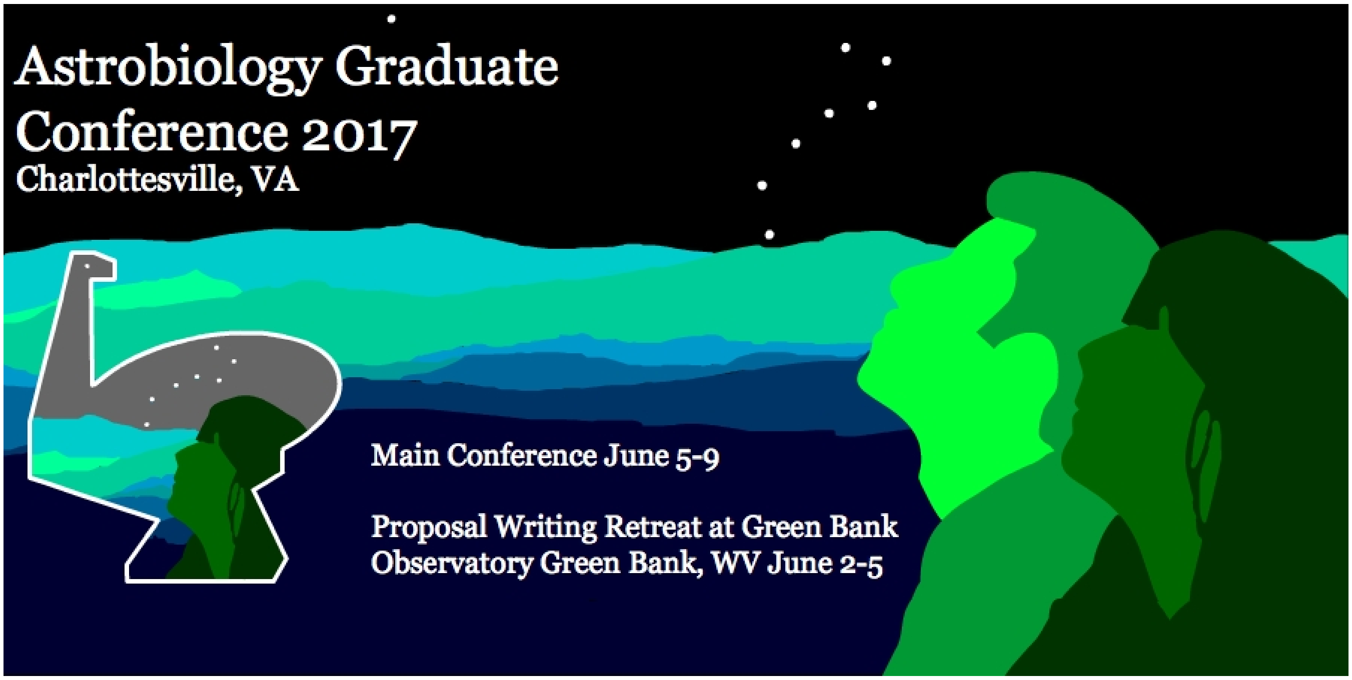

Proposal Writing Retreat: June 2 - 5, 2017

Conference: June 5 - 9, 2017

Charlottesville, VA

Sponsored by:
NASA Astrobiology Institute
National Radio Astronomy Observatory
ELSI Origins Network
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ACS Earth and Space Chemistry

Welcome to AbGradCon 2017

On behalf of the entire Organizing Committee, we would like to extend a heartfelt welcome to all participants in the 2017 Astrobiology Graduate Conference. AbGradCon is a unique and exciting opportunity - a meeting organized by and for early-career researchers in all fields of Astrobiology. This year's conference features contributions from nearly 90 participants in an incredible diversity of fields: Astronomy, Chemistry, Biology, Biochemistry, Geology, Planetary Science, Education, Mathematics, Information Theory, and Engineering. We are especially excited to welcome the largest contingent of international participants to the conference in recent memory. This spirit of international participation is strongly reflected by our gracious host institution, the National Radio Astronomy Observatory, which serves as the hub of all North American operations for the Atacama Large Millimeter Array (ALMA). ALMA is the world's premier radio telescope, and is an international partnership between Europe, North America, East Asia, and Chile.

AbGradCon is a chance for us to come together to share our research, collaborate, and network, without the pressure of senior researchers. AbGradCon 2017 marks the thirteenth year of this conference–each time in a different place and organized by a different group of students, but always with the original charter as a guide. These meetings have been wildly successful both when connected to Astrobiology Science Conference (AbSciCon), and as stand-alone conferences. Since it is organized and attended by only early-career researchers, AbGradCon is an ideal venue for the next generation of career astrobiologists to form bonds, share ideas, and discuss the issues that will shape the future of the field.

We hope that this, the 13th incarnation of AbGradCon, will prove as fruitful an experience for all our participants as it has for us in the past. Serving on the Organizing Committee has been a challenging, but extremely rewarding experience. We hope your experiences here this year will motivate many of you to return in future years, both as participants, and as members of the Organizing Committee. Please do not hesitate to reach out to any member of the Organizing Committee should you have any questions – we are committed to making this conference a resounding success!

Brett A. McGuire
Conference Chair

Andrew M. Burkhardt
Local Chair

Local Organizing Committee

Andrew Burkhardt, **local chair**

Aspen Clements

Ilsa Cooke

Brett McGuire, **conference chair**

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PWR Organizing Committee

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2017 Astrobiology Graduate Conference Sponsors

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Hotel Information

Omni Charlottesville Hotel

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Charlottesville, VA 22903

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Charlottesville Emergency Services

Emergency number: 911

Police (non-emergency, off-campus): +1 434-970-3280

Police (non-emergency, on-campus): +1 434-924-7166

Fire (non-emergency, off-campus): +1 434-970-3240

CONFERENCE SCHEDULE

All talks and posters will be held in the Omni Charlottesville hotel

MONDAY, JUNE 5TH

All day	Arrivals
5:15 - 6:30	Welcome Dinner
6:30 - 6:45	Welcome Address (Brett A. McGuire)
6:45 - 8:40	MA. Building Planets and Listening to the Songs of Their Peoples
8:40 - 9:00	Winning PWR Presentation
9:00 - 10:00	Rec Time/Games

TUESDAY, JUNE 6TH

8:00 - 8:45 Breakfast (Omni Hotel)

8:45 - 10:00	TA. Molecules: How Might We Best Blow Them Up?
10:00 - 11:00	PA. Poster Session & Coffee Break
11:00 - 12:00	TB. So Your Molecule Was Blown Up...

12:00 - 1:45 Lunch (Omni Hotel)

1:45 - 3:20	TC. It's Red, But is it Really Dead?
3:20 - 4:20	Career Panel
4:30 - 5:30	PB. Poster Session & Coffee Break
5:30 - 6:50	TD. Form Up! Move Out!

6:50 - 9:00 Dinner (Self-organized, Downtown Charlottesville)

9:00 - 10:00	Rec Time/Games

WEDNESDAY, JUNE 7TH

8:00 - 8:45 Breakfast (Omni Hotel)

8:45 - 10:00	WA. We're Not the Only Rocks in This Here Solar System
10:00 - 11:00	PC. Poster Session & Coffee Break
11:00 - 12:00	WB. Life: Can You Make It?

12:00 - 1:45 Lunch (Omni Hotel)

1:45 - 3:00	WC. Oh the Places You'll Go
3:00 - 4:00	PD. Poster Session & Coffee Break
4:00 - 6:00	Outreach Event

6:00 - 8:00 Dinner (Self-organized, Downtown Charlottesville)

8:00 - 10:00	Pub Trivia (Random Row Brewery)

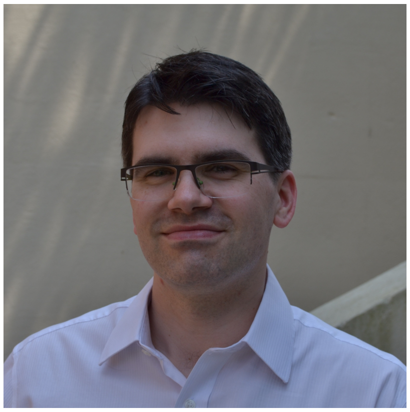
THURSDAY, JUNE 8TH

8:00 - 8:45	Breakfast (Omni Hotel)
8:45 - 6:00	Field Trip (Boxed Lunches Provided)
6:00 - 7:30	Conference Dinner (The Local)
7:30 - 8:00	Keynote Address (Kevin)
8:00 - 10:00	Rec Time/Games

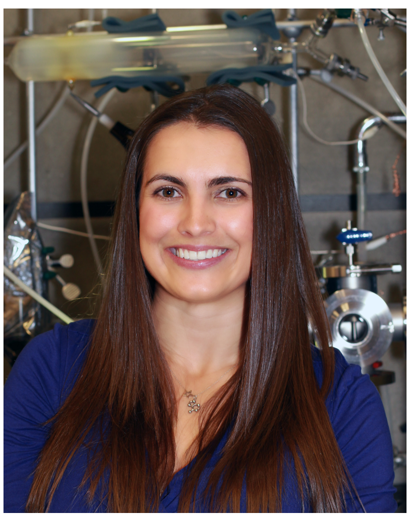
FRIDAY, JUNE 9TH

All day	Departures

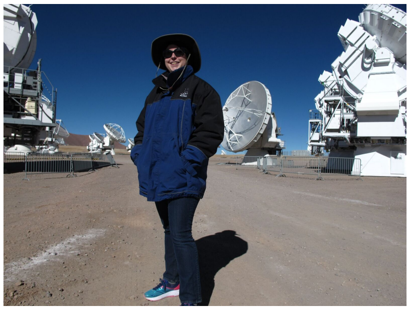
Invited Guests



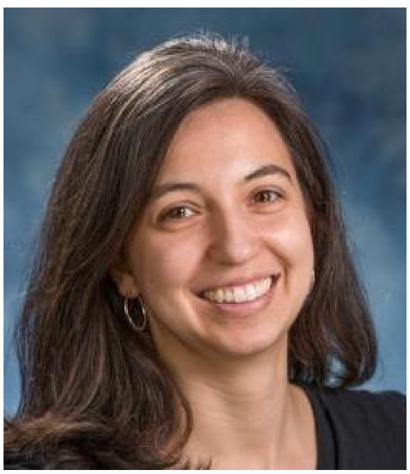
Dr. Garrod works in the field of astrochemistry and is Assistant Professor in the Departments of Astronomy and Chemistry at the University of Virginia. He gained his physics degree at University College London (UK), and continued at UCL to take a PhD in Astronomy in 2005, working with David A. Williams and Jonathan Rawlings. He was a postdoc with Eric Herbst at the Ohio State University, then worked at the Max Planck Institute for Radioastronomy (Bonn, Germany) as a Research Fellow sponsored by the Alexander von Humboldt Foundation. He was Senior Research Associate at the Center for Radiophysics and Space Research at Cornell University before moving to Virginia. Dr. Garrod's research uses computational methods to simulate chemical kinetics and molecular spectral emission in astrophysical regimes. He is interested in the formation and survival of complex organic molecules, and the influence of dust-grain surface processes and ice photolysis on interstellar and solar-system chemistry.



Dr. Sarah Hörst is an Assistant Professor in the Department of Earth and Planetary Sciences at Johns Hopkins University. She studies planetary atmospheric chemistry, in particular the formation and composition of planetary atmospheric hazes, using a combination of laboratory experiments, computer models, and observations. Dr. Hörst has a BS in Planetary Science and Literature from the California Institute of Technology and a PhD in Planetary Sciences from the University of Arizona.

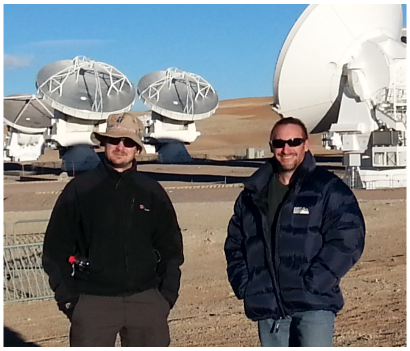


Amanda Kepley, Ph.D., has been playing with radio telescopes since she was a graduate student. She particularly enjoys pushing the limits of what these instruments can do to gain insight into how stars form in galaxies. Her primary research project is a survey of dense molecular gas tracers in 36 nearby galaxies with the new 16-pixel ARGUS receiver on the mighty Green Bank Telescope. The goal of this survey – the largest resolved extragalactic dense gas survey to date – is to quantify the relationship between dense molecular gas and star formation. Amanda has extensive experience with the calibration and imaging of radio telescope data, quantitative and qualitative data analysis, and scientific programming. She has also been significantly involved in both hardware and software testing as well as user support. She is an assistant scientist with the North American ALMA Science Center (NAASC) at the National Radio Astronomy Observatory (NRAO).



Dr. Miriam Friedel has over a decade of experience with scientific modeling, predictive analytics, and software engineering in fields spanning theoretical physics, transportation, neuroscience, and telecommunications. Her unique background enables her to bridge the gap between complex concepts and understandable, actionable results. Dr. Friedel has built and deployed models to predict customer churn and user segmentation, has mined survey responses for a major non-profit, and has wide experience analyzing complex scientific data in physics and biology. Miriam leads the Product Usage Analytics Program at Elder Research, and works closely with the Chief Scientist to provide guidance and leadership to the entire Commercial Data Science Team.

Prior to joining Elder Research, Miriam worked as a management consultant, helping clients to build and deploy software solutions with wide-ranging organizational impact; and as a research scientist in a neuroimaging lab, developing scientific software and performing advanced statistical analysis. Miriam has a B.S. in Physics from Brown University and a Ph.D. in Physics from the University of California, Santa Barbara and is a co-author on over fifteen peer-reviewed journal articles. When she is not at work, you can find her practicing yoga, reading, and spending time with her family.



Anthony Remijan received his Ph.D. in 2003 from the University of Illinois working with Lew Snyder on the identification of biologically important molecule detections in the interstellar medium and comets. His expertise is in the identification and mapping of weak spectral features using interferometers. After obtaining his Ph.D., Remijan received a National Research Council postdoc position working at NASA Goddard Space Flight Center with Mike Hollis. During his time as a postdoc, Remijan and Hollis started the Prebiotic Interstellar Molecular Survey (PRIMOS) using the Robert C. Byrd Green Bank Telescope. Remijan and his colleagues are credited with the detection of over 17 new molecular species since 2003 many of which can be classified as prebiotic. Remijan then transitioned to the ALMA project as the first North American ALMA Postdoc in 2006 working with Al Wootten and the North American ALMA Science Center (NAASC). After several years working as a staff scientist starting in 2008 with the NAASC and developing the ALMA Spectral Line Catalog (Splatalogue), Remijan transition to the Deputy Director of Scientific Support and Research where he led Science User Support for all NRAO facilities. In 2014, Remijan transitioned to working at the Joint ALMA Observatory (JAO) in Chile where he led the Extension and Optimization of Capabilities (EOC) team. The EOC team was responsible for commissioning several highly successful new capabilities including Long Baselines, High Frequencies, VLBI and Solar Observing. The Long Baseline Campaign provided the stunning views of HL Tau. In 2016, Remijan was appointed to the North American ALMA Regional Center (ARC) Manager where he interfaces with science operations at the JAO and the ARC managers in Europe and East Asia. His main responsibility is the overall science output to the North American community including data products and user support. He manages an office of 15 staff scientists and astronomers and 14 data analysts.

TALKS

MA. Building Planets and Listening to the Songs of Their Peoples

MONDAY, JUNE 5TH, 2017 - 6:45 PM

MA01 **7:00**

BREAKTHROUGH LISTEN AND THE FUTURE OF THE SEARCH FOR INTELLIGENT LIFE

J. EMILIO ENRIQUEZ, *University of California, Berkeley*, and ANDREW SIEMION

Unprecedented recent results in the fields of exoplanets and astrobiology have dramatically increased the interest in the potential existence of intelligent life elsewhere in the galaxy. Additionally, the capabilities of modern Searches for Extraterrestrial Intelligence (SETI) have increased tremendously. Much of this improvement is due to the ongoing development of wide bandwidth radio instruments and the Moores Law increase in computational power over the previous decades. Together, these instrumentation improvements allow for narrow band signal searches of billions of frequency channels at once. The Breakthrough Listen Initiative (BL) was launched on July 20, 2015 at the Royal Society in London, UK with a charge to conduct the most comprehensive and sensitive search for advanced life in humanity's history. Here we detail important milestones achieved during the first year of the program, describe the key BL SETI surveys and briefly describe current facilities, including the Green Bank Telescope, the Automated Planet Finder and the Parkes Observatory.
Complementary to the BL initiative (at a smaller scale), pioneering SETI work at low radio frequencies (20-250 MHz) is being undertaken with the LOw Frequency ARray (LOFAR). This program uses simple fixed-stationary antennas and multiple phased-array beams formed in a supercomputer to search many targets at once and will lay the groundwork for future searches with SKA1-low and mid frequency aperture array pathfinders. We will present the results of a volume complete sample of nearby stars (<5pc) observed with LOFAR, searching for drifting narrow band signals with expected Doppler drifts covering a wide range of potential transmitter host planets.
We conclude with a brief view towards future SETI searches with upcoming next-generation radio facilities such as SKA and ngVLA.

MA02 **7:20**

A MULTI-RINGED PROTOPLANETARY DISK AROUND AA TAU

RYAN LOOMIS, *Harvard-Smithsonian Center for Astrophysics*, and KARIN ÖBERG, SEAN ANDREWS, MEREDITH MACGREGOR

Protoplanetary disks are the formation sites for planets, and thus studying their structure and chemical composition is crucial to understanding the initial conditions of nascent planetesimals. ALMA's high spatial resolution and sensitivity have recently begun to reveal previously unresolved sub-structure in these disks, simultaneously shedding light and posing new questions on disk evolution. AA Tau hosts a highly inclined protoplanetary disk, and is the prototypical source for a class of stars with a peculiar periodic photometric variability thought to be dependent on viewing geometry. We present high resolution (∼0.2") ALMA observations of the 1.3mm dust continuum, which surprisingly reveal a multi-ringed transition disk at an inclination of ∼60 degrees. In addition to the ringed sub-structure, we find non-axisymmetric features, including a 'bridge' of flux across the inner-most gap. Observations of HCO^+ 2-1 show bright emission from within the inner-most gap, suggesting that large quantities of molecular gas still reside within the hole. The kinematics of this emission are indicative of a radial flow, possibly associating the gas with gap-crossing streamers. AA Tau may therefore offer a rare glimpse into the dynamical processes governing accretion in planet-forming transition disks. We additionally discuss how resolving the disk geometry and sub-structure may affect interpretations of the mechanism behind AA Tau's variability, and speculate on the nature of the continuum 'flux bridge'.

MA03 **7:40**

RINGS AND GAPS IN PROTOPLANETARY DISKS: FORMATION BY MAGNETIC FIELDS

SCOTT SURIANO, *University of Virginia*, and ZHI-YUN LI, RUBEN KRASNOPOLSKY, HSIEN SHANG

Rings and gaps are being observed in an increasing number of disks around young stellar objects. We illustrate the formation of such radial structures through idealized, 2D (axisymmetric) resistive MHD simulations of coupled disk-wind systems threaded by a relatively weak poloidal magnetic field. We find two distinct modes of accretion depending on the resistivity and field strength. A small resistivity or high field strength promotes the development of rapidly infalling 'avalanche accretion streams' in a vertically extended disk envelope that dominates the dynamics of the system, especially the mass accretion. The streams are suppressed in simulations with larger resistivities or lower field strengths, where most of the accretion instead occurs through a laminar disk. In these simulations, the disk accretion is driven mainly by a slow wind that is typically accelerated by the pressure gradient from a predominantly toroidal magnetic field. Both wind-dominated and stream-dominated modes of accretion create prominent features in the surface density distribution of the disk, including rings and gaps, with a strong spatial variation of the magnetic flux relative to the mass. Regions with low mass-to-flux ratios accrete quickly, leading to the development of gaps, whereas regions with higher mass-to-flux ratios tend to accrete more slowly, allowing matter to accumulate and form dense rings. In some cases, avalanche accretion streams are observed to produce dense rings directly through continuous feeding. We discuss the implications of ring and gap formation driven by winds and streams on grain growth and planet formation.

MA04 **8:00**

BIOSIGNATURES AND UV ENVIRONMENTS OF EARTH-LIKE PLANETS ORBITING WHITE DWARFS

THEA KOZAKIS, *Cornell University*, and LISA KALTENEGGER

Earth-like planets orbiting white dwarfs would be exposed to different UV environments than planets hosted by main sequence stars of the same temperature, impacting both biosignatures and atmospheric photochemistry. We present model atmospheres and spectra of 1 AU equivalent white dwarf planets at different points in the white dwarf cooling process. Particular focus is put on changes in abundances for species that are thought to indicate habitability, along with biosignatures that can be detected by JWST as well other future missions. We find that cooler white dwarf models differ more from their main sequence temperature counterparts more so than hotter models, due to the greater difference in UV radiation with decreasing temperatures. These models can be used as inputs for instrument simulators for current and future missions.

MA05 **8:20**

A COHERENT CONTENT STORYLINE ON EXOPLANETS

DANIEL BARRINGER, *Pennsylvania State University*, and CHRIS PALMA

Previously, we presented an outline of the work we have done developing ASTRO-850, a course on exoplanets for in-service teachers. We discussed the basic design frameworks of the course, including the Coherent Content Storyline and Claims-Evidence-Reasoning. Here, we focus on the development of curriculum with a Coherent Content Storyline, with a particular focus on how the Storyline contributes to the lesson planning and design. Because the course is designed to give high school teachers lessons and activities that they can use, it is particularly important that our lesson design meets the latest iteration of state science standards (NGSS Lead States, 2013). We thereby also address how the lessons address the three dimensions of NGSS standards (disciplinary core ideas, science and enginnering practices, and crosscutting concepts; National Research Council, 2012). We may also provide some insights on the newly designed material from testing of the lessons in undergraduate introductory astronomy labs.

TA. Molecules: How Might We Best Blow Them Up?

TUESDAY, JUNE 6, 2017 - 8:45 AM

TA01 **9:00**

PHOTODESTRUCTION OF ASTROPHYSICALLY-RELEVANT ICE SPECIES

ILSA R. COOKE, *University of Virginia*, and KARIN I. ÖBERG

Our outer solar system is home to ice-laden bodies consisting predominantly of water and trapped volatile species. These include planetary satellites, comets, Kuiper Belt objects (KBOs), trans-Neptunian objects (TNOs) and minor planets. The ubiquity of water ice extends to interstellar space, in which water-rich ices are condensed on dust grains. Photochemistry in these ices is a major source of the complex molecules that are observed in the interstellar medium and our solar system. Despite the importance of ice photodestruction in astrophysical environments, there are relatively few laboratory studies that record photodissociation cross sections of solid species; therefore, many astrochemical models still rely on those measured in the gas phase. Previously measured ice photodestruction cross sections have been limited by uncertainties in the lamp photon flux and UV-spectrum, as well as the ice UV penetration depths. There is limited data on the dependencies of ice photodissociation rates on wavelength, temperature and photo-fragment diffusion.
We have initiated a survey of ice photodestruction cross sections using a hydrogen discharge lamp with a strong Lyman-alpha line. We are studying a range of astrophysically-relevant ice species and measuring their photodestruction cross sections at several temperatures in pure ices and in water and rare-gas matrices. An accurate knowledge of these cross sections is fundamental to our understanding of the role of photochemistry in producing complex organic molecules and will be especially critical in the era of highly sensitive infrared telescopes like the James Webb Space Telescope (JWST) that will shed new light on astrophysical ices.

TA02 **9:20**

A NEW MODEL OF THE CHEMISTRY OF IONIZING RADIATION IN SOLIDS

CHRISTOPHER SHINGLEDECKER, *University of Virginia*, and ERIC HERBST

Cosmic rays are a form of high energy radiation found throughout the galaxy that can cause significant physical and chemical changes in the solids they encounter, such as the ice mantles that cover many interstellar grains. These particles, which consist mostly of energetic protons, can initiate solid-state irradiation chemistry, which is of significant astrochemical interest, since it represents a non-thermal means of forming "complex" interstellar molecules, i.e. those of about six atoms or more, in the interstellar medium and are potentially relevant to questions about the origin of life in the universe. In order to better understand the chemical effects of long-term exposure to ionizing radiation, we have written a new kinetic Monte Carlo model, CIRISS: the Chemistry of Ionizing Radiation in Solids Simulation, which is, to the best of our knowledge, the first successful program of its kind to follow the damage and subsequent chemistry or an irradiated solid over time. In our code, two distinct regimes are considered. One is dominated by the atomic physics of track calculations in which both the primary ion and the subsequently generated secondary electrons are followed on a collision by collision basis. The second occurs after the ion-target collision, in which mobile species are free to randomly diffuse throughout the bulk of the ice and react with other species in the bulk. As an initial test of our code, we have modeled previous experimental work and have successfully reproduced the resultant steady-state results.

TA03 **9:40**

DESTRUCTION OF $C_2H_4O_2$ ISOMERS IN ICE-PHASE BY X-RAYS AND IMPLICATION ON THEIR ABUNDANCE IN THE ISM

MARINA G. RACHID, *Universidade do Vale do Paraíba*, and KARLA FAQUINE, SERGIO PILLING

$C_2H_4O_2$ isomers, methyl formate ($HCOOCH_3$), acetic acid (CH_3COOH) and glycolaldehyde ($HOCH_2CHO$), have been detected in molecular clouds in the interstellar medium, as well as, hot cores, hot corinos and around protostellar objects. These molecules have great astrobiological interest because they are involved in the synthesis of important biomolecules, such as glycine (NH_2CH_2COOH), the simplest amino acid. Despite the same molecular formula, their abundances are very different. Methyl formate is much more abundant than the other two isomers. This fact may be related to the different destruction by ionizing radiation of these molecules. The goal of this work is to experimentally study photodissociation processes of methyl formate and acetic acid ices when exposed to broadband soft X-ray from 6-2000 eV. The experiments were performed coupled to the SGM beamline in the Brazilian Synchrotron Light Source (LNLS/CNPEM) at Campinas, Brazil. The two simulated astrophysical ices (12 K) were monitored throughout the experiment using infrared vibrational spectroscopy (FTIR). The analysis of processed ices allowed the determination of physicochemical parameters and determination of daughter molecular species such as. CO, CO_2, H_2O, H_2CO and hydrocarbons. Molecular half-lives at ices toward YSOs and inside molecular clouds (e.g. Sgr B2, W51) due to the presence of incoming soft X-rays were estimated. The relative abundance between the isomers in different astronomical scenarios and the evolution of column density in the presence of X-rays were calculated. Our results suggest that such radiation field can be one of the factors that explain the difference in the $C_2H_4O_2$ isomers abundances.

TB. So Your Molecule Was Blown Up: How to Pick Up the Pieces and Put Humpty Back Together Again

TUESDAY, JUNE 6TH, 2017 - 11:00 AM

TB01 **11:00**

TIME-SENSITIVE CHEMICAL TRACERS WITHIN SHOCKED ASTROPHYSICAL SOURCES

ANDREW M. BURKHARDT, *University of Virginia*, and CHRISTOPHER N. SHINGLEDECKER, BRETT A. MCGUIRE, NIKLAUS M. DOLLHOPF, ANTHONY J. REMIJAN, ERIC HERBST

In regions of star formation, astrophysical shocks have been found to be both common and influential on the molecular make-up of the surrounding material. The formation of complex organic molecules (COMs) in the interstellar medium relies on interplay between gas-phase and grain-surface physical and chemical processes, including shock-induced non-thermal desorption of COMs formed on the grain. Here, we utilize the gas-grain chemical network model NAUTILUS, along with the inclusion of a high-temperature network, a parametric shock model, and sputtering processes, in order to study the effects shocks have on the chemical complexity of a prototypical shocked outflow over a range of chemically-relevant timescales.

TB02 **11:20**

POSSIBLE GAS-PHASE FORMATION ROUTES OF COMPLEX ORGANIC MOLECULES IN ISM : FORMAMIDE AND CYANOMETHANIMINE ISOMERS

FANNY VAZART, *Scuola Normale Superiore di Pisa*, and DIMITRIOS SKOUTERIS, NADIA BALUCANI, CECILIA CECARELLI, VINCENZO BARONE

The question of the formation of COMs in ISM is a main issue in the field of prebiotic chemistry. More particularly, cyanomethanimine and formamide are important species in this context. The first one because of its potential role as an intermediate towards the formation of adenine,[1] and the second thanks to it ability to connect metabolism (conversion of energy), which is ruled by proteins, and genetics (passage of information), ruled by RNA and DNA.
Moreover, their key roles in ISM appear to be also remarkable since E-cyanomethanimine has been recently detected in Sgr B2(N) in the Green Bank Telescope (GBT) PRIMOS survey by Zaleski et al. [2] and formamide in the galactic center sources Sgr A and Sgr B2,[3] in the Orion-KL region (an active site of high-mass star formation embedded in OMC-1) [4] and more recently in a solar-type protostar.[5]
In this contribution it is demonstrated, using a computational strategy integrating state-of-the-art electronic structure calculations and kinetic calculations, that the reaction between two widely diffuse species, that are the cyano radical and methanimine, can easily account for cyanomethanimine formation and that several reaction channels can lead to the formation of formamide, under the characteristic conditions of interstellar clouds.

[1] A. Eschenmoser 2007, Tetrahedron, 63, 12821
[2] D. Zaleski, N. Seifert, A. Steber, M. Muckle, R. A. Loomis, J. Corby, O. Martinez, Jr., K. N. Crabtree, P. R. Jewell, J. M. Hollis, F. J. Lovas, D. Vasquez, J. Nyiramahirwe, N. Sciortino, K. Johnson, M. C. McCarthy, A. J. Remijan, B. H. Pate 2013, ApJ, L10
[3] C. Gottlieb, P. Palmer, L. J. Rickard, B. Zuckerman, Astrophys. J., 182 699 (1973)
[4] R. A. Motiyenko, B. Tercero, J. Cernicharo, L. Marguls, A&A, 548 A71 (2012)
[5] C. Kahane, C. Ceccarelli, A. Faure, E. Caux, Astrophys. J., 763 L38 (2013)

TB03 **11:40**

PREDICTING COMPLEX ORGANIC MOLECULE EMISSION FROM TW HYA

SHREYAS VISSAPRAGADA, *Columbia University*, and CATHERINE WALSH

The Atacama Large Millimeter/submillimeter Array (ALMA) has significantly increased our ability to observe the chemistry associated with stars and planet formation. ALMA has recently been used to detect the complex organic molecules (COMs) CH_3OH (methanol) and CH_3CN (methyl cyanide) in protoplanetary disks; these molecules may be important indicators of the COM ice reservoir in the comet-forming zone. We have constructed a physicochemical model of TW Hya, a well-studied protoplanetary disk, in order to explore the different formation mechanisms of complex ices. By running our model through a radiative transfer code and convolving the results with beam sizes appropriate for ALMA, we have obtained synthetic observations of methanol and methyl cyanide. Here, we compare these synthetic observations to real data, and comment on their astrochemical significance.

TC. It's Red, But is it Really Dead?

TUESDAY, JUNE 6, 2017 - 1:45 PM

TC01 **2:00**

PRESERVATION OF RAMAN BIOSIGNATURES IN CYANOBACTERIA AND GREEN ALGAE AFTER SPACE EXPOSURE

MICKAEL BAQUÉ, *German Aerospace Center*, and U. BÖETTGER, T. LEYA, J-P. DE VERA

The BIOMEX (BIOlogy and Mars EXperiment) experiment aims at investigating the endurance of extremophiles and stability of biomolecules under space and Mars-like conditions in the presence of Martian mineral analogues (de Vera et al. 2012). To this end, extensive ground-based simulation studies and a space experiment were performed. Indeed, BIOMEX was part of the EXPOSE-R2 mission of the European Space Agency which allowed a 15-month exposure, on the outside of the International Space Station, of four astrobiology experiments between July 2014 and February 2016. The preservation and evolution of Raman biosignatures under real space conditions is of particular interest for guiding future search-for-life missions to Mars (and other planetary objects) carrying Raman spectrometers (such as the Raman Laser Spectrometer instrument on board the future ExoMars rover). Among the potential biosignatures investigated, the photoprotective carotenoid pigments (present either in photosynthetic organisms such as plants, algae, cyanobacteria and in some bacteria and archaea) have been classified as high priority targets for biomolecule detection on Mars and therefore used as biosignature models due to their stability and easy identification by Raman spectroscopy (Böttger et al. 2012). We report here on the first results from the analysis of two carotenoids containing organisms: the cyanobacterium Nostoc sp. (strain CCCryo 231-06; = UTEX EE21 and CCMEE 391) isolated from Antarctica and the green alga cf. Sphaerocystis sp. (strain CCCryo 101-99) isolated from Spitsbergen. Desiccated cells of these organisms were exposed to space and simulated Mars-like conditions in space in the presence of two Martian mineral analogues (phyllosilicatic and sulfatic Mars regolith simulants) and a Lunar regolith analogue and analyzed with a 532nm Raman microscope at 1mW laser power. Carotenoids in both organisms were surprisingly still detectable at relatively high levels after being exposed for 15 months in Low Earth Orbit to UV, cosmic rays, vacuum (or Mars-like atmosphere) and temperatures stresses regardless of the mineral matrix used. Further analyses will help us to correlate these results with survival potential, cellular damages or stability and the different extremophiles tested in the BIOMEX experiment.

TC02 **2:20**

INTERPRETATION OF MANGANESE OXIDE ON GALE CRATER AND OXIDIZING ENVIRONMENT ON EARLY MARS.

NATSUMI NODA, *University of Tokyo*, and S. IMAMURA, Y. SEKINE, S. UESUGI, M. KURISU, C. MIYAMOTO, H. TABATA, T. MURAKAMI, Y. TAKAHASHI

The Curiosity rover has observed Mn enrichments on Mars by in-situ analyses within sandstones of the Kimberley region on Gale crater. The high abundances of Mn are coupled with those of trace metals, particularly Ni, Zn and Cu; meanwhile, Si, Ca, Cl or S are inversely correlated with Mn. These results imply the presence of Mn as oxide phase, rather than silicate, carbonate, chloride or silicate. Since oxidation of Mn requires high levels of redox potential, the observations indicate a possible coexistence of a highly oxidizing atmosphere and wet conditions on early Mars. In the present study, we conducted laboratory experiments aiming at constraining an atmospheric O_2 level that was capable of explaining the coprecipitation pattern observed in Mn oxides by Curiosity. Our results show that the observed Mn oxides are highly likely MnO_2, which implies that the presence of a high-O_2 atmosphere (>0.01 mbar: comparable to that of Earth today) at the time of deposition. This conclusion further suggests that an accumulation of O_2 would have occurred due to limited amounts of reductants and liquid water on the surface.

TC03 **2:40**

ARCHAEAN CHEMOTROPHIC BIOSIGNATURES: ANALOGUES FOR A PUTATIVE MARTIAN BIOSPHERE?

KEYRON HICKMAN-LEWIS, *CNRS Centre de Biophysique Moléculaire, and Università di Bologna*, and BARBARA CAVALAZZI, FRANCES WESTALL

The geological records of Earth and Mars from greater than 3 billion years ago (3 Ga) reflect a time at which their geodynamic and environmental conditions appear to have shared many characteristics: standing water, insulating atmospheres, magnetic dynamos and, presumably, nutrient cycling on geological scales. For Mars, this period (the Noachian) is the sole era during which a surface biosphere might have existed. Consequently, one must study the fossilised signatures of time-equivalent life in Early Archaean volcano-sedimentary successions (found in Western Australia and South Africa) to appraise the variety of such ancient biotic diversity, and mechanisms of the long-term preservation of these signatures. Early Archaean life is legendarily difficult to decode, and we advocate for a multi-technique approach to appraise morphology and geochemistry of these dominantly carbonaceous biosignatures. Techniques include optical and confocal laser scanning microscopy for two- and three-dimensional analyses of morphological biosignatures, and SEM, Raman, proton-induced X-ray emission spectroscopy (PIXE), laser-ablation ICP-MS, FIB techniques and SIMS for multi-scalar measurements of geochemical characteristics. These techniques produce datasets complementary to those which will be gathered by upcoming astrobiology-oriented rovers. In multiple Archaean cherts, among them the 3.33 Ga Josefsdal Chert, 3.45 Ga Kittys Gap Chert and 3.46 Ga 'Apex chert', a strong correlation of chemotrophic biosignatures with hydrothermal activity is noted, while the silica produced by hydrothermalism encapsulates and preserves carbonaceous matter. With the discovery of apparently hydrothermal deposits on Mars, we suggest such localities as the most promising environments for the flourishing and preservation of a fossilised Martian biosphere.

TC04 **3:00**

THE LIPID RECORD OF LIFE ON MARS

JONATHAN S. W. TAN, *Imperial College London*, and M. A. SEPHTON

Past life on Mars will have generated organic remains that may be preserved in present day Mars rocks (Summons, 2011). The latest period in Mars history that retained widespread surface water (Milliken, 2010) was the late Noachian and early Hesperian and will have sustained the most evolved and widely distributed Martian life.
Guidance for investigating late Noachian and early Hesperian rocks is provided by studies of analogous acidic and sulfur-rich environments on Earth. This study reports organic responses for an acid stream containing acidophilic organisms whose post-mortem remains are entombed in iron sulphates and iron oxides. Acid stream data indicate that the organic records of life on Mars will comprise microbial lipids. The quantities of lipids are substantial and represent a sizeable reservoir of fossil carbon. Mineralogical signposts of fossils organic compounds are available and concentrations of lipids are highest in goethite layers that have replaced pre-existing jarosite and reflect persistent aqueous conditions and therefore habitability. Future Mars missions should seek to detect fatty acids or their diagenetic products in the iron oxide remnants of sulphur-rich environments.

TD. Form Up! Move Out!

TUESDAY, JUNE 6TH, 2017 - 5:30 PM

TD01 **5:30**

THE HISTORY OF PROTEIN FOLDING

NICHOLAS A. KOVACS, *Georgia Institute of Technology*

The ribosome is imprinted with a detailed molecular chronology of the origins and early evolution of proteins. Here we show that when arranged by evolutionary phase of ribosomal evolution, ribosomal protein (rProtein) segments reveal an atomic level history of protein folding. The data support a model in which aboriginal oligomers evolved into globular proteins in a hierarchical step-wise process. Complexity of assembly and folding of polypeptide increased incrementally in concert with expansion of rRNA. (i) Short random coil proto-peptides bound to rRNA, and (ii) lengthened over time and coalesced into β-β secondary elements. These secondary elements (iii) accreted and collapsed, primarily into β-domains. Domains (iv) accumulated and gained complex super-secondary structures composed of mixtures of α-helices and β-strands. Early protein evolution was guided and accelerated by interactions with rRNA. rRNA and proto-peptide provided mutual protection from chemical degradation and disassembly. rRNA stabilized polypeptide assemblies, which evolved in a stepwise process into globular domains, bypassing the immense space of random unproductive sequences. Coded proteins originated as oligomers and polymers created by the ribosome, on the ribosome and for the ribosome. Synthesis of increasingly longer products was iteratively coupled with lengthening and maturation of the ribosomal exit tunnel. Protein catalysis appears to be a late byproduct of selection for sophisticated and finely controlled assembly.

TD02 **5:50**

SELF-ASSEMBLED CATIONIC TRIPEPTIDE NANOSTRUCTURES AS PREBIOTIC RNA BINDING SCAFFOLDS

TONY Z. JIA, *Earth-Life Science Institute*, and ALBERT C. FAHRENBACH, NEHA P. KAMAT, KATARZYNA P. ADAMALA, JACK W. SZOSTAK

Before the emergence of the first RNA polymerase ribozyme, sustained nonenzymatic replication of RNA was crucial to the development of early life. To that end, short, cationic polypeptides have been hypothesized to assist in the replication of early RNA. However, the geochemical scenarios that would allow for the accumulation of high concentrations of these peptide oligomers are not likely. Recently, it has been discovered that certain tripeptide systems can spontaneously self-assemble into hydrogels and fibrillar macrostructures. As the accumulation of high concentrations of peptide trimers is much more likely than longer oligopeptides on the early earth, we probed the self-assembly properties and RNA-binding affinities of six tripeptides, each containing a cationic residue in the N-terminal position followed by an aromatic or hydrophobic dyad. KYF and RFF showed the best fibrillar self-assembly propensityRFF is the first purely-peptidic arginine-containing tripeptide to self-assembleand microscopy and binding assays show that RNA indeed binds to the structures generated by these tripeptides. In fact, binding of a fluorescent RNA to cationic fibrillar macrostructures resulted in a direct label-free method of visualizing the kinetics of nanostructure assembly in real time. As these tripeptide assemblies are also reasonably heat-stable and do not prohibitively inhibit nonenzymatic RNA replication, our studies suggest that cationic tripeptide nanostructures could have been prebiotically-plausible RNA-binders, potentially possessing the ability to assist in the replication and eventual evolution of early genetic systems.

TD03 **6:10**

THE EFFECT OF SURFACES ON FATTY ACID VESICLE GROWTH

ANNA WANG, *Massachusetts General Hospital*, and JACK W. SZOSTAK

Fatty acid vesicles are semi-permeable membranes capable of growing and dividing, ideal candidates for the earliest protocell membranes. At present, filamentous vesicles have the most prebiotically plausible scheme for growth and division: they form when the area of multilamellar vesicles increases rapidly with respect to the vesicle volume, and divide by pearling under sufficient shear forces or osmotic stresses whilst retaining encapsulants [Zhu and Szostak, *JACS* (2009)]. In contrast, spherical or tubular vesicles either dont divide easily, or are prone to releasing their contents when subject to moderate shear [Zhu and Szostak, *JACS* (2009)].

In experiments so far, growth into filamentous vesicles has been initialised by quickly adding 1 to 100 equivalent of extra fatty acid. An increase in fatty acid concentration drives vesicle growth, because fatty acids preferentially partition into vesicles rather than micelles at high fatty acid concentrations [Budin *et al., JACS* (2012)]. However, obtaining a large increase in fatty acid concentration in a prebiotic manner is challenging. For instance, achieving rapid increases in concentration by evaporation is harsh and requires an instantaneous and large increase in temperature. How can we make filamentous vesicles in a prebiotically plausible way?

Here we seek to determine whether surfaces can affect vesicle growth. Various colloidal surfaces have been shown to catalyse the rapid *creation* of vesicles from micelles [Hanczyc *et al., Orig Life Evol Bios* (2006)]. The underlying catalysis mechanism is unclear. If surfaces can also catalyse the *growth* of pre-existing vesicles, then a prebiotically plausible route to filamentous vesicle growth may be possible.

TD04 **6:30**

AQUEOUS PHOTOCHEMICAL OLIGOMERIZATION OF SIMPLE LIPIDS: USING SUNLIGHT TO DRIVE SYNTHESIS AND SELF-ASSEMBLY OF MEMBRANES

REBECCA J. RAPF, *University of Colorado, Boulder*, and RUSSELL J. PERKINS, AND VERONICA VAIDA

Sunlight can provide the energy needed to drive organic photochemical reactions, which, in aqueous environments, generate complex molecular structures required for life. We will report on the robust photochemical mechanism by which a class of molecules, oxoacids, reacts in aqueous solution to form organic radicals. These organic radicals can then recombine to form multi-tailed lipid species. In addition to reactions with radicals formed directly from the photoexcitation, oxoacids can also act as radical initiators for the oligomerization of non-photoactive molecules. The photochemical reactions of alkyl oxoacids are one of the only demonstrated processes by which multi-tailed lipids can be formed simply and in relatively high yields from prebiotically-relevant starting materials. The synthesis of such lipid molecules is interesting, not only because of the formation of a carbon-carbon bond in the absence of enzymes, but also because of their importance in the development of membranous enclosures. These photochemically-generated lipids spontaneously self-assemble into monodisperse, spherical aggregates, which has important environmental implications both for prebiotic chemical evolution on the early Earth.

WA. We're Not the Only Rock in This Here Solar System

WEDNESDAY, JUNE 7TH, 2017 - 8:45 AM

WA01 **9:00**

SEASONAL VARIATIONS IN TITAN'S ATMOSPHERE OBSERVED WITH ALMA

ALEXANDER E. THELEN, *New Mexico State University*, and C. A. NIXON, N. J. CHANOVER, M. A. CORDINER, E. MOLTER, J. SERIGANO, R. K. ACHTERBERG, P. G. J. IRWIN, S. B. CHARNLEY, N. A. TEANBY

Saturn's largest moon, Titan, serves as an invaluable primordial laboratory for solar system chemistry through its substantial atmosphere, surface lakes, and subsurface ocean. Photochemistry of N_2 and CH_4 in Titan's atmosphere produces a wealth of organic compounds - including hydrocarbons (C_XH_Y) and nitriles ($C_XH_Y[CN]_Z$) - which may potentially be of astrobiological significance. Many of these chemicals exhibit latitudinal variations in abundance as observed by Cassini, as a result of atmospheric circulation, photochemical production and subsequent destruction throughout Titan's seasonal cycle. Utilizing flux calibration images of Titan taken with the Atacama Large Millimeter/Submillimeter Array (ALMA), we present spatially resolved temperature and abundance profiles spanning from mid-2012 to early 2016, as Titan transitioned into Northern Summer. Vertical profiles covering Titan's troposphere through the mesosphere ($\sim$50-500 km) were retrieved by modeling high resolution ALMA spectra using the Non-linear Optimal Estimator for MultivariatE Spectral analySIS (NEMESIS) radiative transfer code. Temperature profiles obtained by modeling CO lines and abundance values of HCN, HC_3N, CH_3CN, and C_3H_4 are compared to those found in the infrared by Cassini. Spatial and temporal variations of these species will allow us to observe seasonal changes in the production and circulation of organic molecules, thereby elucidating the role of Titan's rich atmospheric chemistry in determining its potential habitability.

WA02 **9:20**

THE ATMOSPHERIC EVOLUTION OF EARLY VENUS THROUGH HYDROGEN LOSS

SONNY HARMAN, *Pennsylvania State University*, and JAMES F. KASTING

The escape of lighter constituents from a planet's atmosphere has the potential to fundamentally alter its composition and structure. Every terrestrial planet in our solar system has been subjected to atmospheric escape during different phases in their lifetimes, potentially limiting the habitability of these worlds. Venus, for example, is thought to have passed through a moist or runaway greenhouse stage, during which surface temperatures rose high enough that some or all of its surface ocean evaporated. The subsequent photolysis of water ($H_2O + h\nu \rightarrow OH + H$) and loss of hydrogen to space left Venus a desiccated, barren world. To fully constrain this transition, it is vital that we understand the interplay between photochemistry and atmospheric escape.

In this talk, I will present results from a multi-component escape model which explores the behavior of a planetary atmosphere under intense stellar irradiation, analogous to that of early Venus'. The dominant modes are the energy-limited and diffusion-limited regimes, which depend on the availability of both energy (controlled by a planet's proximity to its host star and the star's XUV brightness) and H and H_2 (fed by volcanism and photochemistry), respectively. High escape rates could limit the amount of time a highly reducing atmosphere might exist, hampering the origin of life on that world or prevent the planet from maintaining habitable surface temperatures.

WA03 **9:40**

IDENTIFICATION AND VALIDATION OF BIOGENIC PRESERVATION WITHIN MINERALS: MICROBIOLOGICAL TECHNIQUES FOR FUTURE LIFE DETECTION MISSIONS

ARMAN SEUYLEMEZIAN, *NASA Jet Propulsion Laboratory*, and S. M. PERL, P. A. VAISHAMPAYAN, A. SEUYLEMEZIAN, F. A. CORSETTI2, O. PIAZZA, M. AHMED, P. WILLIS, J. S. CREAMER, K. W. WILLIFORD, D. T. FLANNERY, M. L. TUITE, B. L. EHLMANN, R. BHARTIA, B. K. BAXTER, J. BUTLER, R. HODYSS, W. M. BERELSON, K. H. NEALSON

Minerals precipitated from former and currently receding lake beds can capture and entomb biogenic evidence within its crystal structure. We seek to understand how preservation of DNA and proteins, within such aqueous settings, can sustain preservation of biologically significant molecules on different timescales in order to confine how we view minerals observed within the Martian shallow subsurface both from orbit and on the surface. We have chosen to investigate the evaporate minerals halite and gypsum due to their confirmed detection by the CRISM instrument , their physical transparency, and short-term precipitation timescales. These minerals have been observed within the subsur- face of Mars in proximity to ancient aqueous settings either via groundwater or evaporated lake beds.We have successfully developed protocols for solid sample DNA extraction and verified via qPCR the presence of entombed DNA in our halite crystals. SEM and and lab spectrometer investigations have shown that our field gypsum and halite have similar absorption bands to minerals observed by the CRISM instrument. Ongoing investigations continue to determine protein and bulk organic carbon content.

WB. Life: Can You Make It?

WEDNESDAY, JUNE 7TH, 2017 - 11:00 AM

WB01 **11:00**

STROMATOLITE TEXTURE ANALYSIS: HOT SPRING SPICULAR GEYSERITE

SHANA L. KENDALL, *Portland State University*, and M. C. STORRIE-LOMBARDI, S. L. CADY

Unambiguous proof of microbial activity as the genesis of ancient, Archean and Proterozoic, stromatolites is a cause for debate of some laminated structures. A multidisciplinary analysis gathering many lines of evidence is required to support the argument for their biogenic origin. Additionally, texture analysis has proven useful in many disciplines. Here texture analysis is applied to determine if biotic deposits can be discerned from abiotic deposits with the intent of ultimately being used in conjunction with other capabilities to determine whether laminated sedimentary deposits are of biogenic origin.

WB02 **11:20**

THE METEOROID IMPACT CRATER: AN ASSET FOR EXTRATERRESTRIAL LIFE ESTABLISHMENT

MANISH BAVISKAR, *Lamar University*

Meteoroid impact is considered as one of the most critical events in history the earth planet as well as in universe. Many hypotheses related to evolution of planets are also based on same concept. Primary effect of Meteoroid impact is Catastrophic but after the period of time the Novel bacterial species establish or adapt to that Unique physio-chemical Environments. Our research highlights bacterial adaptation and unique features of Chemo-taxis, magneto-taxis and gravity related adaptation of that bacteria. Recent, studies on meteoroid and evidences of Extraterrestrial life also taken in consideration as theory. This report also covers other parameter which were not taken in consideration for effective adaptation of the bacteria for unique physio-chemical stress compare to the extraterrestrial sample testing methods. Finally, Chemical and microbial deterioration changes of Meteoroid impact craters habitat and need of perseverance is highlighted.

WB03 **11:40**

UV LIGHT-DRIVEN PREBIOTIC SYNTHESIS OF IRON-SULFUR CLUSTERS

CLAUDIA BONFIO, *Center for Integrative Biology - University of Trento*, and LUCA VALER, SIMONE SCINTILLA, SACHIN SHAH, DAVID J. EVANS, LIN JIN, JACK W. SZOSTAK, DIMITAR D. SASSELOV, JOHN D. SUTHERLAND, SHEREF S. MANSY

Iron-sulfur clusters are ancient cofactors that play a fundamental role in metabolism and may have impacted the prebiotic chemistry that led to life. However, it is unclear whether iron-sulfur clusters could have been synthesized on the early Earth. Dissolved iron on prebiotic Earth was predominantly in the reduced ferrous state, but ferrous ions alone cannot form iron-sulfur clusters. Similarly, free sulfide may not have been readily available. We have shown that UV light drives the synthesis of [2Fe-2S] and [4Fe-4S] clusters through the photooxidation of ferrous ions and the photolysis of organic thiols. Iron-sulfur clusters coordinate to and are stabilized by a wide range of cysteine containing peptides, and the assembly of iron-sulfur cluster-peptide complexes can take place within model protocells in a process that parallels extant pathways. Our experiments suggest that iron-sulfur clusters may have formed easily on early Earth, facilitating the emergence of an iron-sulfur cluster dependent metabolism.

WC. Oh the Places You'll Go

WEDNESDAY, JUNE 7TH, 2017 - 1:45 PM

WC01 **2:00**

CHARACTERIZATION OF DEEP MARINE SUBSURFACE FUNGI FROM SOUTH PACIFIC GYRE SEDIMENTS

MORGAN SOBOL, *Texas A&M University - Corpus Christi*, and MAYRA RODRIGUEZ, TATSUHIKO HOSHINO, FUMIO INAGAKI, BRANDI KIEL REESE

The marine deep subsurface harbors one of the most diverse and prolific microbial communities on Earth. Within the last decade, it has been shown that eukaryotes, such as fungi, are thriving in marine sediments alongside prokaryotic communities. It is still poorly understood what role fungi plays in this extreme environment, but it is hypothesized that they contribute to the deep subsurface carbon cycle. Until now, few studies have been able to culture and characterize deep subsurface fungal communities. For this study, sediment samples were collected during the Integrated Ocean Drilling Program Expedition 329 to the South Pacific Gyre on board the D/V JOIDES Resolution in November-December 2010. The South Pacific Gyre is known for some of the most nutrient and organic carbon replete sediments in the world. Whole round sediment cores were collected for culturing and molecular analysis. Fungal isolates from 12 and 124 meters below seafloor were found to be most closely related to Penicillium chrysogenum and Penicillium brevicompactum. These findings were independently verified through in situ 18S rRNA gene sequencing from the sediment. This study aims to fully characterize the isolates by sequencing the entire genome of both species to understand their metabolic potential. P. chrysogenum grew faster than P. brevicompactum under oxic and anoxic conditions at 5 °C. Growth will also be assessed in different nitrate, sulfate and hydrocarbon sources. This will allow us to further analyze their role in subsurface biogeochemical cycles and understand how these organisms have adapted to extreme environments.

WC02 **2:20**

MUTAGENIC ANALYSIS OF A POLYEXTREMOPHILIC β-GALACTOSIDASE FROM AN ANTARCTIC HALOARCHAEON: POTENTIAL ANALOG FOR LIFE ON MARS

VICTORIA LAYE, *University of Maryland*, and PRIYA DasSARMA, WOLF PECHER AND SHILADITYA DasSARMA

The discovery of flowing brine on Mars makes it a candidate in the search for extraterrestrial life. Because the surface of Mars is extremely cold, the brine would have to contain high concentrations of salt in order to remain liquid. Halorubrum lacusprofundi (Hla) is an Antarctic haloarchaeon that survives multiple extremes including extreme cold and high salt concentrations, low pressure, and UV and ionizing radiation, making it a good model for potential life on Mars. To better understand how Hla functions at these extremes, we examined its highly acidic proteins. We used a combination of bioinformatic and experimental approaches to study the haloarchaeons salt and cold-active family 42 β-galactosidase enzyme. We compared the Hla enzyme to the consensus sequence of 7 haloarchaeal family 42 glycoside hydrolases to identify residues likely important for cold-activity. We used site-directed mutagenesis on six of these amino acids, N251, A263, I299, F387, I476, and V482, by partial gene synthesis and overexpression in Halobacterium sp. NRC-1 using an expression vector with a cold-inducible cspD2 promoter. The wild-type and mutated enzymes were purified using nickel affinity chromatography and characterized by steady-state kinetics at various temperatures with the chromogenic substrate, o-nitrophenyl-β-galactoside. All of the mutated enzymes affected temperature activity compared to the wild-type, with five of the six exhibiting increased Km and reduced enzyme efficiency (kcat/Km) at 0 °C. The wild-type enzyme exhibited a direct relationship between the Km and temperature, characteristic of cold-adapted enzymes, while four of the six mutated enzymes showed inverse character, with relatively higher Km at low temperatures. The results confirm the evolutionary importance of the divergent amino acids in the improved function of the β-galactosidase enzyme at colder temperatures.

WC03 **2:40**

COMMUNITY COMPOSITION AND METABOLIC CHARACTERIZATION OF THE BONNEVILLE SALT FLATS

JULIA M. MCGONIGLE, *University of Utah*, and E. R. DART, B. KLEBA, B. B. BOWEN, W. J. BRAZELTON

An 18 square mile salt flat on Mars has recently been speculated to be a remnant of the last large lake which may have potentially hosted life on the red planet [1]. Similar large scale salt deposits exist on Earth, such as the Bonneville Salt Flats in Utah. These salt flats are a remnant of a massive lake that stretched further than the Great Salt Lake in the Pleistocene. Although these salt flats on Earth currently undergo ephemeral wet/dry cycles that the salt flats on Mars no longer experience, they nonetheless represent a Mars analog and provide the opportunity to learn more about extreme ecosystems that support microbial communities on Earth. Comprehensive microbial studies have been conducted on salt flats in other locations, but to date the only studies done at the Bonneville Salt Flats have been limited to culture-based approaches [2]. We are using culture-independent approaches for the first time to investigate the microbial community of these salt flats. Both halophilic archaea and methanogens have been identified as organisms which harbor unique adaptations that might allow them to survive harsh conditions on the surface or subsurface of other planets [3][4].

References:

[1] Hynek B. M. et al. (2015) Geology, 43, 787-790
[2] G. L. Boogaerts (2015) Thesis, The University of Alabama at Birmingham.
[3] Landis, G. A. (2004) Astrobiology, 1, 161-164.
[4] Schirmack, J. et al. (2014) Planet. Space Sci., 98, 198-204.

POSTERS

PA. Poster Session A

TUESDAY, JUNE 6, 2017 - 10:00 AM

PA01

AB INITIO STUDY OF PROPYLENE OXIDE FORMATION IN INTERSTELLAR SPACE

SEYEDSAEID AHMADVAND, *University of Nevada, Reno*, and HAYDON HILL, SERGEY VARGANOV

The recent discoveries of complex organic molecules such as glycoaldehyde, the precursor molecule of RNA, in interstellar space have renewed the interest in astrochemical reaction mechanisms. We investigate two proposed reaction mechanisms for propylene oxide formation, the first chiral molecule in interstellar medium using ab initio quantum chemical methods. The nonadiabatic spin-forbidden reaction between atomic oxygen and propylene characterized as a barrier-less reaction with a significant spin-orbit coupling between the lowest energies singlet and triplet states. We calculate the Landau-Zener probability of transition between the triplet and singlet states, and use nonadiabatic transition state theory to estimate the reaction rate constant of this spin-forbidden reaction. The spin-allowed reaction between molecular oxygen and propylene is another formation pathway of propylene oxide, also investigated in this work. The reaction between atomic oxygen and propylene is a probable mechanism for the formation of propylene oxide due to the barrier-less nature of the reaction. A broad transition state (TS) search for the reaction between molecular oxygen and propylene hasn't lead to a proper TS and yet under more investigation.

PA02

A PROPOSED MULTIPROXY APPROACH FOR MODELING BIOSIGNATURES IN A JAROSITE-RICH NOACHIAN MARS ANALOGUE SEDIMENT

RICHARD ARCHER, *University of Colorado*, and ELDAR NOE DOBREA

Findings by Michalski and Noe Dobrea (2007) suggest that Mawrth Vallis contains sedimentary deposits dating from the Noachian Epoch. Mawrth Vallis represents outflow fluvial and lacustrine deposits of phyllosilicate clays (ibid). Farrand et al. (2009) discovered a region of jarosite located within the Mawrth Valllis region with great potential for preservation of diverse biosignature preservation. Due to similarities in the interpreted hydrological environment and resulting mineralogy, the Painted Desert of Arizona serves as an analogue site (Michalski and Noe Dobrea, 2007). We identified a jarosite rind encasing ancient wood perimineralized by calcite (Noe Dobrea, 2016) and we speculated that this jarosite is anomalous in the context of a clay dominated environment and may be the result of sulfate reducing microbial activity. To test this, we separated the sample by depth and sent splits out for isotopic analysis while simultaneously characterizing the mineralogy by XRD and VNIR spectroscopy, to clarify mineralogical character of microbial associations. Two distinct mineralogical domains were found, partitioned by a layer of pure gypsum. The first mineralogical domain was dominated by natrojarosite while the second domain was dominated by pyrite, graphite and diagenetic products of pyrite. Mineral results suggest biomineralization with diagenetic overprinting of pyrite. We hope to clarify preservation and diagenesis through further study utilizing isotopic, SEM and Raman analysis as they relate to Mawrth Vallis.

PA03

METHANOL FORMATION VIA OXYGEN INSERTION CHEMISTRY IN ICES

JENNIFER BERGNER, *Harvard University*, and KARIN ÖBERG, MAHESH RAJAPPAN

Astrochemical models typically rely on radical recombination chemistry to explain complex organic molecule (COM) production in star-forming regions; however, this framework requires radical mobility in ices and therefore has struggled to reproduce observed abundances of COMs in the very cold interstellar medium. We present experimental constraints on a potential new pathway to chemical complexity via the direct insertion of oxygen atoms into hydrocarbons in icy mantles. Here, we explore the test case of O insertion into CH_4 to form CH_3OH. This is achieved in the lab by irradiating O_2:CH_4 mixtures with a deuterium UV lamp filtered by a sapphire window, resulting in the selective dissociation of O_2 to form O atoms. We observe methanol formation at temperatures as low as 9K, indicating efficiency under astrophysically relevant conditions. We model the CH_3OH growth kinetics and observe no temperature dependence to the reaction rate constant at temperatures below the oxygen desorption temperature of 25K. This implies that, similar to the gas-phase analog, oxygen insertion into methane occurs with a very low or non-existant barrier, and will proceed as long as oxygen atoms are retained in the ice. Oxygen insertion chemistry could therefore provide an additional channel to complex organic molecule formation on grain surfaces in the interstellar medium.

PA04

LIPID FORMATION IN A UREA-BASED EUTECTIC SOLVENT

BRADLEY T. BURCAR, *Georgia Institute of Technology*, and C. MENOR-SALVAN, N.V. HUD

Lipids are an integral part of modern biochemistry. These fatty chemicals provide means of energy storage through the formation of fats and are also the fundamental building block of membranes which encapsulate all of the cell components and protect the cell machinery from the environment. These properties found in modern cells could also have been vitally important for prebiotic cells by affording them protection from the environment while concentrating and trapping important biopolymers on an early Earth. Previous work has demonstrated the capability of fatty acids to form basic membranous structures called vesicles, or for the formation of vesicle forming phospholipids in the presence of urea at temperatures in excess of 100 °C. While both fatty acids and phospholipids can form vesicles, neither is stable in the presence of divalent cations, and the synthetic path for phospholipids is questionably prebiotic at such high temperatures. The prebiotically viable, urea-based eutectic solution containing urea, ammonium formate, and water has recently demonstrated remarkable capabilities for phosphorylating alcohols at temperatures as low as 50 °C. This eutectic also enhances the solubility of minerals containing divalent cations, allowing chemistry to succeed where it had previously failed. This work demonstrates how lipids can be formed under these much more mild conditions and how resistant this environment is to interference from divalent cations in solution.

PA05

OPTIMIZING THE EXOPLANET DIRECT DETECTION METHOD

CAM BUZARD, *California Institute of Technology*, and DANIELLE PISKORZ, GEOFF BLAKE

The upcoming TESS mission is expected to discover around 500 Earth-like exoplanets, many of which will be in the habitable zones of their host stars. Ultimately, we will be able to learn about these planets compositions, histories, and potential habitabilities by looking for features from water vapor and key biogenic elements (especially carbon and nitrogen) in their spectra. Unfortunately, separating the planetary spectrum from the host star spectrum is very difficultthey often contain many of the same constituents and the planetary signal can be on the order of 105x smaller than that of the star, or even smaller. Previously, our group has worked on applying a technique called the direct detection method to Keck NIRSPEC (R$\sim$25,000) data of hot Jupiter systems in order to separate the stellar and planetary signals. Our current work involves optimizing the technique to allow us to apply it to cooler, potentially habitable planets, like those that will be discovered by TESS. These optimizations in combination with the higher resolution (R$\sim$50,000) provided by NIRSPEC2.0 will hopefully allow us to isolate spectra of cool, terrestrial planets in habitable zones. Such techniques will be necessary to understand the chemical compositions, histories, and habitabilities of potentially Earth-like exoplanets.

PA06

OXYGEN ISOTOPE RATIOS ARE PRESERVED IN WATER-POOR JACK HILLS ZIRCONS

EVAN D. CAMERON, *University of Wisconsin - Madison*, and J. W. VALLEY, D. ORTIZ-CORDERO, K. KITAJIMA, A. J. CAVOSIE

The Jack Hills (JH) detrital zircons are notable for being the only "plentiful" source of >4.0 Ga terrestrial material. Values of ^{18}O in >4.0 Ga detrital zircons that are elevated above mantle values suggest that habitable conditions for life (Hadean oceans) existed 800 Ma before the oldest known microfossils. Interest in the ties between the JH zircons and the origin of life has increased recently, but high $\delta^{18}O$ values for some grains are reported to correlate with high OH/O ratios, suggesting alteration. OH correlates with radiation damage that is known to open pathways for exchange in zircon, which could allow alteration. We have reanalyzed ^{18}O by SIMS in zircons first reported to be unaltered based on U-Pb concordance, magnetism and CL. Our new data include measurement of ^{16}OH to monitor "water". When compared against an anhydrous standard, background corrected OH/O is a useful tool for evaluating zircon SIMS domains. We present analyses of 154 detrital JH zircons of >3.8 Ga age for $\delta^{18}O$ and OH/O. OH/O ratios were background corrected by comparing against the KIM-5 standard. Using measured [U], [Th] and U-Pb ages, we calculated alpha-decay doses for each grain. Results show that most grains have OH/O ratios indistinguishable from background. There is no correlation of OH/O to ^{18}O in our data, confirming that some zircons with mildly elevated $\delta^{18}O$ are not altered. The lack of correlation between OH/O and $\delta^{18}O$ strengthens the conclusion that ^{18}O is preserved in select JH zircons, providing evidence for Hadean oceans before 4.3 Ga.

PA07

MIXTURES OF HYGROSCOPIC SALTS AS PREBIOTIC MEDIA FOR THE CONDENSATION OF AMINO ACIDS

THOMAS D. CAMPBELL, *Saint Louis University*, and PAUL J. BRACHER

Many models for prebiotic sources of water (e.g. rain, tides, etc) result in the issue of diluting key molecules to the point where reactivity is diminished. Here, we offer a potential solution by presenting findings on how mixtures of K^+ and Na^+ salts are able to sequester water from the atmosphere in a controlled manner and we report the extent to which specific mixtures absorb water vapor at certain relevant temperatures and relative humidities. We are interested in studying these mixtures as alternative environments for hosting reactions of prebiotic importanceespecially the oligomerization of amino acidswhich we evaluate by measuring the progress of simple hydrolysis and condensation reactions.

PA08

TRACING THE ORIGINS OF NITROGEN-BEARING ORGANICS TOWARD ORION KL WITH ALMA

P. BRANDON CARROLL, *California Institute of Technology*, and NATHAN R. CROCKETT, OLIVIA WILKINS, CECILE FAVRE, EDWIN A. BERGIN, GEOFFREY A. BLAKE

A comprehensive analysis of a broadband 1.2 THz wide spectral survey of the Orion Kleinmann-Low nebula (Orion KL) has shown that nitrogen bearing complex organics trace systematically hotter gas than O-bearing organics toward this source. The origin of this O/N dichotomy remains a mystery. If complex molecules originate from grain surfaces, N-bearing species may be more difficult to remove from grain surfaces than O-bearing organics. Theoretical studies, however, have shown that hot (T=300 K) gas phase chemistry can produce high abundances of N-bearing organics while suppressing the formation of O-bearing complex molecules. In order to distinguish these distinct formation pathways we have obtained extremely high angular resolution observations of methyl cyanide (CH_3CN) using the Atacama Large Millimeter/Submillimeter Array (ALMA) toward Orion KL. By simultaneously imaging $^{13}CH_3CN$ and CH_2DCN we map the temperature structure and D/H ratio of CH_3CN. We will present the initial results of these observations and discuss their implications for the formation of N-bearing organics in the interstellar medium.

PA09

THE POSSIBLE PHOTOCHEMICAL ORIGINS OF BANDED IRON FORMATIONS

PARKER CASTLEBERRY, *Arizona State University*, and STEPHEN ROMANIELLO, AND ARIEL ANBAR

Banded iron formations (BIFs) are among the earliest possible indicators for oxidation of the Archean biosphere. However, the origin of BIFs remains debated. Proposed formation mechanisms include oxidation of Fe(II) by O_2 (Cloud 1973), photoferrotrophy (Konhauser et al. 2002), and abiotic UV photooxidation (Konhauser et. al. 2007; Braterman et. al. 1983). Resolving this debate could help determine whether BIFs are really indicators of O_2, biological activity, or neither. In order to examine the viability of abiotic UV photooxidation of Fe, we revisited photochemical experiments conducted by Braterman et al. (1983). We seek to improve on previous work by by directly measuring the rate of aqueous Fe loss, using light sources that approximate the solar spectrum, and including carbonate in our system. In our experiments we observed Fe photooxidation. Using a series of cut-off filters, we determined the reaction was not caused by light >345 nm. This disagrees with Braterman et al. 1983, who reported photooxidation with light even >400 nm. Further work is being done to resolve this discrepancy. However, we are in agreement with Konhauser et al. (2007) who did not observe any reactions with light >~320 nm in their experiments. Our results lead to modeled Fe photooxidation rates of 9 mg Fe cm^{-2} yr^{-1}–at the low end of published BIF deposition rates 9-43 mg cm^{-2} yr^{-1} (Trendall and Blockley, 1970). These results suggest that photooxidation could contribute to, but is unlikely to be completely responsible for, large rapidly deposited BIFs such those in the Hamersley Basin.

PA10

THE STUDY OF ICE GROWTH BY MOLECULAR DYNAMICS SIMULATION

SAEHYUN CHOI, *Pennsylvania State University*, and EUNSEON JANG, JUN SOO KIM, *Ewha Woman's University*

My observations demonstrate the in-layer stacking competition between hexagonal and cubic ice structures during ice growth by Molecular Dynamics simulations. When ice grows in the direction of perpendicular to the basal face, hexagonal and cubic structures were found together and compete in the same layer. Those two structures eventually dominate the one layer or stay as stacking disordered regions. However, the stacking disorder or competing two different structures were insignificant on prismatic faces, and so the growth rate on prismatic faces is faster than the growth rate on basal plane. The in-layer stacking competition was examined by two-dimensional density maps of water molecules and we investigate the kinetics of layer formation and the size dependence on the growth rates of ice crystals. I concluded that ice growth of basal plane is slower than that on prismatic plane because of this phenomenon.

PA11

MONTE CARLO MODELING OF ASTROPHYSICALLY-RELEVANT ICE EXPERIMENTS

ASPEN R. CLEMENTS, *University of Virginia*, and ROBIN T. GARROD

The formation of molecules in the interstellar medium is significantly driven by grain chemistry, ranging from simple (e.g. H_2) to relatively complex (e.g. CH_3OH) products. The movement of atoms and molecules on surfaces is little understood, and this is a quintessential component of surface chemistry (e.g. mobility of CO through H_2O ices). We show that ice structure created by utilizing an off-lattice Monte Carlo kinetics model is highly dependent on deposition parameters (i.e. angle, rate, and temperature). The model, thus far, successfully predicts the densities of deposition rate- and temperature-dependent laboratory experiments. The simulations indicate, when angle and deposition rate increase, the density decreases. On the other hand, temperature has the opposite effect and will increase the density. We can make ices with desired densities and monitor how molecules, like CO, percolate through H_2O ice pores. The model produces spectra consistent with TPD experiments and is in agreement with literature. The strength of this model lies in the ability to monitor molecules diffusing on and desorbing from user-defined surfaces and ices.

PA12

METABOLOMICS AS A TECHNIQUE FOR THE DETECTION OF BIOLOGICAL ACTIVITY IN EXTRATERRESTRIAL SAMPLES

JOLEEN CSUKA, NINA KOPACZ, *Columbia University*, and BRENT STOCKWELL

The search for extraterrestrial life will no doubt hold many surprises, as we have no example of life beyond our Earth, and no certainty of how similar it may be. The development of various biomarker detection techniques is thus important in preparation for the analysis of extraterrestrial samples, most notably from Mars. We propose metabolomics as a detection method for life. Metabolomics was performed on various Martian analogue soils, including tephra from the Pu'u Nene crater in Hawaii. The amounts of metabolites and their fluxes in the soils were recorded to create a catalogue which might serve as a guide as to whether a soil contains biological activity. This method does not aim to detect specific molecules such as DNA or proteins, which might not be present in other forms of extraterrestrial life, but rather focuses on any small molecules associated with metabolism, a function that is required by all life.

PA13

OPERATION OF PNEUMATICALLY-ACTUATED MEMBRANE-BASED MICRODEVICES DESIGNED FOR IN SITU ANALYSIS OF EXTRATERRESTRIAL ORGANIC MOLECULES AFTER PROLONGED STORAGE AND AT NEGATIVE GRAVITY

ZACHARY DUCA, *Georgia Institute of Technology*, and GEORGE TAN, THOMAS CANTRELL, MICHELLE VAN ENIGE, MAX DORN, MICHAEL CATO, NICHOLAS SPELLER, AARON PITAL, RICHARD MATHIES, AMANDA STOCKTON

Programmable microfluidic architectures (PMAs) are powerful arrays of normally-closed, pneumatically-actuated monolithic membrane microvalves capable of conducting complex fluid manipulation on the microscale, including dilutions, mixing, transfer, reactions, etc. With applications to all disciplines where field analysis is desirable, including point-of-care (POC) diagnostics, environmental science, space exploration, etc, these microvalve systems have been integrated into multiple chemical analysis techniques, including microcapillary electrophoresis (μCE) and ELISA assays. However, these systems have not seen wide-scale deployment in industry or spaceflight due in part to a misperception that the microvalves have a limited shelf-life due to irreversible bonding of the PDMS elastomer to the glass substrate. A further criticism for spaceflight applications has centered around a concern about operation at reduced or no gravity. Therefore, after 10 years of storage under ambient conditions, we tested a Mars Organic Analyzer microdevice fabricated in 2005 and demonstrated that it retained full functionality after 10 years of storage. All pneumatically-actuated valves opened after <5 hours of vacuum cycling at -950 mbar from STP. Using an automated LabVIEW program to actuate multiple valves in series, the microdevice transferred fluid at a flow rate of 122 ± 8 μL/min. Fluid transfer was done at both +1 and -1 g, indicating successful future implementation in a zero g environment. This demonstration that microdevices retain full functionality after over 10 years of storage combined with successful operation in both +1 and -1 g environments validates the value of PMA-based microdevices for fluidic manipulation in outer planetary missions.

PA14

DETERMINATION OF ENANTIOMERIC EXCESS OF UNMODIFIED AMINO ACIDS UTILIZING MICROCHIP CAPILLARY ELECTROPHORESIS ELECTROSPRAY MASS SPECTROMETRY

DEDRA EICHSTEDT, *Georgia Institute of Technology*, and FACUNDO FERNANDEZ, AMANDA STOCKTON

The building blocks of life's most essential biopolymers - proteins, DNA, and RNA - exhibit the property of homochirality. That is, the amino acids and sugars which comprise these polymers use only one of two possible conformations. It is not currently known how this property arose and proliferated in biological molecules. A leading hypothesis suggests that homochirality may have stemmed from an extraterrestrial symmetry-breaking event in chiral organic molecules. This event then led to the eventual amplification of either the L or D enantiomer, prior to or after the delivery of these molecules to Earth, influencing prebiotic chemistry. The discovery of exogenous L-amino acid enantiomeric excess (ee) in carbonaceous chondrite meteorites on Earth supports this hypothesis. Much recent work in testing this theory has focused on capillary electrophoresis as it offers these advantages but there is not currently a method that allows for the complete determination of the ee of all of the natural amino acids. Our new method using microchip CE separation coupled to a highly sensitive mass spectrometer shows promise in addressing these problems. This system can determine amino acid and sugar ee utilizing extremely small sample quantities at high sensitivity, needed due to the scarcity of uncontaminated meteorite samples of underivatized amino acids. Thus far, we have seen separation of the D and L enantiomers for alanine, valine, and glutamic acid using α and β cyclodextrin as chiral selectors. We have also achieved the separation of all 20 amino acids, including leucine and isoleucine, at 50 nM.

PA15

ON CRATER VERIFICATION USING MISLOCALIZED CRATER REGIONS

EBRAHIM EMAMI, *University Of Nevada, Reno*

Automatic crater detection in planetary images is an important task with many applications in planetary science, spacecraft navigation, landing, and control. Typically, crater detection algorithms consist of two main steps: candidate crater region extraction and crater verification. Various methods have been proposed for extracting candidate crater regions, ranging from detecting circular/elliptical regions to detecting highlight and shadow regions. For crater verification, powerful feature extraction and machine learning techniques have been employed. While this two-step approach can be efficient and robust, inaccuracies in the candidate crater region extraction step can result in mislocalized crater regions which could affect verification performance. In this paper, we investigate the robustness of various feature extraction methods to mislocalized crater regions. Using features which are robust to localization errors but also choosing a more representative training set has yielded significant performance improvements on an extensive dataset from the Lunar Reconnaissance Orbiter (LRO).

PB. Poster Session B

TUESDAY, JUNE 6, 2017 - 4:30 PM

PB01

PRODUCTION OF PRECURSOR ORGANIC MOLECULES UNDER SIMULATED HYPERVELOCITY IMPACT CONDITIONS

BENJAMIN J. FARCY, *NASA Goddard Space Flight Center/University of Maryland, College Park*, and A. GRUBISIC, M. FLOYD, X. LI, T. CORNISH, V. PINNICK, W. BRINCKERHOFF

Hypervelocity impacts (HVI's) could have played an important role in producing the inventory of pre-biotic molecules on the early Earth, specifically through impact plasma synthesis of organic and pre-organic molecules. Laser ablation experiments, which mimic impact plasmas, have been performed to study impact plasma generated organic molecules. A C-bearing ($CaCO_3$) and N-bearing (NH_4Cl) dry mineral pellet was ablated using a pulsed 1064 nm Nd-YAG laser, and the constituent neutral and ion plume was analyzed with a Quadruple plasma analyzer. We have detected CN^- in negative ion SIMS mode and HCN^+ in positive ion SIMS mode, showing that impact plasma chemistry can produce CN radicals that serve as amino acid precursors. Based on integrated mass 26 and 27 peak values, the resultant plasma chemistry produces CN radicals efficiently compared to procedural blanks with no added NH_4Cl. This has implications for organic molecule synthesis in meteorites and on the early earth, as HCN is a constituent molecule necessary for Strecker-type synthesis reactions, which are thought to lead to amino acid production in carbonaceous meteorites.

PB02

THE EFFECTS OF METAL IONS ON THE REACTIONS OF THIOESTERS IN PROSPECTIVE PREBIOTIC ENVIRONMENTS

RIO FEBRIAN, *Saint Louis University*, and PAUL BRACHER

We are interested in studying the kinetics of reactions of thioester-containing compounds in water in order to evaluate potential roles of these compounds in the origin of life. Previously, the reactivity of these compounds have been studied in buffered, clean aqueous systems. Given that the prebiotic ocean was unlikely to have resembled such a clean system, we wished to explore the effect of aqueous metal ions on the hydrolysis, aminolysis, and thiol-thioester reactions of thioesters. In addition to diamagnetic metals like Na^+, K^+, Mg^{2+}, and Ca^{2+}, paramagnetic metals such as Fe^{2+}, Mn^{2+}, and Co^{2+} are conjectured to have been present in the ancient ocean.

PB03

A PRELIMINARY INVESTIGATION INTO THE USE OF THE NETWORK TOPOLOGY OF EXOPLANET ATMOSPHERIC CHEMICAL REACTION NETWORKS AS A POTENTIAL BIOSIGNATURES

THERESA M. FISHER, *Arizona State University*, and SARA I. WALKER, HARISON SMITH, MICHAEL R. LINE, JAMES LYONS, AND CORAL RUIZ

One potential new approach for determining the presence of life on an exoplanet is examining the relationship between constituent gases of an exoplanet's atmosphere, in the form of a chemical reaction network (CRN). Previous studies have examined the network structure of every significant planetary atmosphere in the solar system, and found that Earth's is unique: the topology of Earths atmospheric CRN displays a hierarchical and modular structure with a scale-free degree distribution, whereas those of other planets do not. This suggests that the the presence of a global biosphere may influence the network topology.

To verify these results, and further explore network topology as a potential biosignature, we analyzed the network structure of several atmospheres using the Python NetworkX package, including Mars and hot and cool Jupiters, and compared them to that of both early and modern Earth.

Our results are consistent with earlier findings that topological properties can distinguish different planetary atmospheres. The majority of networks studied were too small to confirm whether or not they are indeed scale-free (a power-law fit to the degree distribution could not be confirmed nor refuted). Analyzing other topological measures suggests that biology, atmospheric composition and physical variables such as T and P all contribute to the large scale structure of atmospheric CRNs. These initial results suggest that network topology may be able to indicate the presence of a global biosphere, but that further work must be done to characterize the imprint of biology on large-scale organizational features of atmospheric chemistry.

PB04

THE ATMOSPHERE AND ORBIT OF THE ECCENTRIC HOT JUPITER HAT-P-30b FROM SPITZER ECLIPSES

ANDREW S. D. FOSTER, *Cornell University*, and JOSEPH HARRINGTON, PATRICIO E. CUBILLOS, JASMINA BLECIC, A.J. FOSTER, RYAN C. CHALLENER, JUSTIN GARLAND, EMERSON DELARME, G.A. BAKOS, J.D. HARTMAN

HAT-P-30b is a hot-Jupiter exoplanet that orbits an F star every 2.8106 days at a distance of 0.0419 AU. Using the SST in 2012 we observed two secondary eclipses at 3.6 and 4.5 μm. We present eclipse-depth measurements of 0.177% ± 0.018% and 0.247% ± 0.024% and estimate the infrared brightness temperatures to be 1990 ± 110 K and 2080 ± 130 K for these two channels, respectively, with our Photometry for Orbits, Eclipses, and Transits (POET) pipeline. These may be grazing eclipses, so these are lower-limit temperatures. We refine its orbit by combining our secondary-eclipse measurements with radial-velocity and transit observations from both professional and amateur observers. Using only the midpoint timings of our secondary eclipses, we can constrain $e \cos(\omega)$ to 0.0058 ± 0.0009, where e is the orbital eccentricity and ω is the argument of periastron. This is the component of eccentricity in the plane of view. This small but non-zero eccentricity is independent of the effects that stellar tides have on radial-velocity data. When including radial-velocity data in our model in addition to our secondary-eclipse midpoint timings and ground-based transit midpoint timings, our Markov-chain Monte Carlo finds an $e \cos(\omega)$ of 0.0043 ± 0.0007. Using our Bayesian Atmospheric Radiative Transfer code (BART), we constrain a one dimensional temperature-pressure profile. The eclipse depths give a large lower bound (700 km) for the scale height implying potential for high quality transit spectroscopy observations.

PB05

NANO-SPECTROSCOPIC APPROACHES TO ORIGINS OF LIFE AT MINERAL-ORGANIC INTERFACE

NARANGEREL GANBAATAR, *Tokyo Institute of Technology*, and NINA MATSUZAKI, YUYA NAKAZAWA, REHANA AFRIN, MASASHI AONO, YANO TAKAAKI, TOMOHIRO HAYASHI, MASAHIKO HARA

'Origin of life', this never-ending mystery is believed to originate from chemical reactions at surfaces in the Hadean period on the Earth. While there are many proposals and preliminary experiments to reveal the origins, still no clear evidence has been reported yet because of a lack of the nanoscopic studies. Here we demonstrate the first observations of mineral surfaces to understand the 'Origin of Life' at molecular level using a combination of novel techniques of Raman Spectroscopic Imaging and Atomic Force Microscopy (AFM). Pyrite (FeS_2), hematite, clay minerals are known to be the most common and potential minerals that provide the condensation and the reaction surface for chemical evolution. However, those minerals have mostly been studied from crystallographic viewpoint or in bulk system which cannot fully resolve the exact mechanism of the specific interaction on these minerals' surfaces. Moreover, there has been no direct experimental evidence reported about the minerals as a reaction surfaces initiating the chemical evolution at nano scale. The quantitative force analysis of AFM in which a single amino acid residue was mounted on the tip apex of AFM probe enabled us to find the reaction sites and to study the interaction forces between amino acid and selected mineral surfaces. Our results of Raman Spectroscopic Imaging and force measurements with well-designed AFM probe revealed for the first time that surface specific area, crystal plane of mineral are important factors for biomolecular adsorption on mineral surfaces.

PB06

PHYLOGENY OF PUTATIVE IRON OXIDASE CYC2 REVEALS DETAILS ABOUT THE EVOLUTION OF MICROBIAL IRON-OXIDATION

ARKADIY GARBER, *University of Delaware*, and SEAN MCALLISTER, BEVERLY HALLAHAN, SHARON ROZOVSKY, AND CLARA S. CHAN

Iron is the fourth most abundant element in earth's crust, and its reduced form, Fe(II), was widely available as an energy source for aerobic Fe(II)-oxidation at the onset of O_2 availability prior to the Great Oxidation Event. On modern Earth, chemolithoautotrophic microorganisms use Fe(II) for growth at redox boundaries with steep gradients of available Fe(II) and O_2. However, due to difficulties in cultivating Fe-oxidizing Bacteria (FeOB), relatively little is known about the evolution and mechanisms of iron-oxidation enzymes. Cytochrome Cyc2 has recently been identified as an important component of the iron-oxidation pathway in acidophilic FeOB. Cyc2 has since been found in all known microaerophilic FeOB, including neutrophiles and isolates with no known iron-oxidation phenotype. We compared the genomes of Cyc2-containing organisms to investigate Cyc2 and proteins that are thought to interact directly with it (i.e. periplasmic Cyc1). This analysis may provide clues to the origin of Cyc2 and horizontal gene transfer event(s) that led to its phylogenetic fingerprint. So far, we have found Cyc2 homologs in over 500 genomes, many of which also have homologs to Cyc1, and are identifying isolates to test for iron-oxidation. Moreover, we've expressed Cyc2 in E. coli, and are working in its biochemical characterization. Given the wide range of isolates and metagenomes where Cyc2 has been found, it is possible that microbial iron-oxidation is a more prevalent metabolism than previously thought. Our work will establish a better understanding of the evolution of iron-oxidation and the role of Cyc2.

PB07

ANI AS A TOOL TO UNDERSTAND PHYLOGENETIC RELATIONSHIPS

SEAN GOSSELIN, *University of Connecticut*, and MATTHEW S. FULLMER, J. PETER GOGARTEN

Average nucleotide identity (ANI) has been used in prokaryotic phylogenetics and systematics to allow the discrimination of species. However, the proportion of the genomes contributing to the calculation, the alignment fraction (AF), is often not taken into account by users when reporting ANI values. Varghese et al. (Microbial species delineation using whole genome sequences. Nucleic Acids Res 43:6761-6771), proposed using a combined approach in 2015 using a variation of ANI values in addition to the AF values, which they showed could successfully delineate species at a high level of accuracy. Our research has focused on converting Vargheses method to construct phylogenetic trees with statistical support. We have developed a conversion to combine the ANI and AF numbers into a single distance, which can be used to infer a tree. We also implement a resampling method on this data to rapidly generate a bootstrapped confidence set. These bootstraps can then be used to assess the reliability of the original tree. Initial results point to our distance calculation being useful in constructing phylogenetic trees, and further testing will hopefully prove its robustness. I addition whole genome distance calculations have shown promise in delineating taxonomical groupings above the species level.

PB08

THERMAL STABILITY OF FUNCTIONAL RNA ENHANCED INSIDE COACERVATES

REBECCA M. GUTH, *Pennsylvania State University*, and R. R. POUDYALL, P. C. BEVILACQUA

Modern life uses compartmentalization around and within its cells to maintain dynamic equilibrium. The evolution from prebiotic conditions to compartmentalized organisms may have been achieved in part through coacervation. Coacervates are an attractive system to study the origins of protocells and membraneless organelles. Interactions of oppositely charged polymers and ions cause liquid-liquid phase separation into molecularly concentrated coacervate droplets and dilute bulk solution. The polymer-rich coacervate phase has been shown to concentrate ions, nucleotides, and RNA polymers.[1] To understand the effects of coacervates on functional RNAs, we are studying the stability of RNA within these compartments. In the RNA World theory, RNAs were thought to both carry the genetic code and function as early enzymes before the advent of DNA and proteins. We find that functional RNAs such as the fluorescent aptamer "Broccoli" remain functional within coacervates. Our preliminary studies show that the crowded conditions inside coacervates may stabilize Broccoli's active structure. We are currently exploring the effect of temperature and different ionic conditions on the stability of functional RNAs within coacervates. Thermal stability of RNAs through inclusion within coacervates may have conferred a selective advantage to RNAs within the coacervate-containing environment. Enhanced RNA functionality could be buffered from environmental temperatures. This takes on additional importance when coupled with the hypothesis that life may have begun at hydrothermal vents where temperatures range from near zero to hundreds of degrees Celsius.

[1] Frankel E. A., Keating C.D., and Bevilacqua P. C. (2016) Langmuir, 32, 20412049.

PB09

A MODEL OF THE Hα AND Na TRANSMISSION SPECTRUM OF HD 189733B

CHENLIANG HUANG, *University of Virginia*, and PHIL ARRAS, DUNCAN CHRISTIE, ZHI-YUN LI

The hot gas in the upper thermosphere of hot Jupiter sets the boundary condition for understanding the rate of gas escape. Among current detections, Hα and Na transmission spectrum may play an important role in understanding the conditions in the planet's thermosphere. I present a detailed atmosphere model and comparison of Hα and Na model transmission spectra to the data, with the goal of constraining the temperature, particle densities and radiation field in the region where the absorption line is formed. A hydrostatic atmosphere is constructed over the pressure range $10^{-4} \rightarrow 10$ μbar. Ionization equilibrium and balance of heating and cooling processes are enforced at each level of the atmosphere. The Lyα radiation intensity is computed using a Monte-Carlo code which includes resonant scattering, as well as photon destruction. Both the incident stellar Lyα and internal sources due to recombination cascade and collisional excitation are included. The atomic hydrogen level population is computed including both collisional and radiative transition rates. The model transmission spectra are in broad agreement with the HD 189733b observation data by Jensen et al and Cauley et al. The combination of large Lyα excitation rates and increasing hydrogen density with depth give rise to a nearly flat at n = 2 state density over two decades in pressure. This layer is optically thick to Hα, and temperature is in the range 3000 8500 K. Additional models computed for a range of stellar EUV flux find transit depth changes with EUV level, suggesting that the variability in transit depth may be due to variability in the stellar EUV. Since metal lines provide the dominant cooling of this part of the atmosphere, the atmosphere structure is sensitive to the density of species such as Mg and Na which may themselves be constrained by observations.

PB10

LOW-CO_2 ATMOSPHERE ON EARLY MARS INFERRED FROM MANGANESE OXIDATION EXPERIMENTS

SHOKO IMAMURA, *University of Tokyo*, and N. NODA, Y. SEKINE, S. UESUGI, M. KURISU, C. MIYAMOTO, H. TABATA, T. MURAKAMI, Y. TAKAHASHI

Several lines of evidence show that early Mars had been once warm sufficient to hold liquid water on the surface at least episodically in the late Noachian and early Hesperian. However, an actual pCO_2 level on early Mars has been poorly constrained by geochemical evidence. On the other hand, the Curiosity rover has discovered Mn oxides in fracture-filling materials in sandstones of the Kimberley region of the Gale crater. Given pO_2 levels capable for deposition of Mn oxides ($pO_2 > \sim 0.01$ bar), the findings of Mn oxides indicate that early Mars had a substantial O_2 in the atmosphere. The Curiosity rover also found a lack of Mn carbonate in the Kimberley formation, which could imply a low CO_2 atmosphere at that time. The present study performed laboratory experiments to further constrain the atmospheric composition on early Mars, particularly CO_2/O_2 ratio. Our results suggest that, even when CO_2/O_2 ratio is low ($\sim$0.02), Mn precipitate formed by reactions of Mn^{2+}-bearing solution with a CO_2/O_2 gas mixture is composed mainly of Mn carbonate. Our results show that, in order to form MnO_2 from Mn^{2+} in solution, CO_2/O_2 ratio should be at least lower than 0.02. Assuming pO_2 of $\sim$0.01-0.2 bar, which is sufficient to form Mn oxide, the observations of both a lack of $MnCO_3$ and presence of MnO_2 in the Gale crater infer that pCO_2 on early Mars would have been several mbar or less. This implies that early Mars may have possessed a low-CO_2 and high-O_2 atmosphere.

PB11

EFFECTS OF BOND ENERGY ON A MODEL OF PREBIOTIC EVOLUTION

BEN FREDERICK M. INTOY, *University of Minnesota, Twin Cities*, and A. WYNVEEN, J. W. HALLEY

In earlier work [1,2], we studied models for prebiotic evolutionfollowing Kauffman [3] but imposing the condition that,to be considered lifelike, a system be required to be out of chemical equilibrium. The added condition had a significant effect on the predicted likelihood of appearance of lifelike states. In that previous work, the bond energy associated with connecting polymer chains was set to zero. In this presentation I will review earlier work and report present studies of a 'well-mixed model' (with fast diffusion) taking bond energies into account by imposing a detailed balance requirement on the rates used in the dynamical simulation. The detailed balance requirement is different depending on whether the system is thermally isolated or not. In the latter case we compute temperatures and chemical potentials consistent with the instantaneous energy and polymer number 'on the fly' in order to determine the requirement, whereas in the former case, only the chemical potential is recalculated consistent with the instantaneous polymer number and temperature. In the cases of life-like interest, an equilibrium distribution is never reached. The lifelike systems are kinetically blocked from reaching the equilibrium condition toward which the detailed balance requirement is driving it. I will discuss differences between the fixed external temperature case and the isolated case, and also interesting effects of the results on details of the distribution of small polymers in the 'food set'. This work is supportedby NASA grant NNX14AQ05G.

[1] Physical Review E 89, 022725 (2014).
[2] Physical Review E 94, 042424 (2016).
[3] Kauffman, S.A., 1993. The Origins of Order. Oxford University Press, USA. Ch. 7.

PB12

SELF-ASSEMBLY OF MULTIPLE SMALL RNA FRAGMENTS INTO AN AUTOCATALYTIC PREBIOTIC SYSTEM

THARUKA S. JAYATHILAKA, *Portland State University*, and N.LEHMAN

The RNA World is the theoretical idea that there was a period in the early history of life on Earth when RNA, or something chemically very similar, carried out most of the information processing and metabolic transformations needed for life to emerge from chemistry. Life is based on biopolymers that have the ability to replicate themselves. Ferris et al. described the abiotic synthesis of long prebiotic oligomers in the range of 20-30, from activated monomers on catalytic montmorillonite surface. In an effort to find out how life emerged from chemistry, it would be useful to be able to demonstrate that even shorter RNA oligomers can form stable catalytically active contiguous ribozymes in vitro. This study describes a system that models prebiotic formation of a catalytically active ribozyme by the recombination of inactive RNA oligonucleotides. For a prebiotic system, we use the covalently self-assembling Azoarcus tRNA intron, which was previously described in Hayden & Lehman (2006). Here we show the fragmentation and covalent self-assembly of the Azoarcus group I intron from five shorter inactive RNA fragments. Furthermore, this system illustrates that continuous cycles of hydration-dehydration enhance the chances that random shorter oligomers will recombine. These self-assembly reactions are being tested under different hydration and dehydration conditions for a lengthy period of time to analyze how early Earth conditions such as evaporation, and rehydration could affect the replication of an autocatalytic system.

PB13

IRON PLAYS IMPORTANT ROLE IN RNA WORLD AND EARLY CELLULARIZATION

LIN JIN, *Harvard University/Boston University*, and JACK W. SZOSTAK

Iron, one of the most abundant elements on earth, has long been interested for its prebiotic impact on origin of life. 30 years ago, Wächtershäusers Iron-sulfur world hypothesis proposed that the catalytic transition metal solid surfaces in hydrothermal vents helped to form the metallo-peptides, which was considered precursors of life. However, in the more generally accepted RNA world hypothesis for abiogenesis, it is not obvious to find the linkage between iron and genetic materials. Inspired by the critical catalytic role Mg^{2+} plays in modern biology for the DNA and RNA copying machinary, we wonder whether Fe^{2+}, with the same charge and similar ionic radius as Mg^{2+}, could catalyze some prebiotic RNA chemistry. Here, we mimic the anaerobic condition of the early earth by the oxygen free glove box and study the catalytic effect of Fe^{2+} for non-enzymatic RNA chemistry of template-directed polymerization and ligation, which are key reactions to achieve the RNA self replication. We found not only could Fe^{2+} replace Mg^{2+} for these reactions, it also performs much better in near neutral pH condition and even with low concentration compared to Mg. Apart from the catalytic role of iron for RNA chemistry, compatibility of iron to lipid vesicles is also studied for its function for early cellularization. Our results highly suggest that the abundant Fe^{2+} before great oxygenation event on early earth is closely related to the RNA world and protocell function for origin of life study.

PC. Poster Session C

WEDNESDAY, JUNE 7, 2017 - 10:00 AM

PC01

REMOTELY DETECTABLE ATMOSPHERIC FEATURES FOR EARTHS AND SUPER-EARTHS FOR FGK STARS

ABHINAV JINDAL, *Cornell University*, and LISA KALTENEGGER

We model atmospheres for Earth and Super-Earths orbiting F, G and K-type main sequence stars with effective temperatures ranging from T_{eff} = 4250K to T_{eff} = 7000K in 250K intervals. We compare remotely detectable features in the atmospheres including biosignatures.

PC02

PHOTOCHEMICAL FORMATION OF SULFUR-CONTAINING AEROSOLS

JAY A. KROLL, *University of Colorado, Boulder*, and VERONICA VAIDA

In examining the planetary conditions required for habitability, a clear understanding of planetary climates systems is vital. Aerosol formation plays an incredibly important role in climate systems and is tied to feedback loops that can either warm or cool a planet. Sulfur compounds have been observed in a number of planetary atmospheres throughout our solar system and are known to play an important role in aerosol formation. Our current understanding of sulfur chemistry explains much of what we observe in Earths atmosphere; however, several discrepancies arise when comparing observations of the Venusian atmosphere with model predictions. This suggests that there are still problems in our fundamental understanding of sulfur chemistry. We investigate the role of sunlight as a potential driver of the formation of sulfur-containing aerosols. I will present recent work investigating the generation of large quantities of aerosol from the irradiation of mixtures of SO_2 with water and organic species, using a photochemical lamp that mimics the light that is available in the Earths troposphere and the Venusian middle atmosphere. I will present a proposed mechanism for the formation of sulfurous acid, H_2SO_3, and describe recent experimental work that supports this proposed mechanism. The implications of this photochemically-induced sulfur aerosol formation in the atmosphere of Earth and other planetary atmospheres will be discussed.

PC03

THE ROLE OF MINERALS IN ORGANIC DETECTION EXPERIMENTS ON MARS

JAMES M. T. LEWIS, *NASA Goddard Space Flight Center*, and J. L. EIGENBRODE, H. B. FRANZ, A. C. MCADAM, C. A. KNUDSON, S. ANDREJKOVICOVA, B. SUTTER, P. D. ARCHER, P. B. NILES

The detection and analysis of indigenous organic matter has been a long time goal for missions to Mars. Thermal experiments, capable of liberating organic fragments from powdered samples, were included on the payloads of the Viking and Phoenix landers and on the present-day Mars Science Laboratory (MSL) rover. The Viking landers detected chloromethane while the Phoenix lander observed no organics. However, the Sample Analysis at Mars (SAM) instrument suite within MSL has detected chlorobenzene and dichloroalkanes at elevated levels and provided evidence for refractory organic matter, indicating a contribution from organics present on the surface of Mars. Thermal experiments can also provide constraints on the volatile mineral assemblage within samples. Perchlorate salts were observed by wet chemistry and heating experiments on the Phoenix lander and confirmed to be present in Gale Crater by SAM. Perchlorates thermally decompose to release chlorine and oxygen, which react with organic matter and complicate its detection. In addition, MSL has detected multiple iron and sulfur bearing minerals that will decompose within the temperature range achieved by the SAM oven. Laboratory studies are being used to investigate how different mineral species will impact our ability to detect organic matter on Mars. A SAM-like laboratory evolved gas analysis mass spectrometry (EGA-MS) procedure is being used to examine how volatiles evolve from different mineral-organic mixtures. A range of organic compounds are being utilised, including organic salts and kerogen. These results aid interpretation of existing data and identify amenable mineral assemblages for organic detection on Mars.

PC04

CLOUDS ON THE INNER EDGE

JACK MADDEN, *Cornell University*

Here on Earth the shade of a cloud can provide momentary relief on a brutally hot summer day but for life on exoplanets clouds can mean the difference between life and death. In this work we explore the role water clouds play on the habitability of recently discovered exoplanets on the inner edge of the classically defined habitable zone and how the presence of clouds would influence the detectability of potential biosignatures. Using a coupled climate and photochemistry model we first simulate cloud evolution in these environments to determine surface conditions. Through the modeling process we also obtain the photochemically stable profiles of various molecules that may be present in the atmosphere. These profiles can be used to generate spectra that mimic future observations using reflected light or transmission. Clouds can hinder our ability to identify the atmospheric composition of exoplanets and also play a big roll in the energy balance of the climate. Our work will determine the extent of these effects, provide constraints on the range of habitable environments one would expect to find, and point to which ones would most likely be detectable in the near future. This type of study is very useful in the current stages of exoplanet characterization as the difficulty of these measurements makes fully thought out candidate prioritization an essential component of finding life sooner rather than later.

PC05

INTERSTELLAR REACTION SCREENING VIA MICROWAVE SPECTRAL TAXONOMY

BRETT A. MCGUIRE, *National Radio Astronomy Observatory*, and MARIE-ALINE MARTIN-DRUMEL, MICHAEL C. MCCARTHY

For decades, astronomers have been using broadband spectral line surveys as methods of studying interstellar chemical evolution in interesting sources. A target is selected, and all available molecular signals over a wide range of frequencies are collected in an unbiased fashion. This allows both for specifically-targeted investigations to be conducted, as well as providing a large dataset for later use and new molecular discovery as new laboratory data becomes available.
Recent advances in microwave spectroscopy have allowed us to apply this same principle of unbiased molecular investigation and discovery to the study of chemical evolution in the laboratory. One or more precursor molecules typical of an interstellar source are selected, subjected to an electrical discharge to create reactive species, and the products are probed via broadband microwave spectroscopy. We then use a variety of analytical techniques to determine what known species are produced, understand the formation pathways of these species, and identify previously unknown molecular species. Here, I present our first complete reaction-screening experiment, examining the results of a CS_2 + HC_4H discharge, which produces products such as C_2S and C_3S which are highly-relevant to evolved carbon-star source such as IRC+10216. These stars are one of the primary producers of dust in the interstellar medium.

PC06

rRNA EXPANSION SEGMENTS OF HOMO SAPIENS: FUNCTION AND STRUCTURE

SANTI MESTRE FOS, *Georgia Institute of Technology*

Ribosomes are molecular fossils that have been fitfully increasing in size for around four billion years. Recent growth, over the last 1 billion years, is apparent from comparing secondary and three-dimensional structures of ribosomes across different species. Organismal complexity is correlated with the size of the rRNA: ribosomes (LSU) of metazoans are larger than those of protists. Eukaryotic ribosomes are larger than those of prokaryotes. rRNA additions to the ribosome, which occur at specific sites, are known as "expansion segments" (ESs). ESs are found on the ribosomal surface and do not perturb the common core, which contains the peptidyl transfer center (PTC) and the decoding center. Recent studies indicate that ESs of Homo sapiens and Saccharomyces cerevisiae bind to a wide range of non-ribosomal proteins that are part of multiple cellular processes. Furthermore, based on different CD spectra obtained with different monovalent cations, some ESs of the human ribosome have the potential of forming G-quadruplexes. Based on these recent data, our goal is to determine if these ESs are truly able to form G-quadruplexes and to better understand their function by performing trafficking studies in vivo. Their significantly larger sizes in metazoans compared to those of simpler species suggests that in higher organisms the ribosome has evolved to become a direct player in a wide range of different cellular processes.

PC07

EXPLORATION OF NOVEL SUBSURFACE MICROBIAL COMMUNITIES WITHIN SEAFLOOR MANTLE ROCKS

SHAHRZAD MOTAMEDI, *University of Utah*, and WILLIAM J. BRAZELTON, IODP EXPEDITION 357 SCIENTIFIC PARTY

Ultramafic rocks in Earth's mantle represent a tremendous reservoir of carbon and reducing power. Mixing of these rocks with overlying seawater due to tectonic uplift causes an exothermic reaction known as 'serpentinization' that also releases hydrogen gas, methane, and small organic molecules. The H_2 and CH_4-rich environments provided by serpentinization reactions are thought to be analogous to conditions found on the early Earth and perhaps other planets. During October-December of 2015 the International Ocean Discovery Program Expedition 357 to the Atlantis Massif collected rocks from a subseafloor site of active serpentinization for the first time. One of the main goals of this drilling project is to generate a survey of the archaea and bacteria in marine serpentinite rocks by comparing the 16S rRNA gene sequences between the recovered cores of various holes with each other, to the background seawater, and to previous studies on carbonate chimneys at LCHF. A major challenge of this project is to obtain sufficient high-quality DNA from low-biomass serpentinite rocks for sequencing studies. Customized DNA extraction and purification procedures are currently being optimized for these sample types and to control for and identify contaminating DNA during all stages of sample processing. Currently, almost nothing is known about the biology of the marine serpentinite subsurface. This research project will produce the first census of the diversity of microbes within the serpentinizing rocks collected from the Atlantis Massif.

PC08

LOW-TEMPERATURE HYDROCARBON GENESIS IN SERPENTINIZING ENVIRONMENTS

DANIEL NOTHAFT, *University of Colorado, Boulder*

The processes that produce methane (CH_4) in ultramafic rock aquifers undergoing aqueous alteration (serpentinization) at low temperatures (<150°C) are enigmatic. Although CH_4 is often the thermodynamically favored form of C in the reducing conditions created by serpentinization, there are strong kinetic barriers to CH_4 formation. The pathways to overcome those barriers are important to identify due the role of abiotic C reduction as a means of producing potential prebiotic compounds and feedstocks for microrganisms like methanotrophs. The Samail Ophiolite in the Sultanate of Oman and the United Arab Emirates is the world's largest and best-exposed continental ultramafic rock formation, providing an excellent natural laboratory for studying CH_4 in serpentinizing systems. I will present C and H isotopic data on volatile hydrocarbons sampled from boreholes in the Samail Ophiolite, which is diagnostic of their formation mechanism. Additionally, I am culturing methanogens from the Samail Ophiolite in a continuous flow reactor to quantify the effect of carbon limitation on the expressed isotope fractionation during methanogenesis, building on previous batch culture studies that have suggested that ^{13}C-enriched CH_4 could be a result of slow carbonate dissolution suppressing the isotope fractionation of methanogens, rather than the abiotic processes conventionally invoked to account for this ^{13}C enrichment. These field and laboratory based studies will provide insight into the coupling of methane production and serpentinization processes on silicate bodies of our solar system such as Enceladus, Europa, and Mars.

PC09

COLONIZATION, SUCCESSION, AND S(0) MINERALIZATION OF SULFUR OXIDIZING BIOFILMS IN THE FRASASSI CAVE SYSTEM

MICHAEL PAVIA, *University of Delaware*, and PAULINE HENRI, JENNIFER MACALADY, CLARA CHAN

Elemental S(0) is a key intermediate in sulfur cycling, but we are still learning about how microbes make S(0). Filamentous Epsilonproteobacteria are thought to be key architects of S(0) rich streamer biofilms found in the Frasassi cave system. The biochemical mechanisms by which these microbes produce extracellular S(0) is still not fully known. In order to understand S(0) metabolism by Epsilonproteobacteria we need to determine their role in streamer formation, S(0) biomineralization, and the community ecology of these biofilms. We conducted a colonization experiment using nets placed at the stream-air interface. Within three days the nets were colonized by streamers, and samples were collected over 17 days for geochemical and molecular biological analysis. The biofilms maintained a simple community structure with two operational taxonomic units (OTUs) making up 75% to 95% of the population abundance: an Epsilonproteobacteria Sulfurovumales and a Gammaproteobacteria Thiofaba. Sulfurovumales was at its highest abundance at day 3 (the first time point); due to their ability to produce extracellular S(0) and their filamentous morphology, we hypothesize that these organisms play a role in the early development of these biofilms. We are currently re-analyzing existing metagenomes from the cave and sequencing ones from our new samples. A metatranscriptomic analysis will then be utilized for community function and gene regulation of biogenic S(0) production and biofilm maturation.

PC10

DIFFUSION OF BIOMOLECULES IN VESICLE ASSEMBLED RNA-BASED COACERVATES

FATMA PIR-CAKMAK, *Pennsylvania State University*, and WILLIAM M. AUMILLER, BRADLEY DAVIS, CHRISTINE D. KEATING

Liquid-liquid phase separation is being investigated for understanding cells in terms of membraneless organelles and protocells. Compartmentalization through introducing aqueous two-phase systems could enable concentration of the genetic and catalytic materials that are presumed to have been present at low concentrations on the early earth. Characterizing and utilizing the physical and chemical nature of the compartmentalization models will allow better understanding and control over these systems. We aimed to investigate intra- and inter-droplet exchange of nucleic acids, that is relevant to their evolution, and explore how partial droplet and whole droplet bleach recovers in coacervates composed of RNA and proteins. Here, we show that complex coacervates composed of low complexity RNA and short polyamines compartmentalize biomolecules (peptides, oligonucleotides) in a sequence- and length- dependent manner. These solutes retain mobility within the coacervate droplets, as demonstrated by rapid recovery from photobleaching. We further demonstrate that lipid vesicles assemble at the droplet interface without impeding RNA entry/egress. These vesicles remain intact at the interface and can be released upon temperature-induced droplet dissolution.

PC11

AVOIDING “FALSE POSITIVES” IN EXTRASOLAR LIFE DETECTION: POTENTIAL SIGNATURES OF O_2 FROM ABIOTIC PROCESSES

EDWARD SCHWIETERMAN, *University of California, Riverside*, and VICTORIA MEADOWS, SHAWN DOMAGAL-GOLDMAN, GIADA ARNEY, RORY BARNES, CHESTER HARMAN, RODRIGO LUGER

Molecular oxygen (O_2) and its photochemical byproduct ozone (O_3) are the most studied potential exoplanet biosignatures, because they signal the presence of an active photosynthetic biosphere on Earth. In the past, the potential for abiotic mechanisms to generate oxygen was thought to be regulated to planets outside the traditional habitable zone, and therefore discernible by simple observables like planet-star distance. However, recent modeling studies have elucidated several plausible pathways for producing detectable abiotic oxygen on planets within the habitable zone, particularly for those orbiting M dwarf stars. This talk will present strategies for mitigating against these potential “false positives” for life, focusing particularly on the associated observables that would fingerprint the abiotic source of O_2/O_3. For example, O_2 produced by photolysis of CO_2 should be accompanied by signatures of CO and CO_2, while strong O_4 might indicate accumulation of bars of O_2 from massive hydrogen loss. Likewise, N_2 revealed through N_2-N_2 collisional absorption would rule out O_2-buildup from atmospheres lacking in non-condensing gases. Conversely, the detection of reduced gases, such as CH_4, in combination with O_2/O_3, would confirm the existence of a chemical disequilibrium, more strongly suggestive of life. To make these assessments, the spectrum of the planet must encompass a wavelength range sufficient to capture these complementary absorbing species. Additionally, the mode of observation (direct-imaging or transmission spectroscopy) will strongly affect detectability. By considering these factors, future biosignatures surveys will be able to more robustly assess the case for the biogenic origin of oxygen detected in an exoplanet atmosphere.

PC12

IDENTIFICATION OF BACTERIAL ISOLATES COLLECTED FROM SPACECRAFT AND ASSOCIATED SURFACES AT SUBSPECIES LEVEL USING MATRIX ASSISTED LASER DESORPTION IONIZATION - TIME OF FLIGHT MASS SPECTROMETRY (MALDI-TOF).

ARMAN SEUYLEMEZIAN, *NASA Jet Propulsion Laboratory*, and HEIDI ARONSON, MANDY LIN, JAMES TAN, WAYNE SCHUBERT, PARAG VAISHAMPAYAN

The key objective of NASA's Office of Planetary Protection is to prevent inadvertent biological contamination of other planetary bodies, which may jeopardize life detection efforts, by assembling spacecraft in cleanrooms and monitoring microbial bio-burden on spacecraft and associated surfaces. The Jet Propulsion Laboratory (JPL) has the largest bacterial archive of isolates from spacecraft-associated surfaces. Identification of these isolates was routinely performed by sequencing the 16S rRNA gene. Although this technique is an industry standard, it is time consuming, expensive, and knowledge of bioinformatics tools. Matrix-assisted laser desorption/ionization time of flight (MALDI-TOF) mass spectrometry is widely used in clinical diagnostics and is a promising method to replace standard 16S sequencing at JPL. However, available databases do not include isolates found in spacecraft-assembly cleanrooms. This study developed the first and largest custom database of MALDI-TOF MS profiles of isolates obtained from spacecraft-associated surfaces and cleanroom environments. With the use of this accurate and comprehensive database, 85% of bacterial isolates were identified in accordance with their 16S rRNA-based classifications. Additionally, MALDI-TOF MS was able to resolve sub-species variation within OTUs and distinguish between members of taxonomic groups, which are both not possible using conventional 16S rRNA sequencing.

PC13

COMPUTATIONAL INSIGHTS INTO THE EMERGENCE OF REPLICATION, HEREDITY, AND DIVERSIFICATION IN ABIOTIC SYSTEMS

HARRISON B. SMITH, *Arizona State University*, and W. HORDIJK, S. OTTO, S. I. WALKER

Contemporary biology exhibits many phenomena whose emergence from non-living systems have been studied but not yet fully explained, such as replication, heredity, and speciation. The emergence of these phenomena leads to specific questions fundamental to understanding the origins of life before the hereditary architecture of modern genes first evolved. In particular, how is diversity generated or maintained in prebiotic systems? What characterizes a line of descent? How does information propagate forward through time? Laboratory research has been conducted to investigate these questions, perhaps most directly through a synthetic chemical system composed of self-replicating fibers that compete for molecular building blocks. This system is capable of replication without complementary templating, providing a novel model for heredity in abiotic systems. Aside from replication, this system is found to exhibit other features normally associated with biology, such as diversification, and mutation. Due to the nature of this laboratory work, instrument limitations restrict the amount of information that can be extracted from the system, stymieing our understanding of the mechanisms driving the emergence of these 'life-like' features. We conduct computational simulations based on the model of this synthetic chemical system, featuring the reactions hypothesized to be occurring in-vitro, in order to fully record the features of the system which cannot be probed using laboratory analytics. Here we present the features uniquely investigated by our computational simulations, including preliminary results as they apply to the open questions posed above.

PD. Poster Session D

WEDNESDAY, JUNE 7, 2017 - 3:00 PM

PD01

NO LAUGHING MATTER: NITROUS OXIDE PRODUCTION BY CHEMODENITRIFICATION IN THE FERRUGINOUS PROTEROZOIC OCEAN

CHLOE L. STANTON, *Georgia Institute of Technology*, and C. T. REINHARD, J. F. KASTING, T. W. LYONS, J. B. GLASS

Dimmer solar luminosity required an enhanced greenhouse effect to sustain liquid water on Earths surface prior to ~2 Ga, but evidence for liquid water throughout Earths history is incontrovertible. Solutions to this "Faint Young Sun Problem" are often attributed to CO_2 and CH_4 because the more potent N_2O molecule would have photodissociated in the anoxic Archean atmosphere. However, an N_2O greenhouse may have existed after the Great Oxidation Event at ~2.4 Ga when atmospheric O_2 levels rose to 0.001-0.1 PAL, though the deep ocean remained anoxic and Fe^2+-rich (~3 mM). Chemodenitrification, the abiotic reduction of dissolved oxidized nitrogen to gaseous forms, could have been an important source of Proterozoic N_2O. To achieve N_2O concentrations allowing above-freezing temperatures with modern CO_2 and CH_4 at 0.001-0.1 PAL O_2, 10-500x modern fluxes are needed. We measured N_2O production rates in anoxic seawater with Fe^{2+}, NO_2^-, NO_3^-, or NO. Minimal N_2O was produced with single substrates, less than 0.01% of NO_2^- was converted to N_2O with Fe^{2+}, and greater than 25% of NO was converted with Fe^{2+}. Increasing NO from 13 to 44 μM led to 2.9x higher N_2O yield. Increasing Fe^{2+} from 10 to 500 μM led to 4.5x higher N_2O yield, yielding rate orders of 0.7 and 0.3 with respect to NO and Fe^{2+}, respectively, and a rate constant of 3.6 x 10^-7 sec^-1. 10-500x modern N_2O fluxes are generated at less than nanomolar NO, suggesting chemodenitrification could have contributed to solving the "Faint Young Sun Problem" in the Proterozoic.

PD02

USING A HIGH VACUUM APPARATUS TO TEST ASTROCHEMICALLY-RELEVANT REACTIONS INVOLVING MOLECULAR OXYGEN (O_2)

KAMIL B. STELMACH, *George Mason University*, and PAUL D. COOPER

Oxygen is a common constituent of many astrochemically important molecules, both in interstellar space and local planetary bodies. One of the more obvious is water, H_2O, but they include other molecules like carbon dioxide (CO_2), carbon monoxide (CO), carbon suboxide (C_3O_2), molecular oxygen (O_2), hydrogen peroxide (H_2O_2), and ozone (O_3). Large icy bodies within the solar system have tenuous atmospheres, which have surface pressures similar to what is found within high vacuum (HV) systems. HV systems have a steady supply of O_2 that can co-deposit as an ice on a cold finger or even deposit while irradiating a pre-existing ice sample. Another major component, molecular nitrogen (N_2) is relatively inert. Therefore, we tested the ability of HV systems to act as analogs to the aforementioned environments. Gas mixtures of varying ratios of a carbon source (either CH_4 or CO) and H_2O were prepared and deposited on a cold finger at 6 K and a baseline vacuum of 1 x 10^{-7} Torr. Ice samples were irradiated using 5 keV electrons over varying periods of time. Products were identified using FTIR spectroscopy, UV-Vis Spectroscopy, and a residual gas analyzer. The major products identified were O_3, CO_2, CO, and C_3O_2. This agrees well with other experiments where O_2 is part of the original gas mixture. We conclude that while an ultra-high vacuum (UHV) system would still be preferable for ISM astrochemical research, a HV system could help lead to new insights in oxygens role in the larger planetary bodies in our solar system.

PD03

CHEMICAL MODELS OF STAR FORMATION: TOWARD A MORE REALISTIC MODEL OF HOT CORES/CORINOS

GWENDOLINE STÉPHAN, *University of Virginia*

Hot cores and hot corinos, transient stages of high and low mass star formation respectively, are hot (>100 K), dense (>10^6 cm^{-3}) and compact (<0.1 pc) regions surrounding the newly-born proto-star. Due to their very rich and complex chemistry, these regions have been thoroughly studied and modeled. New molecules, with a special interest for complex organic molecules (COMs) and prebiotic molecules, are regularly discovered in hot cores/corinos, as well as in other environments, due to the increased spectral and angular resolution of the new astronomical facilities. Most models usually fail to reproduce their abundances and the abundances of their precursors either because the formation and destruction mechanisms of the species are poorly known or because the models do not always take into account important physical processes influencing the chemistry of these regions. In this work, part of the survey PILS (Protostellar Interferometric Line Survey; ALMA survey of the low mass proto-star IRAS 16293-2422), we propose to produce a more realistic and physical model of hot cores/corinos by following in particular the infall of a parcel of gas onto the proto-star. We want to investigate the chemical evolution of the infalling gas, focusing on COMs and prebiotic molecules as well as their formation pathways, and finally produce synthetic spectra directly comparable to observations.

PD04

TIDAL INTERACTION IN CLOSE BINARY SYSTEMS CONTAINING RED GIANTS

MENG SUN, *University of Virginia*, and PHIL ARRAS, NEVIN WEINBERG, NICK TROUP, STEVE MAJEWSKI

Motivated by the newly discovered close binary systems in the Apache Point Observatory Galactic Evolution Experiment (APOGEE-1), the tidal evolution of binaries containing a red giant branch (RGB) star with a stellar or substellar companion was investigated. The tide raised by the companion in the RGB star leads to exchange of angular momentum between the orbit and the stellar spin, causing the orbit to contract. The tidal dissipation rate is computed using turbulent viscosity acting on the equilibrium tidal flow, where careful attention is paid to the effects of reduced viscosity for close-in companions. Evolutionary models for the RGB stars, from the zero-age main sequence to the present, were acquired from the MESA code. "Standard" turbulent viscosity gives rise to such a large orbital decay that many observed systems have decay times much shorter than the RGB evolution time. Several theories for "reduced" turbulent viscosity are investigated, and reduce the number of systems with uncomfortably short decay times.

PD05

STABLE, NON-HYDROLYZABLE STRUCTURAL ANALOGUES OF ACTIVATED NUCLEOTIDE PHOSPHOROIMIDAZOLIDES

CHUN PONG TAM, *Harvard University*, and JACK SZOSTAK

The structural basis of nonenzymatic template-directed RNA replication has not been studied in comparable detail. Here we present crystallographic studies of the binding of ribonucleotide monomers to RNA primertemplate complexes, with the goal of improving our understanding of the mechanism of nonenzymatic RNA copying. To explore how activated ribonucleotides recognize and bind to RNA templates, we synthesized an unreactive phosphonate-linked pyrazole analogue of guanosine 5′-phosphoro-2-methylimidazolide (2-MeImpG), a highly activated nucleotide that has been used extensively to study nonenzymatic primer extension. We cocrystallized this analogue with structurally rigidified RNA primertemplate complexes carrying single or multiple monomer binding sites, and obtained high-resolution X-ray structures of these complexes. In addition to WatsonCrick base pairing, we repeatedly observed noncanonical guanine:cytidine base pairs in our crystal structures. In most structures, the phosphate and leaving group moieties of the monomers were highly disordered, while in others the distance from O3′ of the primer to the phosphorus of the incoming monomer was too great to allow for reaction. We suggest that these effects significantly influence the rate and fidelity of nonenzymatic RNA replication, and that even primitive ribozyme polymerases could enhance RNA replication by enforcing WatsonCrick base pairing between monomers and primertemplate complexes, and by bringing the reactive functional groups into closer proximity.

PD06

HIGH-THROUGHPUT SEQUENCING REVEALS DIVERSE MICROBIAL COMMUNITIES IN ICELANDIC MARS ANALOG ENVIRONMENTS

GEORGE TAN, *Georgia Institute of Technology*, and SAM HOLTZEN, DARREN PARRIS, FRANK STEWART, AMANDA STOCKTON

Exploration missions to Mars rely on landers or rovers to perform multiple analyses over geographically small sampling regions while landing site selection is done using large-scale but low-resolution remote sensing data. Utilizing Earth analog environments to estimate small-scale spatial and temporal variation in key geochemical signatures and biosignatures will help mission designers ensure future sampling strategies will meet mission science goals. Icelandic lava fields can serve as Mars analog sites due to conditions that include low nutrient availability, temperature extremes, desiccation, and isolation from anthropogenic contamination. Previous work at Icelandic Mars analog sites found statistically different ATP concentrations and qPCR counts of microbial abundance among sites evaluated at four spatial scales (1 m, 10 m, 100 m, and >1km), but apparent homogeneity of these sites at 'remote imaging' resolution (overall temperature, apparent moisture content, and regolith grain size). We performed the first characterization of soil communities in Maelifellssandur, a recently deglaciated region north of Mýrdalsjökull. A triangular grid of sample locations spaced at 1 m, 10 m, 100 m and 1km intervals was established at Maelifellssandur where the basaltic tephra is homogeneous based on visible color, morphology, and grain size. A triplicate sample set at 10 cm spacing was taken at each grid point. Based on high-throughput sequencing of 16S rRNA gene amplicons, Proteobacteria and Actinobacteria were the dominant microbial phyla representing over 50% of total sequences in all samples. However, a large number of other phyla (22) were also detected in this ecosystem. Although microbial richness did not vary significantly among samples (Chao1 index; $p>0.05$), the phylogenetic composition (weighted Unifrac metric) of the soil microbiome differed significantly among apparent homogenous site separated by >1 km ($p=0.028$), suggesting distinct microbial signatures despite apparent homogeneity. Future work will correlate microbial data with geochemical data to identify determinants of microbial community composition in this unique ecosystem, potentially helping guide future missions to detect analogous environments on Mars.

PD07

STUDYING THE EVOLUTION OF THE WARM DUST ENCIRCLING BD +20 307 USING SOFIA

MAGGIE THOMPSON, *Carnegie Institution for Science*, and ALYCIA WEINBERGER, LUKE KELLER

The small class of known stars with unusually warm, dusty debris disks is a key sample to probe in order to understand cascade models and extreme collisions that likely lead to the final configurations of planetary systems. BD +20 307 is an example of this special class of stars, being the dustiest star known for its age of $\geq$1 Gyr. The system is a tidally-locked spectroscopic binary composed of nearly identical late F-type stars orbiting with a short 3.4-day period, located at $\sim$118 pc from Earth (Weinberger 2008, Gaia Collaboration et al. 2016). Since all of BD +20 307's dust is contained within 1 AU of the binary system, evolutionary changes in the dusts silicate composition are expected to be observable on a short timescale of years (Weinberger et al. 2010). Two previous epochs of data obtained infrared spectra for BD +20 307: the first in 2004-2005 using Keck and Gemini (Song et al. 2005) and the second using Spitzer in 2005-2006 (Weinberger et al. 2010). 8 years later in 2014, we obtained new infrared spectra using the SOFIA airborne observatory. Here we report on the changes in the composition of BD +20 307's debris dust by comparing the infrared spectra from 2006 to 2014. Our preliminary analysis suggests that we detect differences, particularly around 11 microns, between the SOFIA spectrum and those spectra from Spitzer and the ground-based instruments. Further work fitting composition models will reveal plausible explanations for the differences in BD +20 307's spectrum over the course of 8 years.

PD08

BACTERIOCHLOROPHYLL e BIOSYNTHESIS AND LOW LIGHT ECOPHYSIOLOGY IN BROWN-COLORED GREEN SULFUR BACTERIA

JENNIFER L. THWEATT, *Pennsylvania State University*, and DONALD A. BRYANT

Green sulfur bacteria (GSB) are strictly anaerobic photolithoautotrophs that live in the anoxic-sulfidic zones of stratified lakes, sulfidic springs, and stratified sediments. GSB live at the lowest light intensities of any known chlorophototrophic organisms, defining the lower limit of light intensity for phototrophy on Earth. In order to live at such low-light intensities, GSB produce highly efficient, light-harvesting complexes called chlorosomes, which consist of up to 250,000 specialized, self-aggregating bacteriochlorophylls (BChls) enclosed in a protein-lipid monolayer envelope. GSB come in both green- and brown-colored varieties depending on the type of BChl they have in their chlorosomes. The chlorosomes of green-colored GSB contain BChl c or BChl d, while those of brown-colored GSB contain BChl e. Brown-colored GSB are typically found at greater depths in stratified environments with lower irradiance levels than green-colored GSB. In this study we used an inactivation mutant to confirm that a gene designated bciD is necessary for production of BChl e in a brown-colored strain of GSB, Chlorobaculum (Cba.) limnaeum. Mutants of bciD in Cba. limnaeum produce BChl c instead of BChl e. In addition, in vitro characterization of the enzyme encoded by bciD showed that it is sufficient to convert bacteriochlorophyllide (BChlide) c into BChlide e (the direct biosynthetic precursor of BChl e). Ongoing work comparing the growth physiology and energy transfer characteristics of the green-colored bciD mutant of Cba. limnaeum to the brown-colored wild-type strain will allow us to better understand the effects of pigment composition on the low-light physiology of these important chlorophototrophs.

PD09

SOLVATED-ELECTRON PRODUCTION BY CYANOCUPRATES IS COMPATIBLE WITH THE UV-ENVIRONMENT ON A HADEAN EARTH

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Glycolaldehyde and glyceraldehyde are thought to be vital for the prebiotic synthesis of RNA monomers, lipid precursors, and some amino acids. One possibility for the generation of these simplest of sugars makes use of the photochemical redox cycling of cyanocuprate complexes, which when subjected to UV-light, produce solvated electrons initiating a Kiliani-Fisher type homologation mechanism. Here, we investigate the wavelength dependence of the cyanocuprate photoredox cycle from 215295 nm and find that the rate of the reaction is roughly 14 times larger on average for wavelengths less than 250 nm, in comparison to wavelengths between 250 and 295 nm. Furthermore, the most efficient wavelength of 245 nm should be accessible to a range of potential prebiotic atmospheres, including those with significant quantities of sulfur compounds, such as SO2 and H2S, that may have been present during periods of high volcanism. Our results support the idea that cyanocuprate photochemistry may have been a viable method for generating simple sugars under UV conditions thought to have been present on the early Earth.

PD10

MID-IR AND CENTIMETER OBSERVATIONS OF 20 HIGH-MASS PROTOCLUSTERS IN THE MILKY WAY

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On sizescales of 0.1 pc, Extended Green Objects (EGOs, so named due to their extended 4.5 μm emission) are thought to harbor massive young stellar objects in an evolutionary phase in which mass accretion is actively driving outflows. We have been conducting a multi-wavelength examination of a sample of 20 EGOs in the Milky Way with distances of 1 to 8 kpc. Here, we present results from 1.3 cm JVLA observations of these objects with $1''$ - $3''$ resolution ($\sim$5000 AU) in the continuum and in NH_3 inversion transitions from (1,1) to (6,6). Our 1.3 cm continuum observations are the most sensitive observations of these objects to date at this frequency, and have allowed us to assess the presence of free-free emission. The ladder of NH_3 inversion transitions allows us to probe the morphology, kinematics, and physical properties of the dense gas in these EGOs. We will also present new SOFIA mid-IR data for a subset of the sample that will be used to refine the luminosity of these massive protoclusters.

PD11

DIVERSIFICATION OF BIOFILM-FORMING POPULATIONS EVOLVED UNDER SPACE- AND CARBON-LIMITED CONDITIONS POTENTIAL SIGNATURES OF O_2 FROM ABIOTIC PROCESSES

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One of the fundamental features of known life is diversification into ecologically distinct types of organisms which are able to coexist. To study this process of diversification, we conducted an experiment in which initially genetically identical bacteria evolved under controlled laboratory conditions. The bacteria were transferred every day for 90 days under conditions selecting for growth in well-mixed liquid culture (planktonic conditions) and for growth attached to surfaces (biofilm conditions). We also tested the effects of space limitation and carbon limitation in biofilm cultures. Consistent with prior evolution experiments, the populations evolved under biofilm conditions had more diversity than those evolved under planktonic conditions. Diversity was similar in space-limited populations and carbon-limited biofilm populations. However, different mutations were selected for under the two treatments. Whole-population genome sequencing revealed high levels of parallel evolution among replicate populations, both at the level of genes and at the level of specific nucleotides within genes. Some mutations were selected specifically under high or low carbon conditions, regardless of the biofilm treatment. Others were favored under biofilm conditions, regardless of carbon availability. Still other mutations were selected only under a specific combination of carbon availability and biofilm selection.

PD12

EVIDENCE OF LIFE IN SHAPES: USING MORPHOMETRIC ANALYSIS TO IDENTIFY BIOSIGNATURES IN HAMELIN POOL STROMATOLITES

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The earliest macroscopic evidence of life on Earth is found in the form of stromatolites, bioaccretionary structures built by complex microbial communities. These ancient sedimentary structures have persisted on Earth for the past 3.5 billion years and can still be found growing in several locations. The high diversity of stromatolite morphologies in Hamelin Pool, Western Australia makes it an ideal location to investigate the potential presence of emergent patterning resulting from spatial self-organization. Spatial self-organization is the process where coherent spatial patterns emerge through complex internal interactions between biological, chemical and physical processes. Our project utilizes high resolution imagery processed using a novel technique developed at NASA AMES Laboratory for Advanced Sensing, known as Airborne Fluid Lensing. This technology takes aerial imagery of subaqueous environments, removes surface wave distortion and produces a centimeter-scale spatial resolution 3D dataset. The dataset is then segmented to extract stromatolitic structures. These structures can be difficult to describe using standard Euclidean measures like diameter or length, but can be quantitatively assessed using measures of complexity. By applying multifractal analysis data, lacunarity (λ) data, and Fast Fourier Transform (FFT) these segmented structures are examined for trends in size, shape and distribution. These analyses will be used to identify potential patterns of self-organization in Hamelin Pool stromatolites. Such analysis of spatial patterns in microbial systems will provide insight into morphometric patterns, i.e. biosignatures, that may be indicative of life beyond Earth, particularly in Martian paleolakes.

PD13

KINETIC MONTE CARLO SIMULATIONS OF THE GRAIN-SURFACE BACK-DIFFUSION EFFECT

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Astrochemical rate-equation models are widely-used tools to investigate the formation of molecules in the interstellar medium. Despite the advances made to these models since their inception, there are still many avenues of potential improvement, particularly relating to the treatment of grain-surface chemistry. Kinetic Monte Carlo models have the ability to model grain-surface chemistry exactly, but are computationally expensive and cannot be used to model systems on the same scale as the rate-equation method. Here we present a step towards unifying the precise physical treatment of kinetic Monte Carlo models with the simplicity of the rate-equation treatment. Specifically, the failure of the rate equations to correctly model surface diffusion as a random walk is investigated. Results from two Monte Carlo kinetics models (one 2-D, and one fully 3-D) were used to develop a means to incorporate the grain-surface back-diffusion effect into rate-equation methods. Back-diffusion is the phenomenon by which random walkers revisit binding sites on a surface, thus increasing the time required to scan the entirety of the lattice. The effects of grain size, morphology, and surface coverage on the magnitude of the back-diffusion effect were studied for the simple H+H reaction system. These data were fit with simple expressions that can be easily incorporated into astrochemical rate-equation models to accurately reproduce the effects of back-diffusion on grain-surface reaction rates. Rates vary by a factor of a few due to the back-diffusion effect, which may be important to results of interstellar chemistry simulations outside of the accretion limit.

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