar scientific outpost could take advantage of the natural shielding properties of underground lava tubes and reduce exposure levels to solar radiation, cosmic rays, and micrometeorite impacts. This would mitigate several engineering and design challenges as well as prolong the lifespan of infrastructure by reducing material fatigue from thermal cycling. Before a prospective lunar lava tube can be accessed by humans, it will be necessary to assess its suitability for habitation and structural resilience to both natural and anthropogenic disturbances.

This project investigates how such an assessment of a lunar skylight could be undertaken by an in-situ robotic scouting mission through an analogue study that applies both remote and in-situ assessment approaches to a known terrestrial skylight in Victoria, Australia.

Current detection methods used to search for skylights and lava tubes on the Moon will be applied to the terrestrial skylight and lava tube system. Then, a field study using a hypothetical lunar exploratory approach to the terrestrial skylight will evaluate the feasibility of such an approach while considering potential equipment and operational limitations arising from lunar environmental conditions. The lessons learnt from this comparative planetology study will inform a proposed study of lunar lava tube mission parameters.

## Petrogenetic insights from textural complexity of lunar glass beads

[1]*Timms, N.E., [1]Nemchin, A.A., [2]Norman, M.D., [3]Salin, E. & [3]Whitehouse, M.J.

*lead presenter

[1] n.timms@curtin.edu.au, Curtin University, Australia

[2] Australian National University, Australia

[3] Swedish Museum of Natural History, Sweden

Lunar glass beads include spherules, dumb-bells, bars, and irregular glass-rich objects that are typically tens to hundreds of micrometres across and occur in lunar soil at all known landing sites. Lunar glass beads preserve a wide range of glass compositions and ages and are considered to represent quenched molten droplets that are ballistic ejecta from impact cratering events (impact glasses) and/or eruptive volcanic lava fountain products (volcanic glasses). As such, studying glass beads can provide insights into the volcanic and impact history of the Moon. This study investigates the textural complexity of lunar glass beads from various Apollo landing sites revealed by backscatter electron (BSE) imaging and electron backscatter diffraction (EBSD) and energy dispersive spectroscopy (EDS) mapping. Individual beads show a wide range of textures, with variable digestion of remnant mineral and lithic clasts, compositional inhomogeneity of the glass, sizes and abundance of vesicles, immiscible Fe-metal melt droplets, and nucleation and growth of neoformed porphyritic phases or crystalline matrices within the melt droplet. The wide range in textures is explained in terms of differences in the initial composition of the target rock (impact glasses) or magma (volcanic glasses), initial melt temperature, physical mixing, and cooling rate of the beads.

## Colour Analysis of Meteors Using the Desert Fireball Network

[1]*Todd, C.J., [1]Horner, J., [2]Sansom, E.K. & [2]Devillepoix, H.A.R.

*lead presenter

[1]u1141791@usq.edu.au, University of Southern Queensland, Australia

[2]Curtin University, Australia

In this work, I present a preliminary analysis of the colours of fireballs observed by the Desert Fireball Network (DFN) in November and December 2015. Colour-indices are determined for each observed fireball, these results are used to perform a comparative study between the different meteor showers and sporadic meteors in the data. From the data presented, a relationship has been found between the initial velocity of an incoming fireball and the colour-index at an altitude of 75km, which matches previous literature. The ability to study the behaviour of fireballs as a function of altitude is a relatively new development, made possible by the continuing improvements in fireball detection technology. As such, future work will be able to expand upon this finding and investigate trends at a variety of altitudes. Meteors in this dataset tend to become bluer at lower velocities which matches similar trends from previous literature. Though the statistical significance of this study is limited due to the small sample size, the results show the potential for the use of meteor colour to better define a relationship with colour. This result might allow meteors to be classified into their showers from a single camera observation where trajectory and orbit data is not available.

# Ureilite meteorites: Our only extensive sample suite from the mantle of a dwarf planet

[1]*Tomkins, A.G., [2]Jennings, L.A.

*lead presenter

[1]andy.tomkins@monash.edu, Monash University, Australia

[2]University of Münster, Germany

We have generated thermometry data for numerous ureilite meteorites and developed a thermal model for the ureilite parent body (UPB), which we use to examine the effects of size, composition, and formation time on the thermal evolution of the UPB. Our results imply that, (1) the UPB formed within 1 m.y. of initial condensation of the Solar System, and (2) main group ureilites (~80% of all ureilites) formed across a broad range of depths in the mantle with fewer samples coming from the deeper mantle and many samples coming from shallower levels, whereas only rare samples might come from the igneous crust. Pyroxene chemistry suggests that the UPB may have been large enough to achieve pressures >2 kbar in the lower mantle, and coupled with the thermal models, this implies that the parent body had a diameter on the order of 900 – 1000 km. Given the strong evidence of a catastrophic impact in ureilites, we propose that the UPB was not totally destroyed as commonly supposed, but rather, a giant impact entirely removed the crust and the majority of the mantle. This would leave a dense M-type asteroid equivalent in size to some present in the solar system today; Psyche is possibly the remnant of the UPB, but may be slightly too low in FeO.

# Formation and Composition of the Earth's Hadean Protocrust

Simon Turner[1], Bernards Wood[2], Tim Johnson[3], Craig O'Neill[4]

[1]Department of Earth and Environmental Sciences, Macquarie University, Australia simon@turner@mq.edu.au

[2]Department of Earth Sciences, University of Oxford, UK bernie.wood@earth.ox.ac.uk

[3]School of Earth and Planetary Sciences, Curtin University, Australia tim.johnson@curtin.edu.au

[4]School of Earth and Atmospheric Sciences, Queensland University of Technology, Australia craig.oneill@qut.edu.au

Although the Earth together with other terrestrial planets must have had an early-formed protocrust, the composition of this crust has received little attention. The protocrust was extracted from an extensive magma ocean that was formed by accretion and melting of asterodial bodies. Both experimental and chronological data suggest it is probable that the silicate melt ascending from this magma ocean formed in equilibrium with, or after, metal were extracted to form the Earth's core. Here, we show that a protocrust formed under these conditions would have had refractory trace element characteristics remarkably similar to those of the current average continental crust. There are major implications for subsequent planetary evolution. For example, many geochemical and isotopic arguments for when and how plate tectonics began are compromised with the key question changing to when and how did crustal recycling become efficient?