Astrobiology Society of Britain, 4th Biannual Meeting

Royal Holloway

University of London

April 7th-9th 2010

ASB4 Programme

Wednesday 7th April

12:00 Lunch, Registration & Accommodation

MARS: Chair, Karen Olsen-Francis

13:00 James France, A photohabitable zone in the Martian snowpack? A laboratory and radiative-transfer study of dusty water-ice snow.

13:25 Annika Simpson, Effect of Water-Rock Ratios on Microbial Weathering: A Strategy for Site Selection on Mars?

13:50 Hitesh Changela, Hydrothermal Fluids on Mars: Evidence from Martian Meteorites.

14:15 Lewis Dartnell, Effects of cosmic radiation on the detection of biosignatures in the martian surface.

14:40 Satadal Das, Terraforming the Mars with silicon-utilizing microorganisms.

15:05 Tea/Coffee.

15:30 Mars Rover Demonstrations.

ASTROBIOLOGY IN THE UK: Chair, Dave Waltham

16:35 Lewis Dartnell, Survey on Astrobiology Research and Teaching Activities within the United Kingdom.

17:00 Close.

Thursday 8th April

LIFE'S ORIGIN AND EVOLUTION: Chair, Lewis Dartnell

09:00 KEYNOTE ADDRESS. Euan Nisbett, The Evolution of Earth's Atmosphere.

09:40 Michael McCabe, On the Origin and Evolution of Life in the Galaxy.

10:05 Terence Kee, The H-Phosphinate-Pyruvate System; En Route to Proto-RNA?

10:30 Tea/Coffee

11:00 Katie Marriott, Chemical Complexity in the H_3PO_2:Pyruvate System.

11:25 Aidan J. Ross, Carbon in the solar system.

11:50 Sohan Jheeta, An Alcoholic Universe! Irradiation of 1:1 Mixture of NH3:CH3OH Ice at 30 K with 1 keV Electrons

12:15 Lunch

IMPACTS: Chair, Zita Martins

13:15 Jonti Horner, The Neptune Trojans - A New Source for the Centaurs?

13:40 Jonathan Watson, Use of Organic Molecular Parameters to Estimate Post Impact Cooling in the Boltysh Impact Crater.

14:05 Paula Lindgren, Calcite microstructures as a palaeopiezometer in carbonaceous chondrites.

14:30 Adam Nixon, Glycine Survival in Hypervelocity Impacts.

14:55 Mark Burchell, Survival In Hypervelocity Impacts of Complex Organic Compounds.

15:20 Tea/Coffee.

HABITABILITY: Chair, Jonti Horner

16:10 KEYNOTE: Helmut Lammer, The Classification of Habitats and the Evolution of Habitable Planets.

16:50 Martin Leitzinger, Spectral signatures of stellar activity: AD Leo - an example.

17:15 William Bains, How weird can biochemistry be? A biotechnological perspective.

17:40 Lucy Norman, Life in Titan's Liquid Hydrocarbons: Are There Any Plausible Cell Membranes?

18:05 Close.

19:00 – 22:00 Conference Dinner, Royal Holloway Picture Gallery.

Friday 9th April

DETECTING LIFE: Chair, Terence Kee

09:00 KEYNOTE: Giovanna Tinetti, Characterising extrasolar worlds today and tomorrow.

09:40 Susana E. Jorge-Villar, A Tool for Planetary Exploration: Raman Spectroscopy for Bio- and Geo-Marker Detection.

10:05 Jean-Philippe Beaulieu, From frozen Super Earth to Habitable Earth via microlensing.

10:30 Tea/Coffee

11:00 John Parnell, Application of sulphur isotopes to investigate deep biosphere on Earth and Mars

11:25 Samuel Spinks, Sulphur isotopes as a signature for evolving microbial life: an example from the Mesoproterozoic

11:50 Jonti Horner, The search for life: Which "Earth" to target?

12:15 Ingo Waldmann, Characterisations of exoplanetary atmospheres from the ground.

12:40 Lunch

EXTREMOPHILES: Chair, Mark Burchell

13:40 Susana E. Jorge-Villar, A Look At Extremophile Organisms Across Raman Spectroscopy.

14:05 Mariliza Derveni, The effect of space radiation on immunoassay reagents: Implications for the Life Marker Chip Experiment for ESA's ExoMars mission.

14:30 Karen Olsson-Francis, Isolation of an Extremophilic Cyanobacterium Using Low Earth Orbit as a Selection Factor.

14:55 Lottie Davis, Preliminary data on the culturable microbiology of an alkaline soda lake.

15:20 Tea/Coffee.

16:10 Katinka Apagyi, Evolution of Methanogens living in the Polar permafrost.

16:35 Paul Wilkinson, Thermophilic bacteria in cold volcanic basalt.

17:10 Claire Cousins, Differing Bacterial Diversity From Two Basaltic Lava Lithologies In A Cold Volcanic Desert.

17:35 Conference Closes.

Evolution of Methanogens Living in the Polar Permafrost

Katinka Apagyi

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The effects of Global Warming are by far the most noticeable at the Polar regions. The annual shrinking of the ice sheets as well as the increased risk this poses to local and global wild life and human welfare make the research of the Poles all the more relevant.

Methanogenic microorganisms are one of the major contributors to the build up of atmospheric methane, which has been shown to be a more potent greenhouse gas than CO2. Despite their wide distribution and relevance with respect to Global Warming, however, little is known about the diversity and genomic composition of methanogens. The thawing permafrost is predicted to transform into a boggy land with lots of organic matter and anaerobic conditions underground, which would be ideal for the flourishing of methanogenic communities. This, in turn, would lead to the release of even more methane. Such an alarming prospect warrants a better understanding of how temperature changes may affect the rate at which methanogens produce and metabolise methane.

We propose to conduct a study of these communities found in the Siberian permafrost. Samples would be taken on a regular basis and analysed using metagenomic tools. Such a comparative analysis would thus focus on how methanogens living under extreme cold conditions make the transition into a warmer environment and change their methane producing and metabolising potential and population distribution accordingly.

This could ultimately aid the optimization of models predicting the rate of Global Warming.

How Weird Can Biochemistry Be? A Biotechnological Perspective

William Bains

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Living things have distinct characteristics that constrain their possible chemistry, and hence where and how we might look for them. Major limitations are the stability, solubility and reactivity of the chemicals that make up life, and energy sources to drive metabolism. I will discuss a programme for systematically exploring these parameters, to see if we can say whether terrestrial biochemistry of proteins, sugars, nucleic acids and fats is likely to be inevitable for terrestrial planets, and whether life based on radically different chemistry is possible in very different environments. I will illustrate the second of these by discussing life on the surface of Titan and Triton. As well as being entertaining, this has relevance to how we look for biosignatures remotely and with landers.

From Frozen Super Earth to Habitable Earth via Microlensing

J.P. Beaulieu

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In the last fifteen years, astronomers have found over 415 exoplanets including some in systems that resemble our very own solar system. These discoveries have already challenged and revolutionized our theories of planet formation and dynamical evolution. Several different methods have been used to discover exoplanets, including radial velocity, stellar transits, direct imaging, pulsar timing, astrometry, and gravitational microlensing which is based on Einstein's theory of general relativity. So far 10 exoplanets have been published with this method. While this number is relatively modest compared with that discovered by the radial velocity method, microlensing probes a part of the parameter space (host separation vs. planet mass) not accessible in the medium term to other methods. The mass distribution of microlensing exoplanets has already revealed that cold super-Earths (at or beyond the "snow line" and with a mass of around 5 to 15 Earth mass appear to be common (Beaulieu et al., 2006, Gould et al., 2006, Sumi et al. 2010) . We detected a scale 1/2 model of our solar system (Gaudi et al., 2008), several hot Neptunes/Super Earth, shown that our detection efficiencies extends to 1 Earth mass planets (Batista et al., 2009). We have made the first measurement of the frequency of ice and gas giants beyond the snow line, and have shown that this is about 7 times higher than closer-in systems probed by the Doppler method. This comparison provides strong evidence that most giant planets do not migrate very far (Gould et al. 2010). Microlensing is currently capable of detecting cool planets of super-Earth mass from the ground (and on favourable circumstances down to 1 Earth), with a network of wide-field telescopes strategically located around the world, could routinely detect planets with mass as low as the Earth. Statistics about Mars to Earth mass planets, extending to the habitable zone will be achieved with space based wide field imagers such as EUCLID. EUCLID is a 1.2m telescope with optical and IR wide field imagers and slitless spectroscopy, proposed to ESA Cosmic Vision to probe for Dark Energy, Baryonic acoustic oscillation, galaxy evolution, and an exoplanet hunt via microlensing. A 3 months microlensing program will already efficiently probe for planets down to the mass of Mars at the snow line, for free floating terrestrial or gaseous planets and habitable super Earth. A 12+ months survey would give a census on habitable Earth planets around solar like stars. This is the perfect complement to the statistics that will be provided by the KEPLER satellite, and these missions combined will provide a full census of extrasolar planets from hot, warm, habitable, frozen to free floating.

The H-Phosphinate-Pyruvate System; *En Route* to Proto-RNA?

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Contemporary organisms use orthophosphate derivatives (PO_4^{3-}) in their cell biochemistry,[1] yet questions remain as to how Nature was able to accumulate, activate and exploit the orthophosphate group from geological sources with both poorly solubility and low chemical activity.[2] Gulick argued[3] a central role for reduced oxidation state phosphorus (P) oxyacids such as H-phosphonates ($H_2PO_3^-$) and especially H-phosphinates ($H_2PO_2^-$) in prebiotic chemistry on account of the greater water solubility of their metal salts and, with the presence of P-H bonds, a different reactivity profile to that expected of orthophosphate. The recent demonstration that hydrothermal corrosion of P-rich mineral phases such as schreibersite $(Fe,Ni)_3P$ within iron meteorites leads to production of various P-oxyacids including H-phosphonic (H_3PO_3)[4] and H-phosphinic[5] acids as well as orthophosphate has reignited interest in reduced oxidation state P chemistry in prebiotic environments. We are examining the prebiotic potential of reduced oxidation state P-chemistry through reactions with carbonyl substrates with reasonable prebiotic provenance including formaldehyde & glycolaldehyde, both intimately involved in the formose reaction for sugar synthesis[6] and pyruvic acid,[7] a product of glycolysis and feed-stock for the citric acid cycle, a fundamental cellular metablic process whose heritage is considered an ancient one. In this contribution we present some of our latest results on the H-phosphinate-pyruvate system.

References:

[1] Lodish H *et al*. (2000) *Molecular Cell Biology*, 4th Ed., W. H. Freeman & Co., New York. [2] Gulick A. (1955) *Am. Sci., 43*, 479. [3] Gulick A. (1957) *Ann. N. Y. Acad. Sci. 69*, 309. [4] Pasek M. A. (2008) *Proc. Nat. Acad. Sci. USA*, *105*, 853. [5] Bryant D. E.and Kee T. P. (2006) *Chem. Commun.* 2344. [6] Weber A. L. (2000) *Origins of Life and Evol. Biosph., 30*, **33**. [7] Cody G. D. *et. al*. (2000) *Science 289*, 1337.

Survival In Hypervelocity Impacts of Complex Organic Compounds Impacting Water, Sand and Frozen Ice Targets

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We have carried out a series of experiments where we froze a suite of complex organic compounds (anthracene, stearic acid and β,β-carotene dissolved in DMSO) in water ice and fired them in a two stage light gas gun [1] at a variety of targets (water, sand and ice). Impact speeds were 2 and 4 km s^{-1}. This mixture of organic materials was used as a frozen target in a previous set of impact experiments [2]. The intention was to test for successful transfer of complex organic materials from projectiles to targets in high speed impacts. After the shots the targets were sampled and analysed via several analytical methods. We found that DMSO survived the impacts, but are still trying to find trace amounts of the anthracene, stearic acid and β,β-carotene.

[1] Burchell M.J., et al., (1999) *Meas. Sci. Technol*. **10**, 41-50.
[2] Bowden S.A., et al., (2009) *International Journal of Astrobiology*, **8(1),** 19-25.

Survival of Biomarkers in Hypervelocity Impacts

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We report on a set of experiments to determine if bio-markers in a variety of organic compounds can survive in targets and projectile fragments which have undergone hypervelocity impacts. A Devonian siltstone, rich in organic materials was used as both a projectile and a target in different sets of experiments. Impact speeds were 2 – 6 km s^{-1}. Modelling of the impacts indicates peak shock pressures reach over 100 GPa in some experiments, but are a more modest 1 – 5 GPa in the lower speed impacts. We measured ratios of hopanoids and steranes, and the methylphenanthrene ratio. These tend to show an increase in thermal maturity resulting from impact processing. Absolute concentrations of bio-markers also showed changes and indicated change in composition rather than just destruction. We conclude that, at least at the laboratory scales here, complex organic materials of a biological origin can survive hypervelocity impacts.

Hydrothermal Fluids on Mars: Evidence From Martian Meteorites

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The nakhlite SNC meteorites crystallised as cumulates within a basic-ultrabasic lava flow or shallow intrusion on Mars 1.3 Ga.[1, 2] Within the nakhlites secondary mineral assemblages are present in fractures within olivine and mesostasis [2-4]. The secondary mineral assemblages vary between the nakhlites but include siderite, clay-like phases and salts. All of the nakhlites contain hydrated Fe-Mg silicate gel. Using FIB-SEM extraction techniques for TEM and EMPA, we have studied the structure and composition of clay and gel in secondary veins of five of the nakhlites and show that the gel composition varies between them.

TEM studies indicate a progressively oxidizing fluid. We have also identified compositional fractionation in the Mg# and (Fe + Si) abundance of the gel. The sawtooth fracturing found especially within Lafayette, Nakhla and GV has led us to propose a model describing the formation of the secondary assemblages in an impact-induced hydrothermal system terminated by precipitation of the amorphous gel and evaporation of soluble salts [5,6]. The similarity between the nakhlite secondary assemblages and those recently identified on Mars [7,8] also suggest that impact-induced hydrothermal alteration was a major process in the near-surface of Mars and might have provided a habitat for microbial life.

References: [1] Bridges J. C. & Warren P. H. (2006) *J. Geol. Soc.* **163** 229-251. [2] Bridges J. C. & Grady M. M. (2000) *Earth & Planet Sci. Lett.* **176** 267-279. [3] Gooding J. L. *et al* (1991) *Meteoritics* **326** 135-143. [4] Treiman A. H. (2005) *Chemie der Erde* **65** 203–270. [5]. Changela H. G. & Bridges J. C. (2009) *Meteoritics & Planet. Sci.* ***in rev***. [6] Changela H. G. & Bridges J. C. (2010) *LPSC* XXXX **#1407**. [7] Mustard *et al*. (2008) *Nature* **454** 305-309. [8] Ehlmann B. *et al*. (2008) *Science* **322** 1828-1832.

Differing Bacterial Diversity from Two Basaltic Lava Lithologies in a Cold Volcanic Desert

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Basalt is one of the most important and widespread substrates for microbial colonisation on Earth, and potentially on Mars. A molecular-based survey of basaltic lava in Iceland was conducted to identify the bacterial community residing in two basaltic lava lithologies with different mineralogical and textural characteristics: pillow lava and hyaloclastite. We found hyaloclastite supported a significantly higher level of bacterial diversity than the pillow lava, suggesting lithology plays an important role in the selection of phylotypes within the near-Arctic basaltic environment. In a wider context, this also shows how geological processes can influence the habitability of a planetary surface. Clone libraries of 16s rDNA genes constructed for these two lavas show both environments to be dominated by Actinobacteria, with many clones identified as Rubrobacter species. The clone library analysis also led to the identification of 64 and 30 operational taxonomic units (>97% similarity) for hyaloclastite and pillow lava respectively. Many of these shared a high level of similarity with those from other cold and dry environments, such as the Antarctic dry valleys.

Survey on Astrobiology Research and Teaching Activities within the United Kingdom

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While astrobiology is apparently growing steadily around the world, in terms of the number of researchers drawn into this interdisciplinary area and teaching courses provided for new students, there have been very few studies conducted to chart this expansion quantitatively. To address this deficiency, the Astrobiology Society of Britain (ASB) conducted a questionnaire survey of universities and research institutions nationwide to ascertain the current extent of astrobiology research and teaching in the UK [1]. The aim was to provide compiled statistics and an information resource for those who seek research groups or courses of study, and to facilitate new interdisciplinary collaborations. The report here summarizes details gathered on thirty-three UK research groups, which involved 286 researchers (from undergraduate project students to faculty members). The survey indicates that around 880 students are taking University level courses, with significant elements of astrobiology included, every year in the UK. Data are also presented on the composition of astrobiology students by their original academic field, which show a significant dominance of physics and astronomy students. This survey represents the first published systematic national assessment of astrobiological academic activity, and indicates that this emerging field has already achieved a strong degree of penetration into the UK academic community.

[1] Dartnell L.R., Burchell M.J., (2009) Survey on Astrobiology Research and Teaching Activities within the United Kingdom, Astrobiology vol. 9 (8), 717-730

Effects of Cosmic Radiation on the Detection of Biosignatures in the Martian Surface

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Cosmic rays represent a ubiquitous hazard to life on habitable planets and moons. Solar energetic protons (SEP) are accelerated by solar flares, and the galactic cosmic rays (GCR) are composed of protons and heavier ions accelerated to very high energy levels by supernovae throughout the galaxy. This cosmic source of ionising radiation is exceedingly detrimental to the survival of life, and the more energetic ions can penetrate substantial shielding. The surface of the Earth is protected from this exogenous ionising radiation by a deflecting global dipolar magnetic field and deep atmospheric column, but Mars no longer receives such shielding. It is currently poorly understood what effect this exogenous ionising radiation field is likely to have on the long-term survival of microbial life preserved in the martian near subsurface [1], or the ionising degradation of remnant biosignatures indicative of ancient extinct biology [2].

Work is currently focussing on the degradation of potential biosignatures by the cosmic ionising radiation field. Laser-induced epifluorescence has been proposed for up-coming probe instrumentation as a sensitive remote technique for detecting molecules of astrobiological significance [3]. Natural fluorophore targets include prebiotic aromatic compounds such as certain amino acids and polyaromatic hydrocarbons (PAHs), as well as cellular metabolites or pigments, including autofluorescence of the photosynthetic machinery.
Results will be presented from experimental studies conducted on the radiolytic degradation of such epifluorescent biosignatures by the flux of gamma rays, emulating the ionising radiation environment of the martian surface. Understanding the rate of this process is of crucial importance to the potential discovery of different biosignatures after exposure to ionising radiation over geological timescales – determining the detectability window of extinct biology.

[1] **Dartnell** et al (2007), Modelling the surface and subsurface Martian radiation environment: Implications for astrobiology, Geophysical Research Letters, 34, L02207
[2] **Dartnell** et al (2007), Martian sub-surface ionising radiation: biosignatures and geology, Biogeosciences, 4(4), p.545-558
[3] Storrie-Lombardi et al. Laser-Induced Fluorescence Emission (L.I.F.E.): Searching for Mars Organics with a UV-Enhanced PanCam. Astrobiology (2009) vol. 9 (10) pp. 953-964

Terraforming the Mars with Silicon-Utilizing Microorganisms

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Mars, an important planet close to the habitable zone of the Solar System (R=3393 KM, g=3.77 ms^{-2}, rocky planet with a desert like terrain) is probably a suitable planet, which could be terraformed easily. However, this is a cold planet (220K) due to its distance from the Sun (1.52 AU) and there is absence of a good air blanket and moisture. The vital proposals for terraforming the Mars, given by distinguished scientists so far, were too costly. Application of silicon utilizing organisms particularly algae like diatoms will liberate carbon-di-oxide and water from polar caps as well as from regolith, resulting warming up the planet to our desired ~ 290K level. The oxygen required on Mars (~ 240 mbar) may also be generated by activities of these silicon-utilizing organisms. The regolith consisting of ~ 38% SiO_2, ~ 20% water (ground ice), ~ 15% Fe_2O_3, ~ 10% carbonates, ~ 7% MgO, ~ 7% CaO, ~ 5% Al_2O_3 and the troposphere of Mars containing carbon-di-oxide, nitrogen, argon, oxygen, carbon-monoxide, water, neon, krypton, xenon, ozone will have no deleterious effect on the growth of these silicon utilizing diatoms. Constantly floating dust in the atmosphere, which is periodically stirred up by regional or global dust storms, will also have no inhibitory effect on the growth of diatoms. However, ethical issue should be considered before terraforming Mars, as there is a possibility of existence of life on its surface.

Preliminary Data on the Culturable Microbiology of an Alkaline Soda Lake

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Recent data indicates that Mars is a more environmentally heterogeneous planet than previously thought. The identification of a variety of minerals such as Fe/Mg smectite clays and carbonates indicate the presence of neutral to alkaline aqueous environments (Ehlmann, 2009). Soil with a pH of 7.5±0.5 have also been identified (Hecht et al., 2009). This data demonstrates that terrestrial localities with a neutral to alkaline pH are also of relevance to the search for life on Mars.

Lake Magadi is a soda lake in Kenya with a pH>9 and a salinity >30% (Warren, 2006), there are a number of high pH hydrothermal springs which feed into the lake.

Samples of water, sediment and biomass were collected from various sites. Analysis of the water chemistry enabled the design of a growth media with a pH 9-10. The samples were incubated at 37°C and isolated organisms are then identified through sequencing of the 16s rRNA gene.

The study of organisms from different terrestrial environments can provide vital insight into the array of conditions in which life can exist. Through the characterisation of various terrestrial extreme environments we can gain a fuller understanding of the limits of life and the sorts of extraterrestrial localities in which life might be found.

References

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Hecht, M. H., Kounaves, S. P., Quinn, R. C., West, S. J., Young, S. M. M., Ming, D. W., Catling, D. C., Clark, B. C., Boynton, W. V., Hoffman, J., Deflores, L. P., Gospodinova, K., Kapit, J. & Smith, P. H. (2009) Detection of Perchlorate and the Soluble Chemistry of Martian Soil at the Phoenix Lander Site. *Science,* 325**,** 64-67.

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The Effect of Space Radiation on Immunoassay Reagents: Implications for the Life Marker Chip Experiment for ESA's Exomars Mission

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In recent years, the rise of interest in planetary exploration and the emergence of Astrobiology as a promising field of research have lead to a number of programmes aiming to develop sensitive instruments for the detection of the molecular signatures of life in extreme environments. An antibody assay-based life detection instrument, the Life Marker Chip (LMC), is currently under development by a UK-lead consortium, commissioned for the ExoMars mission, the European Space Agency's (ESA) flagship mission to Mars, in collaboration with NASA. The molecular reagents at the core of instruments such as the LMC have no heritage of interplanetary mission use. Therefore, the design of such instruments for space missions must take into account a number of risk factors, among which the intense radiation environment that will be encountered en route to and on the surface of planets. In order to study the effects of space radiation on lyophilised immunoassay reagents, including antibodies and fluorescent dyes, a number of ground-based and space studies were carried out, the latter in the form of ESA's 2007 BIOPAN-6 low-earth orbit (LEO) space exposure platform. These experiments demonstrated the ability of antibodies and dyes to survive radiation doses up to ten times those expected for the ExoMars mission and remain functional after exposure to the physical environment of spacecraft launch and atmosphere re-entry, provided the samples were appropriately pre-treated and packaged. The combined ground and space radiation campaign lead to the conclusion that the radiation dose levels envisaged for the ExoMars mission will not be an insurmountable problem for the immunoassay components of the Life Marker Chip instrument.

A Photohabitable Zone in the Martian Snowpack? A Laboratory and Radiative-Transfer Study of Dusty Water-Ice Snow

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Dusty water-ice snowpacks on Mars may provide a habitable zone for DNA based photosynthetic life. Previous work has over estimated the depths and thicknesses of such photohabitable zones by not considering the effect of red dust within the snowpack. For the summer solar solstice, at 80°N and a surface albedo of 0.45, there is a calculated photohabitable zone in the snowpack between depths of 5.5 cm to 7.5 cm. For an albedo of 0.62, there is a calculated photohabitable zone in the snowpack between depths of 8 cm to 11 cm. A coupled atmosphere–snow radiative-transfer model was set to model the Photosynthetic Active Radiation and DNA dose rates through water-ice snow at the North Polar region of Mars. The optical properties of the polar caps were determined by creating a laboratory analogue to the Mars North Polar deposits, and directly measuring light penetration and albedo. It is important for future exobiology missions to the polar regions of Mars to consider the implications of these findings, as drilling to depths of 11 cm should be sufficient to determine whether life exists within the Martian snows, whether it is photosynthetic or otherwise, as at this depth the snow cover will provide a permanent protection from DNA damaging UV radiation.

Hydrothermal and Plasma Processing of Iron Meteorites

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Meteorites have long been considered as source of pre-biotic chemicals which could have assisted in the origination of life on Earth [1]. Iron meteorites are known to contain Schreibersite [$(Fe,Ni)_3P$] which is a good source of reduced phosphorus (P) capable of inclusion in reactions leading to major pre-biotic components. Between travelling through space and impacting Earth, meteorites are exposed to various conditions such as high energy plasmas, extreme heat during atmospheric entry and moisture from the atmosphere and oceans which could instigate a series of chemical reactions which give rise to chemical precursors required to produce a living organism.
We are currently looking at two different conditions to which Earth impacting meteorites would be exposed. Firstly we are looking at hydrothermal reactions of siderophilic P minerals such as Schreibersite, to identify and quantify any reduced P species produced and identify how these could have been used by Nature *en route* to life. Secondly we are looking at the interaction of high energy cold plasmas (analogous to the polar aurorae) with P minerals aiming to generate reduced, water soluble phosphorus oxy-acid species which could be utilised in the formation of cell membranes, RNA/DNA or possible precursors of these molecules.

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The Search for Life: Which "Earth" to Target?

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In the coming decade, it is likely that the first truly habitable planets will be discovered around nearby stars. As with all other fields of astronomical discovery, the number known will likely grow at an ever increasing rate, presenting observers with a large sample to search for evidence of life. But where should we look? The search for life on a distant planet will require an unprecedented amount of dedicated telescope time, and prove hugely costly. These factors taken together mean that it will clearly be impossible to simultaneously search all exo-Earths for life, and so observers will have to focus their attentions on just one or two targets. The task of selecting these targets will require detailed study of the various factors which can influence the habitability of a planet, such that the best candidates can be chosen. In this talk, intended to provoke discussion, I will briefly cover the wide range of effects that could render an otherwise ideal candidate planet sterile, or at least less likely to host life as we know it.

Jupiter: Friend or Foe

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It has long been believed that the planet Jupiter has played an important role in the development of life on Earth. Without the particular size and placement of Jupiter, it is argued, the Earth would have experienced a greatly enhanced flux of impacts from asteroids and comets, hindering or entirely preventing the development of life.

Despite the vigour with which this belief is held, very little work has been performed to examine the effect of Jupiter on the terrestrial impact flux. We have now completed the first detailed study on the effect of Jupiter's mass on the impact rate of the three types of potentially hazardous objects - the Near Earth Asteroids, the Short Period Comets, and the Long Period Comets. Although a massive Jupiter does act to whittle down the population of Long Period comets threatening the Earth, its role in managing the threat from Near Earth Asteroids and Short Period Comets is much less clear. Indeed, it seems that the impact risk from these families of object is significantly higher in Solar Systems with a Jupiter-mass planet than in those without, although the greatest level of "threat" is posed by a planet in a Jupiter-like orbit with a mass similar to that of Saturn. Above this mass the hazard falls away significantly.

The Neptune Trojans - a New Source for the Centaurs?

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The fact that the Centaurs are the primary source of the short-period comets is well established. However, the origin of the Centaurs is still under some debate, with a variety of source reservoirs being proposed in the last decade. Here, we suggest that planetary Trojans represent an additional significant source of Centaurs. Using dynamical simulations of the first Neptune Trojan discovered (2001 QR322) and integrations following the evolution of theoretical Neptune Trojans captured during simulations of planetary migration, we show that the Neptune Trojan population contains many objects which are unstable on both Myr and Gyr time-scales. Using individual examples, we show how objects that leave the Neptunian Trojan cloud evolve on to orbits indistinguishable from those of the known Centaurs, before estimating the flux from this region to the Centaur population. With only moderate assumptions, we show that the Trojans can contribute a significant proportion of the Centaur population, and may even be the dominant source reservoir. This result is supported by past work on the colours of the Trojans and the Centaurs, but it will take future observations to determine the full scale of the contribution of the escaped Trojans to the Centaur population.

An Alcoholic Universe! Irradiation of 1:1 Mixture of NH_3:CH_3OH Ice at 30 K with 1 keV Electrons

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We live in an alcoholic Universe! Methanol (CH_3OH) is the simplest of the primary alcohols and is the 6th most abundant molecule after H_2O, CO, CO_2, ammonium (NH_3) and O_2 in protostars (~6%) and comets (~2%). NH_3 is the third most common therefore it is likely that reactions between products arising from these two species will occur in comets and the interstellar medium (ISM).

In space there are two types of chemistries taking place gas phase and solid phase. The remit of this experiment was to study solid phase chemistry in simulated space conductions. The necessary space simulations conductions were achieved in an ultra high vacuum. Externally mixed gases of NH_3 and CH_3OH (1:1) were deposited onto an inert substrate made from zinc selenide crystal cooled to low temperatures typical of the ISM, using liquid helium. The deposited ice was then irradiated with I keV electrons. The products of such irradiation of ice were then studied using Fourier Transform Infrared (FTIR) spectrometry.

During the irradiation of pure CH_3OH and NH_3:CH_3OH many new products were formed. These are shown in Table 1 along with results published by other researchers:

Table 1: Bands observed during the electron irradiation of pure CH_3OH and NH_3:CH_3OH ices with 1 keV at 30 K

	As reported by other researchers			This work	
Molecules observed	van Broekhuizen *et al* (photolysis of H_2O:CO:NH_3) v (cm^{-1})	Gerakines *et al* (photolysis of pure CH_3OH) v (cm^{-1})	Moore et al (H^+ radiolysis of CH_3OH) v (cm^{-1})	CH_3OH (pure) e^- radiolysis v (cm^{-1})	NH_3:CH_3OH (1:1) e^- radiolysis v (cm^{-1})
$(CH_3)_2CO$			532-516		
CO2		655	650		
C_2H_5OH			748 (& at 864, 919, 887, 952		
H_3COHCO		910			
C_2H_5OH		1088 Stretch	1091		
H_3COHCO; v(CO)		1161			1167
CH_2OH		1197	1198		
v_6 H_2CO			1211		
v_6 H_2CO		1244	1246		
CH_4		1304	1302	1304	1303
CH_2OH	1352 (HCOOH)	1352		1345	1352
*$HCONH_2$	1386				1384
v_3 H_2CO		1497	1497 stretch		
$HCOO^-$	1580				1589
*$HCONH_2$	1690				1692 (?)
H_3COHCO		1718			

v_2 H_2CO		1719	1721	1724	1722
HCO	1849	1850	1844		1849
HCO		1863			
^{13}CO		2092			
CO		2138	2134	2136	2138
*OCN	2169				2166
*HNCO	2260				2258
$^{13}CO_2$		2278		2275	
v_3 CO_2		2342	2339	2341	2341
CH_4		3011			
?		3738			3738
HOH_2C-CH_2OH		Yes	Not reported	Yes	No

* Important nitrogen containing compounds

From the Table 1, it can be seen that two of the most significant compounds formed were cyannate (OCN^-) and isocyanic acid (HNCO). It has been shown by Shapiro R (1999) that cytosine can be formed from these two compounds. Cytosine, a pyrimidine derivative, is one of the four main bases found in DNA and RNA. The significance of this work for astrobiology and future experiments will be discussed at the conference.

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A Tool For Planetary Exploration: Raman Spectroscopy For Bio- and Geo-Marker Detection

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Raman spectroscopy has demonstrated the ability for bio- and geo- marker detection because of its analytical characteristics that make it a valuable technique for life detection on extraplanetary surfaces. Those characteristics involve the unambiguous molecular identification of organic and inorganic compounds without chemical or physical manipulation as well as the *in situ* macro- and micro- mode data acquisition. That is why both NASA and ESA have thought about Raman spectroscopy to be used for planetary exploration, particularly in the case of Mars, with the goal of finding life signals (although some of those projects have been, at this moment, stopped).

Several parameters have to be taking into account for the construction of a miniaturised Raman spectrometer because of their effect on the spectrum and, then, for the subsequent identification of both organic and inorganic compounds.

Laser wavelength has a powerful effect on fluorescence, sensitivity detection and resonance scattering, which compromise the limit from what a compound can be identified; furthermore, changes in the relative intensity of the bands can also be a problem for the correct signature assignment.

Spectral resolution affects to band definition, which becomes wider, and sometimes an appreciable shift is produced when two or more signatures are close each other. The intensity of laser power can produce mineralogical and organic molecular changes and distort the results.

The Raman spectroscopic study presented here has been carried out using 1064 (Bruker IFS66 spectrometer with FRA 106 Raman module attachment and dedicated microscope), 785, 633, 488 and 514 nm laser excitation (Renishaw inVia Raman Microscope coupled to a Leica DMLM microscope with 20X, 50X objective lenses); for 785 nm also a portable Inspector Delta-Nu spectrometer was used, using a range of spectral resolution from 1 to 64 cm^{-1} as main variables.

In this work, the effect of laser wavelength, laser power and spectral resolution have been studied and their impact and consequences for the observed spectral analysis has been assessed. A wide range of samples were used for that purpose. Comparison between the results obtained allows us to determine the most interesting Raman spectrometer characteristics for the looking for life signals on planetary surfaces.

A Look At Extremophile Organisms Across Raman Spectroscopy

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When life appeared on Earth, the environmental conditions on the surface were different to the present. At that time, probably Mars had similar conditions to those that were on Earth but, opposite to here, Mars evolved to a hardest and inhospitable situation. If life appeared once on Mars, it had to adapt to those more and more extreme circumstances. The looking for life signals on Mars and other planetary surfaces entails the study of terrestrial organisms living in extreme habitats, for instance extremely cold, arid, saline, dry, with high UV radiation level, etc. habitats.

It has been demonstrated that on Earth microorganisms have colonized all known extreme environments using different survival strategies. The most extended strategy is the colonization of interior of a porous rock, sometimes several millimetres below the surface in many cases together with the production of different types of organic molecules and pigments. The role of these biogenic compounds to prevent freezing, drying, damage for UV radiation, saline environments etc. has been widely studied. Mineralogical mobilization as well as polymorphous changes have also been detected in the proximity of microorganism zone inside the evaporates crusts or rocks and in particular cases can be also understood as a protective mechanism against hazardous situations.

All those bio- and geo- strategies can be detected as bio- and geo- markers in rocks and, then, described as signs of life.

For this study, we have analyzed by Raman spectroscopy a wide range of samples, such as endoliths from Antarctica Dry Valleys, algae from the Arctic glaciers, cyanobacteria from extreme saline and dry environments of the Atacama Desert, lichens from hot deserts, biofilms from hot springs and stromatolites from Australia. All specimens were studied without physical or chemical manipulation (except to expose the microorganisms for the analysis, directly on the sample). Raman spectroscopy has demonstrated to be a valuable technique for the detection and study of extremophiles biogenic compounds as well as biominerals. All these compounds could be considered as biosignatures and Raman spectroscopy seems to be one of the most useful techniques in planetary exploration for detect these signs of life.

The Classification of Habitats and the Evolution of Habitable Planets

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Studies of the evolution of Venus and Mars compared to the Earth, the discovery of methane-ethane surface lakes on Saturn's large moon Titan and of subsurface water oceans inside the moons of the Solar System gas giants like Europa, Titan and Enceladus, as well as the discovery of more than 400 exoplanets around other stars indicate that the classical definition of the habitable zone concept neglects more exotic habitats and may fail to be adequate for stars which are different from our Sun. Stellar and geophysical factors which are very important for the evolution of habitable Earth-like planets like the effects of the host star dependent radiation and particle fluxes on the evolution of atmospheres and initial water inventories will be discussed as well as the geodynamical environments which are necessary for planets where plate tectonics keep active over geological time scales and for planets which evolve to one-plate planets. A classification of four habitat-types is proposed. Class I habitats represents bodies on which stellar and geophysical conditions allowed Earth-analogue planets to evolve so that complex multi-cellular life forms may originate. Class II habitats includes bodies on which life may evolve but due to stellar and geophysical conditions that are different from the class I habitats, the planets rather evolve toward Venus- or Mars-type worlds where complex life-forms may not develop. Class III habitats are planetary bodies where subsurface water oceans exist which interact directly with a silicate-rich seafloor, while class IV habitats have liquid water layers between two ice layers, or liquids above ice. Furthermore, we discuss from the present viewpoint how life may have originated on early Earth, the possibilities that life may evolve on such Earth-like bodies and how future space missions may discover manifestations of extraterrestrial life.

Spectral Signatures of Stellar Activity: AD Leo - an Example

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A high level of stellar activity in form of frequent flaring and freuquent mass ejections can lead to the total loss of exoplanetary atmospheres due to evaporation and erosion. Simulations have shown such scenarii for close-in exoplanets orbiting M-stars. Information on stellar flaring activity is accessible more easily than information on stellar mass ejections, simply due to the difference in detection. In NASA/FUSE spectra of the dM star AD Leonis we find an interesting event lasting for only one spectrum. The first component of the OVI (1032A) duplet shows an enhancement of the blue wing, shifted by ~90km/s. This event ocurred one spectrum after a flare. We discuss several solar/stellar phenomena which might produce such a spectral feature and could therefore explain this event.

Calcite microstructures as a palaeopiezometer in carbonaceous chondrites

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Carbonaceous chondrite meteorites are derived from asteroidal parent bodies that formed during the earliest history of the solar system. The carbonaceous chondrites have a primitive chemical composition, but most of them have been subjected to extensive aqueous alteration. The aqueous alteration is indicated by the presence of e.g. calcite. The timing and history of the aqueous alteration is not well-understood, and have been widely discussed in the scientific literature.

Calcite ($CaCO_3$) has a crystal structure with planar CO_3 groups that are bridged via Ca cations. The bonding between the Ca cations and the CO_3 groups is rather weak, which allows calcite crystals to deform with pressure and produce various microstructures. The pressures at which the various microstructures in calcite are formed are not well-constrained.

In order to identify the pressures that the carbonaceous chondrites were subjected to during, or after, aqueous alteration, we carry out two sets of pressure experiments on undeformed terrestrial calcite; shock pressure and static pressure. After the experiments the calcite is analysed by EBSD (electron backscatter diffraction) analysis and Raman spectral analysis, to explore the presence and nature of microstructures and potential changes in the degree of crystallinity. The preliminary results will be presented in the conference.

Specific microstructures in carbonaceous chondrite calcite could indicate that water was present already in the earliest stages of the solar system. The response of calcite to pressure is also relevant to the debate of whether various microtextures in carbonates of the Martian meteorite ALH84001 formed by shock pressure or have a biogenic origin.

On the Origin and Evolution of Life in the Galaxy

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A simple stochastic model for evolution, based upon the need to pass a sequence of n critical steps (Carter 1983, Watson 2008) is applied to both terrestrial and extraterrestrial origins of life. In the former case, the time at which humans have emerged during the habitable period of the Earth suggests a value of $n = 4$. Progressively adding earlier evolutionary transitions (Maynard-Smith and Szathmary, 1995) gives an optimum fit when $n = 5$, implying either that their initial transitions are not critical or that habitability began around 6 Ga ago. The origin of life on Mars or elsewhere within the Solar System is excluded by the latter case and the simple anthropic argument is that extraterrestrial life is scarce in the Universe because it does not have time to evolve. Alternatively, the timescale can be extended if the migration of basic progenotic material to Earth is possible. If extra transitions are included in the model to allow for Earth migration, then the start of habitability needs to be even earlier than 6 Ga ago. Our present understanding of Galactic habitability and dynamics does not exclude this possibility. Galactic punctuated equilibrium (Cirkovic et al. 2009), proposed as a way round the anthropic problem, is not the only way of making life more common.

Chemical Complexity in the H_3PO_2:Pyruvate System. Implications for Abiogenesis

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Phosphorus (P) is found in information polymers (RNA and DNA), lipid bilayers of cell membranes, and in ATP, natures main source source of energy, and therefore is unarguably one of *the* most important elements in today's biology.

For P to play a part in the origins of life, micromolar (mM) levels of phosphate in water would have to have been available. However, phosphate minerals, such as the commonly occurring apatite family [$Ca_5(PO_4)_3(F,OH,Cl)$], are sparingly soluble in water and are significantly un-reactive towards most organic molecules. Recent work on the photochemical hydrolysis and Galvanic corrosion of schreibersite inclusions within iron meteorites suggests that H-phosphinic acid (H_3PO_2) would have been readily accessible to prebiotic environments. H-Phosphinic acid is readily soluble in water and the presence of two , reactive [P-H] bonds shows potential for prebiotic P chemsitry.

We report here an example of how this selective reactivity of H-phosphinic acid with possible prebiotic aldhydes, such as pyruvic acid and glycolaldehyde, could be part of the missing link between the RNA world and todays biology.

Dynamical Simulations of HR8799

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In late 2008, it was announced that the debris disc star HR8799 was host to at least three exoplanets, which had been discovered through direct imaging. The discovery prompted a wealth of dynamical studies intended to determine the stability (or otherwise) of the planetary system. The first studies suggested that the current three planet configuration is likely to be unstable over periods as short as 1 Myr. Subsequent studies favoured a configuration of the three planets in 1:2:4 resonance for maximum stability, with a system lifetime of the same order as the star (~ 100Myr). These results lead to speculation that the system could be in the process of a catastrophic orbital restructuring similar to that proposed to explain the hypothesised Late Heavy Bombardment in our own Solar system. In this work, we study the influence of planetary eccentricity on the stability of the HR8799 system, examining a wide range of potential orbital architectures matching the current observational constraints. Through systematic variation of the orbital eccentricities and radii of the three planets, we provide dynamical stability maps of the planetary system, revealing that the situation is far more complicated than originally thought.

Although many hypothetical architectures of the HR8799 are decidedly unstable, a broad range of initial conditions can give systems of dramatically greater stability, as a result of mutual resonant behaviour between the planets in question. We show that it is not infeasible that the planetary system could by dynamically stable on timescales at least as long as the lifetime of the parent star, even if we observe the system orientated face-on.

Are Sub-Surface Methanogenic Archaea a Likely Source of Methane on Mars?

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Methane was first detected in the atmosphere of Mars by ground-based infrared spectroscopy in 2003, and confirmed by independent observations shortly afterwards. Given that the e-folding time of methane in the martian atmosphere is on the order of 300–600 years, these findings point to a current or recent source of the gas.

There are two likely sources. The first hydrological: hydration and serpentization of ultramafic silicate minerals; the second biological: production of methane as a by-product of methanogenic microbe metabolism in the planetary sub-surface. Our work is designed to assess the likelihood this second scenario by determining the viability of methanogenic Archaea living on, and interacting with, Mars analogue igneous rocks and related minerals. We will be quantifying this relationship using the Archaea strains *Methanosarcina barkeri* and *Methanobacterium formicicum* as models of putative martian life.

The Evolution of the Earth's Atmosphere

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The early atmosphere was of inorganic origin. The geological record imlies the existence of liquid oceans at least sicne the early Archaean (3.8 Ga ago) and likely throughout the Earth's history. Under the Faint Young Sun, this poses a challenge – why didn't the ocean surface freeze? Perhaps in the Hadean it was indeed frozen, though the deep water would have bene kept liquid by the geothermal heat flux.

Since 3.5 Ga ago or earlier, the atmosphere has been manipulated on a large scale by life, to the extent that the air has become a biological construction, regulating the planetary climate. Anoxygenic photosynthesis may date back to 3.5 Ga or earlier. Methanogens may be of similar or greater antiquity, with methane emission helping to maintain liquid Archaean oceans, despite a faint young Sun.

Oxygenic photosynthesis may have begun around 2.9 Ga ago. This is the date of the first appearance of large-scale carbonate reefs, and from this date begins the distinctive partitioning of carbon isotopes between carbonate and organic carbon. Transition from the anoxic to the oxic state risks glaciation. CO_2 build up during a global snowball may be an essential precursor to a CO_2-maintained greenhouse with high levels of atmospheric O_2.

The modern atmosphere (last few Ma in a mainly glacial epoch) may be set by photosynthetic competition, close to Rubisco compensation limits. Rubisco I's specificity, which today may be almost perfectly tuned to the task of cultivating the global garden, controls the balance of carbon gases and dioxygen in the modern air/ocean system. In turn, this sets the global greenhouse, which maintains liquid oceans and sustains microbial ecology. Nitrogenase supports productivity by supplying fixed nitrogen. The balance between nitrifying and denitrifying bacteria, supplemented by anammox planctomycetes, manages the atmospheric nitrogen reservoir and thus air pressure.

Collectively, rubisco and nitrogenase may sustain the air in either of two permissible stable states: *either* an anoxic system with greenhouse warming supported by high methane mixing ratios, as well as by carbon dioxide, *or* an oxygen-rich system in which methane is necessarily only a trace gas and CO_2 alone acts as the managing greenhouse gas.

Glycine Survival in Hypervelocity Impacts

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In [1] it was reported that the amino acid glycine, had been discovered in samples returned by the NASA Stardust mission from comet 81P/Wild 2 [2-3]. Here we report on experiments to determine the survival of glycine in hypervelocity impacts such as those experienced in the Stardust encounter with comet 81P/Wild2. We investigated the interaction and potential decomposition of glycine in impacts with aerogel and foil similar to those on Stardust. Glycine was fired at the Stardust encounter velocity of ~6.1 kms^{-1} using the Light Gas Gun at the University of Kent [4]. The aerogel and foil samples were analysed using optical microscopy then Raman Spectroscopy and additionally SEM-EDX for the foils. We found residues in the foil and optical evidence of projectile fragments in the aerogel but no distinctive spectral signatures were obtained.

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Life in Titan's Liquid Hydrocarbons: Are there any Plausible Cell Membranes?

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The ultimate goal of our study is to determine the habitability of Titan's polar lakes, and the possible nature of any resident organisms.

We are working on building a thermodynamic model of solvent-solute interactions for the liquid and solid compounds thought to exist on Titan's surface, using similar techniques to Raulin (1987), Dubouloz *et al*. (1989) and Cordier *et al.* (2009), which may indicate differences in habitability between river, lakes and seas on Titan. We expect our model to reveal differences in the composition of rivers, seasonal and permanent lakes over time due to the influx of solutes and the precipitation /evaporation of solvents, which could support missions such as the proposed boat mission, 'TiME' (Stofan *et al*, 2009).

Indigenous biota of hydrocarbon lakes may have cell membranes that are reverse vesicles (having a hydrocarbon-based cytoplasm), or else 'extremophile' biota that originated in the subsurface ocean and adapted to surface conditions could have cells which are reverse micelles (having an aqueous cytoplasm). Whether certain amphiphiles and organo-silicon compounds will present micellization or liposomal behavior within liquid hydrocarbons, and to analyse their structure, we will perform experimental (microscopy, small-angle neutron scattering and small-angle x-ray scattering) and computational (coarse-grained molecular dynamic simulations) studies using environmental conditions comparable to those found on the surface of Titan.

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Implications of Stellar Activity for Exoplanetary Atmospheres

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Stellar XUV radiation is an important driver of the escape of planetary atmospheres. Young stars emit high XUV fluxes which decrease as they age. Since the XUV emission of a young star can be orders of magnitude higher than that of a comparable older one, this evolution has to be taken into account when studying the mass loss history of a planet. The temporal decrease of activity is closely related to the operating magnetic dynamo which depends on rotation and convection in Sun-like stars. Using a sample of nearby M dwarfs we study the relations between age, rotation and activity and discuss the influence on planets orbiting these low-mass stars.

Isolation of an Extremophilic Cyanobacterium Using Low Earth Orbit as a Selection Factor

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Cryptoendolithic cyanobacteria can survive long periods of desiccation, low temperature, and UV radiation; which are all prerequisites for life in space and on Mars (1). Although several extremophilic cyanobacteria have been exposed to space conditions, this is the first communication that uses Low Earth Orbit (LEO) to select for extremophilic cyanobacteria from a natural, non-extreme, cryptoendolithic environment (2).

A cryptoendolithic community from cliffs in Beer, Devon, UK was exposed to LEO. 16S rDNA analysis demonstrated that the cyanobacteria community consisted of the orders Pleurocapsales, Oscillatoriales, and Chroococcales. The rocks were sent into LEO for 10 days as part of the ESA funded BIOPAN VI mission and returned for analysis.

An extremophilic cyanobacterium, which was coccoid in nature and phylogenetically identified as a member of the order Chroococcales, survived 10 days in LEO. Ground-based experiments showed that the isolate was also able to survive 28 days of exposure to desiccation and Mars simulated conditions, 10 days of exposure to vacuum, and ionization radiation (3 KGy). The isolate was unable to survive exposure to UV radiation. Additional cyanobacteria were isolated after the ground- based experiments but none of these isolates survived exposure to LEO (3).

Little is known about the microbial requirements for survival in space. Extremophilic microbes isolated on Earth are not necessarily capable of surviving in this adverse environment. Consequently, the use of LEO as a selection factor, as demonstrated in this communication, is an ideal approach for isolating extremophilic microbes that can be used to study the physiological requirements for life in space.

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Sulphur isotopes as a window on the deep biosphere, Earth and Mars

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The evidence of methane in the martian atmosphere indicates that Mars may be venting gases. It is highly likely that if Mars supports life it will be in a deep biosphere where temperatures are high enough to allow liquid water and the dangers of oxidation/irradiation at the surface are mitigated. Methane seepages could, for example, originate at depths of several kilometres, and could help to fuel microbial sulphate reduction. The terrestrial record shows that microbial sulphur metabolizers are widespread, including in the deep biosphere. Sulphur species occur in both igneous and sedimentary rocks on Mars, so sulphur cycling occurs and could be the basis of metabolism. On Earth, sulphur isotope systematics allow the detection of microbial activity, and investigation of the isotopic composition of martian sulphur-bearing minerals is a feasible means of searching for a deep martian biosphere. Several domains of the terrestrial deep biosphere yield evidence of microbial activity through the precipitation of sulphides where sulphur isotope composition indicates fractionation greater than explainable by non-biological processes. These include altered basaltic glasses below the ocean floor and serpentinites, sandstone aquifers containing redox-controlled metalliferous deposits, and hydrothermal systems within impact craters. In several terrestrial examples, there is a clear link between microbial activity and the exploitation of, or generation of, methane. Serpentinites are of particular interest, given the discovery of olivine-rich rocks and serpentinite on Mars, and their potential for methanogenesis on Mars.

Carbon in the Solar System

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Carbon is the basis for all known life on Earth. Hence the abundance and distribution of carbon within our Solar System, and the wider galaxy, has implications for the possibility of extraterrestrial life.

The largest carbon reservoir in our Solar System is the Sun, with carbon being more common than both iron and silicon. The terrestrial planets display an average carbon isotope ratio that is within the range for the Sun, but much lower carbon abundances. Jupiter, however, has a higher abundance of carbon than the terrestrial planets. This tells us about the heterogeneity of the starting material of our Solar System and possible fractionation effects within the solar nebula.

Meteorites contain carbon as graphite, diamond, other pure C polymorphs, carbonates and (non-biological) organic molecules. With samples spanning a range of origins and compositions, from the basic building-blocks of the Solar System to asteroids to Mars, meteorites are an excellent resource for studying carbon in our Solar System.

We will present a review of carbon abundances and isotopic compositions for the Solar System using evidence from meteorites, interplanetary dust particles and astrophysical measurements and compare them with data for carbon on the Earth.

Effect of Water-Rock Ratios on Microbial Weathering: A Strategy for Site Selection on Mars?

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Several paleoclimate models have shown early Mars to have been a wet and warm planet, similar to early Earth, before losing its atmosphere and becoming a cold, dry planet. Elemental and mineralogical data from the Mars Rover Missions have revealed both low and high water-rock ratio alterations on Mars. The aim of this work is to, through understanding the influence of water-rock ratios on microbial rock weathering, find suitable sites that would or could have sustained life.

The experiment investigated how pH and rates of elemental release were affected by changing the water-rock ratio. Batch cultures of the acidophilic iron-oxidising bacterium *Acidithiobacillus ferrooxidans* were set up in flasks and monitored for 37 days using Icelandic basalt as the iron source. Three different water-rock ratios were used: large (2g in 800ml), medium (2g in 100ml) and low (25g in 25ml).

The optimum water-rock ratio was found to be the medium ratio, which achieved the highest cell numbers. Experiments showed that in the low ratio case neither an increase in pH due to proton quenching in rock weathering reactions or high heavy metal concentrations present in rocks was the cause of cell death. XANES at the Fe-K edge analysis showed localised areas of heamatite but the surface of the rock also showed Fe oxidation without a change in gross mineralogy. It is proposed that Fe^{3+} ions bind to the rock surface and preventing the release of reduced iron to provide energy for the bacteria. High water-rock ratios create too dilute an iron source for energy acquisition. This suggests that sites on Mars of medium water-rock ratios would be more likely to support or have supported microbial life.

HST Observations of Europa In and Out of Eclipse

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Europa is one of the most important astrobiological targets and there are planned future flagship missions. It is important therefore that we advance our understanding of Europa, its ocean and physical environment as much as possible. Here, we describe observations of Europa obtained during its orbital eclipse by Jupiter using HST. We obtained ACS/SBC FUV low-resolution spectra that show oxygen line emission both in and out of eclipse. We also used WFPC-2 and searched for broad band optical emission from fluorescence of the surface material, arising from the very high level of incident energetic particle radiation on potentially organic substances. The radiation levels at the surface of Europa are extremely intense, and incident radiation is responsible for the production of tenuous gaseous oxygen line emission. We discuss the detection limits of the optical emission, which allow us to estimate the fraction of incident radiation energy reradiated at optical wavelengths, through electron excited emission, Cherenkov radiation in the ice and fluorescent processes.

Reduction Spots in the Mesoproterozoic: Implications for Life in the Early Terrestrial Record

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Reduction spots which occur within continental and marine red beds are common in the geological record. The method of formation of reduction spots is a subject of debate but they are thought to be the result of the reducing nature of bacterial or microbial life present in the sediment during burial – which caused areas of reduction in sediment which was otherwise oxidised during diagenesis. Reduction spots often have dark cores which contain concretions commonly enriched in elements such as Vanadium and Uranium. This enrichment is also believed to be associated with the microbial reduction of the sediment. Here we report the presence of reduction spots with vanadium-rich mica (roscoelite) enriched cores within a terrestrial redbed sequence of Mesoproterozoic age. These findings may be a possible indicator of life within the terrestrial geological record during the Mesoproterozoic.

Sulphur Isotopes as a Signature for Evolving Microbial Life: An Example from the Mesoproterozoic

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Sulphur isotopes offer a means of tracing the evolution, and therefore the potential for life, through planetary history. Earths early atmosphere contained little free oxygen. Oxygen was introduced into the atmosphere sometime during the Archaean-Proterozoic transition as a microbial by-product. The current model for oxygenation implies two significant rises in oxygen levels during the Proterozoic – at 2.3Ga and 0.8Ga. Increased oxygen content during the Palaeoproterozoic (2.3Ga) resulted in sulphate formation from reactions between atmospheric oxygen and terrigenous sulphides. Sulphates were then reduced back to sulphide through the evolution of sulphate reducing microbes. The Neoproterozoic (0.8Ga) rise in atmospheric oxygen witnessed the subsequent evolution of metazoa. Iron sulphide (pyrite) nodules which are abundant within the shales of the Mesoproterozoic Stoer Group of NW Scotland provide an opportunity to test this oxygenation history. $\delta^{34}S$ values of the sulphides can be used as an indication of atmospheric oxygen levels. Sulphate reducing microbes independently fractionate sulphur from sulphate to sulphide. This study shows sulphides within the Stoer Group were sufficiently fractionated to indicate deposition in an environment with significantly more oxygen available than was previously thought at this time.

Modal Mineralogy of the Martian Meteorites Zagami, EETA 79001, SAU 005 and DaG 476

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The geology of Mars is characterised using remote sensing techniques applied to data acquired from the many orbiting and lander missions to Mars, alongside the analysis of Martian meteorites. Zagami, EETA 79001, SAU 005 and DaG 476 are all Martian (SNC) meteorites of the basaltic shergottite variety. Accurate modal mineralogy with respect to Martian meteorites is used to further understand its geology and the history of the rock, as well as to draw comparisons between other meteoritic samples and terrestrial analogues. Modal mineralogy is also important with respect to the search for life, or the evidence of past life, on Mars.

In this work we explore several techniques in attempting to accurately define modal mineralogy of the Martian meteorites. A new method for point-counting is presented alongside a position sensitive detector x-ray diffraction (PSD-XRD) method. We show that determining accurate modal mineralogies for SNC meteorites is highly dependent on the analytical method chosen and that thin sections may have different modes based on mineral heterogeneity in the samples. Our ultimate goal is to establish the modal mineralogy for a variety of Martian meteorites and then determine a calibration curve to be used for deconvolution of thermal infrared (TIR) spectral data from the surface of Mars.

Characterising Extrasolar Worlds Today and Tomorrow

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Half a century ago, Space Age began with the launching of the Sputnik. Now at the completion of a fairly detailed study of the planets of our own solar system, we are at the dawn of the Age of Exoplanets. More than 420 exoplanets, i.e. planets orbiting a star different from our Sun, are now known thanks to indirect detection techniques. In the first decade after their initial discovery in 1995 by Mayor and Queloz, the task was to find more and more of these astronomical bodies: the biggest, the smallest; the hottest, the coolest. In recent years, attention has switched from finding planets to characterising them. Among the variety of exoplanets discovered so far, special attention is devoted to those planets which transit their parent star. Most recent observations, in fact, have proved being possible to use the wavelength dependence of the reduction in the brightness of the central star as the planet passes in front to identify key chemical components in the planet's atmosphere. Molecules such as water, methane, carbon monoxide and dioxide have already been detected in the atmospheres of hot, giant exoplanets with Hubble and Spitzer Space Telescopes or from the ground. These planets are unsuitable for life, but the next generation of space telescopes -the James Webb Space Telescope or other mission concepts entirely devoted to the observation of exoplanet atmospheres- will guarantee the characterisation of fainter targets, in particular transiting large telluric planets (Super-Earths) in the habitable zone of stars colder than the Sun.

Characterisations of Exoplanetary Atmospheres from the Ground

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Among the 400-plus exoplanets discovered to date, an ever-growing sample of the transiting variety present themselves as good targets for further characterisation. Using transmission and emission spectroscopy it is possible to study the atmospheric compositions of these so-called "hot Jupiters" in more and more detail. The feasibility of such measurements has been demonstrated with great success using space-based observatories in the recent years. However, with the end of the Spitzer cold-phase, a gap in space-based observatories in the near- to mid-infra-red has emerged. As this gap will remain until the advent of the JWST, the importance of developing means of ground-based spectroscopic analysis is apparent. Recently it has been shown that the ground-based characterisation of exoplanetary atmospheres is indeed possible using only medium-sized telescopes in the near infra-red. My talk will give an overview of what has been done from the ground, what we have learned from these observations, and how to build upon our results in future developments.

Use of Organic Molecular Parameters to Estimate Post Impact Cooling in the Boltysh Impact Crater

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The Boltysh impact crater (65.17±0.64 Ma), is a 24km diameter complex structure formed on the Ukrainian shield. The crater fill sediments were successfully drilled in 2008 with over 400m of core recovered covering ~1 Ma post-impact. Impact events have the potential to generate sources of heat however the duration is unclear. To investigate the thermal history post-impact isomeric distributions of hopane biomarkers were investigated. Biologically derived isomers are thermodynamically unstable and rearrange to the more stable configuration. Throughout most of the core the organic matter is extremely immature as highlighted by the hopane ββ ratios of around 0.3. Between the depth of 565m to 577.25m the ββ/αβ+βα+ββ hopane maturity parameter progressively drops to 0; other ratios (βα/(αβ+βα) suggest that even as deep as 575m the samples have still not entered the 'oil window'. This indicates that temperatures above 575m were never in excess of 100 °C. The crater-fill sediments and their bio/carbon-isotope stratigraphy enable the timescale of the crater's cooling to be estimated; the crater remained warm for only 10,000 to 20,000 years post-impact. A short duration of warming post-impact has implications for impact craters to be considered as suitable environments for habitability and evolution of life on early planetary surfaces.

Thermophilic Bacteria in Cold Volcanic Basalt

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Cold terrestrial volcanic basaltic rock is abundant on Earth and is closely analogous to Martian volcanic basalts. Analysis of the ubiquitous presence of microorganisms within these terrestrial basalts allows for inference on the possible extremophilic organisms capable of surviving in Martian basalts.

16s RNA Phylochip community profiling of cold volcanic basalt retrieved from the area surrounding the Hekla stratovolcano, Iceland, revealed many interesting organisms and lineages, of note is the presence of thermophilic heterotrophic organisms. Some of these organisms were successfully cultured, with an optimal growth temperature of 65°C, on rich organic media. In order to determine whether these organisms were active *in situ* heavy metal susceptibility to Ni, Cu, Cr, Zn and minimal growth temperature of these organisms was determined. The organisms were capable of growth at heavy metal concentrations present in the basalt and at the sub optimal temperatures measured inside basaltic rocks.

The detection and possible growth of heat-loving organisms in a cold basaltic desert has important ramifications on the current attitudes towards the search for and impact of terrestrial extremophilic organisms and current thinking on the current and past habitability of Mars.