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Book of Abstracts

Contents

139

Modelling planet formation

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I will discuss our attempts to understand recent imaging of protoplanetary discs taken with the ALMA telescope with 3D modelling. We now have direct evidence for large (2-3 times the mass of Jupiter) planets formed within 1-2 Myr after the birth of the star. We stand at the edge of a hugely exciting discovery space in this area, with new observations giving very direct evidence for newborn planets. I will also discuss new perspectives on protoplanetary discs – namely that they are not "protoplanetary" at all, but rather "planet hosting".

125

Constraining Ejecta Blanket Conditions of Dhofar 018 from a Single Pristine Chondrule

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Introduction: A thin section of howardite Dhofar 018 preserving an pristine radial pyroxene chondrule has been analysed in order to constrain ejecta blanket conditions on asteroid 4 Vesta. This meteorite is known to contain clasts and fragments of exogenic material, including ordinary and chondrites, enstatite meteorites, and ureilites [1]. However, a single intact chondrule has yet to be reported.
Results: The chondrule has a mean composition of En70.6Fs23.6Wo7.0 and Mg#76 (n=24), and is most likely associated with ordinary chondrites. Electron microprobe analysis reveals a sharp unaltered contact with the surrounding howardite with no major element diffusion across the chondrule itself. Sulfur veins are observed cutting through both the chondrule and surrounding howardite matrix. The matrix is composed of diogenite/eucrite associated pyroxenes, olivine, and plagioclase.
Discussion: Studying the chondrule in Dhofar 018 allows the conditions of the ejecta blanket at the time of entrainment to be constrained. The unaltered matrix-chondrule contact and lack of major element diffusion suggests that the ejecta blanket was moderately cool during lithification, as noticeable Mg-Fe diffusion is typically observed at temperatures well exceeding 900 ℃ in experimental conditions [2, 3] – thus giving an upper limit to the temperature conditions experienced by the chondrule within the howardite. Following lithification of the ejecta blanket into the Dhofar 018 howardite, a period of sulfurization occurred and resulted in the narrow sulfide veins that cut through both the howardite matrix and into the chondrule. This process is often observed in brecciated HED meteorites, and is thought to occur rapidly (on a timescale of weeks) at approximately 800 ℃ from impact heating [4]. These conditions are further supported by observations of troilite-metal interactions in chondritic meteorites, in which small-volume post-impact metamorphism allows for the rapid precipitation of sulfides without altering the silicate phases [5]. This therefore constrains ejecta blanket conditions at the time of chondrule entrainment in Dhofar 018 to 800-900 ℃. Pressure has not yet been calculated but is assumed to be low as the meteorite does not show shock features. 40Ar-39Ar dating of Dhofar 018 gives an approximate age of ejection of 2.3 Ga [6], meaning that ordinary chondrite-associated chondrules were available in the inner Solar System post-Late Heavy Bombardment, and that these "micro" meteorites may be incorporated into various planetary surfaces and preserved in other groups of meteoritic breccias.
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Meteoritics & Planetary Science 44:1133-1149; [6] Korochantseva et al. (2010), 73rd Annual Meeting of the Meteoritical Society #5349.

137

Cryptic impact cratering during lunar magma ocean solidification

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The lunar cratering record is traditionally used to constrain the bombardment history of both the Earth and the Moon. It was suggested from different perspectives, including asteroid dynamics, lunar Apollo samples, impact simulations, and lunar evolution modelling, that the Moon could be missing evidence of its earliest cratering record. Recent studies suggested that lunar magma ocean (LMO) solidification could have been prolonged up to ~200 Myrs. This would then suggest that a significant portion of the large impact bombardment on the Moon must have occurred while the LMO was still solidifying. Our impact simulations show that impact basins forming during this time should have been susceptible to immediate and extreme crustal relaxation, rendering them likely invisible to gravitational, and possibly topographic, surveys. Any impact bombardment that occurred during LMO solidification is unlikely to have been entirely retained in the Moon's cratering record.

136

Seismic efficiency of meter-size impact craters forming on Mars

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The NASA's InSight mission has placed the seismometer SEIS less than a year ago on the surface of Mars. SEIS was designed to detect planet's seismic activity. One of the suspected seismic sources could be meteorite impacts. It was been previously estimated that impacts forming up to 30 m diameter craters could be detected by SEIS. They are large enough yet frequent enough to occur during the InSight mission lifetime.
We simulated the formation of meter-size impacts on Mars, using the iSALE-2D numerical shock physics hydrocode. It has previously been shown that the properties of target medium (bedrock or porous regolith) influence the crater formation process and final crater morphology. In this work, our investigation focused on the propagation of impact-generated pressure waves in the target medium. We showed that the seismic efficiency, k (part of the impactor's kinetic energy that is transferred to seismic energy) is heavily dependent on the existence of pore space in the target medium. Previous works placed broad constraints that span 5 orders of magnitude for impact events in lunar and planetary environments. Our work helps narrow down this range; The seismic efficiency for porous targets was k~$10^{-5} - 10^{-4}$ and for bedrock targets $k = 10^{-3} - 10^{-2}$.
Together with the InSight science team, this is the first time numerical impact modelling is being connected with the seismic generation and propagation modelling. Defining seismic efficiency for meter-size craters on Mars is of great interest to the NASA InSight science, because it helps determine conditions of impact events that we hope to detect.

135

Australian Participation in Mars 2020

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I will present an introduction of NASA's upcoming Mars 2020 rover mission, an update on it's progress, and an overview of Australian participation.

134

Comparing search techniques and terrain types on the rates of meteorite cold finds: analysing the close line and petal search techniques on the Nullarbor Plain, South Australia.

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Searching for meteorites in the Australian deserts has increased in the past 10 years with the inception of both the Desert Fireball Network (DFN) and Monash Meteorite Collection Teams (MMCT). These groups have different methodologies derived from the primary objective. Notably, the DFN search technique relies more on close line search techniques similar to that employed in evidence searches at crime scenes. Given the target of these searches are single stones tracked to a fall line by cameras, this search technique makes sense. A single target stone will often be missed if there are large gaps in search paths, and therefore it is important to cover as much of the target area as possible. By contrast, the MMCT have developed a search technique more related to trail searches for missing persons. This technique, termed 'petal search', allows searchers to spread out across a much larger area. As there is no defined search line, searchers are free to pick the best terrain to search.

In addition, petal searches more easily identify meteorite strewn fields; groupings of related meteorites from a single fall breaking up during atmospheric entry in a broader area. This effectively makes these meteorites a much larger target for searchers. Hence, searchers who are more widely spaced are more likely to find individual stones belonging to a strewn field, and therefore more likely to find more stones from the same fall.

Here we present data from the past two years of collection trips to the Nullarbor Plain by the MMCT using petal search technique and compare this to the line search in the recent Hughes fall target area. In 2019, the MMCT search area amounted to 4.07 km2 , in which 46 meteorites were found, at a rate of 11.3 cold find meteorites per km2 . By comparison, the DFN Hughes fall search, covering approximately 1 km2 found only a single cold find. This would indicate that meteorite searches for cold finds should only utilise the petal technique, however terrain conditions require investigation due to the difference in these sites. The 2018 MMCT collection expedition covered a similar area to the 2019 area, collecting 23 meteorites, reducing the rate to 5.8 meteorites per km2 . Notably,

the region searched in 2018 consisted of more wet erosion features in comparison to the 2019 area. By comparison, the Hughes search area lacked oases and consisted mostly of hummock sands and low xeric scrubland. Terrain factors are little understood, but it is likely that they have a significant impact on find rates. Petal searches allow searchers to select the most open terrain, and therefore allow for more effective searching than intensive close line searches.

132

High survivability of micrometeorites on Mars: Sites with enhanced availability of limiting nutrients

Andrew Tomkins[None] ; Matthew Genge[None] ; Alastair Tait[None] ; Sarah Alkemade[None] ; Andrew Langendam[None] ; Prudence Perry[None] ; Siobhan Wilson[None]

NASA's strategy in exploring Mars has been to follow the water, because water is essential for life, and it has been found that there are many locations where there was once liquid water on the surface. Now, to narrow down the search for life on a barren basalt-dominated surface, there needs to be a refocusing to a strategy of "follow the nutrients". Here, we model the entry of metallic micrometeoroids through the Martian atmosphere, and investigate variations in micrometeorite abundance at an analogue site on the Nullarbor Plain in Australia, to determine where the common limiting nutrients available in these (e.g., P, S, Fe) become concentrated on the surface of Mars. We find that dense micrometeorites are abundant in a range of desert environments, becoming concentrated by aeolian processes into specific sites that would be easily investigated by a robotic rover. Our modeling suggests that micrometeorites are currently far more abundant on the surface of Mars than on Earth, and given the far greater abundance of water and warmer conditions on Earth and thus much more active weather system, this was likely true throughout the history of Mars. Because micrometeorites contain a variety of redox sensitive minerals including FeNi alloys, sulfide and phosphide minerals, and organic compounds, the sites where these become concentrated are far more nutrient rich, and thus more compatible with chemolithotrophic life than most of the Martian surface.

133

Micrometeorite PGEs: Opening the window to ancient atmospheres

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Friction heating of FeNi metal micrometeorites during atmospheric transit causes melting and oxidation by atmospheric gases. Due to differences in the oxidation and evaporation rates of platinum group metals, this process causes Os/Ir fractionation. The Os/Ir ratio increases as a function of extent of oxidation because Os is easily oxidised and evaporates at low temperature as an oxide, whereas Ir is not oxidised. We have found through LA-ICP-MS of a large number of modern micrometeorites that there is a broad range of Os/Ir ratios, reflecting the range of particle sizes and atmospheric entry velocities and angles, which produces a range in the duration of atmospheric entry that is characteristic of the modern Earth's density and O2 concentration. We hypothesise that this range could be compared with that found in ancient fossil micrometeorites, or the Os/Ir of bulk rock samples, to investigate differences in atmospheric density at specific points in geologic time. Our next steps will be to model the entry conditions experienced by micrometeorites as a function of atmospheric density, and to conduct bulk rock analyses of ancient sedimentary rocks lacking detrital input.

131

Stellar cluster production of SLRs and their impact on planetary

formation

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The short-lived radionuclides (SLRs), such as 26Al and 60Fe, were the major heat sources responsible for the melting and differentiation of planetesimals in the early Solar system. The Earth and other terrestrial planets formed by accretion of such differentiated planetesimals. An interesting question is, how is heating provided by these SLRs related to the planetary conditions for life? The melting and differentiation of planetesimals is crucial to creating planets with iron-rich cores. The Earth's liquid iron core generates our planet's magnetic field, which acts as a shield from irradiation by powerful solar winds, and thus provides radiation-free conditions for complex life thrive. Our project focuses on understanding accumulative effect of abundance of SLRs from stellar clusters which then trigger a new generation of stars and planets to form, and how that that contributes to the habitability conditions of those newly formed planets.

128

Grazing Fireballs and What They Can Tell Us About Our Dynamic Solar System

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Extremely long-lived fireball events have been described previously in scientific literature, the first of which being the Great Daylight Fireball of 1972 (Ceplecha, 1979; 1994). Since then, there have been several similar grazing events reported. In just four years of operation of the Desert Fireball Network (DFN), the largest fireball network in the world, we have recorded two skipping events. One of which covered over 1300 km before returning to space. These events are incredibly interesting for numerous reasons: they are natural aerobraking experiments, they push the limits of our understanding of how to accurately model the atmospheric passage of meteoroids, and close encounters like these events may play a role in diffusing different planetary materials throughout the solar system. There are three situations that can occur when an object has a grazing encounter with the Earth's atmosphere: the object has a high amount of energy when it impacts the atmosphere allowing it to successfully escape back to interplanetary space, the object has a low total energy and it begins to graze the atmosphere but does not have sufficient energy to escape and either fully ablates or falls to the surface, and finally the object could have the 'Goldilock's energy' and just barely escape the atmosphere but be captured into a geocentric orbit. The events observed by the DFN fall into the first two categories described respectively.

129

Droning for Meteorites

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We have devised a new way to find meteorite falls observed through the Desert Fireball Network, by using deep learning algorithms and unmanned aerial vehicles (drones). This new methodology is aimed to reduce labor spent in the field and increase the rate of meteorite recovery.

126

Suspected seismic signals from DFN fireballs

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The Desert Fireball Network (DFN) is the world's largest fireball camera network and is located in the Australian outback. It consists of 52 observatories, covering an area of 3 million km^2 aimed to detect fireballs, recover meteorites and to calculate their orbits [1]. The observatories are optimised to image 1-100 m size objects having a brightness between 0 to 15 magnitudes [1].

The aim of this study is to search for seismic signals from fireballs observed by the DFN. Data of the DFN was used together with data from several stations of the Australian National Seismograph Network operated by Geoscience Australia. The DFN provides information of major fireball events including their exact time and location. The nearest seismic station(s) for each fireball event within a distance of 200 km was searched and the data was checked for marking seismic signals. Seismic signals were searched for 1161 fireball events observed by the DFN. About 12 weak seismic events were found that could be associated with fireballs. The peaks in the time series data are consistent with the calculated arrival times of the direct airwave, suspected to have originated from the meteoroid break-up. These signals cannot be explained through earthquakes or other sources of seismic signals.

Through the study of fireballs on Earth we can get more information on Martian fireballs as the atmospheric pressure on Mars is compatible to Earth's atmospheric pressures at 30-60 km where meteors, fireballs and bolides break-up. However, the effect of attenuation of such signals due to the different atmospheric composition on Mars is yet unknown, but we can focus on the fragmentation of these meteoroids. This is the general direction the future work will focus which may also help with the analysis of data from the InSight mission.

References:

[1] Devillepoix H. A. R. et al. (2019) MNRAS, 483:5166-5178.

127

Fabrics in the Martian Shergottites: Implications for Emplacement on Mars

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Martian meteorites are mostly igneous, with only one notable exception, which still contains igneous clasts. Within the igneous samples that have not undergone brecciation, crystallographic textures can be used to infer the environment of emplacement, such as is commonly applied to terrestrial igneous rocks. Such textures have already been used to deduce the igneous setting for the Martian nakhlite meteorites, and provided further information regarding the lava flow that the suite of nakhlites originated from (e.g. Daly et al., 2019).

Shergottites encompass a wide variety of petrologic textures, ranging from 'fine-grained' to poikilitic. Here, we focus on the 'fine-grained' and diabasic shergottites to investigate the presence or lack of crystallographic and shape alignments across six samples. At the meeting, we will present our findings in the context of the environment of emplacement of each sample on Mars.

130

Kinematic detection of embedded protoplanets

Christophe Pinte[None] ; Daniel Price[None] ; Valentin Christiaens[None] ; Daniel Mentiplay[None]

We still do not understand how planets form, or why extra-solar planetary systems are so different from our own solar system.
Recent observations of protoplanetary discs have revealed rings and gaps, spirals and asymmetries. These features have been interpreted as signatures of newborn protoplanets, but the exact origin is unknown, and remains poorly constrained by direct observation.
In this talk, we show how high spatial and spectral resolution ALMA observations can be used to detect embedded planet in their discs.
We report the kinematic detections of Jupiter-mass planets in the discs of HD 163296 and HD 97048. For HD 97048, the planet is located in a gas and dust gap. An embedded planet can explain both the disturbed Keplerian flow of the gas, detected in CO lines, and the gap detected in the dust disc at the same radius.
While gaps appear to be a common feature in protoplanetary discs, we present a direct correspondence between a planet and a dust gap, indicating that at least some gaps are the result of planet-disc interactions.

124

Spectral Characterization of Martian meteorites: Searching for the Source Craters on Mars

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There are ~130 confirmed Martian meteorites, yet their source craters on Mars still remain unknown. Locating their source craters would be extremely significant in providing geological context to the only samples from Mars that we have. Geological context is essential if we wish to fully develop our understanding of these meteorites, and therefore develop our understanding of Mars and geological past. Infrared spectroscopy is a powerful remote sensing tool, used in many industries to unravel

the composition of target surfaces. NASA and ESA have sent multiple satellite and rover missions to Mars with infrared spectrometers on board, which have generated large global thermal infrared (TIR) datasets of the Martian surface. To use these datasets, you have to compare the bulk spectra acquired from the surface to known terrestrial spectra. In doing so, you can pick apart the Martian surface spectra to determine its mineralogy and composition. There has been limited use of comparing TIR spectra of Martian meteorites directly to the Martian surface. This is due to a number of issues such as the destructive process of acquiring TIR spectra and the rarity of Martian meteorites. However, recent advances in non-destructive analysis has opened up new opportunities. We present new TIR spectra of Martian meteorites acquired using non-destructive micro-Fourier Transform Infrared (μFTIR) spectroscopy. Not only can we acquire TIR spectra of the bulk meteorite, but also its individual mineralogy. This allows us to create our own Martian meteorite mineral spectral library. This can be used to fill in the compositional blanks in the terrestrial mineral spectral library and then also create whole synthetic Martian rock spectra derived from real Martian meteorites to map the surface geology of Mars, and search for their source craters.

123

Automatic surface age dating of impact events on Mars

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Counting impact craters on surfaces of terrestrial bodies is currently the only way to estimate the age of a planetary surface and the duration of geological processes occurred in the past. This approach requires a tedious mapping and morphological inspection of a large number of impact craters. We created a Crater Detection Algorithm trained on Martian orbital imagery in order to compile all small impact craters on the Martian surface down to around 100m in diameter. We applied our algorithm on the CTX mosaic (6m/px) between 45 degrees of North and South covering more than 70% of the entire Martian surface, and detected around 17M of impact structures >50m. From these detection, we are now able to obtain an estimation of the age of any geological structures having shaped the surface of Mars at different spatial scales. We primarily focused on impact event dating. Results on the estimation of the age of ~200 impact craters formed during the Amazonian and Hesperian period (<3.5 Ga), will be presented. A spatial analysis of the distribution of impact craters detected on their blanket will be also introduced in the aim to distinguish primary impact crater population from secondaries. Finally, an analysis of the age distribution of these impacts will allow us to estimate the impact flux on Mars.