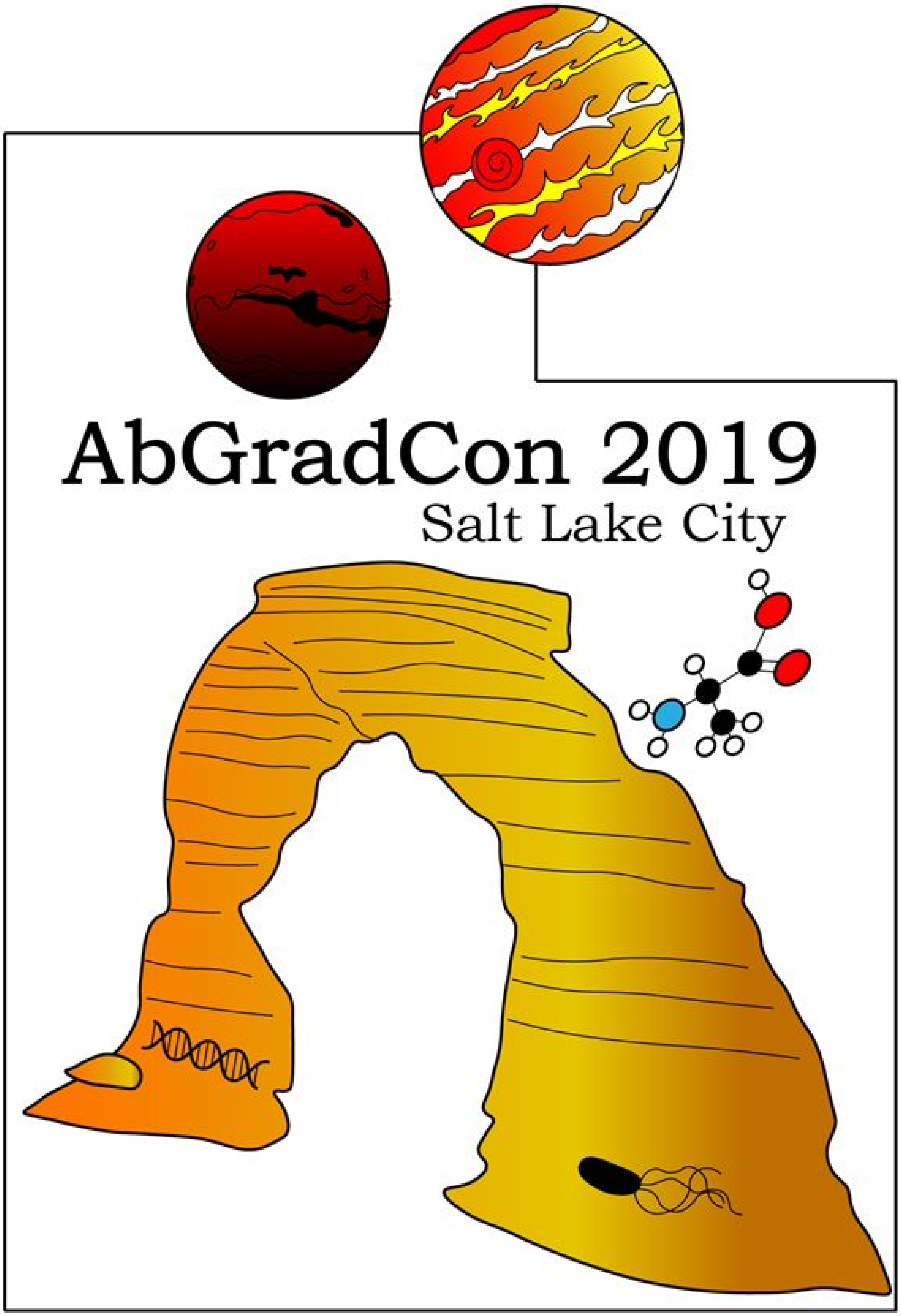

AbGradCon 2019
Salt Lake City

Organizers

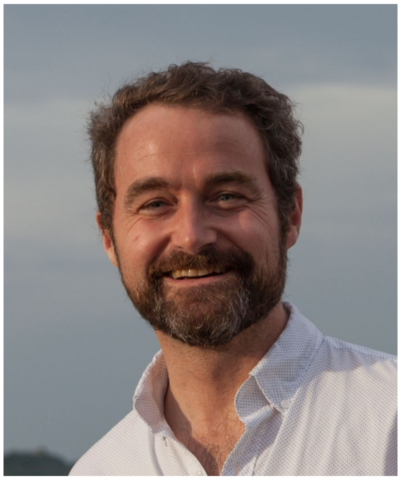
Conference Chair: Julia McGonigle
Conference Co-Chair: Shahrzad Motamedi

Additional Organizers:
Osama Alian
Richard Archer
Amber V. Britt
Hayley Bunn
Andew Burkhardt
Elle Chimiak
Casey Duncan
Emilio Enriquez
Rio Febrian
Jessica Hobson
Tony Z Jia
Jay A. Kroll
Amy LeBleu-DeBartola
Joshua Leehan
Ganbaatar Narangerel
Lizethe Pendleton
Becky Rapf
Harrison Smith
Elizabeth Spiers
Kamil Stelmach
George Tan
Ngoc Truong
Shreyas Vissapragada
Azarin Yazdani
Katarina Yocum

Thank You To Our Sponsors!

<table>
<tr><td>6:30 am</td><td rowspan="17">Arrive</td><td>Breakfast (at hotel)</td><td>Breakfast (at hotel)</td><td>Breakfast (at hotel)</td><td>Breakfast (at hotel)</td></tr>
<tr><td>8:30 am</td><td>Session 1 (8:30 am - 9:45am)</td><td rowspan="2">Session 3 (8:30 am - 10:05am)</td><td rowspan="15">Field Trip Timpanogos Cave (8:10am - 4:00pm)</td><td rowspan="21">Depart</td></tr>
<tr><td>9:45 am</td><td>Break</td></tr>
<tr><td>10:05 am</td><td rowspan="2">Session 1 continued (10:05 am - 10:45am)</td><td>Break</td></tr>
<tr><td>10:25 am</td><td rowspan="3">Session 3 continued (10:25am - 11:45am)</td></tr>
<tr><td>10:45 am</td><td>Lightning Talks</td></tr>
<tr><td>11:00 am</td><td rowspan="2">SciCom Panel (11:00am - 12:00pm)</td></tr>
<tr><td>11:45 am</td><td>Lightning Talks</td></tr>
<tr><td>12:00 pm</td><td rowspan="3">Lunch + Work Shop (12:00pm - 1:30pm)</td><td>Lunch</td></tr>
<tr><td>1:00 pm</td><td rowspan="2">Session 4 (1:00pm - 2:15pm)</td></tr>
<tr><td>1:30 pm</td></tr>
<tr><td>2:15 pm</td><td rowspan="2">Session 2 (1:30pm - 2:45pm)</td><td>Break</td></tr>
<tr><td>2:35 pm</td><td rowspan="3">Session 4 continued (2:35pm - 3:55pm)</td></tr>
<tr><td>2:45 pm</td><td>Break</td></tr>
<tr><td>3:05 pm</td><td rowspan="2">Session 2 continued (3:05pm - 4:25pm)</td></tr>
<tr><td>4:05 pm</td><td rowspan="3">POSTER SESSION 2 (4:05pm - 6:30pm)</td></tr>
<tr><td>4:35 pm</td><td rowspan="3">POSTER SESSION 1 (4:35pm - 7:00pm)</td><td>AGC 2020 Organizer Meeting</td></tr>
<tr><td>6:00 pm</td><td rowspan="5">Opening Reception Officer's Club (6:00pm - 10:00pm)</td><td rowspan="5">Closing Reception NHMU (6:00pm - 10:00pm)</td></tr>
<tr><td>6:30 pm</td><td>Dinner</td></tr>
<tr><td>7:00pm</td><td>Dinner</td><td rowspan="3">Triva/Game night (7:30pm - 10:00pm)</td></tr>
<tr><td>8:30 pm</td><td rowspan="2">Outreach (8:30pm - 10:00pm)</td></tr>
<tr><td>10:00 pm</td></tr>
</table>

Keynote Speakers



Kevin Hand, Ph.D.
NASA JPL Deputy Project Scientist, Europa

Dr. Kevin Peter Hand is a planetary scientist at NASA's Jet Propulsion Laboratory in Pasadena, California. His research focuses on the origin, evolution, and distribution of life in the solar system with an emphasis on Jupiter's moon, Europa. His work involves both theoretical and laboratory research on the physics and chemistry of icy moons in the outer solar system. Hand is the Director of the Ocean Worlds Lab at JPL. He served as co-chair for NASA's Europa Lander Science Definition team and he is the Project Scientist for the Pre-Phase-A Europa Lander mission. From 2011 to 2016 he served as Deputy Chief Scientist for Solar System Exploration at JPL. He served as a member of the National Academies Committee on Astrobiology and Planetary Sciences. His work has brought him to the Dry Valleys of Antarctica, the sea ice near the North Pole, the depths of the Earth's oceans, and to the glaciers of Kilimanjaro. Dr. Hand was a scientist onboard James Cameron's 2012 dive to the bottom of the Mariana Trench, and he was part of a 2003 IMAX expedition to hydrothermal vents in the Atlantic and Pacific oceans. He has made nine dives to the bottom of the ocean. In 2011 he was selected as a National Geographic Explorer. Hand earned his PhD from Stanford University and bachelors degrees from Dartmouth College. He was born and raised in Manchester, Vermont.

William Brazelton, Ph.D.
Assistant Professor, School of Biological Sciences, University of Utah

Billy Brazelton has been involved with astrobiology since he started as a graduate student in the University of Washington's Astrobiology Program in 2002. As a graduate student, he participated in multiple AbGradCons, starting with the first-ever AbGradCon in 2004. After graduating from the UW

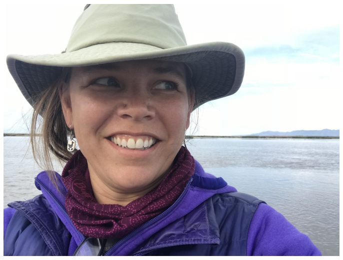
Astrobiology Program, he continued his research on serpentinization-fueled microbial ecosystems as a NASA Astrobiology Institute Postdoctoral Fellow. He is currently Assistant Professor of Biology at the University of Utah, where the Brazelton lab studies subsurface microbes through a variety of interdisciplinary and collaborative research projects, including as a member of the NAI Rock-Powered Life team. In 2018, Brazelton was Co-Chief Scientist of a deep-sea expedition to the Lost City hydrothermal field during which a team of oceanographers, biogeochemists, and microbiologists collected samples and conducted experiments to investigate subsurface microbial communities fueled by energy and carbon from Earth's mantle.

Julia DeMarines
Research Associate at the Berkeley SETI Research Center

Julia DeMarines is an Astrobiologist and science educator. She is a research scientist at Berkeley SETI Research Center and the Blue Marble Space Institute of Science. She teaches with the international team of scientists/educators called the Ad Astra Academy. She is a 2019 AGU Voices for Science advocate, a National Geographic Explorer and 2018 Grosvenor Teacher Fellow. She holds a Masters degree in Space Studies from the International Space University and a Bachelor's in Astronomy from the University of Colorado. Her research involves biosignature and technosignature detections, the ethics behind messaging extraterrestrials, and the impact of educational activities. Julia also runs her own outreach events called "Space in Your Face!" – a space variety show involving comedy, local artists, and cover songs. When she's not doing science and communication she can be found cracking Uranus jokes, trying not to kill her plants, trail running, and hanging with her cat, Bella.

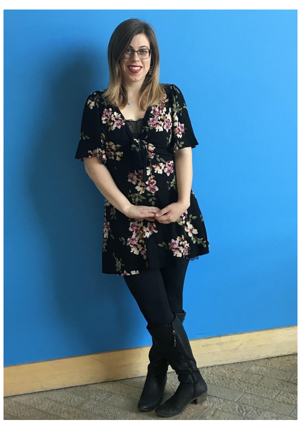
http://juliademarines.com/
Twitter: @LifeNspace
Instagram: @mote_of_dust
Facebook: @JuliaDeMarines

Science Communication Panel



Jaimi Butler
Coordinator, Great Salt Lake Institute at Westminster College

Jaimi Butler never shuts up about Great Salt Lake! She is the coordinator of Great Salt Lake Institute, housed at Westminster College. After graduating with her Fisheries and Wildlife degree from Utah State University in 1999, Jaimi has helped increase knowledge and shape perceptions of the Lake through work in the private sector, government, and academia. Jaimi's primary areas of studies include the brine shrimp and bird populations that thrive at Great Salt Lake. She knew she had reached "nerdvana" when she was featured on NPRs ScienceFriday and when she saw the children's book she co-authored on the shelves at the local natural history museum.



Audrey Rutz
Creator of Science on Tap SLC, Pediatric Genetic Counselor

Audrey Rutz is a licensed and certified Pediatric Genetic Counselor who received her Masters of Science in Genetic Counseling back in 2016. Her passion for science communication led her to head a local volunteer group called Science on Tap in 2017 with a mission to broaden science education and better science communication. Now she heads Science on Tap SLC which has a similar mission to bring science to the general public in an understandable and approachable way. In 2018 she completed a Science Communication Communication Fellowship through the Natural History Museum and continues to volunteer her time at the museum by educating the general public on her profession as a genetic counselor.

Daniel Potters
Science Journalist

Daniel Potter is a freelance science writer based in Berkeley, California. A longtime public radio journalist, he first became interested in astrobiology in 2015 while reporting for KQED Science in San Francisco. He has appeared on Science Friday and The PBS NewsHour and regularly produces episodes of KQED's Bay Curious podcast while also writing for the Monterey Bay Aquarium. He thinks often of Ellen Stofan's prediction of "definite evidence" of alien life within the next few decades. The last audiobook he listened to was Carl Sagan's Contact. Samples of his work are at hellodanpo.com.

Sgt Carri Shaw
Programs sergeant for INSPIRE, Salt Lake County Metro Jail

Detailed Program Schedule

	Tuesday (7/23)
6:30 - 8:30	Breakfast
8:30 - 8:45	*Session 1 Warm Up* (**Andrew Burkhardt**)
8:45 - 9:05	*Formation and Destruction of Molecules in the Atmosphere of Titan* (**Aline Ramos Ribeiro**)
9:05 - 9:25	*Measuring the Rotational Spectrum of Aminomethanol for Comparison to Radio Telescope Data* (**Hayley A. Bunn**)
9:25 - 9:45	*A Study of a Lifeless Archean Earth as an Analog for Abiotic Terrestrial Exoplanets* (**Ryan Felton**)
9:45 - 10:05	**Break**
10:05 - 10:25	*Reported organic chemistry on Enceladus supports Origin of Life in a Lipid-World scenario* (**Amit Kahana**)
10:25 - 10:45	*Choosing a Maximum Drift Rate in a SETI Search: Astrophysical Considerations* (**Sofia Sheikh**)
10:45 - 11:00	*Poster Lightning Talks*
11:00 - 12:00	**SciCom Panel**
12:00 - 1:30	**Lunch+WkShop**
1:30 - 1:45	*Session 2 Warm Up* (**Rebecca Rapf**)
1:45 - 2:05	*Emergence of Chiral Asymmetry in Biochemical Networks through the Transition from Non-life to Life* (**John Malloy**)
2:05 - 2:25	*Towards a novel planetary biosignature: In-situ isotopic and elemental analysis of pyrite* (**Maria C. Figueroa**)
2:25 - 2:45	*Evaluating δ15N as a pH Proxy for High-pH Closed-basin Lacustrine Systems* (**Christopher Tino**)
2:45 - 3:05	**Break**
3:05 - 3:25	*Peptide formation via astronomical delivery on pre-biotic surfaces* (**Amy LeBleu-DeBartola**)
3:25 - 3:45	*Identity and Biogenesis of CoA linked RNA* (**Krishna Sapkota**)
3:45 - 4:05	*Assembly of Membraneless Polyester Microdroplet Compartments Synthesized From Alpha Hydroxy Acids Under Plausible Prebiotic Conditions* (**Tony Z. Jia**)
4:05 - 4:25	*Unevolved De Novo Proteins Have Innate Tendencies to Bind Transition Metals* (**Michael Wang**)
4:35 - 7:00	**POSTER SESSION 1**
7:00	**Dinner**
8:30 - 10:00	**Outreach**

	Wednesday (7/24)
6:30 - 8:30	**Breakfast**
8:30 - 8:45	*Session 3 Warm Up (**H. Lizethe Pendleton**)*
8:45 - 9:05	*Metagenomic Profiling of the Methane-Rich Anoxic Basin of Lake Untersee as an Ocean Worlds Analog* (**Nicole Wagner**)
9:05 - 9:25	*Low-pressure adapted Bacillus subtilis exhibit upregulated expression of antibiotic biosynthesis, biofilm- and cell wall-associated genes* (**Joshua Leehan**)
9:25 - 9:45	*Growth temperature of the last common ancestor of a deeply-branching bacterial lineage* (**Anne Farrell**)
9:45 - 10:05	*Understanding the biospace: large-scale survey and classification of halophilic microorganisms* (**Ana Paula Muche Schiavo**)
10:05 - 10:25	**Break**
10:25 - 10:45	*Real-time Autonomous Instrumentation for Lab-based Microbe Experimental Evolution* (**Chinmayee Govinda Raj**)
10:45 - 11:05	*Application of capillary electrophoresis to monitor meteorite simulant bioleaching by Acidithiobacillus ferrooxidans* (**Gabriel Gonçalves Silva**)
11:05 - 11:25	*Phylogenetic history of scytonemin biosynthesis proteins* (**Erik Tamre**)
11:25 - 11:45	*Greenhouse gases as potential biomarkers for microbial activity in underground environments* (**Adrian Barry-Sosa**)
11:45 - 12:00	*Poster Lightning Talks*
12:00 - 1:00	**Lunch**
1:00 - 1:15	*Session 4 Warm Up (**Amber Britt**)*
1:15 - 1:35	*Groundwater upwelling and redox-based habitability within Gale crater lake on early Mars (**Natsumi Noda**)*
1:35 - 1:55	*Atmospheric Ammonia: Modelling Archean Biogeochemistry (**Julia Horne**)*
1:55 - 2:15	*1D Exoplanet Habitability: Now in Technicolor! (**Jack Madden**)*
2:15 - 2:35	**Break**
2:35 - 2:55	*Detecting a population of planets around Kepler's faintest stars (**Pedro Henrique Nogueira**)*
2:55 - 3:15	*Measuring the atmospheres of extrasolar planets from the ground with Palomar/WIRC (**Shreyas Vissapragada**)*
3:15 - 3:35	*Dying to Live: Post-Main Sequence Habitability (**Thea Kozakis**)*
3:35 - 3:55	*The Search for Habitable Worlds: An Astroecology Model for Characterizing Exoplanet Habitability (**Alma Y. Ceja**)*
4:05 - 6:30	**POSTER SESSION 2**
6:30	**Dinner**
8:00 - 10:00	**Trivia/Game night**

Tuesday (7/23)	
POSTER SESSION 1	
Roberta Almeida Vincenzi	Siderite as an unexplored growth substrate for the extreme acidophilic bacterium Acidithiobacillus ferrooxidans
Iskinder Arsano	Molecular Dynamics Computer Simulations of Primitive Polymerization in Clay Channels
Sandra Bastelberger	A hot early Earth? Assessing Archean and Proterozoic temperature history under different geological constraints.
Jennifer Berry	Gas-phase Organic Chemistry in Exoplanet Atmospheres and Implications for Haze Formation
Amber Britt	Simulated Exoplanet Observations with HabEx and LUVOIR: Preparing the Hunt for Biosignatures
Kunmanee Bubphamanee	Carbon isotope fractionation by cyanobacteria under light-limiting conditions
Vasanta Chivukula	Propensity of amino acids in ribosomal proteins
Ellen Costa de Almeida	Atmospheric Parameters and Ages of M-Dwarfs in the Solar Neighborhood
Ebrahim Emami	Increasing the Resolution of Planetary Images using Artificial Intelligence: Small Crater Detection Case Study
Raquel Farias	Search for exoplanets with potential to host life
Isabella Gaião da Silva	Growth of halophiles from Lagoa Vermelha, Brazil, at high concentrations of MgSO4 simulating Martian environments
Narangerel Ganbaatar	Nano spectroscopic approaches to the Origins of Life: A Model for Prebiotic Accumulation of Amino Acid Oligomers on a Mineral Surfaces
Claire Geneser	Evaluating the Significance of Spin-Orbit Misalignment in Hot Jupiter Systems
Andrea Halling	Snowball Earth: The Effect of Viscosity on the Multicellularity of Chlamydomonas reinhardtii
Jordyn Lucas	Functional or fashionable? Exploring the role of coenzyme A-linked transcripts
Dylan Mankel	Chemical Gradients at the Lost City Hydrothermal Field: an Analog for Icy-Moons
Petar Penev	New alignment score for studying ancestry of ribosomal proteins
Anais Roussel	Preservation of Organic Molecules on the Irradiated Martian Surface
Kenneth Seaton	Determining Molecular Biomarker Survivability in Enceladus Plume Capture Conditions using Laser-Induced Particle Impact Testing
Monica Vidaurri	Science Shaping International Law: The Need for a Policy Approach to Exploration
Connor Wright	Extending the Laboratory Millimeter/Sub-millimeter Spectrum of Interstellar Glycine Precursor Protonated Formaldehyde
Farzaneh Zohrabi	Companion Search Using MagAO data

Wednesday (7/24)	
POSTER SESSION 2	
Seyedsaeid Ahmadvand	The Authentic Reality
Osama Alian	Modeling Habitability at the Rock-Water Interface
Adrian Broz	Organic matter preservation in clay-rich environments of Earth and Mars
Andrew Burkhardt	Using Shock Chemistry to Probe Interstellar Ice Chemistry
Jacob Cosby	Searching for Life-Like Chemical Systems under Prebiotic Conditions
Jameson D'Amato-Faulkner	Planetary Protection: The Microbes We Bring With Us
Jessica Frankle	Constraining the water flux through a serpentinite-hosted hydrothermal vent field
Sean Gosselin	Elucidating Early Life Evolution via Protein Structure Comparison
Mojhgan Haghnegahdar	First-principles Models of Equilibrium Tellurium Isotope Fractionation
Jay Kroll	Spectral Analysis of a Methylamine and Ozone Mixture: A Study to Aid in the Detection of Glycine Precursors in the Interstellar Medium
Matthew Lehmitz	Letting the sun in - Plants grown under natural sunlight and artificial gravity.
Aaron Mau	Hydrothermal H2 generation and export footprint at the Atlantis Massif
Kathleen Miller	Investigating Growth, Global Gene Transcription, and Epigenetic Responses to Pressure Extremes in Carnobacterium Species
Amir Mirzanejad	Formation of Amide Molecules in the Interstellar Medium: Computational Modeling
H. Lizethe Pendleton	Tracking Contamination in Subseafloor Rock Cores
Nathan Reed	Planetary Organic Haze: Evolution, Habitability, and Biosignatures
Tyler Roche	Prebiotic Relevance
Luke Steller	Boron isotopes in the Puga geothermal system, India, and their implications for the habitat of early life
Scot Sutton	Microbial Population and Distribution at a Mars Analog Alluvial Plain Dyngjusandur, Iceland 2016
Jennifer Thweatt	Extreme Phototrophs and Where to Find Them: Reviewing Earth Organisms and Analogs for Astrobiology
Lena Vincent	A Candidate Self-Propagating System Enriched by Chemical Ecosystem Selection
Hannah Woodward	Viking GCMS data restoration and digitization
Azarin Yazdani	Adaptive Evolution of Bacteria to High Salinity
Katarina Yocum	Laboratory Submillimeter Spectroscopic Analysis of Desorbed Interstellar and Cometary Ices

Session 1 Abstracts

Choosing a Maximum Drift Rate in a SETI Search: Astrophysical Considerations

Sofia Sheikh - Pennsylvania State University

Sofia Sheikh, Jason Wright, Andrew Siemion, and Emilio Enriquez

A radio transmitter which is accelerating with a non-zero radial component with respect to a receiver will produce a signal that appears to change its frequency over time. This effect, commonly produced in astrophysical situations where orbital and rotational motions are ubiquitous, is called a drift rate. In radio SETI (Search for Extraterrestrial Intelligence) research, it is unknown a priori which frequency a signal is being sent at, or even if there will be any drift rate at all besides motions within the solar system. Therefore a range of potential drift rates need to be individually searched, and a maximum drift rate needs to be chosen. The middle of this range is zero, indicating no acceleration, but the absolute value for the limits remains unconstrained. A balance must be struck between computational time and the possibility of excluding a signal from ETI. In this work, we examine physical considerations that constrain a maximum drift rate and highlight the importance of this problem in any narrowband SETI search. We determine that a normalized drift rate of 200 nHz (eg. 200 Hz/s at 1 GHz) is a generous, physically motivated guideline for the maximum drift rate that should be applied to future narrowband SETI projects if computational capabilities permit.

Measuring the Rotational Spectrum of Aminomethanol for Comparison to Radio Telescope Data

Hayley Bunn - Emory University

Hayley A. Bunn, Jay A. Kroll, Chase P. Schultz, Samuel Zinga, Susanna L Widicus Weaver

If we wish to understand the chemical evolution of the interstellar medium (ISM) we need to be able to provide a full inventory of the molecules present in the ISM and model the potential chemistry. The ISM is a unique environment that allows for the existence of a variety of compounds that are unstable under terrestrial conditions. However, in order to accurately measure these compounds in the ISM we need laboratory spectra for comparison to radio telescope observations. One particularly promising method for formation of these unstable molecules in the lab is via insertion of excited oxygen atoms ($O(^1D)$)into stable precursor molecules. This method has proved an efficient way of producing important interstellar molecules that are highly reactive or otherwise unstable. Here I will present on our efforts made towards producing aminomethanol, via insertion of $O(^1D)$ into the C-H bond of methylamine, and collecting its rotational spectrum. Aminomethanol has been predicted to form from radical recombination reactions on interstellar ice grains and be stable under interstellar conditions. It is of particular interest in astrobiology as it is predicted to be a primary precursor to the simplest amino acid, glycine. Detection of aminiomethanol in the ISM would greatly increase the likelihood that glycine and other amino acids are formed in the ISM and delivered directly to planets during formation. This may explain the rapid formation of life on the early Earth and increase the chances that life similar to that on Earth has or will arise elsewhere in the universe.

Formation and Destruction of Molecules in the Atmosphere of Titan

Aline Ribeiro - Valongo Observatory, Universidade Federal do Rio de Janeiro

Aline Ramos Ribeiro, Diana P. P. Andrade, Heloisa M. Boechat-Roberty

Titan is one of the only solar system bodies to present complex organic molecules formation in its present-day atmosphere. Many studies focused on analyzing the possible formation of these organic compounds, in the form of experiments (e.g. Pilling et al., 2009, which revealed the presence of adenine ($C_5H_5N_5$) and theoretical models (e.g. Willacy et al., 2016, which studied the formation of acrylonitrile (C_3H_3N) simulating the satellite's atmosphere.

The possible existence of these organic molecules in its atmosphere means that Titan could be a viable habitat to support life, following the example of the early Earth. Considering Titan's astrobiological interest, the purpose of this project is to study the chemical reactions that generate complex molecules in the satellite's atmosphere using the UMIST database (McElroy et al., 2012). We will consider previous experiments from our research group and also results from the literature (e.g. Pilling et al., 2009; Willacy et al., 2016) to simulate these reactions.

The most relevant molecules, such as hydrocarbons, amino acids and nitriles, will be selected in order to test its stability, reproducing an environment similar to Titan's surface and atmosphere. We will then be able to confirm literature results, and also verify the stability of other complex molecules, comparing to these compounds' real lifetime in the Saturn moon.

Reported organic chemistry on Enceladus supports Origin of Life in a Lipid-World scenario

Amit Kahana - Weizmann Institute of Science

Amit Kahana and Doron Lancet

A recent breakthrough publication by Postberg and colleagues reported complex organic molecules in the plumes of Enceladus, comprising largely unsaturated monomers and polymers. This may be viewed as the first observed primordial soup example, a conceivable milieu for life’s origin. Intriguingly, the reported monomers have a high carbon to heteroatom ratio, akin to simple lipids. In turn, the organic polymers resemble insoluble kerogens and refractory macromolecules in carbonaceous meteorites. Postberg et al suggest that upon hydrous interactions such polymers might break down to micelle-forming amphiphiles. Likewise, a published analysis of extracts of the Murchison meteorite portrays 30,000 atomic compositions, enriched in molecules with 1-2 oxygens and 10-30 carbons, suggesting amphiphiles, but not other biomolecular classes. The above observations lend credence to a Lipid-World scenario for the origin of life. In this realm, we have developed a chemical kinetics formalism, the Graded autocatalysis replication Domain (GARD) model. GARD simulations reveal a mutually catalytic network behavior, leading to compositional homeostasis upon assembly growth and fission, akin to assembly reproduction. We further demonstrated GARD’s capacity for selection and Darwinian evolution. The Enceladus finds thus lean towards GARD – Lipid-World origin, which could be further supported by molecular resolution capacities on future Enceladus missions.

A Study of a Lifeless Archean Earth as an Analog for Abiotic Terrestrial Exoplanets

Ryan Felton - Catholic University of America
Ryan Felton, Marc Neveu, Shawn Domagal-Goldman, Giada Arney

Studying Earth's previous eons allows us to use Earth as an analog for exoplanet research and analysis. The Archean eon is of special interest because it is when simple life first appeared; it thus provides an environment to study questions regarding abiotic and biotic concepts well before complex life began. We are interested in the carbon cycle on lifeless terrestrial planets to ultimately better understand the biosignatures and false positives produced by terrestrial exoplanets.

In this presentation we present the results from using a 1D photochemical model and simulated spectra to study an abiotic version of Archean Earth. We compare it to an already completed and validated biotic Archean model, while placing the models at various orbiting distances around F, G, K and M stars. Updates have been made to the species, boundary conditions and amount of chemical reactions by using a Titan-like atmosphere (Hebrard et al., 2012) and adjusting it to fit Archean conditions while removing molecular oxygen and ozone to make it abiotic.

We expect these results will contribute to more accurate understandings of abiotic terrestrial exoplanets due to their influence on the carbon cycle. We will be able to say more confidently which exoplanets should be considered when selecting candidates for investigation with future large-aperture space and ground based observatories.

Session 2 Abstracts

Assembly of Membraneless Polyester Microdroplet Compartments Synthesized From Alpha Hydroxy Acids Under Plausible Prebiotic Conditions

Tony Jia - Earth-Life Science Institute

Tony Z. Jia, Kuhan Chandru, Yayoi Hongo, Rehana Afrin, Tomohiro Usui, Kunihiro Myojo, H. James Cleaves II

Compartmentalization was likely essential to primitive chemical systems during the emergence of life due to their ability to prevent diffusion of important system components, such as evolving genetic materials, and their ability to enhance chemical reactions. At some point in evolution, early cells began to use lipid bilayer membrane boundaries, but before the emergence of lipid membrane-based systems, it is possible that living systems depended on membraneless compartmentalization. In this study, we synthesized and characterized membraneless microdroplets generated from simple α-hydroxy acid (αHA) monomers. We find that homo- and hetero-polyesters produced from drying aqueous solutions of αHAs with various side-chain functionalities (e.g., hydrophobic, aromatic, aliphatic, sulfur-containing, or mixtures of types) form gel-like phases of polydisperse polyesters that form microdroplets. These microdroplets coalesce on a slower scale than known coacervate or aqueous two-phase systems, and can preferentially and differentially segregate and compartmentalize fluorescent dyes and even fluorescently-tagged RNAs, providing readily-available compartments that could potentially protect, exchange, encapsulate, and facilitate the chemical evolution of prebiotic compounds. This facile polymerization of αHAs to form combinatorially diverse phase-segregated structures potentially provides a novel pathway to the assembly of primitive membraneless compartments on early Earth, and demonstrates the possibility of the emergence of different “phenotypic” traits from a relatively simple monomer pool.

Unevolved De Novo Proteins Have Innate Tendencies to Bind Transition Metals

Michael Wang - Princeton

Michael Wang, Kenric Hoegler, Michael Hecht

Life as we know it would not exist without the ability of protein sequences to bind metal ions. Transition metals, in particular, play essential roles in a wide range of structural and catalytic functions. The ubiquitous occurrence of metalloproteins in all organisms leads one to ask whether metal binding is an evolved trait that occurred only rarely in ancestral sequences, or alternatively, whether it is an innate property of amino acid sequences, occurring frequently in unevolved sequence space. To address this question, we studied 52 proteins from a combinatorial library of novel sequences designed to fold into 4-helix bundles. Although these sequences were neither designed nor evolved to bind metals, the majority of them have innate tendencies to bind the transition metals copper, cobalt, and zinc with high-nanomolar to low-micromolar affinity.

Identity and Biogenesis of CoA linked RNA

Krishna Sapkota - University of Southern Mississippi
Krishna Sapkota and Faqing Huang

The ability of RNA to store genetic information and to catalyze biochemical transformations led to the speculation of RNA world before the evolution of DNA and enzymes. While coenzyme A and its thioesters play a crucial role in enzymatic catalysis, recent discovery of their covalent attachment at the RNA 5’ end not only opened a new horizon in the study of RNA function but also supported the RNA world hypothesis. As both RNA and coenzymes are believed to have existed since the RNA world, existence of CoA-RNA conjugates in modern life is may reveal a fundamental molecular secret involved in evolution from eons ago. However, the sequence, metabolism, and biological role of these RNA species are still an enigma. To study these novel RNA species, we have developed an enzymatic method to synthesize dephospho coenzyme A that can be used to prepare synthetic CoA-RNA in vitro. In our attempt to investigate these CoA-RNA and CoA-thioester RNAs, we are synthesizing novel radiolabelled CoA analogs, designed to diffuse through the bacterial cell wall. These analogs will help in understanding CoA related processes including CoA-RNA in vivo. Furthermore, to investigate the mechanism of CoA-RNA thioesterification, we have cloned, expressed, and purified various acyl CoA synthetases using our unique cloning expertise. Our preliminary study suggests that thioesterification occurs after dephospho-CoA is installed in 5’ end of RNA by some of the metabolic enzymes. The identification of sequences and metabolism of these CoA-RNA and CoA-thioester RNA will elucidate the novel biological function of RNA.

Evaluating δ15N as a pH Proxy for High-pH Closed-basin Lacustrine Systems

Christopher Tino - University of California, Riverside
Christopher Tino, Eva Stüeken, Daniel Gregory, Gernot Arp, Dietmar Jung, Timothy Lyons

The pH-dependent nature of reduced nitrogen species allows for stable isotope investigations of high-pH, closed-basin lacustrine rock records. Determining the environments in which such a proxy is valid could have major implications for future δ15N interpretations of crater paleolakes on Earth and Mars. As pH increases, a greater proportion of gaseous NH3 volatilizes out of solution (pKa=9.25). This imparts a fractionation favoring the volatilization of 14N, leaving behind an NH4+ pool enriched in 15N [1].

Two data sets from the rock record have been generated to explore this effect. The first involves the 15-Ma-old Nördlinger Ries impact crater in Germany, a Mars analog of the highest order because—like craters on Mars—it possesses a well-preserved dual-layer ejecta blanket composed of materials that resettled after impact [2]. δ15N values range from 3.82‰ to 17.47‰. The second data set is from the alkaline Eocene Green River Formation of west-central USA. There, δ15N values range from 5.97‰ to 21.44‰.

For modern calibration, samples were collected from five closed-basin alkaline lakes in Coorong National Park, South Australia. The δ15N trends of each lake appear dependent on multiple factors. We hypothesize that the largest controls outside of pH include salinity, anoxia, and evaporation. Alkaline systems are among the most biologically productive on Earth; this study also speaks broadly to habitability on high-pH bodies such as Enceladus and exoplanetary water worlds as targets in the search for extraterrestrial life.
[1] Li et al. (2009) GCA 73, 6282. [2] Sturm et al. (2013) Geology 41, 531.

Towards a novel planetary biosignature: In-situ isotopic and elemental analysis of pyrite

Maria C. Figueroa - University of California, Riverside
Maria C. Figueroa, Daniel D. Gregory, Kenneth Williford, David Fike, Timothy W. Lyons

Current methods for identifying signatures of life are challenging due to the rarity of unambiguous fossils and difficulties associated with preservation of ancient organic materials. Minerals that form through direct or indirect biological processes while incorporating trace elements in concentrations that are proportional to those in the surrounding fluid provide details about past environmental conditions and the life present at the time of formation. Here we show how in-situ analyses of trace elements (TE) and sulfur isotopes of pyrite can help us interpret evidence for life in the rock record. Sedimentary pyrite is inextricably linked to life through microbial sulfate reduction, and biological processes affect the TE abundance and sulfur isotope composition of pyrite. Sedimentary pyrite has TE and sulfur isotope (δ34S) properties that differ from those of hydrothermal and magmatic pyrite (abiotic origin). We have coupled trace element and sulfur isotope data from 400 pyrite measurements from diverse pyrite deposits. Random Forest (RF), a machine learning algorithm with proven value in statistical classification, was used to classify pyrite into deposit types. Our results demonstrate the strength that TE and δ34S have when coupled together in effectively identifying sedimentary pyrite. Through validation and calibration of our data, we will increase our ability to recognize pyrite linked to microbial life, providing a novel window in the search for ancient and distant life. We will apply the approach across a wide range of samples from modern terrestrial analogues, thus expanding the reach of the analytical and statistical techniques within the astrobiological community including applications to Mars research.

Peptide formation via astronomical delivery on pre-biotic surfaces

Amy LeBleu-DeBartola - University of Central Florida

Life emerged ~ 3.9 billion years ago, following closely on the end of the Late Heavy Bombardment. The raw materials for this genesis are likely to have been delivered primarily by extraterrestrial sources. Modern meteorites such as Murchison and Allende show that primitive meteorites with aqueous alteration and some thermal alteration possess several types of amino acids, hydroxy acids, and various catalytic surfaces. Initial results of peptide formation with several combinations of essential amino acids, hydroxy acids, and catalysts known to exist in carbonaceous chondrites are presented. Our method utilizes a high cadence sample rate, allowing for time evolution of key organics to be tracked over a period of 48 hours. Results are obtained via liquid chromatography coupled with mass spectrometry, with a simple Python code determining atomic makeup of detected molecules. Mechanisms of formation may be discussed depending on project progress at time of conference. Ultimately, the project goal is to form large scale (40+ amino acid) peptides, with the idea that larger proteins may function as genetic molecules. While formation of large scale peptide chains does not imply this is how life formed on earth, it certainly provides a pathway for life where other phenomena notable to earth, such as deep sea thermal vents, are non existent.

Emergence of Chiral Asymmetry in Biochemical Networks through the Transition from Non-life to Life

John Malloy - Arizona State University

A “metabolism-first” approach to life is one where life can be understood as the evolution of biochemical reactions. The map which provides a guide to this evolution is the network of interactions between biochemical reactions, consisting of the compounds necessary for life and the reactions which utilize them. The evolution of this network is necessary in order to understand the transition from non-living to living systems. Here, we deal specifically with chirality. Within a majority of biochemistry, only one isomer of a compound is found in a given reaction, leading to an asymmetry in chiral metabolites. In contrast, an equal mixture of left-handed and right-handed isomers are found in inorganic reactions.

Asymmetrical chiral reactions are found within all three domains of life. This suggests reactions that were asymmetrically chiral have persevered throughout evolutionary time. The impact of chirality over the history of life is explored using network expansion, an algorithm where a set of initial compounds (the seed set) are introduced to a reaction network, then reacted together to determine the influence of the initial seed set. In addition, phylogenetic mapping of the history of asymmetric chiral reactions tracked evolutionary changes to find those reactions present in LUCA. These reactions compare to similar, inorganic achiral reactions, elucidating the initial leap from an abiotic signal to a biotic one. This transition is essential to the origin of life and provides clues to the emergence of chirality and potential transitions between biotic and abiotic reactions.

Session 3 Abstracts

Growth temperature of the last common ancestor of a deeply-branching bacterial lineage

Anne Farrell - Dartmouth

Anne Farrell, Olga Zhaxybayeva, and Camilla Nesbø

The properties of the environment inhabited by the Last Universal Common Ancestor (LUCA) of life on Earth remains hotly debated. The traits of early lifeforms can be informed by examining deeply branching lineages that are assumed to retain some of the characteristics of the ancient organisms. The bacterial phylum Thermotogota represents one such early diverging clade on the tree of life. The phylum was initially thought to be composed solely of thermophiles descended from a hyperthermophilic ancestor. However, the phylum is now known to include ubiquitous anaerobic organisms that collectively grow from 20°C to 90°C in various terrestrial, marine and deep subsurface settings. Recent isolation of Mesoaciditoga lauensis placed the assumption of Thermotogota's hyperthermophilic ancestor into question. Although M. lauensis is the deepest-branching of the Thermotogota isolates based on ribosomal RNA and ribosomal proteins' phylogenies, it is a moderate thermophile. Utilizing genome sequences from 53 Thermotogota with known optimal growth temperatures, we examined whether the deeply-branching placement of M. lauensis is supported by the rest of the genome and inferred the optimal growth temperatures of the phylum's ancestral nodes. We found that the Thermotogota's last common ancestor was a thermophile, and that evolution of both hyperthermophily and mesophily within this phylum is secondary. Our findings are in concordance with several recent analyses that suggest a non-hyperthermophilic nature of the LUCA and a later evolution of hyperthermophilic lifestyle.

Metagenomic Profiling of the Methane-Rich Anoxic Basin of Lake Untersee as an Ocean Worlds Analog

Nicole Wagner - Georgetown University

Nicole Y. Wagner, Aria S. Hahn, Dale T. Andersen, Mary B. Wilhelm, Mia Vanderwilt, Sarah S. Johnson

Lake Untersee is located in Queen Maud Land, East Antarctica. It is perennially covered in 3m of ice and closed off from the outside world by the Anuchin glacier. The lake contains an aerobic and an anoxic basin. The anoxic basin has a maximum depth of 100m. While the top 50m of the anoxic basin are well-mixed, similar to the aerobic basin, the level of dissolved oxygen drops from 70-75m below which is a uniformly anoxic environment, and comprises one of the most methane-rich naturally-occurring aquatic ecosystems on Earth.

Using Lake Untersee as an analog allows us to study the chemosynthetic pathways used by life forms that dwell in an extreme environment that bears strong similarities to ocean worlds that are characterized by bodies of water permanently covered in ice, with low temperature, a lack of oxygen, and the presence of methane as a potential energy source.
In November of 2018, we collected samples from Lake Untersee using sterile techniques. DNA and RNA were extracted in quadruplicates using custom protocols from samples collected ~75m, ~86m, ~92m and ~99m in depth, as well as a sediment sample from the bottom of the water column (~100m in depth). Library preparation and sequencing will soon be completed for these samples. Metagenomic analysis will identify potential gene clusters and emergent pathways developed as adaptation mechanisms to this cold,

methane-rich environment. Metatranscriptomics will give a detailed look at gene expression, enabling analyses of metabolic coupling among microbes living in the water column of this lake.

Low-pressure adapted *Bacillus subtilis* exhibit upregulated expression of antibiotic biosynthesis, biofilm- and cell wall-associated genes.

Joshua Leehan - University of Florida

Joshua D. Leehan, Adrián Barry-Sosa, Kathleen M. Miller, Wayne L. Nicholson

Martian atmospheric pressure ranges from 0.1 to 1 kPa, which is less than 1% of Earth's sea-level atmospheric pressure (~101 kPa). Growth of most microorganisms is inhibited at pressures below 2.5 kPa, although a few can grow at 0.7 kPa. Understanding how microorganisms can adapt to low pressure (LP) is essential to the search for life on Mars. Previously we had reported genomic changes in *Bacillus subtilis* grown at a nearly inhibitory LP (5 kPa) for 1000 generations including a 9 bp, in-frame deletion in rnjB (rnjB9) which encodes RNase J2. This mutation exhibited greater competitive fitness compared to the wild-type grown at LP. To understand the mechanisms behind this increase in competitive fitness, three congenic strains of *Bacillus subtilis* were grown at 5 kPa: WN1589 containing rnjB9, WN1602 containing an insertion-deletion knocking out rnjB (rnjB::spc) and WN1591 the wild-type background for these strains. RNA-seq analysis revealed that when grown at 5 kPa, WN1589 upregulated the expression of several uncharacterized proteins including a putative amino acid transporter (YuiF) and a putative cell wall-binding protein (YwsB) in addition to the major protein component of the B. subtilis extracellular biofilm matrix (TasA) compared to the wild-type. WN1602 grown at LP upregulated the expression of many secreted proteins associated with biofilm formation (BslA, TapA, etc.) and proteins associated with the biosynthesis of several different antibiotics (AlbA, BacB, etc.) compared to the wild-type. This evidence suggests that upregulation of genes associated with biofilm formation and antibiotic biosynthesis may contribute to increased fitness at LP.

Greenhouse gases as potential biomarkers for microbial activity in underground environments.

Adrián Barry-Sosa - University of Florida

Adrian Barry-Sosa, Madison K. Flint , Tatiana Summerall, Johnathan B. Martin and Brent C. Christner

The karstic Upper Floridian Aquifer (UFA) underlies Florida and parts of Georgia and Alabama and contains a vast network of water-filled caves and sinkholes. Few studies have examined the microbial life inhabiting this oligotrophic habitat, and even less is known about how these communities affect the geochemical composition of water within and discharged from the UFA.

Water samples were collected from 6 spring systems that discharge water from the UFA. Microbial cells in spring effluent ranged from 10^6 to 10^8 cells L-1. Organisms currently isolated belongs to 3 different Bacteria phyla and 3 fungal species. All sampled springs were found to be sources of N_2O emitted to the atmosphere. Relationships between N_2O and dissolved oxygen saturation state, which ranges from 1.4% to 55%, were positive in springs with low dissolved organic matter (DOM) concentrations and negative in those with elevated DOM concentrations. These data imply that microbial nitrification and denitrification processes may be the source of N_2O in the UFA. Excesses of CH_4 up to 100-times that of atmospheric

equilibrated gases and the isolation of putative methanotrophs supports previous reports that methane cycling occurs in the UFA.

The permanently dark, solution-filled environments of the UFA may share similarities with extraterrestrial habitats such as lakes under Mars’ south ice cap or oceans that lie beneath the ice shells of Europa and Enceladus, opens the possibility that similar mechanisms might support life there. Therefore, the UFA can be a model to test life-searching strategies using N_2O and CH_4 as biosignatures.

Phylogenetic history of scytonemin biosynthesis proteins

Erik Tamre - Massachusetts Institute of Technology

Erik Tamre, Gregory P. Fournier

Cyanobacteria rely on access to sunlight for photosynthesis, but good access comes with considerable stress from UV radiation. To protect themselves, some cyanobacteria make scytonemin, a photoprotective pigment absorbing in the UV range. In high-albedo environments, the need for such a pigment is particularly obvious: high quantities have been found in the top layers of modern polar cyanobacterial mats, for instance. We present a phylogenetic history of proteins involved in scytonemin biosynthesis, looking out for differentiation, radiation, and transfer during periods when environmental conditions might make UV protection especially important. We particularly focus on the Cryogenian (720-635 Ma), since cyanobacterial photosynthesis in cryoconite ponds on top of the ice is one potential mechanism for continued primary production during the Cryogenian glaciations. This mechanism would expose cyanobacteria to a highly reflective environment under a thinner ozone layer than today – potentially a strong selective pressure on UV protection pathways. The study is intended as a first step in a broader search for a phylogenetic signature of Neoproterozoic glaciations.

Real-time Autonomous Instrumentation for Lab-based Microbe Experimental Evolution

Chinmayee Govinda Raj - Georgia Institute of Technology

Chinmayee Govinda Raj, Aryamitra Bake, Ali-Imran Tayeb, Carrie Ludman, Purva Joshi, Jonathan Wang, Diana Gentry

Experimental evolution (EE) is a laboratory procedure for applying desired environmental stressors to grow generations of robust microbes that have acquired improved tolerance to stresses. EE protocols are long, repetitive processes and are highly prone to human errors. An automated fluidics device to carry out EE procedures has been developed at NASA Ames – the Automated Adaptive Directed Evolution Chamber (AADEC). AADEC uses UV-C radiation as the stressor and has real-time temperature and microbe biomass monitoring capabilities. A miniature magnetic agitator and a peristaltic pump are used to ensure continuous nutrient availability. Escherichia coli has been used for performance verification.

As an upgrade, the current second generation device has pH, oxidation-reduction potential (ORP), electrical conductivity (EC), and dissolved oxygen (DO) wet chemical microsensors for continuous, real-time biochemical measurements. The fluidics chamber is remodeled to have dedicated growth/radiation exposure and sensor installation chambers. Each of the sensor parameters can be used to design various combinations of environmental stressors. Combined with genetic or protein engineering and analysis, EE can help in understanding changes in protein structure, metabolic pathways and genetic sequences of microbes with acquired tolerance. With further instrument automation, the method can be extended to simulate extreme environment analogues in a lab setting to better study extremophile adaption. As a peripheral study, the device can be optimized to grow robust microbes capable of supporting extended spaceflight missions by helping enhance the ecosystem for cycling food, water, air, and waste.

Understanding the biospace: large-scale survey and classification of halophilic microorganisms

Ana Paula Muche Schiavo - University of São Paulo

Ana P. M. Schiavo, Fabio Rodrigues

The discovery of extremophile organisms and the understanding of their survival mechanisms has been modifying our understanding of life on Earth and in the cosmic context. Among them, there is a class called halophiles, which survive in high salt (NaCl) concentrations. Nowadays, there is a classification between different levels of halophilicity (tolerant or slight, moderate and extreme halophiles) depending on the optimum salt concentration for growth. For this classification, it is used the assumption that the higher salt concentration, the fewer organisms can survive, but there is not a large-scale review on the literature that support that premisse. Thus, we did a extensive bibliographical survey from the description of species' articles of microorganisms classified as "halophilic" or "halotolerant", considering optimal concentrations of growth and the overall survival concentration range. So far, we have collected information available in literature of more than 300 species, with representatives of the 3 domains of the three of life. An algorithm was developed to summarize and graphically represent the information obtained, and is being implemented in a way that can be openly used. The results will show the reported diversity of microorganisms for each concentration, allowing the analysis whether the current classification of these organisms in slight, moderate and extreme is adequate. This way, it will be possible to estimate the real diversity of halophiles and to use as a support information to study the possibility of the presence of microbial life in Earth-like exoplanets with high salt concentration.

Application of capillary electrophoresis to monitor meteorite simulant bioleaching by *Acidithiobacillus ferrooxidans*

Gabriel Gonçalves - Chemistry Institute, São Paulo University (IQ/USP)

Gabriel Gonçalves Silva, Eiji Yamassaki de Almeida, Zuzana Cieslarova, Fabio Rodrigues

The importance of microbial biotechnology in space exploration and planetary colonization has been extensively discussed in the literature. Meteorites are interesting samples to obtain natural resources in space and so to study microbe-mineral interaction focused on space exploration. The chemolithotropic bacterium *Acidithiobacillus ferrooxidans* is used as model to understand the iron and sulfur oxidation in inorganic compounds and minerals. In this work, capillary electrophoresis with capacitively coupled contactless conductivity detection and UV detection was used to monitor bacterial growth in a meteorite simulant by measuring the conversion of Fe (II) into Fe (III). The effect of Co (II) and Ni (II) (metals also found in meteorites) on the bacterial growth was also evaluated. The presented method allowed the analyses of all metals in a single run (less than 8 min). The background electrolyte was composted of 10 mmol/L -hydroxyisobutyric acid / histidine. For comparison purpose, the samples were also analyzed by UV-Vis spectrophotometry. The Fe (II) conversion into Fe (III) by *A. ferrooxidans* was observed up to 36 h with the growth rate constant of 0.19 ± 0.01 /h and 0.21 ± 0.01 /h in Tuovinen and Kelly (T&K) and in meteorite simulant media, respectively. The developed method presents favorable prospect to monitor the

growth of other chemolithotropic microorganisms for biotechnology applications and, due to its characteristics, in space exploration.

Session 4 Abstracts

HabitabilityGroundwater upwelling and redox-based habitability within Gale crater lake on early Mars

Natsumi Noda - ELSI

N. Noda, Y. Sekine, S. Tan, H. Genda, T. Shibuya

NASA's Curiosity rover has investigated lacustrine sediments within Gale crater, which are key to reconstruct paleoenvironments on early Mars. To assess the habitability within the early Gale lake, knowledge on availability of reductants within the lake becomes important. Gale's lacustrine mudstone of Murray Formation is characterized by authigenic deposition of silica and iron oxides (Rampe et al. 2017). This suggests inputs of dissolved SiO_2 and Fe^{2+} into the early Gale lake possibly by upwelling groundwater, latter of which could be a reductant in the lake. Here, we perform hydrological modeling to constrain the past climate capable of explaining the presence of paleolakes around Gale crater. We also perform hydrothermal experiments to understand the controlling factors of the composition of groundwater. We find that (semi-)arid climate around Gale is favorable to explain the paleolake distribution. Under such arid climate conditions, groundwater would have upwelled vigorously owing to efficient evaporation of surface waters. Our experimental results suggest that the concentrations of dissolved SiO_2 and Fe^{2+} in groundwater are likely to be controlled by quartz and siderite, respectively. Combining both of the results, we calculate input fluxes of SiO_2 and Fe^{2+} due to upwelling groundwater. The estimated deposition rate of silica suggests that lamina of Murray mudstone would correspond to varve. Through Fe^{2+} oxidation by atmospheric O_2 with proposed atmospheric levels on early Mars (Noda et al. 2019), the estimated Fe^{2+} input could provide available catabolic energy as high as ~1 J per kg of upwelling groundwater.

Dying to Live: Post-Main Sequence

Thea Kozakis - Cornell University, Carl Sagan Institute

Thea Kozakis, Lisa Kaltenegger

During the post-main sequence phase of stellar evolution the orbital distance of the habitable zone, which allows for liquid surface water on terrestrial planets, moves out past the system's original frost line, providing an opportunity for outer planetary system surface habitability. We use a 1D coupled climate/photochemistry code to study the impact of the stellar environment on the planetary atmosphere of an Earth-like planet/moon throughout its time in the post-main sequence habitable zone. We also explore the ground UV environments of such planets/moons and compare them to Earth's. We model the evolution of star-planet systems with host stars ranging from 1.0 to 3.5 $M_{\odot}$ throughout the post-main sequence, calculating stellar mass loss and its effects on planetary orbital evolution and atmospheric erosion. The maximum amount of time a rocky planet can spend continuously in the evolving post-MS habitable zone ranges between 56 and 257 Myr for our grid stars. Thus, during the post-MS evolution of their host star, subsurface life on cold planets and moons could become remotely detectable once the initially frozen surface melts. Frozen moons or planets, like Europa in our Solar System, experience a relatively stable environment on the horizontal branch of their host stars' evolution for millions of years.

Measuring the atmospheres of extrasolar planets from the ground with Palomar/WIRC

Shreyas Vissapragada - California Institute of Technology

Shreyas Vissapragada, Heather Knutson

Over the past 25 years, there have been ~4000 planets discovered to orbit stars other than our Sun. Surveys have revealed incredible diversity in the sizes, masses, and orbits of these exoplanets, reorienting our definitions of habitability in the process. The field has made great strides in characterizing the atmospheres of these alien worlds primarily via observations of transiting exoplanets with space telescopes, and future space telescopes seem poised to push towards detecting more interesting atmospheric species. Such observations, however, are expensive, and in most cases this precludes large statistical analyses of exoplanetary atmospheres. Ground-based surveys are easier to implement with existing facilities, but suffer from the deleterious effects of our own atmosphere. Recently, we have implemented some new methodologies that mitigate the effects of the Earth's atmosphere and allow for ground-based observations of exoplanet atmospheres. Here, I will describe a few such techniques we have used at Palomar Observatory, including diffuser-assisted photometry and slitless grism spectroscopy that are complementary to — and in some cases, more precise than — corresponding measurements with space-based facilities.

Atmospheric Ammonia: Modelling Archean Biogeochemistry

Julia Horne - University of Victoria

Julia E. Horne, Colin Goldblatt

Ammonia (NH_3) is the best greenhouse gas, with a broad absorption feature coincident with the 8-14 micron water vapour window. It was the original suggestion for resolving the Faint Young Sun Paradox (Sagan and Mullen, 1972), with few other greenhouse gases capable of doing so (Byrne and Goldblatt, 2014). However, recent notions of a weakly-reducing Archean atmosphere, coupled with ammonia's high solubility and susceptibility to photolytic destruction, have lead to ammonia falling out of fashion as a solution to the Faint Young Sun Paradox.

Here, we produce a new box-model for an Archean ocean, biosphere, and atmosphere, including solute and photolytic reactions, illustrating that ammonia was likely present as a trace atmospheric gas. Our nominal model runs have a steady state atmospheric reservoir of 0.1 ppm NH_3, which gives a radiative forcing of 3 W/m2. This is a non-trivial contribution to the total of 50 W/m2 which are required (Goldblatt and Zahnle, 2011). Ammonia contributes even more when only 30 W/m2 are required after accounting for cloud feedbacks. More interesting still are feedbacks with other greenhouse gases; CO_2 incursions reduce ocean pH, shifting the ocean equilibrium to favour ammonium over ammonia, incurring ammonia draw down from the atmosphere. Thus, in response to perturbation, we find a feedback relationship between the CO_2 and NH_3 greenhouses.

The Search for Habitable Worlds: An Astroecology Model for Characterizing Exoplanet Habitability

Alma Ceja - University of California, Riverside

Alma Y. Ceja, Stephen R. Kane

A primary objective of the field of astrobiology is to identify worlds outside of our own which are capable of supporting life. Here, an integrative approach is applied to characterize the habitability of selected exoplanets. We explore the relationship between alien environments and terrestrial life with a novel astroecology model which can be used as a tool to assess the habitable regions on exoplanet surfaces. In this model, simulated exoplanet environments are convolved with a real biological layer. Exoplanet thermal environments are simulated using the climate model, Resolving Orbital and Climate Keys of Earth and Exoplanet Environments (ROCKE-3D, Way et al. 2018). ROCKE-3D is a fully-coupled 3-dimensional oceanic-atmospheric general circulation model (GCM) featuring interactive atmospheric chemistry, aerosols, the carbon cycle, vegetation, and other tracers, as well as the standard ocean, sea ice, and land surface components. The GCM output is coupled in the astroecology model with empirically-derived thermal performance curves of 1,627 cell strains representing extremophiles from all six Kingdoms, termed the biokinetic spectrum for temperature (Corkrey et al. 2016). The spectrum arises from a meta-analysis of cellular growth rate as a function of temperature. In this agent-based model, the survivability of a biological organism is determined by its thermal response to simulated local and global exoplanet temperature dynamics. This work produces a list of exoplanets with the highest probability of having temperate surface conditions compatible with terrestrial-based thermophysiology, as well as surface maps highlighting potentially thermally habitable regions.

1D Exoplanet Habitability: Now in Technicolor!

Jack Madden - Cornell University

Jack Madden, Lisa Kaltenegger

Modeling the atmosphere of a potentially habitable exoplanet has commonly been accomplished using 1D climate and photochemistry codes. These codes calculate the temperature and pressure profiles along with the mixing ratios of the various components of the atmosphere as they react with each other and the incoming UV light. As a simplification, these codes have usually contained a single value for the surface reflectivity across all wavelengths. We have added color into the code by turning these gray, single value, planet albedos into wavelength dependent inputs spanning the UV, visible, and near infrared. The interaction between the incoming stellar flux and the surface is now much more realistic and gives habitability measures, like surface temperature, a much stronger dependence on stellar type. We have found that using a wavelength dependent albedo in such a code produces significant deviations in surface temperature from what would be seen using a single value. These models are frequently used to help determine the best places to look for life around other stars and our results show that realistically modeling the surface albedo can have a large impact on how the habitability of a system is characterized. This could lead to searches for life in regions previously considered uninhabitable or save telescope time by cautioning against older model predictions of the habitable zone.

Detecting a population of planets around Kepler's faintest stars

Pedro Henrique Nogueira - Observatório Nacional, Rio de Janeiro, Brazil
Pedro Henrique Nogueira, Luan Ghezzi, Benjamin Montet, Thaís Madruga

The Kepler Mission was designed to search for exoplanets in our Galaxy, with enough precision to detect Earth-sized planets around main-sequence stars. This is accomplished by seeking transiting events in the light curves of the observed stars. In order to do that, the Kepler telescope observed, from 2009 to 2013, the brightness of approximately 150,000 stars with the Kepler passband Kp > 16, which led to the discovery of planet candidates, eclipsing binary systems and brown dwarfs. However, the 115.6 square degrees Kepler field of view captured ~4,5 millions of stars in total. The remaining ~4,35 million stars were observed only 53 times over the Kepler mission, in a series of observations known as the "Full Frame Images" (FFIs). 8 FFIs were obtained during telescope commissioning over a span of approximately 36 hours. The other 45 FFIs were then obtained monthly, immediately before the telescope reoriented itself to downlink its stored data to Earth. Our study is based on the precise photometry of those fainter stars with the goal of detecting variability in these stars due to Jupiter-size planets (decrease in flux by ~1%) or eclipsing binaries (decrease by ~50%). Given the large numbers of stars not observed with Kepler and extrapolating from the hot Jupiter yield from the primary Kepler mission, it is possible that more than 100 planetary systems can be detected in this data set, improving the statistics about the populations of giant planets and binaries in our Galaxy.

Poster Session 1 Abstracts

Siderite as an unexplored growth substrate for the extreme acidophilic bacterium *Acidithiobacillus ferrooxidans*

Roberta Almeida Vincenzi - Univesity of São Paulo

Roberta A. Vincenzi, Gabriel G. Araújo, Isabella Gaião, Ana P. M. Schiavo, Gabriel G. Silva, Fabio Rodrigues

The iron(II) carbonate (siderite) has been detected on the surface of Mars and also on Mars-derived SNC meteorites. Despite this mineral being a potential reduced iron source for chemolithoautotrophic microbial metabolism, such as for the extreme acidophile *Acidithiobacillus ferrooxidans*, this interaction has been unexplored to date. In this work we show that *A. ferrooxidans* can utilize siderite as its sole energy source for growth. *A. ferrooxidans* was cultured in bioreactor batch containing modified T&K medium at pH~1.8 supplemented with siderite as Fe(II) only source. An abiotic assay was performed as a control to quantify the natural iron oxidation. The concentration of Fe(II) and Fe(III) ion in solution and in the mineral phase was measured by colorimetric methods. In biotic experiments, the concentration of Fe(III) ion was used as an indirect indicator of the bacterial growth. As expected, the Fe(II) concentration of the abiotic experiment increased over time due to solubilization of the mineral, while the Fe(III) concentration remained almost constant as a consequence of the natural slow oxidation of the Fe(II) ion at low pH. In contrast, Fe(III) concentration on the biotic experiment have increased significantly over time, while the Fe(II) decreased. This indicates the accelerated biological oxidation of Fe(II) in Fe(III) by the *A. ferrooxidans* energy metabolism, suggesting bacterial growth. Therefore, our data unveils that *A. ferrooxidans* is capable of using siderite as its sole energy source, a still unexplored ability of this Astrobiology-relevant extremophile, and providing bases to further studies on biosignatures for the search of extinct Martian life.

Molecular Dynamics Computer Simulations of Primitive Polymerization in Clay Channels

Iskinder Arsano - The University of Akron

Iskinder Arsano

An active area in current Origins of Life studies is the attempt to understand how nucleotide oligomerization can be brought about on mineral substrates such as montmorillonite clay as a possible route to primitive polymers that served as the first life forms. Defects in the montmorillonite were reported to create negatively charged channel surfaces [1] where metal ions such as those of calcium and magnesium may accumulate. A recent experimental evidence [2] suggests that small magnesium ion concentrations comparable to those available on early earth were enough to co-catalyze nucleotide oligomerization. The same work [2] has shown that the accessibility of phosphate moieties during the adsorption of activated adenosine monophosphates plays a more crucial role than the amount of adsorption. Inspired by these two observations, here we have used Molecular Dynamics computer simulations to systematically assess the roles of ion concentration and molecular orientation in the polymerization of nucleotides in a typical Mg^{2+} montmorillonite channel.

References

[1] Mathew, Damien C., and Zaida Luthey-Schulten. Origins of Life and Evolution of Biospheres 40, no. 3 (2010): 303-317. [2] Kaddour, Hussein, et al. The Journal of Physical Chemistry C 122, no. 51 (2018): 29386-29397.

A hot early Earth? Assessing Archean and Proterozoic temperature history under different geological constraints.

Sandra Bastelberger - University of Maryland College Park, CRESST II, NASA GSFC
Sandra Bastelberger, Shawn Domagal-Goldman

The temperature evolution of Proterozoic and Archean Earth remains controversial. The “Faint Young Sun” paradox has been a long-standing problem, attempting to resolve evidence for oceans back to at least 4 billion years ago with knowledge that the Sun was likely significantly dimmer. Further, geochemical reconstructions based on $\delta^{18}O$ and $\delta^{30}Si$ data from cherts indicate temperatures over 30 °C throughout most of the Proterozoic, and exceeding 50 °C in the Archean and early Proterozoic. Isotopic analyses of phosphates point to warm Archean temperatures below 40 °C. These estimates are all higher than modern-day Earth’s average temperature of ~ 15 °C. Similarly, a lack of evidence for glaciation in the mid-Proterozoic seems to corroborate the narrative of a hot early Earth.

Here, we use Atmos, a 1-D coupled photochemistry/climate model to study Archean and Proterozoic surface temperatures for a comprehensive set of literature constraints including atmospheric pressure, composition and albedo. We systematically assess which combinations of constraints are compatible with different temperature reconstruction approaches when applied simultaneously.

Our results- in agreement with previous studies- resolve the classic “Faint Young Sun” paradox - demonstrating average global surface temperatures easily permitting bands of ice-free oceans. However, they struggle to reconcile the geochemical evidence for high surface temperatures with the reduced insolation from a faint young Sun if all geological and geochemical constraints suggested in the literature (e.g. CO_2 concentrations inferred from paleosols) are considered. They cannot explain the “hot early Earth” hypothesis from isotopic data unless other geological constraints are ignored.

Gas-phase Organic Chemistry in Exoplanet Atmospheres and Implications for Haze Formation

Jennifer Berry - University of Colorado Boulder
Jennifer L. Berry, Melissa Ugelow, Margaret Tolbert, Eleanor Browne

Atmospheric organic chemistry can lead to climate-altering organic haze and potentially form prebiotic molecules, making hazy planetary bodies of astrobiological interest. Despite extensive investigation into the composition of organic haze in laboratory simulations, there is a lack of understanding in the gas-phase composition and how this evolves temporally in simulation experiments. These measurements are necessary to inform models of planetary atmosphere. Here, we use an ethanol Chemical Ionization Mass Spectrometer (CIMS) to measure the chemical composition and temporal change of gas-phase products during the formation of haze analogs in Titan-like atmospheres. With Hierarchical Clustering Analysis (HCA), the evolution of gas-phase products was found to go from only organic species to organic nitrogen species that increase in mass with time. The SIMPOL.1 group contribution method can estimate the vapor pressure of these detected compounds, informing the expected composition of aerosols from condensation of larger species. At these experimental conditions, compounds with molecular weights $^{>}$

350 g/mol are expected to be at least 50% in the particle phase and suggest that the complex, unsaturated organic nitrogen compounds formed would play an important role in aerosol composition. When considering Titan-like temperatures, the SIMPOL.1 method calculates that compounds with molecular weights ≥ 130 g/mol would be more than 50% in the aerosols. Our results suggest that that the types of molecules contributing to aerosol formation varies with atmospheric temperature. The SIMPOL.1 method and CIMS experiments are widely applicable to exoplanetary atmospheres and can be used to inform models in determining exoplanet habitability.

Simulated Exoplanet Observations with HabEx and LUVOIR: Preparing the Hunt for Biosignatures

Amber Britt - Fisk University
Amber V. Britt

In the past decade, numerous discoveries with the Kepler mission have shown us that planetary systems are quite common throughout the cosmos, with roughly 25% of stars having at least one planet orbiting within the habitable zone of its parent star (Petigura et al., 2013). With a plentiful supply of systems to study, the exoplanet astrobiology community can now start to move toward characterization analyses. The goal would be to detect signs or signatures of life that can be seen over the vast interstellar distances of space. These signs are referred to as biosignatures and can be defined as a substance or pattern that is of biological origin (Des Marais et al., 2008). In an atmosphere, biological processes can produce spectroscopic features which in turn can be remotely characterized. There are several key species associated with biological processes that are pertinent to the search for life elsewhere including but not limited to water/water vapor, O3, O2, and CH4. Future space based efforts like LUVOIR (Large UV/Optical/IR Surveyor) , and HabEx (Habitable Exoplanet Observatory) aim to use direct imaging to perform spectroscopic observations, enabling us to probe an exoplanet atmosphere and characterize its spectroscopic signatures. Crucial to the development of these mission concepts, is to predict the integration times necessary to retrieve spectroscopic signatures with sufficient signal to noise ratio. Using a coronagraph modeling tool adapted from Robinson et al., 2016, our work aims to calculate the integration times needed to retrieve life bearing spectral analogs in order to help optimize observing strategies for these missions. We simulate both the HabEx and LUVOIR architectures with the coronagraph model which produces simulated spectra that include the effects of instrument noise (dark current, read noise) as well as astrophysical nuisance signals (zodiacal light, exo-zodiacal light, etc.). Additional tunable parameters in the model include telescope aperture, spectral resolution, throughput, distance to target, coronagraph inner and outer working angles, as well as target star distance. Here, we present results for Earth and Archean Earth systems modeled at different distances within the stellar neighbor (out to 10pc) and discuss the integration times needed to retrieve these spectra and key spectral features with HabEx and LUVOIR.

Des Marais, D. J., Nuth, J. A., III., Allamandola, L. J., Boss, A. P., Farmer, J. D., Hoehler, T. M., … Spormann, A. M. (2008). The NASA Astrobiology Roadmap. Astrobiology, 8, 715–730.
Petigura, E. A., Howard, A. W., & Marcy, G. W. (2013). Prevalence of Earth-size planets orbiting Sun-like stars. Proceedings of the National Academy of Sciences, 110(48), 19273–19278.
Robinson, T. D., Stapelfeldt, K. R., & Marley, M. S. (2016). Characterizing Rocky and Gaseous Exoplanets with 2 m Class Space-based Coronagraphs. Publications of the Astronomical Society of the Pacific, 128(960), 025003.

Carbon isotope fractionation by cyanobacteria under light-limiting conditions

Kunmanee Bubphamanee - University of Colorado Boulder

Kunmanee Bubphamanee

The evolution of oxygenic photosynthesis and the resulting accumulation of oxygen in the atmosphere, known as the Great Oxidation Event (GOE), is one of the most prominent transitions in Earth history. While cyanobacteria are thought to be responsible for the accumulation of oxygen during the GOE, the timing of the evolution of oxygenic photosynthesis, and the abundance of different primary producers during this time remain unconstrained. The carbon isotopes provide a continuous record through this time period and may be a way to investigate the dominant primary producers during this time. In order to interpret the geologic carbon isotope record, or the offset between preserved carbonate rocks and synchronous organic carbon (ε_TOC), we need to understand the underlying carbon isotope fractionation by primary producers (εp). Here we investigate the influence of CO_2 concentration and the growth rate on carbon isotope fractionation by four cyanobacterial strains. Under light-limiting conditions, we find a single relationship between εP values and growth rate across all strains. Our results suggest that carbon isotope fractionation by cyanobacteria is not strain-specific, but is instead controlled by underlying physiology. These results support the use εP values as a proxy for unicellular cyanobacteria. Further work is necessary to understand the factors influencing εp values in different conditions and to understand how εP values relate to the geologic carbon isotope record.

Propensity of amino acids in ribosomal proteins

Vasanta Chivukula - Georgia Institute of Technology

Chivukula, V., Penev, P., Petrov, A. and Williams, L

The translation system is ubiquitous with the ribosome acting as the hub for synthesis of protein. Ribosome contains two catalytic structures to decode mRNA and coordinate the intricate translation process with highest precision. Ribosomal proteins can provide us with insights into the evolution of proteins and history of protein folding as they can be considered molecular fossils that existed before LUCA. The propensity of residues within a protein helps predict its native conformation and determine whether a protein sequence has the potential to form α- helix or β-sheet. We use the amino acid (AA) propensities to understand the evolution of ribosomal proteins and the evolutionary relationships between the three domains. Propensities differ based on the location of the AA and the solvent accessibility both for α-helices and β-sheets with a higher difference in β-sheets due to combinations such as parallel, anti-parallel and mixed. Our calculations on the distribution of each residue for various ribosomal proteins and RNA polymerases show a higher affinity for aliphatic AAs within some beta barrel and hammerhead proteins. The most common AAs seen in these proteins were hydrophilic residues, arginine, lysine, and glycine. Some of these residues are plausible prebiotic AAs as proposed by previous studies including the Miller-Urey experiments. A few hydrophobic residues, valine and leucine, were also found dominating in certain proteins. Data across the three domains showed similar trends in the AA propensities. Comparing the ribosomal proteins across the tree of life helps understand the complexity of assembly and folding of polypeptide chains.

Atmospheric Parameters and Ages of M-Dwarfs in the Solar Neighborhood

Ellen Costa de Almeida - Valongo Observatory, Universidade Federal do Rio de Janeiro
de Almeida, E. C.

M-dwarfs are the most numerous stars in the Galaxy, accounting for more than ~70% of nearby stars, making them the most likely hosts of habitable planets. They are prime candidates to shelter habitable earthlike planets, as stressed by the recent discoveries of terrestrial exoplanets inside the habitable zones of the nearby M-dwarfs Proxima Centauri and Ross 128. Both the transit and radial velocity techniques for detecting exoplanets are much more sensitive to the presence of earth-size planets around M-dwarfs than in solar-type dwarfs. Thus the first habitable exoplanet will probably be detected and characterized in a M-dwarf environment, making these stars extremely relevant to both astrobiology and planetary science. Even though they are hotspots for the detection of habitable earthlike planets, our knowledge of their properties and their accurate census stills lags behind with respect to more massive stars. We aim to improve our knowledge of the T_{eff}/[Fe/H] of nearby, still poorly studied M-dwarfs, by means of moderate resolution, high S/N NIR spectra, obtained at the coudé spectrograph of the Brazilian 1.6m telescope. We derived a competitive PCA spectral line index calibration able to derive T_{eff}/[Fe/H] with internal errors < 100K and < 0.1 dex respectively, calibrated against stars with interferometric Teff and [Fe/H] from solar-type binary companions. We present results for 180 stars, about half of which has no previous T_{eff}/[Fe/H] determination. We estimated stellar ages by measuring chromospheric fluxes using an activity-age calibration specifically tailored to M-dwarfs derived by our own group.

Increasing the Resolution of Planetary Images using Artificial Intelligence: Small Crater Detection Case Study

Ebrahim Emami - University of Nevada, Reno
Ebrahim Emami

Size of craters on planetary images depends on the image resolution, and such images are often captured in low resolution. Thus, the manual detection of smaller craters is often laborious and challenging. Despite these challenges, smaller craters are abundant and have great importance for planetary scientists as finer spatial resolution of geologic stratigraphy can better be obtained from statistics of smaller craters. In this research, we deploy the latest methods in Artificial Intelligence to generate high resolution planetary images from the already captured lower resolution images. A category of deep neural networks are specifically designed for the task of “Single Image Super Resolution”. Given a single input image, an SR network tries to generate an output with details which were not visible in the input. Deep Residual Network (RDN) is the state-of-the-art network proposed for this purpose which won the single image super resolution challenge (CVPR NITRE) in 2018. In this research, we significantly improve the performance RDN for the task of increasing the resolution of planetary images. We named the improved model Planetary Deep Residual Network (PRDN). We show how the performance of small crater detection algorithms can be improved when applied on the output images of PRDN. We further explain how similar to our task, customized deep neural networks can be used to increase the resolution of images for other tasks in planetary science and deep space exploration, considering the limited resolution of images in these fields.

Search for exoplanets with potential to host life

Raquel Farias - Federal University of Rio de Janeiro

Raquel G. Gonçalves Farias, Anna B. S. Bocatto, Beatriz B. Siffert, Gustavo F. Porto de Mello and Marcelo Borges Fernandes

The discovery of a large number of planets outside the Solar System naturally raises our curiosity about the possibility of the existence of life outside the Earth. Although quite diverse on Earth, we cannot yet say whether life is a common or a rare phenomenon in the Universe. So far life on Earth remains as the only known example that we have. The concept of stellar Habitable Zone (HZ), which can be defined as the region around a star in which liquid water can exist on the surface of a rocky planet with an atmosphere, is crucial when looking for life in exoplanets. In this work, we present the results of a thorough search in the exoplanet.eu open access database, in each we look for rocky exoplanets inhabiting their stellar HZ. We have collected data regarding characteristics of around 4,000 exoplanets (mass, radius and available information about the orbit) and their host stars (effective temperature, magnitude, distance, and spectral type), and then calculated each planet's density, in order to determine if it is rocky, the orbital distance, and the boundaries for the HZ for each star. Since our goal is to produce a set of exoplanets with the potential to host life, we have flagged the exoplanets lying inside their star's HZ, according to their host star type, to signal possible hostile environments that could exist around some stars, such as active stars, for example.

Growth of halophiles from Lagoa Vermelha, Brazil, at high concentrations of $MgSO_4$ simulating Martian environments

Isabella Gaião da Silva - University of São Paulo

Isabella Gaião, Bianca de Freitas Brenha, Douglas Galante, Fabio Rodrigues

Brines have become important objects of study on the search for life on Mars. It has been shown that significant amounts of magnesium sulfate (MgSO4) are present in Martian soil and that this salt would be abundant in brines' composition as well. Therefore, salt tolerance should be a determining factor for survival in this context, and halophiles, more prone to be epsotolerants, could be used as model organisms. In the present work, halophilic bacteria isolated from Lagoa Vermelha (Rio de Janeiro, RJ), a hypersaline lagoon in Brazil, were tested in different MgSO4 concentrations to verify their tolerance to this salt.

Twenty isolates were cultivated in LB medium under agitation, and accustomed to higher concentrations of MgSO4 at each generation, reaching a maximum of 2.9 mol L-1. Growth was measured by optical density (OD) at 600 nm during fourseven days of incubation. Four isolates survived at the maximum concentration and, for those, the growth curve was obtained with two different concentrations (0.5 mol L-1 and 2 mol L-1 of MgSO4). It was observed that, for those isolates, growth in 0.5 mol L-1 was faster than in 2 mol L-1. The final concentration of viable cells, measured by CFU counting, was similar on both cases. Thus, our data showed that the isolated halophilic bacteria could grow at high concentrations of MgSO4 without compromise of the carrying capacity, and corroborates that Brazilian environments have potential as Martian analogues.

Nano spectroscopic approaches to the Origins of Life: A Model for Prebiotic Accumulation of Amino Acid Oligomers on a Mineral Surfaces

Narangerel Ganbaatar - Tokyo Institute of Technology, Earth-Life Science Institute (ELSI)

G. Narangerel, R. Afrin, M. Aono, T. Yano, and M. Hara

In the study of origin of life, selective accumulation of abiotically synthesized amino acids to a high enough concentration for the subsequent creation of functional peptides and proteins has been regarded as a very important but least understood step. It is often discussed that certain mineral surfaces played a role in adsorbing amino acids selectively for further polymerization reactions. Adsorption of amino acids to various mineral surfaces or to lipid vesicles has been proposed and studied both experimentally and theoretically but more solid knowledge about this process is expected to be established. In the present study, the single molecule force spectroscopy technique based on atomic force microscopy (AFM) was used to verify the binding-interaction of several amino acids to different mineral surfaces known as potential candidates for biomolecules were first synthesized in a prebiotic “inorganic” environment. Amino acid molecules were covalently crosslinked to an AFM probe and their unbinding event from the mineral surfaces was investigated. Our results clearly indicated the ionic nature of the single molecular adsorption/desorption reaction on the iron minerals such as pyrite and hematite. Changes in the local reaction environment may have influenced the binding reaction in addition to surface properties of minerals as investigated by Raman spectroscopy and other surface science related techniques.

Evaluating the Significance of Spin-Orbit Misalignment in Hot Jupiter Systems

Claire Geneser - Mississippi State University

Claire Geneser, Dr. Angelle Tanner

We have analyzed a set of ten stars with known transiting planets with the intention of discovering additional planets or brown dwarfs at wider separations. The high contrast visible and infrared images were gathered with the use of the Magellan VisAO and Clio instruments. Observed 2014 and 2015, the targets were chosen based on their measured spin-orbit misalignment with respect to their host stars rotation axis. One explanation for the orbit misalignment is the Kozai mechanism, which operates through the exchange of orbital inclination and eccentricity between a planet and a distant massive companion. Follow up measurements of common proper motion with the host star will either confirm or reject the presence of any stellar companion. Final analysis was completed through the use of Vortex Image Processing package (VIP) which utilizes high-contrast image processing algorithms to improve sensitivity to faint companions. Here, we present the details and results of this analysis including whether any of our ten targets have bona fide companions based on common proper motion confirmation.

Snowball Earth: The Effect of Viscosity on the Multicellularity of *Chlamydomonas reinhardtii*

Andrea Halling - University of Colorado, Boulder
Andrea Halling, Boswell Wing, Carl Simpson, Jesse Colangelo

The Snowball Earth hypothesis proposes that multiple times in Earth's history, Earth's surface froze over nearly entirely for many millions of years. The decreased temperatures of the Snowball Earth would have resulted in the increased viscosity of ocean waters under the global icecap. The most recent of these events is thought to be the trigger for the evolution of multicellularity resulting in the Cambrian explosion almost 550 million years ago. To test this hypothesis, the single-celled green algae, *Chlamydomonas reinhardtii*, was used in order to observe the effects that viscosity has on the development of multicellularity. An agar plate was created with three sections of media ranging in relative viscosities from 1X to 10X, and *Chlamydomonas* was inoculated at the low viscosity end. Growth was observed as the algae spread into the higher viscosity sections and two distinct phenotypes emerged. The phenotype in the lower viscosity tended to be diffuse and largely single celled. As the viscosity increased, discrete clumps became apparent. Microscopy was used to view the phenotypes in each section. The microscope images revealed that not only were the *Chlamydomonas* clumping as the viscosity increased, but in some cases the orientation of the flagella in these clumps were aligned in the same direction. These finding suggest that increased viscosity of ocean water as a result of Snowball Earth could have played a major role in the diversification of early life.

This work was supported in part by Jesse Colangelo's C-DEBI Postdoctoral Fellowship Grant as well as the Interdisciplinary Quantitative Biology (IQ Biology) program at the BioFrontiers Institute, University of Colorado, Boulder.

Functional or fashionable? Exploring the role of coenzyme A-linked transcripts

Jordyn Lucas - University of Missouri, Columbia
Jordyn K. Lucas*, Matthew F. Lichte*, & Donald H. Burke

Cells take advantage of abundant nucleobases to generate nucleotide analogs such as cyclic adenosine monophosphate (cAMP), nicotinamide adenine dinucleotide (NAD), and coenzyme A (CoA). These analogs are important as signaling molecules, energy carriers, and enzyme cofactors. Additionally, previous studies established the presence of cofactor-linked RNAs in bacterial cells, where NAD, CoASH and acyl-CoAs are in the most 5' position of transcripts. Studies describe NAD's protective, cap-like function in bacteria and its role in promoting mRNA degradation in eukaryotic cells. In contrast, the functional roles, if any, of CoA-linked RNA have not yet been explored. It's possible that these cofactor-linked RNAs utilize their modifications to enhance RNA's chemical diversity for a variety of reactions (like metabolic chemistry) or to differentiate RNAs for actions like signaling, trafficking, or regulation. One long-term goal is to determine whether these modified RNAs are the product of random incorporation or potentially a positively selected cellular function. To determine the functions provided by a CoA modification, we are identifying which bacterial transcripts carry these modifications under various growth conditions. Taking advantage of CoA's free sulfur, we've developed a partition method that enriches sulfur-containing RNA from cellular RNA extract. We are using high-throughput sequencing to determine relative enrichment/depletion of each transcript to determine whether certain RNAs have a higher/lower tendency to be linked to CoA. Identifying enriched CoA-RNA transcripts will help illuminate

the roles of these modifications. We will utilize this information to explore possible cap functions provided by CoA and its impact on the RNA's chemical properties.

Chemical Gradients at the Lost City Hydrothermal Field: an Analog for Icy-Moons

Dylan Mankel - Michigan State University

Dylan Mankel, Miranda Pryde, Osama Alian, Matthew Schrenk

The possibility of life on icy-moons, such as Europa and Enceladus, has drawn attention to studying the nature of extreme environments. However, evidence for life on these moons has yet to be shown in the data collected during the *Cassini* probe flybys. The chemistry of these places are what characterize the life therein, so studies of similar environments here on Earth provide insight into what we might find on these rocky bodies. The Lost City hydrothermal field (LCHF) is of particular interest because it is a site of relatively low-temperature serpentinization reactions that produce necessary nutrients to support submarine life. Here we show laboratory experiments that can model the chemistry associated with the hydrothermal vents at LCHF in the presence of microbe-mineral and microbe-microbe interactions. Chimney and plume samples were inoculated in appropriate broths and gradients that would be analogous to the site's geochemistry to further isolate the individual species seen in the microbial community, a task that has yet to be demonstrated. Preliminary results also show that these microorganisms were able to survive in an Enceladus-like oceanic environment derived by current models using the plume chemistry collected by *Cassini*. The fortran-based reactive transport code, Crunchflow, was also used to assess the conditions under which those organisms were able to grow along the constructed gradients. These experiments can help to discern the influence of biology on the geochemistry of LCHF and could be extended to other chemistries and conditions, particularly those of Europa, Enceladus and Titan.

New alignment score for studying ancestry of ribosomal proteins

Petar Penev - Georgia Institute of Technology

Petar Penev, Anton S. Petrov, Vasanta Chivukula, Nicholas Kovacs, and Loren Dean Williams

Multiple sequence alignments are very important for phylogenetic analysis, they give information about evolutionary relationships and supplement structural data. Often conservation within alignment data is indicated with variability measure for an entire aligned column. While there is enormous number of available sequences, there is no robust way to compare groups of sequences within an alignment. Ribosomal proteins as well as other universal proteins appear to have evolved via multiple gene duplications, therefore for a thorough study of ribosomal proteins, the use of proper alignment scores is crucial.

Here we discuss a new method for alignment score calculation that takes in account protein function and species identities. It does this by separating groups of sequences based on species and protein function. This allows us to calculate a measurement for the likelihood of group to 'transform' to the other giving greater depth of the phylogenetic analysis.

The ribosome is a molecular fossil containing a readable record of the evolutionary history of proteins. Universal rProteins are naturally split in two orthologous groups – Archaeal and Bacterial, allowing us to study in detail conserved regions likely to have existed in the last universal common ancestor (LUCA). The ancestry and origins of domain specific ribosomal proteins can be studied by evaluating alignments of different possibly paralogous rProteins. Combining present rProteins in single alignments can give us insights on their real origins. I will present latest results on the origin of multiple domain specific rProteins, portraying an important mechanism of ribosomal evolution at the quantitative level.

Preservation of Organic Molecules on the Irradiated Martian Surface

Anais Roussel - Georgetown University

NASA's Mars2020 and ESA's ExoMars2020 missions will soon launch with the principal objective of finding signatures of life. Yet high energy radiation has been bombarding the Red Planet for the last four billion years, and it remains unclear how organics are degraded by surface radiation.

My project aims to characterize the preservation of biosignatures in Mars' radiation environment. It will give critical insights on different preservation potentials depending on mineralogy and help identify the best locations to aim for the recovery of organics on Mars. The interactions between a rock matrix and the molecular fossils trapped inside natural samples have never been studied in terms of radiation. The surrounding minerals may have a protective effect by shielding organic matter from radiation, but they may also have a destructive effect by releasing hazardous secondary products when exposed to the cosmic rays. Interestingly, the destructive effects may be linked with hydrated minerals, which are often considered good targets for biosignatures.

I plan to look at organic's preservation in five natural terrestrial analog samples under radiation and characterize (1) which mineralogies are the most protective, (2) which classes of organics are best preserved, (3) the timelines over which detections persist. The samples will be exposed to an equivalent dose of 1, 10 and 100 million years of exposure on Mars' surface using 1 MeV gamma-rays. They will then be analyzed using a Gas Chromatograph Mass Spectrometer using the wet chemistry protocols from the MOMA (Mars Organic Molecule Analyzer) instrument on the ExoMars2020 rover.

Determining Molecular Biomarker Survivability in Enceladus Plume Capture Conditions using Laser-Induced Particle Impact Testing

Kenneth Seaton - Georgia Institute of Technology

Kenneth M. Seaton, Bryana L. Henderson, Isik Kanik, Thomas Orlando, Amanda Stockton

Enceladus has becomee a highly attractive target for astrobiology studies due to compelling evidence for ongoing geophysical activity and a subsurface liquid ocean beneath its crust, as well as new evidence for the possibility of large organic compounds in this ocean. Cryovolcanism occuring at the southern region of Enceladus results in plumes of water ice grains being ejected into space at high velocities, which makes a flyby mission to analyze plume ejecta a viable approach, but these sampling strategies assume that any biosignatures present would survive hyper-velocity impact onto the sampling plate. A good understanding of the survivability of biosignatures in captured material at spacecraft velocities from the Enceladus plume is required for future mission design studies. However, biomarker survivability through these conditions is presently unknown, so the study of how molecular biomarkers are affected by high-impact conditions is crucial to the development of effective sampling approaches for future missions to Enceladus. In this work, we aim to identify capture conditions under which potential biosignatures may be preserved during a fly-by using various capture media. To accomplish this, we are performing hypervelocity impact experiments with ice grains containing organics using Laser-Induced Projectile Impact Testing onto relevant capture media. Understanding how potential biomarkers are affected by Enceladus plume capture conditions is of utmost importance if we hope to find life on Enceladus, and this research would represent the first coordinated analysis of the preservation of organic molecules during hypervelocity impact of ice grains with potential capture materials in Enceladus plume conditions.

Science Shaping International Law: The Need for a Policy Approach to Exploration

Monica Vidaurri - George Mason University

Given the inevitability of the private sector influencing future crewed and non-crewed missions, both in and beyond low Earth orbit, it is especially crucial that the science community strengthens, agrees upon, and adopts planetary protection, bioethics, and anti-colonization protocol on an international level, beginning with establishment of norms. As future PIs and managers, we must create the internal and international norm of collaboration with planetary protection at the forefront. These norms ultimately shape international law, and the custom of early and regular collaboration with ethicists and planetary protection specialists is absolutely critical for not only mission safety, but mission and science integrity. The most critical of these norms is establishing within the science mission traceability matrix planetary protection, ethics, and anti-colonization, which must fall shortly after mission conception. Creating a safe, responsible, and anti-imperialist space for peaceful purposes only cannot wait for the international space community to create these practices de jure, but must be started at the individual level and regarded as custom for integration into international law, de facto. In order to achieve an international foundation of space policy and ethics, scientists must seek out and receive proper communications, ethics, and law training, including law language, so as to ensure our science is well understood and legally protected from any uncertainty.

Extending the Laboratory Millimeter/Sub-millimeter Spectrum of Interstellar Glycine Precursor Protonated Formaldehyde

Connor Wright - Emory University

Connor Wright, Kevin Roenitz, Jay (Alec) Kroll, Susanna Widicus Weaver

Molecular ions and plasmas have long been known to drive rich, complex chemistry in the interstellar medium (ISM). While it is well established that conditions on early Earth lead to the formation of amino acids and sugars, two of the main precursors to life, it is much more likely that life similar to that on Earth will arise elsewhere if these are formed in the ISM and delivered to newly forming planets. We hypothesize that glycine (NH_2CH_2COOH), the simplest amino acid, is formed as a result of this ion chemistry. To test this hypothesis, the rotational spectra of ionic glycine precursors must be measured in the laboratory. Once these spectra are obtained, they can be compared to observations from radio telescopes and their presence in the ISM can be conclusively determined. Of particular interest is the protonated formaldehyde ion (H_2COH^+). It is an ionic product of methanol (H_3COH), one of the most ubiquitous molecules in the ISM, and is a precursor to glycine. The known $3_{1,2} \leftarrow 2_{0,2}$ rotational transition of protonated formaldehyde at 190079.131 MHz has been previously detected in our lab utilizing a pulsed supersonic expansion/high voltage discharge source coupled with a multipass optical arrangement. Experiments are currently underway to maximize the molecular signal. Once this is done, we will extend the spectrum from 385 GHz to 1 THz. We will then compare the laboratory spectra to radio astronomical observations of star forming regions. Here we present the status of the experiment and the results obtained thus far.

Companion Search Using MagAO data

Farzaneh Zohrabi - Mississippi State University

Farzaneh Zohrabi, Angelle Tanner, Graeme Salter

Discovering thousands of planets beyond our solar system counts as a giant step in science history but the most significant achievement of exoplanets research is finding the earth-like planets. Using adaptive optics system in Magellan-AO telescope gives us this opportunity to validate and confirm the properties of the exoplanet host stars. This companion search around host stars can help recognize any potential astrophysical false classification of habitable planets. In this research project, we are reducing direct imaging data from 10 southern hemisphere targets which Graeme Salter and his team collected from Magellan-AO using Clio2 instrument (IR camera). We have used Angular Differential Imaging (ADI) method in analyzing the AO data with Python packages. ADI method is one of the best technics of detecting exoplanets that are relatively close to the host star and the companion search in Infrared wavelength increases the chance of observing the exoplanets in the field of view. Through this reduction, we hope to find possible low mass stellar or non-stellar companions around these planet host stars.

Poster Session 2 Poster Abstracts

The Authentic Reality

Seyedsaeid Ahmadvand - University of Nevada, Reno

Seyedsaeid Ahmadvand, Behrooz Abbasi, Bahman Abbasi

This article discusses precedence and self-perpetuity of the physical subjective realities, improvised to define the observable Universe. A few thought experiment, philosophical edifice, and experimental observation are employed to deduce an ultimate for an acceleratively expanding universe, based on which the authenticity of the subjective realities is examined. Herein, whatever holds definition invariance and self-perpetuity in an entire evolutionary process is defined as authentic. Throughout the evolvements, it has been attempted to take the fewest possible assumptions into account, postulating that: 1) a system naturally takes the most economic, i.e., probable path, to globally but not greedily reach its equilibrium state, 2) there are no extra complexities and/or interactions with external forces added to the system, i.e., no a priori assumption about the causality of the system, 3) based on the previous postulates, the predicted destiny of such system is used to analyze authenticity. Within the aforementioned assumptions and postulates, this paper speculates that in a hypothetical system, similar to our Universe, an infinitesimal local heterogeneity in a highly dense equilibrium state induces an enormous probabilistic imbalance disequilibrating the system. Thereafter, restoring the global equilibrium in a probabilistic, yet lucrative, way is the only authentic provocative force driving the system to the most probable state (entropic state). Eventually, such a system will reach equilibrium, stop expanding, and undergo recurrence.

Modeling Habitability at the Rock-Water Interface

Osama Alian - Michigan State University

Osama Alian, Dylan Mankel, Matthew Schrenk

The Lost City Hydrothermal Field (LCHF) is a serpentinite hosted vent system, releasing clear, hot, reducing, convective fluids from mafic and ultramafic rocks of the Mid-Atlantic Ridge (MAR) subsurface and is host to a unique microbial consortia. While traditional analysis has focused on bulk fluid and chimney sampling, habitability at LCHF may be linked to energetic gradients on the microscopic scale permitting redox reactions to take place. Such microenvironmental variables may not be apparent in overall site analyses, and may shed light on the structural and functional arrangement of consortia. Utilizing chimney and fluid samples collected from the recent LCHF expedition AT42-01 in fall 2018, we propose testing various gradients conditions possible within biofilms at rock-water interfaces of LCHF along different temperature and pH regimes for microbial activity and growth. Data gathered from these experiments will provide the quantitative basis for a model of habitability in serpentinizing systems, with derivation possible to ocean worlds such as Europa and Enceladus. This presentation will serve to discuss the theoretical and preliminary knowledge derived from this analog site and how it may inform our understanding of microbial activity in extreme environments on Earth and beyond.

Organic matter preservation in clay-rich environments of Earth and Mars

Adrian Broz - University of Oregon

Adrian Broz, Dr. Greg Retallack, Dr. Briony Horgan

Thousands of locations on Mars have Noachian (4.1-3.7 Ga) sedimentary rocks containing Fe/Mg phyllosilicate clay minerals. These clays may effectively preserve organic matter (OM) via sorption to mineral surfaces and interlayer spaces. However, the mechanisms of OM preservation in phyllosilicate-rich rocks of ancient Mars have not been clearly defined. Here I present a unique approach to determine what controls OM preservation in dioctahedral phyllosilicate sequences by examining OM preservation in dioctahedral clay-rich paleosols, which may be abundant on Mars. Vertical sequences of dioctahedral phyllosilicates have been recently named a high priority site for biosignature detection and Mars Sample Return, but our ability to assess the best locations within these surface paleoenvironments is majorly limited by the current lack of understanding what controls OM preservation in terrestrial paleosols. I will test the hypothesis that chemically reduced paleosols with abundant (> 70 wt %) dioctahedral phyllosilicates best preserve total organic carbon (TOC). I will collect TOC data for Eocene and Oligocene paleosols at the John Day Fossil Beds, Oregon, and then acquire visible/near infrared (VNIR) and powder XRD spectra of all pedotypes analyzed for TOC. Next, I will search for areas of similar clay mineralogy and distribution in Noachian surface paleoenvironments on Mars using orbital spectral datasets. This research will advance our understanding of the fundamental processes controlling OM preservation over geological time, which is aligned with the NASA Science Mission Directorate (SMD) planetary science goals to "explore and find locations where life could have existed or could exist today”.

Using Shock Chemistry to Probe Interstellar Ice Chemistry

Andrew Burkhardt - Center for Astrophysics | Harvard & Smithsonian

It is believed that many of the most complex, and potentially prebiotic, molecules known in the interstellar medium are formed within the ice mantles on dust grains. While infrared absorption of vibrational features has allowed us to detect the solid-phase population for a limited number of molecules, the majority of ice chemistry remains observationally unconstrained. However, low-velocity astrophysical shocks may prove to be crucial probes of this phase of astrochemistry. Due to non-thermal desorption in these regions, the chemically-rich ices can be temporarily lifted into the gas phase, where they can be detected with rotational spectroscopy, before redepositing onto the dust grains. Here, we discuss recent interferometric observational and modeling efforts to study the chemical evolution within shocked regions within protostellar outflows. In particular, we find certain gas-phase molecules are solely enhanced by this non-thermal desorption, while others undo significant post-shock gas-phase chemistry.

Planetary Protection: The Microbes We Bring With Us

Jameson D'Amato-Faulkner - Salt Lake Community College

Jameson D’Amato-Faulkner and Katrina I. Twing

The transmission of microbes, including highly antibiotic-resistant microbes, from terrestrial environments to outer space, including the International Space Station, is cause for concern. There are, for example, bacteria that have evolved to thrive in clean-room environments in the absence of competitors (Sanderson, 2007). While microbes that evolve in such conditions do not always display human

pathogenicity, this demonstrates the proclivity of microbes to survive and adapt in environments conventionally considered to be extreme.

A literature review exploring the capability of resilient microbes to spread to astrobiologically relevant environments was conducted. Current evidence shows numerous concerns, including antibiotic resistance (Singh et al, 2018), accelerated mutation (Tirumali et al, 2017), and biofilm formation (Kim et al, 2013). These issues can lead to the contamination of a foreign planet with terrestrial microbes, a matter of utmost concern, as well as other problems.

The microbes we bring with us present a scope of issues. The presence and transmission of genes conferring a high level of resistance to environmental conditions, coupled with the capacity of microbes to spread widely and evolve quickly when put under extreme stress, present considerable problems. One such problem is the possibility of highly antibiotic-resistant microbes. These phenomena also have implications in related issues: resistant, pathogenic microbes can lead to untreatable crewmember illness, and biofilm growth is capable of degrading the integrity of a vessel (Gu et al, 1998).

Summarily, the central concerns of outer-space microbial transmission extend to planetary contamination, biofilm formation, accelerated mutation, antibiotic resistance, and pathogenicity.

Constraining the water flux through a serpentinite-hosted hydrothermal vent field

Jessica Frankle - University of South Carolina

Jessica D. Frankle, Willard S. Moore, Claudia R. Benitez-Nelson, Susan Q. Lang

Extraterrestrial ocean worlds like the moons Europa and Enceladus are postulated to host serpentine hydrothermal systems. On Earth, these water-altered subsurfaces contain elevated concentrations of reduced compounds (H_2, CH_4) and are therefore studied for their ability to provide energy for chemosynthetic life. The flux and replenishment of these fuel sources are largely unconstrained due to a lack of information on the rate and volume of water that circulates through such systems. Naturally-occurring radioisotopes are promising tracers for constraining the water flux through hydrothermal vent systems.In September 2018, we carried out a 22-day expedition to the Lost City hydrothermal field, an iconic serpentinite-hosted hydrothermal system. We analyzed vent fluids, chimney carbonates, and local rocks for the Radium Quartet (223, 224, 226, 228Ra) and their parent radioisotopes (Thorium, Actinium, and Protactinium). Surpassing any previously published measurements, we found highly elevated activities of 223Ra (half-life = 11.4 days) in the fluids. We theorize that a parent radioisotope, 231Pa (half-life = 34,000 years), is surface-scavenged when seawater circulates through the subsurface, eventually generating 223Ra which then leaches into percolating fluids. By combing measurements of Radium and their parent activities in the three sample matrices (fluids, chimneys, and rocks), we expect to calculate a fluid flux and residence time. Understanding the fluid flux within this system could place the much needed constraints on the rate at which energy and raw materials are supplied to chemosynthetic communities in serpentinite-hosted systems.

Elucidating Early Life Evolution via Protein Structure Comparison

Sean Gosselin - University of Connecticut

Sean Gosselin, Peter J Gogarten

As one tries to look further and further back in evolutionary time the nucleotide sequences of genes become muddled, and therefore amino acid sequences tend to be the better choice. However, even this reaches its limit and as mutations lead to the same gene having less than 35-20% sequence similarity between different organisms, it becomes nigh impossible to gain meaningful data about their evolution. This problem could be overcome by substituting structural data in place of the nucleotide or amino acid sequence data. Since protein catalytic sites need to retain certain structural features to remain functional, they remain highly conserved over immense periods of time. Thus, a structure-based approach could be used to look further back in evolutionary history than a sequence based approach. Yet there still remains the problem of sample size, as often times there is a lack of structures for a given protein outside of those from very well studied organisms.

Our research has focused on taking the necessary preliminary steps to make this approach a reality. We have tested a number of distance metrics through which to compare the structures of proteins and converted several into phylogenetic distances which can be used to construct an evolutionary tree, while also providing potential solutions to the problem of sample bias. Additionally we outline several test cases wherein this technique will be invaluable; specifically the phylogeny of viral coat proteins, and the evolution of the core 20S proteasome.

First-principles Models of Equilibrium Tellurium Isotope Fractionation

Mojhgan Haghnegahdar - UCLA

Mojhgan A. Haghnegahdar, Edwin A. Schauble, Paul Spry, Andrew Fornadel

We present theoretical models of tellurium isotope signatures, which are of interest as geochemical tracers for ore forming processes. Tellurium has a unique crystal-chemical role as a bond partner for gold and silver in epithermal and orogenic gold deposits. We predict $^{130}Te/^{125}Te$ isotope fractionations in representative tellurium-bearing species and crystals of varying complexity and chemistry, combining gas-phase calculations with supermolecular cluster models of aqueous and solid species. These in turn are compared with plane-wave density functional theory calculations with periodic boundary conditions. In general, heavyTe/lightTe is predicted to be higher for more oxidized species, and lower for reduced species, with $^{130}Te/^{125}Te$ fractionations as large as 3‰ at 100°C between coexisting Te (IV) and Te (-II) or Te (0) compounds. We compare the predicted fractionations with observed isotopic compositions, however, these data are not well suited make any conclusive statements about fractionation processes. More focused experimental investigations on naturally occurring redox pairs (i.e., Te (0) or Te (-II) vs. Te (IV) species) are needed.

Spectral Analysis of a Methylamine and Ozone Mixture: A Study to Aid in the Detection of Glycine Precursors in the Interstellar Medium

Jay Kroll - Emory University

Jay A. Kroll, Samuel Zinga, and Susanna L. Widicus Weaver

Reactions on grain surfaces in the interstellar medium (ISM) dominate the chemistry in space and allow for the formation of complex organic species that determine the chemical inventory of the ISM. One such reaction is predicted to form aminomethanol. Aminomethanol is of particular interest as it is a precursor molecule in the reaction predicted to form glycine, the simplest amino acid, in the ISM. Confirmation of the precursors for glycine formation in the ISM would add significant weight to modeling studies that predict the formation of glycine and show that amino acids are likely delivered to all planetary bodies and are not unique to the conditions on early Earth. Under terrestrial conditions, aminomethanol is unstable and must be produced in a supersonic expansion for spectral characterization. Once spectral characterization of aminomethanol is completed, comparison with observations from radio astronomy of star forming regions can be made to confirm the existence of aminomethanol in the ISM. Previous work in our lab has used the photolysis of ozone to form electronically excited oxygen atoms, O(1D), which insert into a C-H bond in methylamine to form aminomethanol. Analysis of this spectrum has proved difficult due to a significant number of transitions present in the spectrum as a result of the reaction of ozone with methylamine. We have collected spectra of methylamine and ozone mixtures under dark conditions to determine the reaction products and assign the spectra in order to clarify the laboratory spectral measurements under photolysis conditions. I will report on this analysis.

Letting the sun in - Plants grown under natural sunlight and artificial gravity.

Matthew Lehmitz - University of Wyoming

Among the more consistent issues that has been noted in dealing with space environments is the need for life support systems. As a step toward building a space portable ecosystem my team is currently engaged in design and construction of a 3U cubesat to test induced artificial gravity on the growth of Bromeliad species. The Bromeliads will be grown using primarily natural insolation in the orbital environment and their resource production/consumption rates will be carefully recorded. Testing Bromeliads in a space environment and developing these novel features in a satellite will aid in the long term development of self-sustaining ecosystems in orbital and space environments.

Hydrothermal H_2 generation and export footprint at the Atlantis Massif

Aaron Mau - University of South Carolina

Aaron Mau, Tamara Baumberger, Marvin Lilley

Since their discovery in 1977, hydrothermal vents have transformed human perception of extraterrestrial life thriving from alternative energy sources in remarkable environments devoid of sunlight. With temperatures, pH, dissolved gasses, minerals, and inorganic carbon sources in stark contrast to the surrounding seawater, the fundamental requirements for life are made available to vast and unexplored

regions of the Earth's oceans. One energy source for such organisms is hydrogen, a byproduct of many geochemical reactions, particularly those that occur at the Lost City Vent Field along the Mid-Atlantic Ridge.

When faulting occurs in the oceanic crust, olivene is uplifted and exposed to seawater, enabling serpentinization to release H2 and CH4 from the source rock.

$$\text{Olivine} + H_2O \rightarrow \text{Serpentine} + \text{Magnetite} + H_2$$

This reaction is particularly unique in that it can occur wherever olivine is exposed and is not necessarily dependent on an underlying magma chamber to take place [1]. The H2 produced by the reaction is ejected in the vent fluids, which then is utilized by many different microbes [2]. In 2018, a crew of researchers went to the Lost City field and collected and analyzed distributions of H2 and other gasses from the vents and surrounding waters. We found that the dissolved H2 concentrations are not only significantly higher than in the ambient waters surrounding the field, but that abyssal currents carry H2 a considerable distance away from the source which may have sweeping influences over biological activity away from the vent field.

References available upon request.

Investigating Growth, Global Gene Transcription, and Epigenetic Responses to Pressure Extremes in *Carnobacterium* Species

Kathleen Miller - University of Florida

Kathleen Miller, Flora Tang, Sixuan Li, Kelli Mullane, Douglas Bartlett, and Wayne L. Nicholson

The complete pressure range for prokaryotic life has yet to be fully characterized. Multiple studies have been undertaken to determine the limits of life in high pressure, but fewer studies have investigated the growth and genetic responses of organisms to low pressure environments. Most prokaryotes can only grow in a relatively limited range of pressure, but the psychrotolerant, facultatively anaerobic, Gram-positive genus *Carnobacterium* encompasses species capable of surviving a pressure range of over 5 orders of magnitude, from 10^3 Pa (Mars surface) to $>10^7$ Pa (ocean floor). *Carnobacterium spp.* have been isolated from a wide variety of cold niches including the Aleutian trench and Siberian permafrost. In order to understand the ability of microbes to adapt in a range of pressure, including low pressure in the near subsurface of Mars, we cultivated 14 *Carnobacterium spp.* in a cold (2°C), CO_2 atmosphere environment, in ten-fold increments of pressure spanning 10^3 – 10^7 Pa, then harvested samples for RNA-seq and Methyl-seq. Previous research on *C. inhibens subsp. gilichinkskyi* indicated that this species alters its DNA methylation pattern when cultured at low pressure. We propose that this epigenetic response, in conjunction with the global transcriptomic response, allows the species to adapt to different pressures. Bioinformatic analyses of Methyl-Seq and RNA-Seq data generated from the 14 *Carnobacterium spp.* cultures grown at different pressures will facilitate our understanding of genetic responses of prokaryotes living in diverse pressure environments. Supported by NASA Exobiology (NNH16ZDA001N-EXO) and DOE-JGI (CSP 502927).

Formation of Amide Molecules in the Interstellar Medium: Computational Modeling

Amir Mirzanejad - University of Nevada, Reno
Amir Mirzanejad, Sergey A. Varganov

Small amide-containing molecules are considered to be precursors to peptides and proteins, which are building blocks of life. Therefore, understanding the formation mechanisms of these molecules in interstellar medium (ISM) is highly relevant to astrochemistry and astrobiology. The gas phase chemistry in ISM is mainly driven by two-body collisions between atomic and molecular species because of the extreme conditions characterized by very low temperature and pressure. These unique conditions lead to the chemistry that is very different from the one we observe under typical Earth conditions. In this theoretical study, we investigate several formation mechanisms of the N-methyl-formamide (CH_3NHCHO) and acetamide (CH_3CONH_2) molecules in the north region of Sagittarius B2 from the atomic and molecular species present in that region.

Our theoretical investigation using the B3LYP density functional and CR-CC(2,3) coupled cluster method with the def2-TZVP basis set demonstrates that both spin-allowed and spin-forbidden reaction paths are energetically favorable for the formation of CH_3CONH_2 and CH_3NHCHO from the formamide and CH_2 precursors in the gas phase. Because the CH2 radical has triplet ground state, the spin flip transitions are important for the formation of the target molecules. To include these transitions into the reaction rate calculations, we estimate the probability of spin flip with the Landau-Zener formula.
The rate constants for the proposed mechanisms are calculated as functions of temperature. Because the reactants in the proposed mechanisms are neutral, we use the neutral-neutral version of capture theory with the long-range interaction potential. The studied reactions have a long-range centrifugal barrier, and the energy to surpass this barrier comes from the translational energy of the colliding reactants. The rate constant expression is simplified using the steady-state approximation. Therefore, the overall rate constant has a simple expression, kcPLZ, where kc is the capture theory rate constant, and PLZ is the Landau-Zener probability. The results of this study will be useful for understanding the molecular evolution in space and formation of molecules containing peptide bond, which represent building blocks of life.

Tracking Contamination in Subseafloor Rock Cores

H. Lizethe Pendleton - University of Utah
H. L. Pendleton, K. I. Twing, W. J. Brazelton

The Lost City is a unique hydrothermal system that releases hydrogen, methane, and other chemicals that can potentially fuel microorganisms through chemosynthesis. The International Ocean Discovery Program (IODP) Expedition 357: "Serpentinization and Life" drilled shallow rock cores in several locations near the Lost City in October 2015. The 60 m of subseafloor rock cores collected during IODP Exp. 357 are the first of their kind, meaning the analysis and interpretation of these samples required new methodologies, including a specialized approach for distinguishing true subsurface inhabitants from surface contaminants. In this study, we specifically tested the possibility of drilling lubricants as sources of microbial contamination to rock core samples. Various background samples of potential contamination sources were collected during sampling, including 109 seawater samples in the form of 0.22 μm filters (before, during, and after drilling), and 26 grease and oil samples used during the drilling process. Despite the wide usage of drilling lubricants and the importance of controlling for contamination in drill-core samples, no studies to date have looked at DNA in drilling grease and oil samples. Therefore, several possible DNA extraction methods were evaluated and optimized for this project. DNA extraction, purification, and preparation of the samples for environmental sequencing of the 16S rRNA gene were completed. This work could help to improve current practices for monitoring microbial contamination in any research project that involves drilling.

Planetary Organic Haze: Evolution, Habitability, and Biosignatures

Nathan Reed - University of Colorado Boulder

Nathan Reed, Maggie Tolbert, Eleanor Browne

Organic haze is a planet-wide atmospheric layer comprised of complex organic molecules and aerosol formed by methane ultraviolet photochemistry. A modern example of organic haze is on Saturn's largest moon, Titan. Another example is the 2.5 billion-year-old Archean Earth, which had large fluxes of methane due to biology. Organic haze should have major effects on planetary habitability and biology. For instance, the haze could either scatter or absorb solar radiation, creating either a greenhouse or anti-greenhouse effect, respectively, and thus affecting surface temperatures. Similarly, an organic haze can act as a shield from harmful UV radiation, protecting surface life. Further, it has been proposed that an organic haze can be a potential biosignature, since high methane fluxes that form the haze are possibly biological in origin, as they were on the Archean Earth. Since organic haze formation produces complex organic molecules, it is also possible that it can play a pivotal role in prebiotic chemistry and a nutrient source via haze deposition to the surface. My research focuses on lab simulations of organic haze formation and the fundamental photochemistry behind it. I study the mechanism of haze formation, the gas phase and aerosol products, and the relevant optical properties. Furthermore, my research studies how each of these properties vary due to the presence of trace gases in the haze-forming mixture. The results of my research are interpreted to apply to planetary habitability and the evolution of early life on Earth and possibly future observations of organic haze on exoplanets.

Prebiotic Relevance

Tyler Roche - Georgia Institute of Technology

Tyler Roche, David Fialho, Gary B. Schuster, Ramanarayanan Krishnamurthy, Nicholas V. Hud

Life today uses a specific type of sugar, called ribose, as the template for the backbones of its genetic material. We don't yet understand how ribose or any other sugars came about. Many have suggested that a simple molecule called formaldehyde reacted with itself and other simple molecules to form the sugars found in life, but this would form many sugars, not just ribose, and these sugars would degrade quickly. Another hypothesis suggests reactions of a different molecule called glyoxylate were responsible for forming sugars. Studies show that sugars formed in this way were primarily ketoses, or sugars with the carbon-oxygen double bond placed inside the carbon chain, rather than on the end. Furthermore, studies have shown that over time, a fraction of these ketose sugars will convert to aldose sugars like ribose.
We hypothesize that ketose sugars played an important role in the formation of life's genetic material due to the fact that they can be formed by plausible prebiotic reactions, as well as the fact that they can act as a source of aldose sugars, including ribose. Our experiments detail the difference in stability of these ketose sugars and their aldose counterparts.

Boron isotopes in the Puga geothermal system, India, and their implications for the habitat of early life

Luke Steller - University of New South Wales, Australia

Luke Steller, Martin Van Kranendonk, Eizo Nakamura

Boron is associated with several Archean stromatolite deposits, including the tourmaline-rich Barberton stromatolites in South Africa and tourmaline-bearing pyritic laminae associated with stromatolites of the 3.48 Ga Dresser Formation in the Pilbara Craton, Australia. Boron is also a critical element in prebiotic organic chemistry, including in the formation of Ribose, a crucial component in RNA. As geological evidence and advances in prebiotic chemistry are now suggesting that hot spring activity may be associated with the origins of life, an understanding of boron and its mobility and isotopic fractionation in geothermal settings may provide important insights into the setting for the origin of life.
During this presentation I will report on the boron isotopic compositions and elemental concentrations in a range of fluid, sediment, and mineral samples from the active, boron-rich Puga geothermal system in the Himalayas, India. This includes one of the lowest boron isotope values ever recorded in modern settings; diatom-rich sediments ($\delta 11B = -41.0$ ‰) in a multi-phase fractionation system where evaporation is not the dominant form of isotope fractionation. I will explain how these findings expand the known limits and drivers of boron isotope fractionation, as well as provide insight into the concentration and fractionation of boron in Archean hot spring environments. I will also present on the importance of boron in general in the study of astrobiology.

Microbial Population and Distribution at a Mars Analog Alluvial Plain Dyngjusandur, Iceland 2016

Scot Sutton - The Georgia Institute of Technology

S.M. Sutton, A.M. Stockton, M. L. Cable, T.P. Cantrell, Z.A. Duca, G.K. Tan, D. Cullen, W. Geppert

Earth analogs of extraterrestrial environments can provide insight into the potential habitability of the locations while also providing information about the terrestrial biota at terrestrial extremes. The limited nutrient availability, extreme temperatures, and desiccation of Arctic volcanic regions provide a unique opportunity to study environments with multiple similarities to extraterrestrial systems. In July 2016, FELDSPAR conducted a field campaign to Dyngjusandur, Iceland, an alluvial plain of nutrient-poor volcanic basaltic tephra with spectroscopic similarities to analogous geological features observed on Mars. Sampling collection was conducted as in prior campaigns in 2013 and 2015 (Amador et al., 2015, Gentry et al., 2017). Nested triangular grids of samples beginning at the 10 cm scale and increasing to the 1 km scale were sampled in this study. A portable near-IR reflectance spectrometer provided in situ mineralogical analysis of samples at time of collection. After return to the Georgia Institute of Technology, biological analyses included bacterial and archaeal DNA quantification by qPCR and analysis by 16S rRNA sequencing. Geophysical assays included grain size and moisture content measurements. Initial results indicate total DNA concentrations ranging from 15-80 ng/g, and bacterial DNA concentrations of 50-12000 16S rRNA copies/g. The multiple measurements were related by exploratory factor analysis methods in R studio. There appear to be variations in DNA concentration at different spatial scales that may be correlated with vis/NIR reflectance parameters or other geophysical parameters. Continued analysis of the Dyngjusandur samples will inform our sampling on future expeditions, acting as a starting point for temporal analysis.

Extreme Phototrophs and Where to Find Them: Reviewing Earth Organisms and Analogs for Astrobiology

Jennifer Thweatt - Pennsylvania State University

Phototrophs, organisms that get energy from light, are a key component of Earth's biosphere. Phototrophs have existed on earth for most of the history of life and are represented in all three domains of life. Studying the extreme limits of phototrophy on Earth can give us insights into where phototrophs may be found elsewhere in the universe.

One of the most important determinants of where a particular phototrophic organism will grow is the light available for phototrophy. Phototrophs on earth are able to use light for energy over a wide range of wavelengths with the current extremes between 350nm and 1050nm (Ritchie et al., 2018). Additionally, photoautotrophic organisms in the Black Sea have been found growing at light levels of 0.002 umol photons m-2 s-1, approximately 0.0001% of the solar irradiance at Earth's surface (Manske et al, 2005). Phototrophs are also represented in the traditional categories of extremophiles. Thermophilic phototrophs are found in hot spring environments with phototrophic bacteria living up to 73°C. Psychrophilic phototrophs have been found living in below freezing temperatures in Antarctic environments that can act as analogs for studying icy worlds. Additionally phototrophic organisms have been found living in the dry conditions of the Atacama Desert, and at high salinity in salt evaporation ponds (Madigan, 2003; Seckbach, 2007; Hamilton et al., 2012). The reasons for these limits and the types of stars and geological phenomena that could support phototrophs elsewhere in the universe will be discussed.

A Candidate Self-Propagating System Enriched by Chemical Ecosystem Selection

Lena Vincent - University of Wisconsin-Madison

Lena Vincent, H. James Cleaves, & David A. Baum

The surface metabolism theory for the origins of life posits that adaptive evolution initiated when autocatalytic chemical systems became spatially localized on mineral surfaces. We searched for such surface-limited metabolisms (SLiMes) using a chemical ecosystem selection paradigm. This involved creating a prebiotic microcosm containing mineral grains and a "soup," rich in food and potential sources of chemical energy, and then serially transferring a subset of the grains to a new microcosm containing fresh soup and new grains. This repeated dilution would enrich for chemical systems that can self-propagate more rapidly than the rate of serial dilution, and such enrichment should be detectable based on changes in microcosm chemistry over the course of multiple transfers. We deployed the chemical ecosystem selection approach on several different soups and minerals and identified a combination that appears to be conducive to the enrichment of a SLiMe. In these conditions, chemical changes were observed over the first 12-18 transfers, most notably a loss of both orthophosphate and organics (as detected by optical density) from the bulk solution. This loss correlated with the appearance of fractal structures on the surface of the grains when viewed under environmental scanning electron microscopy. The putative SLiMes show clear evidence of self-propagation ability and manifest basic ecological dynamics. Ongoing work is evaluating the systems' potential for evolvability.

Viking GCMS data restoration and digitization

Hannah Woodward - International Space University

Hannah Woodward, Melissa Guzman

The Viking landers arrived on the Martian surface in 1976, its objective to use GCMS to collect data and detect organic molecules to prove there was life on the red planet. These missions were deemed a failure and the data badly stored then forgotten about for over 40 years. Since the discovery of perchlorate by the Phoenix landers and confirmation of chlorobenzene in the Martian soil by SAM, it has implored us to revisit the Viking data and adjust the search for organic compounds, accommodating the modern findings. The Viking GCMS data exists today as 1) bar graphs on 16-mm microfilm, and 2) full and reduced versions of the data stored as binary data. The digital data (2) is undocumented and unreadable. This project explores the initial efforts to restore this data and ascertain a background by digitizing a portion of the microfilm. This was done by hand using the software ImageJ and the data compiled for analysis. The analysis is ongoing but it is predicted the presence of chlorohydrocarbons will be confirmed.

The second part of this project is an initiative to crowdsource the efforts to decode the binary data. Two video advertisements have been filmed and produced along with common social media platforms established to enable the public to assist with the decoding of the raw data files that were previously unreadable. This has given the project a new perspective and opened it up to the public to be a part of history.

Adaptive Evolution of Bacteria to High Salinity

Azarin Yazdani - University of Arkansas

Azarin Yazdani, Sudip Nepal, Vincent Chevrier, Pradeep Kumar

Although high salinity, low temperature and high pressure create extreme environments on Europa, these conditions are not unknown to terrestrial life. Bacteria have different strategies to adapt to these conditions including regulating the expressions of various genes. The current study provides a quantitative understanding of the effects of long-term exposure to high concentrations of Magnesium Sulfate, the dominant salt in Europa’s ocean, and investigates the adaptive strategies used by a model gram-negative bacterium for survival at these concentrations. We also discuss the effects of high salinity on the bacterial motility.

Laboratory Submillimeter Spectroscopic Analysis of Desorbed Interstellar and Cometary Ices

Katarina Yocum - Emory University

Katarina Yocum, Ayanna Jones, Ethan Todd, Susanna Widicus Weaver, Perry Gerakines, Stefanie Milam

A new laboratory astrochemistry technique is being developed to reveal information about the relationship between the gas and ice compositions of early star-forming regions and planetary/cometary atmospheres. It is of importance in astrobiology to better understand these environments as they provide the chemical inventory for the prebiotic soup from which life emerged on early Earth or other planetary bodies. This new technique employs submillimeter spectroscopic analysis of desorbed products from thermally processed and Lyman-α photo-processed ices. Being that submillimeter spectroscopy is the same technique used for determining gas-phase compositions of the interstellar medium and planetary/cometary atmospheres, our laboratory spectra are directly comparable to remote observations from ground- and space-based telescopes. Furthermore, submillimeter spectroscopy can distinguish branching ratios of desorbed isomers (e.g. CH_3O and CH_2OH). This is something that typical laboratory ice studies that use mass spectrometry have always struggled with. The ability to distinguish between these chemical branches will allow us to better constrain chemical models of the interstellar medium and predictions of the ingredients that are delivered to young planets with potential of hosting life. Experimental design and results from desorbed H_2O, D_2O, and CH_3OH ices will be discussed.

Undergraduate Poster Competition Winner

Searching for Life-Like Chemical Systems under Prebiotic Conditions

Jacob Cosby - University of Wisconsin-Madison

Our current understanding of biology is that the most basic unit of life as we know is the cell, preceded by the protocell in early biological history. The leap from inorganic molecules to cells is simply impractical as there must have been a path to the first organized biological system. Rethinking the origins of life begins by redefining our perceptions for what is considered life. NASA's working definition for life is "a self-sustaining chemical system capable of Darwinian evolution". Instead of assuming that the first entity capable of those two processes was a protocell, we argue that autocatalytic systems, which are contained chemical environments capable of self-propagating, may be candidates for the first life-like systems to arise spontaneously on early Earth. We hypothesize we can enrich for autocatalytic systems capable of evolving adaptively that arise so long as they are continuously supplied fresh reactants and energy. Minerals are thought to be an important part in the formation of autocatalytic systems. They can catalyze important reactions because of their chemical composition and abundance during early earth, which provides an ideal surface for prebiotic chemistry. Minerals can also concentrate organic building blocks. Our lab has developed an experimental framework in which organic-rich soups are mixed with mineral grains to promote the appearance of autocatalytic systems. We enrich for those that are better at propagating by serial transferring "colonized" grains to new environments containing fresh food and mineral surface. Our lab has tried many different conditions so far and found that at least one combination produced evidence of autocatalysis. The conditions just mentioned included some non-prebiotic components, and so I am carrying out two different variations to see if I can detect autocatalysis under more prebiotic conditions. For instance, in contrast to our previous solutions, the current experiment incorporates less molecules that could only arise from biotic pathways. Phosphates are a major source of energy in biology and so we decided to use them as fuel in our experiments. It is still unknown how and when phosphate became such an important part of biology as there wasn't many sources of phosphate available on early Earth. But apatite, a phosphate-containing mineral, may offer a solution, so I am using it in one set of my experiments. Although apatite is not soluble in water, it is soluble in our organic and salt-rich solutions, which releases some free orthophosphate. I am also trying an experiment in which I add ATP but use a different mineral, natural pyrite, which is known to catalyze many interesting chemical reactions. I combined the organic soup with mineral grains and kept them under anaerobic conditions. Following incubation, I transfer a small subset of grains from one generation to the next containing fresh grains and organic mix. I track the amount of orthophosphate released into the bulk solution at each generation using a basic colorimetric test. I have carried out the protocol for 7 generations so far. The experiment which produced evidence of autocatalysis displayed steep decline in the amount of free orthophosphate detected. I hope to observe similar patterns in my experiments to show that a similar outcome can be achieved under more prebiotic conditions. While it is too early for me to know if this is the case, I have already observed a gradual decrease in orthophosphate concentration in the variant that contains apatite mineral. If I am able to confirm this, the next step will be to figure out specific chemistry of the autocatalytic system that is producing this pattern and eventually test whether it is evolvable while still incorporating the framework we have developed thus far.