
Rensselaer Polytechnic
Institute School of Science

July 27 - 31, 2014

Troy, NY

Sponsored By

NASA Astrobiology Institute
Rensselaer Polytechnic Institute School of Science

NASA ASTROBIOLOGY INSTITUTE

Rensselaer

# *Welcome to the 2014 Astrobiology Graduate Conference*

*On behalf of the entire Organizing Committee, we would like to extend a heartfelt welcome to all participants in the 2014 Astrobiology Graduate Conference. AbGradCon is a unique and exciting opportunity - a meeting organized by and for early-career researchers in all fields of Astrobiology. This year's conference features contributions from more than 70 participants in an incredible diversity of fields: Astronomy, Chemistry, Biology, Biochemistry, Geology, Planetary Science, Education, Mathematics, Information Theory, and Engineering.*

*AbGradCon is a chance for us to come together to share our research, collaborate, and network, without the pressure of senior researchers. AbGradCon 2014 marks the tenth year of this conference–each time in a different place and organized by a different group of students, but always with the original charter as a guide. These meetings have been wildly successful both when connected to Astrobiology Science Conference (AbSciCon), and as stand-alone conferences. Since it is organized and attended by only early-career researchers, AbGradCon is an ideal venue for the next generation of career astrobiologists to form bonds, share ideas, and discuss the issues that will shape the future of the field.*

*We hope that this, the 10$^{th}$ incarnation of AbGradCon, will prove as fruitful an experience for all our participants as it has for us in the past. Serving on the Organizing Committee has been a challenging, but extremely rewarding experience. We hope your experiences here this year will motivate many of you to return in future years, both as participants, and as members of the Organizing Committee. As with any endeavor which relies on a new group of leaders with each iteration, there are bound to be bumps in the road. Please do not hesitate to reach out to any member of the Organizing Committee should you have any questions – we are committed to making this conference a resounding success!*

Bradley Burcar
Chair, Local Organizing Committee

Brett A. McGuire
Chair, Scientific Organizing Committee

## Local Organizing Committee

Daniel Angerhausen
Bradley Burcar, Chair
Kristin Coari
Emily Hardegree-Ullman

## Scientific Organizing Committee

Brett A. McGuire, Chair
Chester (Sonny) Harman
Lucy Stewart

## RFG Organizing Committee

Bradley Burcar
Chester (Sonny) Harman
Brande Jones, Chair

## Financial Committee

Bradley Burcar
Kristin Coari, Chair

## Outreach Committee

Daniel Angerhausen
Kristin Coari
Emily Hardegree-Ullman
Brande Jones
Samantha Waters
Mehmet Yesiltas

## International Advisory Committee

Daniel Angerhausen
Katja Nagler
Lena Noack
Marina Raguse

# 2014 Astrobiology Graduate Conference Sponsors

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SAGANet

Presentations will be live-streamed via SAGANLive

Social Action for a Grassroots Astrobiology Network

# Local Contacts

### Local Organizer Contacts

Bradley Burcar: 213-605-5700
Kristin Coari: 847-924-4226
Daniel Angerhausen: 424-278-3873
Emily Hardegree-Ullman: 518-961-0933

### Local Taxi Services

Black & White Cab System: 518-272-6961
Northway Taxi: 518-925-6099
Capitaland Taxi: 518-203-1234

### RPI Contacts

<u>Residence Hall</u>

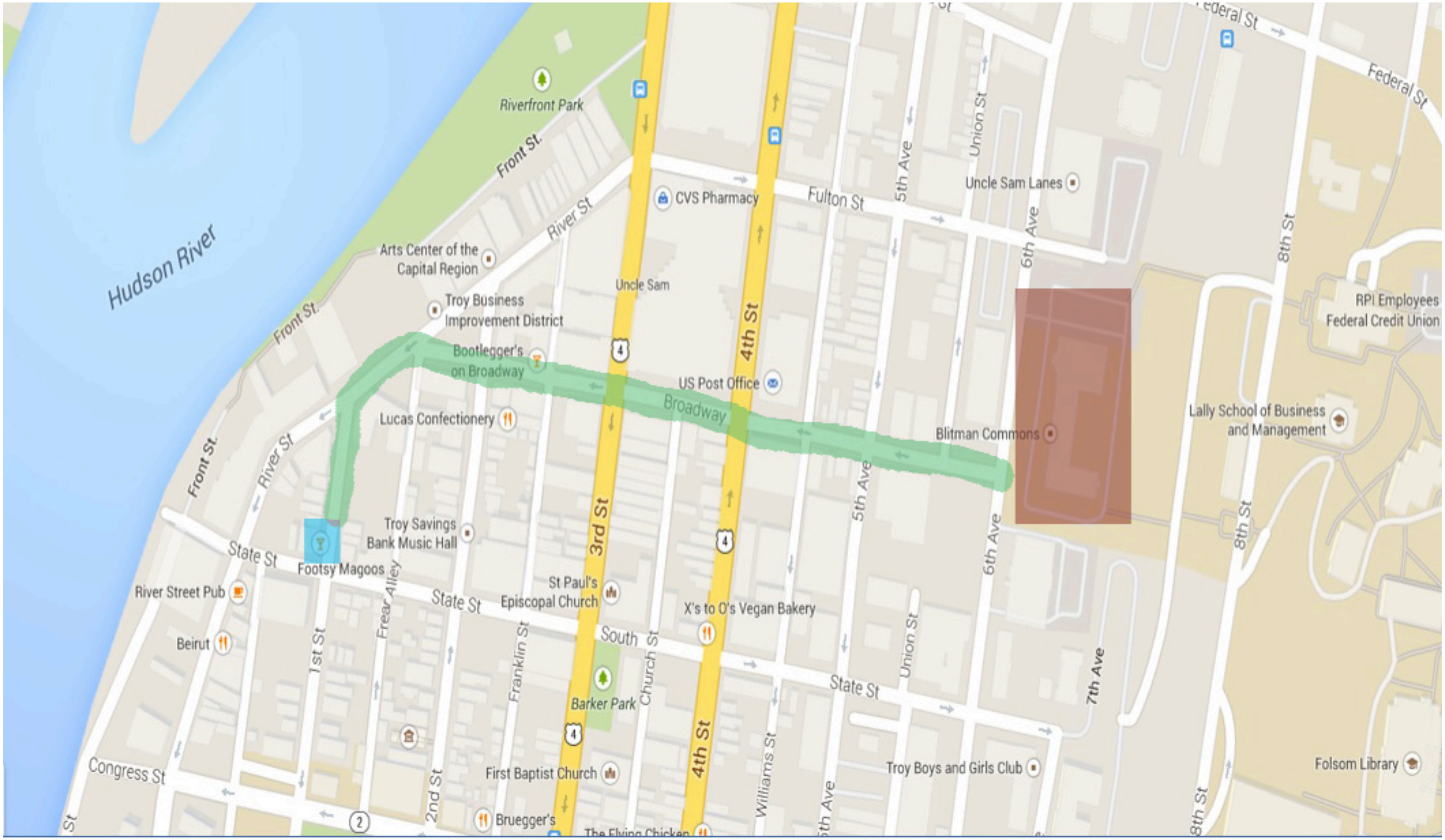
Blitman Commons
1800 6th Ave.
Troy, NY 12180
518-276-6000

<u>Public Safety</u>

Emergency (on-campus): 518-276-6611
Non-Emergency (on-campus): 518-276-6656
RPI Safety Escort (on-campus): 518-276-6656

### Troy Police, Fire, and Ambulance

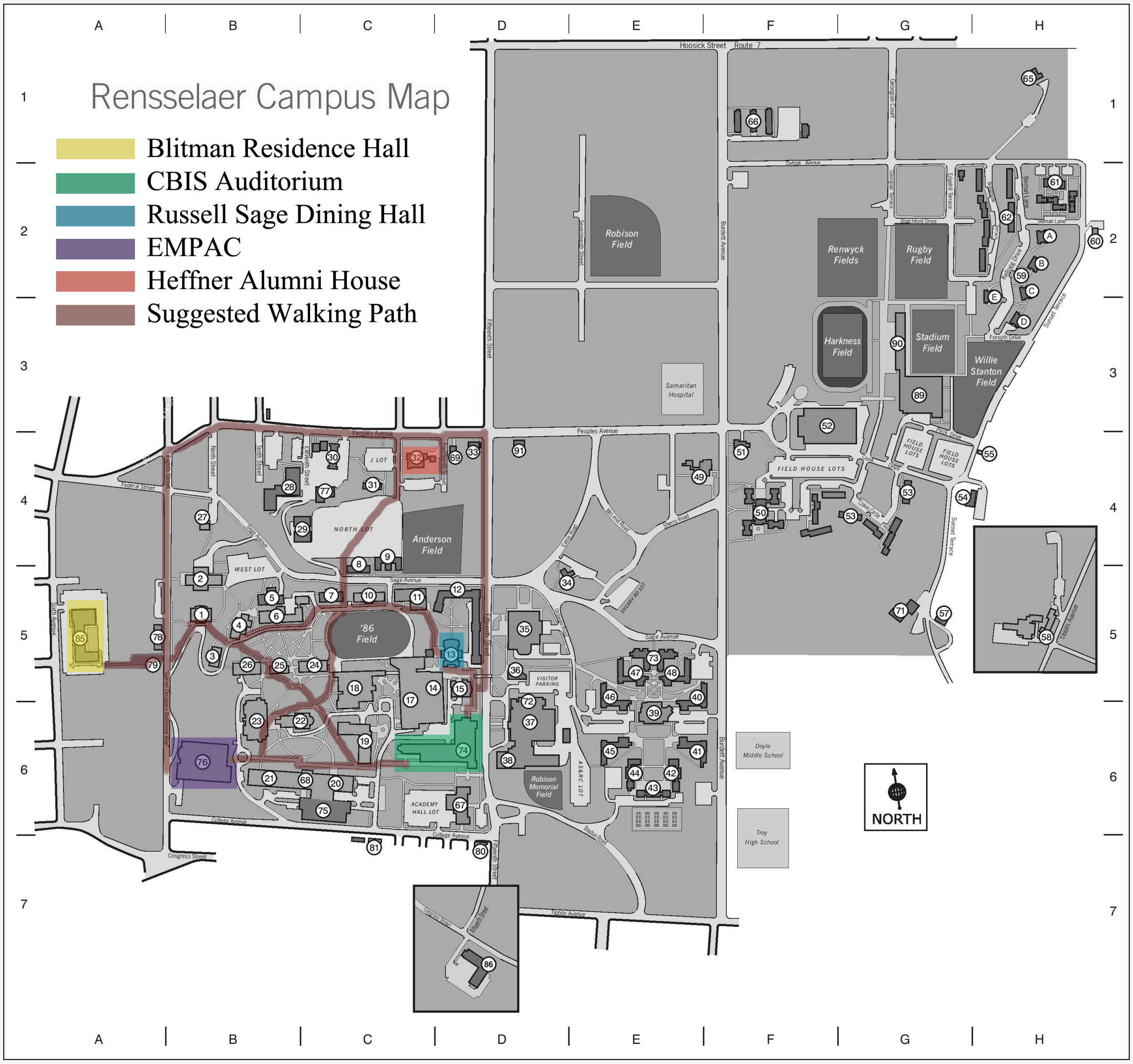
Emergency (off-campus): 911
Non-emergency (off-campus): 518-270-4421




Blitman Commons Residence Hall
Footsy Magoos
Suggested Walking Route

Blitman Commons Residence Hall:
1800 6th Ave, Troy, NY 12180

Footsy Magoos:
17 1st St # 1, Troy, NY 12180




| # | Building Name | Map Location |
|---|---|---|
| 67 | Academy Hall (Financial Aid, Student Life Services Center, Health Center) | 6D |
| 34 | Admissions | 5E |
| 32 | Alumni House (Heffner) | 4C |
| 37 | Alumni Sports & Recreation Center | 6D |
| 26 | Amos Eaton Hall | 5B |
| 73 | Barton Hall | 5E |
| 69 | Beman Park Firehouse | 4D |
| 29 | Blaw-Knox 1 & 2 | 4C |
| 85 | Blitman Residence Commons | 5A |
| 5 | Boiler House, Sage Avenue | 5B |
| 77 | Boiler House, 11th Street | 4C |
| 48 | Bray Hall | 5E |
| 61 | Bryckwyck | 2H |
| 51 | 2144 Burdett Avenue | 4F |
| 50 | Burdett Avenue Residence Hall | 4F |
| 3 | Carnegie Building | 5B |
| 47 | Cary Hall | 5E |
| 74 | Center for Biotechnology and Interdisciplinary Studies (CBIS) | 6D |
| 14 | Center for Industrial Innovation, Low (CII) | 5D |
| 49 | Chapel and Cultural Center | 4E |
| 20 | Cogswell Laboratory | 6C |
| 66 | Colonie Apartments | 1F |
| 39 | Commons Dining Hall | 6E |
| 40 | Crockett Hall | 5E |
| 17 | Darrin Communications Center (DCC) | 6C |
| 42 | Davison Hall | 6E |
| 9 | E Complex | 5C |
| 89 | East Campus Athletic Village Arena (ECAV) | 3G |
| 90 | East Campus Athletic Village Stadium | 3G |
| 68 | Empire State Hall | 6C |
| 18 | Engineering Center, J. Erik Jonsson | 5C |
| 76 | Experimental Media & Performing Arts Center (EMPAC) | 6B |
| 52 | Field House, Houston | 3F |
| 23 | Folsom Library | 6B |
| 91 | Graduate Education, 1516 Peoples Avenue | 4D |
| 24 | Greene Building | 5C |
| 57 | Greenhouses and Grounds Barn | 5G |
| 11 | '87 Gymnasium | 5C |
| 31 | H Building | 4C |
| 46 | Hall Hall | 6E |
| 30 | J Building | 4C |
| 80 | Java++ Cafe, 1527 Fifteenth Street | 7D |
| 25 | Lally Hall | 5B |
| 58 | LINAC Facility (Gaerttner Laboratory) | 5H |
| 79 | Louis Rubin Memorial Approach | 5A |
| 21 | Materials Research Center (MRC) | 6B |
| 72 | Mueller Center | 6D |
| 41 | Nason Hall | 6E |
| 27 | 41 Ninth Street | 4B |
| 8 | North Hall | 5C |
| 44 | Nugent Hall | 6E |
| 75 | Parking Garage (Faculty/Staff) | 6C |
| 65 | Patroon Manor | 1H |
| 33 | 2021 Peoples Avenue | 4D |
| 1 | Pittsburgh Building | 5B |
| 15 | Playhouse | 5D |
| 86 | Polytechnic Residence Commons | 7D |
| 36 | Public Safety | 5D |
| 12 | Quadrangle Complex | 5D |
| 60 | Radio Club W2SZ | 2H |
| 53 | Rensselaer Apartment Housing Project RAHP A Site (Single Students) | 4G |
| 62 | Rensselaer Apartment Housing Project RAHP B Site (Married Students) | 2H |
| 35 | Rensselaer Union | 5D |
| 10 | Ricketts Building | 5C |
| 38 | Robison Swimming Pool | 6D |
| 81 | RPI Ambulance | 7C |
| 13 | Russell Sage Dining Hall | 5D |
| 6 | Russell Sage Laboratory | 5B |
| 19 | Science Center, Jonsson-Rowland (Hirsch Observatory) | 6C |
| 55 | Seismograph Laboratory | 4H |
| 28 | Service Building | 4B |
| 43 | Sharp Hall | 6E |
| 59 | Stacwyck Apartments | 2H |
| 59A | Rousseau Apartments | 2H |
| 59B | Williams Apartments | 2H |
| 59C | Wiltsie Apartments | 2H |
| 59D | McGiffert Apartments | 2H |
| 59E | Thompson Apartments | 2H |
| 71 | 133 Sunset Terrace | 5G |
| 54 | 200 Sunset Terrace | 4H |
| 7 | Troy Building | 5C |
| 22 | Voorhees Computing Center (VCC) | 6C |
| 4 | Walker Laboratory | 5B |
| 45 | Warren Hall | 6E |
| 2 | West Hall | 5B |
| 78 | Winslow Building | 5A |

| | Sunday | Monday | Tuesday Fame Lab | Tuesday Non-Fame Lab | Wednesday | Thursday | |
|---|---|---|---|---|---|---|---|
| 8:00 AM | | Breakfast | Breakfast | Breakfast | Breakfast | Breakfast | 8:00 AM |
| 8:15 AM | | | | | | | 8:15 AM |
| 8:30 AM | | | | | | | 8:30 AM |
| 8:45 AM | | | | | | | 8:45 AM |
| 9:00 AM | | Warm Up Talk | Morning Competition | Transportation to Howe Caverns | Warm Up Talk | Shuttles to Airport | 9:00 AM |
| 9:15 AM | | MA. Astrochemistry | | | WA. Evolutionary Biology | | 9:15 AM |
| 9:30 AM | | | | | | | 9:30 AM |
| 9:45 AM | | | | | | | 9:45 AM |
| 10:00 AM | | | | Field Trip to Howe Caverns | | | 10:00 AM |
| 10:15 AM | | | | | | | 10:15 AM |
| 10:30 AM | | | | | | | 10:30 AM |
| 10:45 AM | | Coffee Break | | | Coffee Break | | 10:45 AM |
| 11:00 AM | | MB. Solar System Bodies | | | Astrobiology Education and Social Networking | | 11:00 AM |
| 11:15 AM | | | | | | | 11:15 AM |
| 11:30 AM | | | | | | | 11:30 AM |
| 11:45 AM | | | | | WB. Large Biomolecules | | 11:45 AM |
| 12:00 PM | Shuttles from Airport | Lunch | Group Lunch | | | | 12:00 PM |
| 12:15 PM | | | | | | | 12:15 PM |
| 12:30 PM | | | | | Lunch | | 12:30 PM |
| 12:45 PM | | | | | | | 12:45 PM |
| 1:00 PM | | Warm Up Talk | Communications Workshop | | | | 1:00 PM |
| 1:15 PM | | MC. Planetary Atmospheres | | | | | 1:15 PM |
| 1:30 PM | | | | | Warm Up Talk | | 1:30 PM |
| 1:45 PM | | | | | | | 1:45 PM |
| 2:00 PM | | | | | WC. Early Earth Geobiology | | 2:00 PM |
| 2:15 PM | | Astrobio Journal Clubs | | | | | 2:15 PM |
| 2:30 PM | | Coffee Break | | | | | 2:30 PM |
| 2:45 PM | | Warm Up Talk | | | | | 2:45 PM |
| 3:00 PM | | MD. Life in Extreme Environments | | | | | 3:00 PM |
| 3:15 PM | | | | | Coffee Break | | 3:15 PM |
| 3:30 PM | | | | | WD. Isotopic Studies | | 3:30 PM |
| 3:45 PM | | | | | | | 3:45 PM |
| 4:00 PM | | | | | | | 4:00 PM |
| 4:15 PM | | Poster Setup | | | | | 4:15 PM |
| 4:30 PM | | | Pizza Party and Collaboration Time | | | | 4:30 PM |
| 4:45 PM | | Poster Session and Burrito Bar | | | Afternoon Tea | | 4:45 PM |
| 5:00 PM | | | | | Astrobiology and Science in Society Panel | | 5:00 PM |
| 5:15 PM | | | | | | | 5:15 PM |
| 5:30 PM | | | | | | | 5:30 PM |
| 5:45 PM | | | | | | | 5:45 PM |
| 6:00 PM | Welcome Barbecue | | | | | | 6:00 PM |
| 6:15 PM | | Poster Takedown | | | | | 6:15 PM |
| 6:30 PM | | | | | | | 6:30 PM |
| 6:45 PM | | | | | | | 6:45 PM |
| 7:00 PM | | Pub Night and Board Games | Evening Competition and Finals | | | | 7:00 PM |
| 7:15 PM | | | | | | | 7:15 PM |
| 7:30 PM | | | | | Conference Banquet | | 7:30 PM |
| 7:45 PM | | | | | | | 7:45 PM |
| 8:00 PM | | | | | | | 8:00 PM |
| 8:15 PM | | | | | | | 8:15 PM |
| 8:30 PM | | | | | | | 8:30 PM |
| 8:45 PM | | | | | | | 8:45 PM |
| 9:00 PM | | | Reception | | | | 9:00 PM |

# DETAILED CONFERENCE SCHEDULE

*All Talks Held in Center for Biotechnology and Interdisciplinary Studies (CBIS) Auditorium*

## SUNDAY, JULY 27

| | |
|---|---|
| *All Day:* | Arrivals |
| *6:00 – 9:00:* | Welcome Barbecue (Russell Sage Dining Hall) |

## MONDAY, JULY 28

### 8:00 – 8:45: Breakfast (Blitman Residence Hall)

| | |
|---|---|
| *9:00 – 9:30:* | Warm-up Talk |
| *9:30 – 10:30:* | MA. Astrochemistry |
| *10:30 – 10:45* | RFG Winners Proposal Presentation |
| *10:45 – 11:00* | Coffee Break |
| *11:00 – 12:00:* | MB. Solar System Bodies |

### 12:00 – 1:00: Lunch (Russel Sage Dining Hall)

| | |
|---|---|
| *1:00 – 1:15:* | Warm-up Talk |
| *1:15 – 2:15:* | MC. Planetary Atmospheres |
| *2:15 – 2:30:* | Journal Clubs in Astrobiology / 2015 AbGradCon Info Session |
| *2:30 – 2:45:* | Coffee Break |
| *2:45 – 3:00:* | Warm-up Talk |
| *3:00 – 4:15:* | MD. Life in Extreme Environments |
| *4:15 – 4:45:* | Poster Setup |

### 4:45 – 6:15: Dinner (Russel Sage Dining Hall)

| | |
|---|---|
| *4:45 – 6:15:* | ME. Poster Session |
| *6:15 – 6:30:* | Poster Takedown |
| *7:00 – 11:00:* | Astrobio Pub Trivia (Footsy Magoo's) |
| *7:00 – 11:00:* | Board Game Night (Blitman Commons Conference Room) |

## TUESDAY, JULY 29 - FAME LAB

### 8:00 – 9:00: Breakfast (CBIS Auditorium)

*9:00 – 12:00:* Morning Competition
*CBIS Auditorium*

### 12:00 – 1:00: Group Lunch (CBIS Auditorium)

*1:00 – 4:00:* Communications Workshop
*CBIS Bruggerman Conference Center*

### 4:30 - 6:30: Pizza Party and Collaboration Time (Heffner Alumni House)

*7:00 – 9:00:* Evening Competition and Finals
*Experimental Media and Performing Arts Center*

*9:00 – 10:30:* FameLab Reception

## TUESDAY, JULY 29 - FIELD TRIP

### 8:00 – 9:00: Breakfast (Blitman Residence Hall)

*9:00 – 4:00:* Field Trip to Howe Caverns (Includes Lunch)

### 4:30 - 6:30: Dinner and Collaboration Time (Heffner Alumni House)

*7:00 – 9:00:* Evening Competition and Finals
*Experimental Media and Performing Arts Center*

*9:00 – 10:30:* FameLab Reception

## WEDNESDAY, JULY 30

### 8:00 – 8:45: Breakfast (Blitman Residence Hall)

| | | |
|---|---|---|
| *9:00* | – *9:30:* | Warm-up Talk |
| *9:30* | – *10:45:* | WA. Evolutionary Biology |
| *10:45* | – *11:00:* | Coffee Break |
| *11:00* | – *11:45:* | Astrobiology Education and Social Networking |
| *11:45* | – *12:30:* | WB. Large Biomolecules |

### 12:30 – 1:30: Lunch (Russell Sage Dining Hall)

| | | |
|---|---|---|
| *1:30* | – *2:00:* | Warm-up Talk |
| *2:00* | – *3:15:* | WC. Early Earth Geobiology |
| *3:15* | – *3:30:* | Coffee Break |
| *3:30* | – *4:45:* | WD. Isotopic Studies |
| *4:45* | – *5:00:* | Afternoon Tea |
| *5:00* | – *6:30:* | Astrobiology and Science in Society Panel |

### 7:30 - 9:00: Conference Banquet (Russell Sage Dining Hall)

## THURSDAY, JULY 31

| | | |
|---|---|---|
| *All Day:* | | Departures |
| *8:00* | – *9:00:* | Breakfast (Blitman Residence Hall) |

# SPECIAL PROGRAMMING

Monday:

*Pub Night:* Join us for a night of fun with your old and new friends from AbGradCon! This event, taking place at Troys historic Footsy Magoos, will include astrobiology-themed trivia hosted by Alex Lockwood along with a Foosball and Skee Ball tournament. The Pub Night is open to the public and is an excellent opportunity to share your love of all things science and astrobiology with the local community!

*Board Gaming After Dark:* Can you not go for five days without playing a game? Still want to hang out with your new and old friends, but the pub scene is not your thing? Well, the shadow biosphere of previous AbGradCons has been released as an official event! Come join us for an evening of board and card games – some of which are even astrobiology themed! Play as bacteria evolving in the primordial soup of the Archaean or ferret out the dastardly government agents undermining your science expedition to Mars! No experience required and all skill levels are welcome.

Tuesday:

*Pizza Party and Collaboration Time:* What better way to take a break after a day of science communication or exploring Howe Caverns than to have a pizza party and talk science? This is a great opportunity to seek out fellow conference attendees whose work youve found awesome, and try to get a project going with them. Many collaborations have formed between participants from previous AbGradCons, so add your next great experiment to the list! This is also a great time to form multi-institutional astrobiology journal clubs or discuss who will be hosting AbGradCon next year. Space will be available for all of your discussion needs.

Wednesday:

*Astrobiology Education and Social Networking:* Listen to Sarah Rugheimer, a fellow early career astrobiologist, talk about her experiences teaching astrobiology at multiple universities and institutions. This is a great opportunity to find out more about getting involved with teaching astrobiology at your local institution, as well as finding out how to make your teaching experiences as successful as possible! Also, please join Sanjoy Som as he discusses the social networking site SAGANet (Social Action for a Grassroots Astrobiology Network). This is a great resource for early career astrobiologists to stay connected with each other and the latest events in astrobiology!

*Astrobiology and Science in Society Panel:* Come and hear our invited guests talk about their diverse roles in promoting astrobiology and science to the public at large. Our panel of scientists consists of Kevin Grazier – a Hollywood science adviser for science fiction shows and movies, Daniella Salice – the NAIs EP/O lead, Alex Lockwood – an early career astrobiologist focusing in EP/O and the creator of the PhDetours webseries, as well as some surprise special guests from research and academia! Hear about their varied paths to science outreach and ask them questions about how to promote science and astrobiology to society, or get career advice to follow in their footsteps.

# Invited Guests

**Professor Bruce Watson** received his PhD from MIT in 1976, and for most of the subsequent 38 years he has been teaching and doing research at Rensselaer Polytechnic Institute (RPI), where he holds the title Institute Professor of Science (plus faculty appointments in the departments of Earth & Environmental Sciences and Materials Science & Engineering). Watson and his research team develop and apply high pressure-temperature experimental techniques to explore the inner workings and chemical processes of the Earth and terrestrial planets. A primary interest area for the past 10 years concerns the environmental conditions on earliest Earth and how these might bear on the origin of life. Among numerous honors and awards, Watson is a member of the National Academy of Sciences.

Since 2000, **Daniella Scalice** has been the Education, Outreach, and Communication Lead for the NASA Astrobiology Institute at NASA Ames Research Center. As such she manages NAIs extensive portfolio of educational projects, oversees curriculum and website development, provides content to media and educational outlets, and delivers workshops to educators and students all over the world. In 2005 she developed the NASA and the Navajo Nation project, an ongoing, NASA-funded initiative wherein cultural and scientific knowledge about our origins are brought together into new classroom materials for Navajo teachers and summer field camps for Navajo students. Daniella believes these two ways of knowing the world have more in common than not, but leaves the making of connections between the two up to the learner. In 2011, Daniella began managing the FameLab initiative for the NASA Astrobiology Program  the first ever in the United States! Akin to American Idol... but for scientists... FameLab builds communication skills for early career scientists within the unique construct of an international competition. Daniella holds a BS in Molecular Biology from UC Santa Cruz, and pursued an MA in Film at Humboldt State University. She currently lives in both Santa Cruz, CA and Annapolis, MD, but her heart is in the Southwest  specifically New Mexico where she and her husband just bought a small farm.

**Professor Linda B. McGown** began her faculty career as a pre-doctoral lecturer at Texas A&M University from 1978-79, and then as an assistant professor of chemistry at California State University, Long Beach from 1979-82. She then joined the Department of Chemistry at Oklahoma State University and was promoted to associate professor with tenure in 1985. She left O.S.U. in 1987 to join the faculty at Duke University where she remained until coming to Rensselaer as professor and department head from 2004-2009. In 2006, she was appointed to the William Weightman Walker Chair in Chemistry and Chemical Biology.

A frequent public speaker, McGown has offered dozens of presentations at universities and conferences throughout the United States, Canada, Latin America and Europe. She has authored or co-authored over 100 refereed journal publications and more than 200 conference presentations. A Fellow of the American Association for the Advancement of Science (AAAS) since 2001, McGown received the Gold Medal Award from the New York Section of the Society for Applied Spectroscopy in 1994. She has served on numerous panels and committees including the National Institutes of Health Bioanalytical Engineering and Chemistry Study Section and the Analytical and Physical Chemistry Grant Selection Committee of the Natural Sciences and Engineering Research Council of Canada. She served as program co-chair for the 1996 Federation of Analytical, Spectroscopy Societies (FACSS) Meeting in Austin and is a member of the Scientific Committee of the Frederick Conference on Capillary Electrophoresis/Proteomics. She has served on the editorial boards of several journals including *Chemical and Engineering News, Analytical Chemistry, and Applied Spectroscopy.*


**Dr. Alex Lockwood** got her B.S. in Physics and Astronomy from the University of Maryland, her Master's and PhD from Caltech in Planetary Sciences. Her thesis focused on planet formation studied using near-Infrared spectroscopy. Outside of her scholarly activities, she participated in many outreach activities, including leading hands-on workshops, teaching at the elementary- and high-school levels, and creating, hosting, and producing a webseries called PhDetours. Alex is moving to the King Abdullah University of Science and Technology in the fall to work with the President as a Postdoc in Science Outreach.

**Dr. Shawn Domagal Goldman** is a Research Scientist at NASAs Goddard Space Flight Center. His research focuses on ascertaining as much as possible about "alien planets" using sparse data sets. For the early Earth and other terrestrial planets, he works on utilizing isotopic trends as proxies for atmospheric processes and elemental cycling. This includes work on the fundamental controls on Fe isotope fractionation and on global controls on mass-independent Sulfur isotope fractionation (S-MIF). For extrasolar planets, he helps develop (and sometimes critique) spectroscopy-based characterization techniques that can inform us about a planet's surface climate, habitability, and ecosystems.

He's also extremely passionate about science communication, and believe it is our responsibility as publicly-funded scientists to bring the results of our research back to the public. To this end, he has helped organize FameLab events in the US and is always looking for new opportunities to talk about NASA science in public forums.

# MA. ASTROCHEMISTRY

## MONDAY, JULY 28, 2014 – 9:00 A.M.

**Chair: BRETT A. McGUIRE, California Institute of Technology**

**MA00** **9:00**

WARM-UP TALK

BRETT A. McGUIRE, *Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA 91125.*

**MA01** **9:30**

WATER, FORMALDEHYDE, AND FORMIC ACID VAPORS IN SPITZER-IRS SPECTRA OF PROTOPLANETARY DISKS

B. SARGENT, W. FORREST, DAN M. WATSON, N. CALVET, E. FURLAN, K.-H. KIM, J. GREEN, K. PONTOPPIDAN, I. RICHTER, and C. TAYRIEN, *Rochester Institute of Technology.*

**MA02** **9:45**

UNDERSTANDING COMPLEX ORGANIC MOLECULES THROUGH THz SPECTROSCOPY: A SEARCH FOR GLYCINE

MARCO A. ALLODI, *Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA 91125*; SERGIO IOPPOLO, *Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125*; BRETT A. McGUIRE, *Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA 91125*; GEOFFREY A. BLAKE, *Divisions of Chemistry and Chemical Engineering and of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.*

**MA03** **10:00**

TIME-DOMAIN TERAHERTZ SPECTROSCOPY OF POLYCYCLIC AROMATIC HYDROCARBONS

P. BRANDON CARROLL, MARCO A. ALLODI, *Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA 91125*; and GEOFFREY A. BLAKE, *Divisions of Chemistry and Chemical Engineering and of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125*.

**MA04** **10:15**

EFFECTS OF A GRAIN SIZE DISTRIBUTION ON SIMULATIONS OF INTERSTELLAR GAS-GRAIN CHEMISTRY

TYLER PAULY and ROBIN T. GARROD, *Cornell University*.

# MB. SOLAR SYSTEM BODIES

## MONDAY, JULY 28, 2014 – 11:00 A.M.

**Chair: BRETT A. McGUIRE, California Institute of Technology**

**MB01** **11:00**

EXPERIMENTAL EVIDENCE FOR THE FORMATION OF LIQUID BRINES ON MARS

ERIK FISCHER, GERMAN M. MARTINEZ, HARVEY M. ELLIOTT, and NILTON O. RENNO, *University of Michigan.*

**MB02** **11:15**

DEEP ICE FORMATION IN CONVECTING ICE OCEAN SYSTEMS: IMPLICATIONS FOR MATERIAL TRANSPORT IN EUROPA

DIVYA ALLU PEDDINTI and ALLEN MCNAMARA, *Arizona State University.*

**MB03** **11:30**

THE ENERGY IMPLICATIONS OF FRAGMENTATION PROCESSES IN EUROPA'S ICE SHELL

CATHERINE C. WALKER and BRITNEY E. SCHMIDT, *Georgia Institute of Technology.*

**MB04** **11:45**

PHYSISORBED LIQUID-LIKE WATER IN MARS GALE CRATER

G. M. MARTÍNEZ, E. FISCHER, H. ELLIOTT, C. BORLINA, and N. RENNÓ, *University of Michigan.*

# MC. PLANETARY ATMOSPHERES

## MONDAY, JULY 28, 2014 – 1:00 P.M.

**Chair: DANIEL ANGERHAUSEN, Rensselaer Polytechnic Institute**

**MC00** **1:00**

WARM-UP TALK

DANIEL ANGERHAUSEN, *Rensselaer Polytechnic Institute.*

**MC01** **1:15**

DISEQUILIBRIUM AND THE EFFECT OF LIFE ON PLANETARY ATMOSPHERE(S)

EUGENIO SIMONCINI, *INAF-Astrophysical Observatory of Arcetri.*

**MC02** **1:30**

OXYGEN FALSE POSITIVES IN PLANETARY ATMOSPHERES

CHESTER HARMAN, JAMES SCHOTTLEKOTTE, and JAMES KASTING, *Pennsylvania State University.*

**MC03** **1:45**

THREE-DIMENSIONAL MODELING OF TITAN'S ORGANIC HAZE WITH IMPLICATIONS FOR THE EARLY EARTH

ERIK J.L. LARSON, OWEN B. TOON, ANDREW J. FRIEDSON, and ROBERT A. WEST, *University of Colorado.*

**MC04** **2:00**

PRELIMINARY MODELING OF THE VENUSIAN ATMOSPHERE AS MICROBIAL HABITAT

THOMSON MASON FISHER, *Washington State University.*

# MD. LIFE IN EXTREME ENVIRONMENTS

## MONDAY, JULY 28, 2014 – 2:45 P.M.

**Chair: LUCY STEWART, University of Massachusetts, Amherst**

**MD00** **2:45**

WARM-UP TALK

LUCY STEWART, *University of Massachusetts, Amherst.*

**MD01** **3:00**

ANALYSES OF MUTATIONS THAT OCCURRED DURING AN EVOLUTION EXPERIMENT OF *BACILLUS SUBTILIS* AT 5 kPa

SAMANTHA MARIE WATERS and WAYNE L. NICHOLSON, *Department of Microbiology & Cell Science, University of Florida.*

**MD02** **3:15**

GROUND-PENETRATING RADAR TO SEARCH FOR WATER ON MARS AND OTHER PLANETARY BODIES

HARVEY ELLIOTT, GERMAN MARTINEZ, ERIK FISCHER, and NILTON RENNO, *University of Michigan.*

**MD03** **3:30**

EXTREMOPHILE ELEMENTAL COMPOSITION RESPONSE TO NUTRIENT SUPPLY IN A NITROGEN- AND PHOSPHORUS-LIMITED HYPERSALINE POND

MARC NEVEU, AMISHA T. PORET-PETERSON, ZARRAZ M. P. LEE, JAMES J. ELSER, and ARIEL D. ANBAR, *Arizona State University.*

**MD04** **3:45**

RESPONSES TO ENVIRONMENTAL STRESSES WITHIN THE PHYLUM ROTIFERA

BRANDE L. JONES, *Georgia Institute of Technology.*

**MD05** **4:00**

UNVEILING THE RESPONSE OF BIOLOGICAL SYSTEMS UNDER SIMULATED PLANETARY AND SPACE CONDITIONS

GABRIEL ARAUJO, FABIO RODRIGUES, and DOUGLAS GALANTE, *Brazilian Synchrotron Light Laboratory.*

**MD06** **4:15**

BIOLOGICAL EXTRACTION OF METALS AND MATERIALS USING A SYNTHETIC BIOLOGY APPROACH

JESICA URBINA-NAVARRETE and LYNN J. ROTHSCHILD, *NASA Ames Research Center.*

# ME. POSTER SESSION

## MONDAY, JULY 28, 2014 – 4:45 P.M.

**Chair: BRADLEY BURCAR, Rensselaer Polytechnic Institute**

**ME01**

MICROBIAL EPS-MEDIATED CRYSTALLIZATION OF LOW-TEMPERATURE DOLOMITE IN A HYPERSALINE LAKE: A POTENTIAL BIOSIGNATURE

MINGLU LIU and HUIFANG XU, *University of Wisconsin-Madison.*

**ME02**

TOWARDS A COMPUTATIONAL MODEL FOR METHANE PRODUCING ARCHAEUM

PIYUSH LABHSETWAR, JOSEPH PETERSON, JEREMY ELLERMEIER, PETRA R. KOHLER, ANKUR JAIN, TAEKJIP HA, WILLIAM W. METCALF, and ZAIDA LUTHEY-SCHULTEN, *University of Illinois at Urbana-Champaign.*

**ME03**

INTERSPECIES $H_2$ TRANSFER AND $H_2$ COMPETITION AMONG THERMOPHILES IN DEEP-SEA HYDROTHERMAL VENTS

BEGUM TOPCUOGLU and JAMES F. HOLDEN, *University of Massachusetts.*

**ME04**

THERMALLY INDUCED CHEMISTRY OF METEORITIC COMPLEX ORGANIC MOLECULES: A NEW THERMAL-DIFFUSION MODEL FOR THE ATMOSPHERIC ENTRY OF METEORITES

CHRISTOPHER N. SHINGLEDECKER, *University of Virginia.*

**ME05**

CLUMPED ISOTOPES IN CARBONATES AS A POTENTIAL BIOSIGNATURE

NICHOLAS LEVITT, HUIFANG XU, and CLARK JOHNSON, *University of Wisconsin - Madison.*

**ME06**

PROBING ACTIVITY AND COMPANIONSHIP OF M-DWARF STELLAR SYSTEMS THROUGH LIGHT CURVES

YUTONG SHAN, *Harvard University.*

**ME07**

INVESTIGATING THE REACTIONS BETWEEN OH AND CO USING THE MATRIX ISOLATION TECHNIQUE: IMPLICATIONS FOR PLANETARY AND INTERSTELLAR CHEMISTRY

KAMIL STELMACH, YUKIKO YARNALL, FEREDUN AZARI, and PAUL COOPER, *George Mason University.*

**ME08**

DETERMINING SIGNATURES OF MICROBIAL LIFE IN DIFFERENT ENVIRONMENTS USING MICROBIAL FUEL CELLS

BONITA LAM, AARON NOELL, and KENNETH NEALSON, *University of Southern California.*

**ME09**

WARMING EARLY MARS WITH $H_2$ AND $CO_2$

NATASHA BATALHA and JAMES KASTING, *Pennsylvania State University.*

**ME10**

DOMAIN 0: THE CENTRAL CORE OF THE ANCESTRAL RIBOSOME

KATHRYN LANIER, JESSICA BOWMAN, and LOREN WILLIAMS, *Georgia Institute of Technology.*

**ME11**

USING MICROFLUIDICS TO EXPLORE ADAPTATION AND EVOLUTION OF ESCHERICHIA COLI UNDER CONSTRAINT ENVIRONMENTAL CONDITIONS

LANG ZHOU, REINALDO ALCALDE, RODERICK MACKIE, ISAAC CANN, BRUCE FOUKE, and CHARLES WERTH, *University of Illinois at Urbana-Champaign.*

**ME12**

EVOLUTION OF THE RIBOSOME AT ATOMIC RESOLUTION

NICHOLAS A. KOVACS, *Georgia Institute of Technology.*

**ME13**

THE EFFECTS OF VISCOSITY ON NUCLEIC ACID ASSEMBLY: A POSSIBLE SOLUTION TO STRAND INHIBITION

CHRISTINE HE, *Georgia Institute of Technology - Center for Chemical Evolution.*

**ME14**

CHARACTERIZATION OF MICROBIAL Fe(III) OXIDE REDUCING COMMUNITIES IN CHOCOLATE POTS HOT SPRINGS, YELLOWSTONE NATIONAL PARK

NATHANIEL W. FORTNEY, ERIC E. RODEN and ERIC S. BOYD, *University of Wisconsin-Madison.*

**ME15**

3-DOMAIN TREE VERSUS EOCYTE TREE AND HISTONES

AMANDA DICK and J. PETER GOGARTEN, *University of Connecticut.*

**ME16**

A MICROBIAL IRON SHUTTLE IN A REDOX-STRATIFIED OCEAN 2.9 BILLION YEARS AGO

BREANA M. HASHMAN, BRADLEY M. GUY, NICOLAS J BEUKES, BRIAN L. BEARD, and CLARK M. JOHNSON, *University of Wisconsin-Madison.*

**ME17**

UNDERSTANDING STRESS-INDUCED MICROBIAL EVOLUTIONARY MECHANISMS VIA MICROFLUIDIC CELLS

REINALDO ALCALDE, LANG ZHOU, ISAAC CANN, ROD MACKIE, BRUCE FOUKE, and CHARLES WERTH, *University of Illinois at Urbana-Champaign.*

**ME18**

ECOLOGICAL RESPONSE AND ISOTOPIC VARIABILITY DURING EARLY PALEOGENE HYPERTHERMALS

ROSS H. WILLIAMS, SABINE MEHAY, SURYENDU DUTTA, and ROGER E. SUMMONS, *Massachusetts Institute of Technology.*

**ME19**

TRACE ELEMENTS IN QUARTZ OF THE JACK HILLS METACONGLOMERATE

M.R. ACKERSON, N.D. TAILBY, and E.B. WATSON, *Rensselaer Polytechnic Institute.*

**ME20**

SIMS $\delta^{18}$O MICROANALYSIS OF THE STRELLEY POOL CHERTS AT THE TRENDAL LOCALITY IN THE PILBARA CRATON OF WESTERN AUSTRALIA. INSIGHT INTO FLUID SOURCES, ALTERATION, AND PALEOENVIRONMENTAL CONDITIONS

JAKE N. CAMMACK, JOHN W. VALLEY, REINHARD KOZDON, MIKE J. SPICUZZA, and AARON J. CAVOSIE, *Rensselaer Polytechnic Institute.*

**ME21**

UNDERSTANDING HOW CHEMICAL CONSTRAINTS SHAPE EVOLUTION THROUGH COMPUTATIONAL MODELING OF CHEMICAL NETWORKS

HARRISON B. SMITH, JASON RAYMOND, and SARA WALKER, *Arizona State University.*

**ME22**

NUTRIENT AVAILABILITY IN THE ARCHEAN OCEAN

HILLARY EMICK, *Arizona State University.*

**ME23**

RECONSTRUCTION OF ANCIENT MICROBIAL BIODIVERSITY AND METABOLISM FROM FOSSIL TRAVERTINE

ABIGAIL ASANGBA, *University of Illinois at Urbana-Champaign.*

**ME24**

SELF-ASSEMBLY OF TITAN THOLINS IN ENVIRONMENTS SIMULATING TITAN'S LAKES

JUN KAWAI, *FfAME.*

**ME25**

PROBING THE ORIGINS OF CATALYSIS WITH A DEOXYRIBONUCLEIC ACID (DNA) SYSTEM

RACHEL GYSBERS, KHA TRAM, JIM GU, and YINGFU LI, *McMaster University.*

**ME26**

ELECTRIC CABLE BACTERIA AND SIGNATURES OF LIFE

ANJA BAUERMEISTER, *Department of Civil and Environmental Engineering, Rensselaer Polytechnic Institute, Troy, NY*; JEFF SCHRAMM, *Department of Biology, Rensselaer Polytechnic Institute, Troy, NY*; and YURI GORBY, *Department of Civil and Environmental Engineering and Department of Biology, Rensselaer Polytechnic Institute, Troy, NY.*

**ME27**

PREBIOTIC PHOSPHORYLATION ON THE EARLY EARTH

MAHEEN GULL and MATTHEW A. PASEK, *School of Geoscience, University of South Florida, 4202 E Fowler Ave, Tampa FL 33620.*

**ME28**

MICROMETEORITE MATERIAL COLLECTION FROM OUTER SPACE AND ASTROBIOLOGICAL CHARACTERIZATION OF MICROBIA BY THE UPR-NASA ROCKSAT-X TEAM

REBECA RIVERA et al., *University of Puerto Rico.*

**ME29**

CREATING AN UNDERGRADUATE ASTROBIOLOGY COURSE FOR NON-SCIENCE MAJOR STUDENTS

PATRICK LATHROP *Marist College.*

# WA. EVOLUTIONARY BIOLOGY

## WEDNESDAY, JULY 30, 2014 – 9:00 A.M.

**Chair: KRISTIN COARI, Rensselaer Polytechnic Institute**

**WA00** **9:00**

WARM-UP TALK

KRISTIN COARI, *Rensselaer Polytechnic Institute.*

**WA01** **9:30**

FOLDING OF ANCIENT RIBOSOMAL RNA UNDER EARLY EARTH CONDITIONS

TIMOTHY K. LENZ, NICK V. HUD, and LOREN DEAN WILLIAMS, *Georgia Institute of Technology.*

**WA02** **9:45**

VARIATION IN EVOLUTIONARY RATE MODELS IN PROKARYOTES

ANAIS BROWN and FABIA BATTISTUZZI, *Oakland University.*

**WA03** **10:00**

INFORMATION HIEARCHIES OF COUPLED LOGISTIC MAPS AS A PROXY FOR EVOLUTIONARY TRANSITIONS

RYAN BROSCH, *Arizona State University.*

**WA04** **10:15**

MATHEMATICAL MODEL OF EVOLUTION OF COMPLEXITY

F. JAFARPOUR and N. GOLDENFELD, *University of Illinois at Urbana-Champaign.*

**WA05** **10:30**

INFRARED SPECTRAL INVESTIGATIONS OF UV IRRADIATED NUCLEOBASES ADSORBED ON MINERAL SURFACES

TERESA FORNARO, *Scuola Normale Superiore of Pisa*; JOHN BRUCATO, *INAF-Astrophysical Observatory of Arcetri*; MALGORZATA BICZYSKO, *CNR-Institute of Chemistry of Organometallic Compounds*; and VINCENZO BARONE, *Scuola Normale Superiore Di Pisa*.

# WB. LARGE BIOMOLECULES AND THEIR INTERACTION WITH RADIATION AND ENERGETIC PARTICLES

## WEDNESDAY, JULY 30, 2014 – 11:45 A.M.

**Chair: KRISTIN COARI, Rensselaer Polytechnic Institute**

**WB01** **11:45**

NUCLEOBASE PHOSPHORYLATION BY A KINASE RIBOZYME

RAGHAV R. POUDYAL, PHUONG DM NGUYEN, MACKENZIE K. CALLAWAY, and DONALD H. BURKE, *University of Missouri.*

**WB02** **12:00**

CONTROLLING GENE EXPRESSION IN AN RNA WORLD BY mRNA PHOSPHORYLATION

RAGHAV R. POUDYAL, MACKENZIE K. CALLAWAY, and DONALD H. BURKE, *University of Missouri.*

**WB03** **12:15**

REACTIVE OXYGEN SPECIES ARE REQUIRED FOR ENVIRONMENTAL-STRESS INDUCED MUTATIONS

JM MOORE, PC THORNTON, SM ROSENBERG, and PJ HASTINGS, *Baylor College of Medicine.*

# WC. EARLY EARTH GEOBIOLOGY

## WEDNESDAY, JULY 30, 2014 – 1:30 P.M.

**Chair: BRADLEY BURCAR, Rensselaer Polytechnic Institute**

**WC00** **1:30**

WARM-UP TALK

TBD

**WC01** **2:00**

PHOTO-INTIATED PRODUCTION OF SELF-ASSEMBLED VESICLES: A PLAUSIBLE ORIGIN OF A PRIMITIVE ENCLOSURE

REBECCA J. RAPF, ELIZABETH C. GRIFFITH, RICHARD K. SHOEMAKER, BARRY K. CARPENTER, and VERONICA VAIDA, *The University of Colorado at Boulder*.

**WC02** **2:15**

THE GEOBIOLOGY OF HIGH-ARCTIC SULFUR SPRINGS

GRAHAM E. LAU, *The University of Colorado at Boulder*.

**WC03** **2:30**

Z-RAY VISION: PRECAMBRIAN MICROFOSSILS AND APPLICATIONS TO ASTROBIOLOGY

KIRA N. LORBER and ANDREW D. CZAJA, *University of Cincinnati*.

**WC04** **2:45**

GEOCHEMISTRY OF THE 1.4 Ga ROPER GROUP, THE EARLY OCEAN AND LIFE

KEVIN NGUYEN, AMY KELLY, GORDON LOVE, CHUNFANG CAI, MEGAN ROHRSSEN, STEVEN BATES, JEREMY OWENS, and TIMOTHY LYONS, *University of California*.

**WC05** **3:00**

ANAEROBIC METHANE OXIDATION COUPLED TO IRON REDUCTION IN AN ARCHAEAN OCEAN ANALOGUE

BENJAMIN C. REED, THOMAS J. DICHRISTINA, FRANK J. STEWART, DAVID A. FOWLE, SEAN A. CROWE, and JENNIFER B. GLASS, *Georgia Institute of Technology.*

# WD. ISOTOPIC STUDIES

## WEDNESDAY, JULY 30, 2014 – 3:30 P.M.

**Chair: BRADLEY BURCAR, Rensselaer Polytechnic Institute**

**WD01** **3:30**

METHANOGEN SURVIVAL FOLLOWING EXPOSURE TO LOW PRESSURE

R. L. MICKOL and T. A. KRAL, *University of Arkansas.*

**WD02** **3:45**

STABLE CARBON ISOTOPE FRACTIONATION BY METHANOGENS GROWING ON DIFFERENT MARS REGOLITH ANALOGUES

NAVITA SINHA and TIMOTHY A. KRAL, *University of Arkansas, Fayetteville, AR.*

**WD03** **4:00**

THE CARBON ISOTOPE RECORD AND THE RISE OF OXYGEN

JOSHUA KRISSANSEN-TOTTON and DAVID C. CATLING, *University of Washington.*

**WD04** **4:15**

STABLE ISOTOPES OF PERIGLACIAL PALEOSOLS FROM SOUTH AUSTRALIA AND IMPLICATIONS FOR THE CRYOGENIAN SNOWBALL EARTH

JEFF T. OSTERHOUT, GREGORY J. RETALLACK, and BROOKLYN N. GOSE, *University of Cincinnati.*

**WD05** **4:30**

INFLUENCE OF UV ACTIVITY ON THE SPECTRAL FINGERPRINTS OF EARTH-LIKE PLANETS AROUND M DWARFS

S. RUGHEIMER, L. KALTENEGGER, A. SEGURA, J. LINSKY, and S. MOHANTY, *Harvard University.*

# MA. ASTROCHEMISTRY

## MONDAY, JULY 28, 2014 – 9:00 A.M.

**Chair: BRETT A. McGUIRE, California Institute of Technology**

**MA00** **9:00**

WARM-UP TALK

BRETT A. McGUIRE, *Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA 91125.*

**MA01** **9:30**

WATER, FORMALDEHYDE, AND FORMIC ACID VAPORS IN SPITZER-IRS SPECTRA OF PROTOPLANETARY DISKS

B. SARGENT, W. FORREST, DAN M. WATSON, N. CALVET, E. FURLAN, K.-H. KIM, J. GREEN, K. PONTOPPIDAN, I. RICHTER, and C. TAYRIEN, *Rochester Institute of Technology.*

The materials in protoplanetary (i.e., planet-forming) disks around young stars are assembled early in the lifetime of the star. These gas disks are relatively short-lived, with a half-life of about 3 million years, as chemical reactions modify the reservoir of material from the natal molecular cloud. We present 5 – 7.5 micron wavelength Spitzer Space Telescope Infrared Spectrograph (IRS) spectra of 13 T Tauri stars in the Taurus-Auriga star-forming region showing emission from water vapor and absorption from other gases in these stars' protoplanetary disks. Seven stars' spectra show an emission feature at 6.6 microns due to the $\nu_2$ = 1–0 bending mode of water vapor, with the shape of the spectrum suggesting water vapor temperatures >500 K, though some of these spectra also show indications of an absorption band, likely from another molecule. The other six stars have spectra showing a strong absorption band, peaking in strength at 5.6 – 5.7 microns, which for some is consistent with gaseous formaldehyde ($H_2CO$) and for others is consistent with formic acid (HCOOH). There are indications that some of these six stars may also have weak water vapor emission. Modeling of these stars' spectra suggests these gases are present in the inner few AU of their host disks, consistent with recent studies of infrared spectra showing gas in protoplanetary disks. The presence of hot water vapor in the inner few AU suggests its very early presence in the eventual habitable zones of stars.

**MA02** **9:45**

UNDERSTANDING COMPLEX ORGANIC MOLECULES THROUGH THz SPECTROSCOPY: A SEARCH FOR GLYCINE

MARCO A. ALLODI, *Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA 91125*; SERGIO IOPPOLO, *Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125*; BRETT A. McGUIRE, *Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA 91125*; GEOFFREY A. BLAKE, *Divisions of Chemistry and Chemical Engineering and of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.*

Did prebiotic molecules first form in space or first form on Earth? This is a key question concerning the origins of life on Earth to which we don't have a clear answer. As such, understanding how prebiotic molecules can form in space could provide important insight into this question. Recent work has show that complex organic molecules (COMs) are more likely to form on ice-covered dust grains rather than in the gas phase in the interstellar medium (ISM). Thus, laboratory investigations of interstellar ice analogs have a great potential to provide new evidence for possible formation channels of COMs and prebiotic species.

Spectroscopy is the laboratory tool of choice for comparison with astronomical data, since detecting a molecule in space requires it to interact with light and, eventually, have that light reach a telescope. Terahertz time-domain spectroscopy is poised to be a fundamental tool to investigate ices in the laboratory given that the newest, and most powerful observational facilities for molecular astronomy (Herschel and ALMA) operate in the frequency range covered by these experiments (300 GHz – 7000 GHz or 1000 $\mu$m – 43 $\mu$m). Spectra of molecular ices at THz frequencies show the long range interactions between molecules. As such, they are particularly sensitive to the structure of the ice, which plays a key role in the chemistry. I will present our latest results showing the spectra of COMs that could participate in the pathway of glycine formation. Specifically, we will discuss the spectra of alcohols and carboxylic acids and how our work could allow for the identification of prebiotic molecules in the ISM.

**MA03** **10:00**

TIME-DOMAIN TERAHERTZ SPECTROSCOPY OF POLYCYCLIC AROMATIC HYDROCARBONS

P. BRANDON CARROLL, MARCO A. ALLODI, *Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA 91125*; GEOFFREY A. BLAKE, *Divisions of Chemistry and Chemical Engineering and of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125.*

Polycyclic aromatic hydrocarbons (PAHs) are the most abundant class of molecules in the interstellar medium (ISM) and have been the subject of intense laboratory and astronomical study in recent years. PAHs are ubiquitous in interstellar environments and are believed to play a key role in numerous astrochemical processes. In particular, PAHs are frozen into ice mantles surrounding dust grains. PAHs may then be processed by cosmic rays and UV photons to form large amphiphilic molecules that have been proposed to play a key role in the formation of early life on earth.

Once formed, these molecules can then be incorporated into meteorites and comets and delivered to planetesimals such as early earth. The discovery of PAHs in meteorites supports this hypothesis. However, evaluation of the extent to which PAHs influence these processes is hampered by our inability to detect PAHs concurrently with other chemical species using radio astronomy, due to their low dipole moments and large partition functions. A possible solution is observations in the TeraHertz (THz) regime, where observed transitions are specific to each molecule. Recent advances in THz technology have enabled both laboratory spectroscopy and astronomical observations in this region. A first step in both laboratory and astronomical studies of PAHs is the acquisition of spectra of pure PAH samples. We present the THz time-domain spectra (0.3 – 7 THz) of several PAHs, including naphthalene, anthracene, and pyrene, and discuss the utility of these spectra for future laboratory and astronomical studies.

**MA04** **10:15**

EFFECTS OF A GRAIN SIZE DISTRIBUTION ON SIMULATIONS OF INTERSTELLAR GAS-GRAIN CHEMISTRY

TYLER PAULY and ROBIN T. GARROD, *Cornell University.*

The fully coupled, three phase (gas/grain/mantle) chemical model of Garrod & Pauly (2011) is upgraded to include the effects of a grain size distribution and grain growth on the chemical evolution of the interstellar medium. We add these effects to improve our model's agreement with astronomical observations of bulk ice composition in quiescent dark clouds. The grain size distribution gives rise to change in chemical evolution through modifying both the grain temperature and the number of binding sites on a grain surface. For models of dark clouds with a mean grain temperature near 10 K and $n_H \approx 2 \times 10^4$ cm$^{-3}$, we find the distribution in number of binding sites has little effect. We find that the temperature plays a much more important role, as the formation of $CO_2$ from CO becomes highly efficient at or above a grain temperature of ≈ 12 K. The addition of grain growth due to ice accumulation causes the grain temperature distribution to evolve in time, further complicating the bulk chemical evolution. Our results show the classical single-grain approximation does not adequately reproduce the chemical complexity of a dark cloud, and incorporating a grain size distribution is an important step in improving gas-grain chemical models.

# MB. SOLAR SYSTEM BODIES

## MONDAY, JULY 28, 2014 – 11:00 A.M.

**Chair: BRETT A. McGUIRE, California Institute of Technology**

**MB01** **11:00**

EXPERIMENTAL EVIDENCE FOR THE FORMATION OF LIQUID BRINES ON MARS

ERIK FISCHER, GERMAN M. MARTINEZ, HARVEY M. ELLIOTT, and NILTON O. RENNO, *University of Michigan.*

Liquid water is one of the necessary ingredients for the development of life as we know it. The behavior of various liquid states of $H_2O$ such as liquid brine, undercooled liquid interfacial water, subsurface melt water and ground water needs to be understood [1] in order to address the potential habitability of Mars for microbes and future human exploration.

Here we present experiments conducted under polar Martian conditions in the Michigan Mars Environmental Chamber. We show that bulk liquid brines of perchlorate salts form diurnally under conditions similar to those of the Mars Phoenix mission landing site when the salts are in direct contact with water ice, but that when salts are exposed only to atmospheric water vapor, bulk deliquescence of brines does not occur [2].

We tested bulk samples of $NaClO_4$, $Mg(ClO_4)_2$ and $Ca(ClO_4)$. We used Raman spectroscopy to observe spectral changes in the perchlorate band (930 – 990 $cm^{-1}$) and the O-H vibrational stretching band (3000 – 3700 $cm^{-1}$) of the samples as the temperature was raised stepwise across the eutectic point of each salt. Those samples exposed only to the saturated Martian atmosphere did not show signs of bulk deliquescence within the time of the diurnal cycle when conditions are favorable. Those in contact with water ice showed spectral changes indicating liquid brine formation within minutes after crossing the eutectic temperature.

This indicates that liquid aqueous solutions could form temporarily during diurnal cycles where salts and ground ice co-exist in the shallow Martian subsurface [3] and on the surface when frost or snow is deposited on saline soils [4].

[1] Martinez, G. M., & Renno, N. O. (2013). Space Sci Rev, 175(1-4), 29-51.
[2] Fischer et al. (2014), Proc. Natl. Acad. Sci. U.S.A (Submitted).
[3] Renno, N. O., et al. (2009). J. Geophys. Res.: Planets, 114(E1).
[4] Martinez, G. M., et al. (2012). Icarus, 221(2), 816-830.

**MB02** **11:15**

DEEP ICE FORMATION IN CONVECTING ICE OCEAN SYSTEMS: IMPLICATIONS FOR MATERIAL TRANSPORT IN EUROPA

DIVYA ALLU PEDDINTI and ALLEN MCNAMARA, *Arizona State University.*

Planetary missions and telescopic investigations have identified a plethora of astrobiologically intriguing objects exhibiting characteristics suggestive of liquid water, chemical circulation, perhaps optimal temperature and nutrient conditions that favor life as we know it. Europa, in particular with its deformed surface and a putative ocean underneath its icy surface still presents one of the most accessible astrobiological targets. Of critical interest is whether chemistry of the subsurface liquid water ocean can be transported to the surface which can be detected by orbital missions. We hypothesize that for a convecting ice shell, the ice-ocean interface involves melting in downwelling regions and freezing in upwelling regions. The new ice formed could capture trace amounts of oceanic chemistry and hence studying the propagation of new ice in the convecting shell could reflect on the transport of oceanic chemistry towards the surface. We developed numerical models for two phase convective system in order to study the convective transport of new ice. First by use of a proxy fluid for liquid water, we establish a solid ice-proxy fluid system as an approximation of the real system. The proxy fluid employed is more viscous than liquid water yet remains orders of magnitude less viscous than solid ice and we have demonstrated that this sufficiently decouples the dynamics of the two layers. The numerical models employ tracers to track the new ice and the fractional density of the new ice is mapped throughout the shell. This tracer density represents the relative concentration of new ice in the shell as the plumes transport it upwards. Presented results indicate that new ice that forms by freezing at the phase boundary can be transported by warm plumes in the ice shell towards the surface. Study suggests that small amounts of new ice could surface provided the ice lid weakens.

**MB03** **11:30**

THE ENERGY IMPLICATIONS OF FRAGMENTATION PROCESSES IN EUROPA'S ICE SHELL

CATHERINE C. WALKER and BRITNEY E. SCHMIDT, *Georgia Institute of Technology.*

Because of the important role that the ice shell plays in Europa's evolution as a mediator between its interior and surface, a study of Europa's habitability must consider dynamics within its near-surface ice shell. Europa's surface is riddled with fractures, which betray a long history of geophysical activity. With an ∼100 km deep ocean lying atop a silicate interior, Europa is an intriguing target for astrobiological study. On the Earth, ice and the ice-water interface are repositories of life. Thus, ice cycling may provide nutrients to the Europan ocean, and pores, basal cracks, and grain boundaries in its ice may serve as harbors for life. Such ice shell-ocean communication must occur geologically short timescales in order for Europa to be habitable. One way in which this can occur is through disruption of the ice shell. Thus active geological areas have strong implications for the recycling of the ice shell, and the habitability of the ice shell itself. Recent work suggests that chaos terrain formation may include a collapse phase, and that the eventual appearance of the chaos terrain is determined in part by the fracture density within the background terrain (Schmidt et al., 2011). Here, we will present an estimate of the energy released in chaos terrain collapse through application of fragmentation theory and iceberg capsize analysis. This approach allows us to understand the mechanism behind dynamic collapse of the ice shell as well as its potential for mixing material in the upper ∼5km of the ice shell downward, providing input to a recycling ice shell. Thus, in determining the fragment size distribution, and thus the dynamic history of that ice, we will constrain physical properties of the ice shell and their implications for Europa's habitability.

**MB04** **11:45**

PHYSISORBED LIQUID-LIKE WATER IN MARS GALE CRATER

G. M. MARTÍNEZ, E. FISCHER, H. ELLIOTT, C. BORLINA, and N. RENNÓ, *University of Michigan.*

Physisorbed water can exist and evolve in a liquid-like state via adsorption on mineral surfaces at the ground surface and in the shallow subsurface of Mars [1]. This water is physically bound to mineral surfaces without involving chemical reactions on the surface of the mineral. This form of liquid water is relevant to habitability because microorganisms could survive by utilizing adsorbed water [2]. Van der Waals forces between mineral surfaces and water ice molecules cause a freezing point depression that allows physisorbed water to be liquid-like at temperatures well below the freezing point [3].

Here, we use ground-based measurements taken by the Rover Environmental Monitoring Station (REMS) onboard the Mars Science Laboratory Curiosity rover to calculate the amount of adsorbed water exchanged between the shallow subsurface and the atmosphere. We have found that the upper layers of adsorbed water could freeze on sols 533, 534, 555, 557 and 560 between 4 and 6 am LTST, when the ground temperature falls below the frost point ( 190 K). Van der Waals forces between the mineral surface and water ice molecules could depress the freezing point, allowing physisorbed water to be liquid-like. REMS was developed to assess the environmental conditions along Curiositys traverse by measuring atmospheric pressure, atmospheric relative humidity, ground and atmospheric temperatures, UV radiation flux and horizontal wind speeds [4].

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[1] Martínez, G., and N. Rennó (2013), Space Science Reviews, (175), 29-51.

[2] E. Rivkina, E. Friedmann, C. McKay, D. Gilichinsky, Appl. Environ. Microbiol., 66(8), 3230-3233 (2000).

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# MC. PLANETARY ATMOSPHERES

## MONDAY, JULY 28, 2014 – 1:00 P.M.

**Chair: DANIEL ANGERHAUSEN, Rensselaer Polytechnic Institute**

**MC00** **1:00**

WARM-UP TALK

DANIEL ANGERHAUSEN, *Rensselaer Polytechnic Institute.*

DISEQUILIBRIUM AND THE EFFECT OF LIFE ON PLANETARY ATMOSPHERE(S)

EUGENIO SIMONCINI, *INAF-Astrophysical Observatory of Arcetri.*

It has long been observed that Earth's atmosphere is uniquely far from its thermochemical equilibrium state in terms of its chemical composition. Studying this state of disequilibrium is important for its potential role in the detection of life on other suitable planets [1][2][3].

We developed a methodology to calculate the extent of atmospheric chemical disequilibrium [3][4]. This tool allows us to understand, on a thermodynamic basis, how life affected – and still affects – geochemical processes on Earth, and if other planetary atmospheres are habitable or have a disequilibrium similar to the Earth's one.

A new computational framework called KROME has been applied to atmospheric models in order to give a correct computation of reactions' kinetics [5].

In this work we present a first computation of the extent of disequilibrium for the present Earth atmosphere, considering the specific contribution of the different atmospheric processes, such as thermochemical reactions, eddy diffusion, photochemistry, deposition, and the effect of the biosphere. We then assess the effect of life on atmospheric disequilibrium of the Earth and provide a useful discussion about how the study of atmospheric disequilibrium can help in finding habitable (exo)planets.

We finally compare the chemical disequilibrium of Earth and Mars atmospheres, for present and early conditions, and we apply the same methodology to some sample exoplanets.

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**MC02** **1:30**

# OXYGEN FALSE POSITIVES IN PLANETARY ATMOSPHERES

CHESTER HARMAN, JAMES SCHOTTLEKOTTE, and JAMES KASTING,
*Pennsylvania State University.*

Oxygen ($O_2$) and ozone ($O_3$) in the present Earth's atmosphere are byproducts of oxygenic photosynthesis coupled with organic carbon burial. On Earth, no known abiotic surface process would be able to generate such an atmosphere, and by extension, lifeless exoplanets are expected to be devoid of $O_2$. As a result, molecular oxygen and ozone are often seen as convincing signposts for life. Recently, however, a number of authors have demonstrated the abiotic generation of molecular oxygen in a planetary atmosphere, either in $CO_2$-rich atmospheres (Hu et al., 2013), in the atmospheres of planets around M stars (Tian et al., 2013), or in an atmosphere poor in non-condensable gases (Wordsworth and Pierrehumbert, 2014). This false positive', if verified, would remove oxygen and ozone from an already short list of easily detectable biosignatures.

The work presented here is an attempt to replicate the published false positives, and identify the source of the differences between models. Using a photochemical model modified from Segura et al. (2007), we will show that we cannot reproduce the false positives of other authors, and place upper limits on the amount of abiotic oxygen we would expect on a lifeless Earth twin. We will also demonstrate that there are other factors than those considered by other researchers that influence the redox state of the atmosphere, namely the redox balance of the ocean.

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**MC03** **1:45**

THREE-DIMENSIONAL MODELING OF TITAN'S ORGANIC HAZE WITH IMPLICATIONS FOR THE EARLY EARTH

ERIK J.L. LARSON, OWEN B. TOON, ANDREW J. FRIEDSON, and ROBERT A. WEST, *University of Colorado.*

An organic aerosol haze that obscures the surface at visible wavelengths enshrouds Titan's atmosphere. This haze is thought to be analogous to possible haze formation on the early Earth. Elucidating the nature of this haze is key to understanding the complex climate system of Titan or the early Earth. To approach this problem, we used a global circulation model coupled to an aerosol microphysical model to explore the physical properties of Titan's haze, its spatial and temporal distribution, and effects on the atmosphere. We established a best-guess set of microphysical properties that describes the aerosol in Titan's atmosphere based on sensitivity tests of the parameters. From this approach we confirmed that the aerosol haze is comprised of aggregate particles with a fractal dimension of about 2. A charge on the particles equal to 7.5 electrons/micron radius best fist observations of phase function and number density, and a production rate of 10–14 g/cm$^2$/s best matches vertical extinction profiles in Titan's atmosphere. This production rate affects the surface temperature through the anti-greenhouse affect. We look at the effects of varying haze production on early Titan and early Earth surface temperature. We also present a formation mechanism for Titan's detached haze layer based on a balance between the vertical winds and particle fall velocities, and use a simple analytical model to reproduce the mechanism and match it to vertical extinction profiles from Cassini observations. Our simulations suggest that the detached haze layer will reappear at high altitude, around 550 km, between mid 2014 and early 2015. Through analysis of model output and comparison with spacecraft observations, we have been able to provide a coherent picture for the origin and evolution of Titan' s mysterious haze as well as plausible early Earth analogues.

**MC04** **2:00**

PRELIMINARY MODELING OF THE VENUSIAN ATMOSPHERE AS MICROBIAL HABITAT

THOMSON MASON FISHER, *Washington State University.*

While the surface of Venus is widely considered uninhabitable due to its extreme temperature and pressure, the atmosphere may be far more hospitable. At altitudes of 51 – 57 kilometers, temperatures and pressures occur in a more Earth-like range, varying from 0 to 38°C and 0.1 to 1.0 MPa, respectively, and nitrogen and phosphorus are present in detectable quantities. Energy is available, either in the form of sunlight, and likely in the complex cycling of carbon and sulfur driven by photochemisty in the upper atmosphere and abiotic redox reactions in the lower atmosphere. Water, while scarce, is not entirely absent in the atmosphere, and metabolically, it is possible that any putative Venusian organisms may have evolved the ability to "fix" water. Furthermore, the lack of a physical substrate may not present a significant obstacle, due to the relatively long residency time (months or greater) of individual particles in the atmosphere. Furthermore, the microbial activity in terrestrial clouds has been shown to be much higher than previously assumed.

However, can the atmosphere actually sustain a microbial ecosystem? Computer modeling can help answer this question. A model can be constructed using the Monod equation

$$\mu = \mu_{max} \left( \frac{S}{K_s} + S \right)$$

(where $\mu_{max}$ is the maximum growth rate, $S$ the concentration of substrate, and $K_s$ is the half-saturation constant), with parameters derived from terrestrial thermophilic acidophiles to approximate a putative Venusian microbe. Parameters defining the atmospheric chemistry can be derived from remote sensing data. The model can then be used to estimate the amount of biomass the Venusian atmosphere could potentially support, and to identify possible biosignatures of an atmospheric ecology.

# MD. LIFE IN EXTREME ENVIRONMENTS

## MONDAY, JULY 28, 2014 – 2:45 P.M.

**Chair: LUCY STEWART, University of Massachusetts, Amherst**

**MD00** **2:45**

WARM-UP TALK

LUCY STEWART, *University of Massachusetts, Amherst.*

**MD01** **3:00**

ANALYSES OF MUTATIONS THAT OCCURRED DURING AN EVOLUTION EXPERIMENT OF *BACILLUS SUBTILIS* AT 5 kPa

SAMANTHA MARIE WATERS and WAYNE L. NICHOLSON, *Department of Microbiology & Cell Science, University of Florida.*

On Earth, there exists a number of extreme environments at which microbial life is found. The molecular understanding of what enables organisms to survive under extreme conditions is highly relevant to the field of Astrobiology. Pressure is a fundamental thermodynamic parameter acting on all biological processes. High-pressure environments ranging from sea level ($\sim 10^5$ Pa) to the depths of the Mariana Trench ($\sim 10^8$ Pa), are widespread beneath the worlds oceans. In contrast, low-pressure (LP) Earth environments are scarcely represented– nearly all surface life is found in the troposphere, where the lowest pressure is slightly above $10^4$ Pa. Despite a lack of natural LP (hypobaric) environments on the Earths surface, hypobaric microbiology is gaining importance due to: (i) hypobaric chambers becoming increasingly used for long-term food and plant storage; (ii) microbial sampling of the limits of the upper atmosphere; and (iii) the search for life in the extraterrestrial LP environment of Mars. To test the hypothesis that microbes could evolve the ability to grow better at LP, we propagated wild-type *Bacillus subtilis* strain WN624 for 1,000 generations at 5 kPa, a pressure at which it grows very poorly, and isolated a strain called WN1106 that showed increased growth at 5 kPa. Whole genome re-sequencing, PCR and bioinformatics analyses of the data have confirmed 6 single nucleotide polymorphisms (SNPs) and one Insertion / Deletion mutation (InDel) located in coding regions of strain WN1106's genome. Mutation analyses, competition experiments, and transcriptome analyses have been utilized to reveal the adaptive role of these genes in LP growth of *Bacillus subtilis*.

**MD02** **3:15**

GROUND-PENETRATING RADAR TO SEARCH FOR WATER ON MARS AND OTHER PLANETARY BODIES

HARVEY ELLIOTT, GERMAN MARTINEZ, ERIK FISCHER, and NILTON RENNO, *University of Michigan.*

Here, we present a low-cost ground-penetrating radar concept that supports the search for habitable zones by identifying soil composition, stratigraphy and water content. This instrument is being developed for use on a future Mars rover to investigate the soil water content, identify the presence of dry stream beds or lakes, and provide an in-situ measurement of possible present day liquid water in the shallow subsurface. If selected for a future orbiter to an icy moon like Enceladus or Europa this measurement technique could also be used to map the depth of an ice table and identify regions of liquid water contained within the ice.

This ground-penetrating radar concept makes dual use of a spacecraft's existing telecommunication system to conduct scientific measurements. This technique requires only the addition of a small electronics box to process the data, a calibration source, and a special coded transmission. The current instrument design is intended to integrate with the Small Deep Space Transponder common to many spacecraft and once installed allows the spacecraft to probe the shallow subsurface at minimal cost, mass and risk. This instrument can shed light on the Martian soil water content and flag potentially habitable zones in the subsurface for sample collection.

**MD03** **3:30**

EXTREMOPHILE ELEMENTAL COMPOSITION RESPONSE TO NUTRIENT SUPPLY IN A NITROGEN- AND PHOSPHORUS-LIMITED HYPERSALINE POND

MARC NEVEU, AMISHA T. PORET-PETERSON, ZARRAZ M. P. LEE, JAMES J. ELSER, and ARIEL D. ANBAR, *Arizona State University.*

Living things require trace elements (e.g., Mg, Ca, Mn, Fe, Ni, Cu, Zn, Mo), which play a key role in metabolic pathways that contribute to the biogeochemical cycling of major elements such as C, N, P, or S [Morel and Price 2003, Science 300, 944]. However, we know little about (a) the elemental compositions of astrobiologically relevant, extremophile microorganisms [Neveu et al., L&O Methods, submitted]; and (b) how this composition depends on elemental supply from the environment.

We previously analyzed the elemental compositions of microbial communities of considerable physicochemical diversity collected in hot springs of Yellowstone National Park (YNP; USA). Surprisingly, the measured compositional ranges matched those previously determined for microorganisms inhabiting less extreme environments [Neveu et al., in preparation].

Here, we investigate the response of cellular elemental composition to N and P supply in a N- and P-limited hypersaline pond in Cuatro Ciénegas, Mexico. Four enclosures were established in the pond: one control (#C); one fertilized with P only (#P); and two fertilized with N and P at N:P molar ratios = 16 (#NP) and 75 (#NNP).

We find that the biomass C content was the same for all treatments. Cellular N:P and P:C ratios increased in treatments #NP and #NNP and treatments #P and #NP, respectively, compared to #C. This is consistent with nutrient limitation of the cells in #C. Further, we observed higher Zn, Mg, and Ca in treatments #P and #NP, whereas Mo was higher in treatments #NP and #NNP. These observations may indicate increased use of Zn and Mg-containing enzymes that fix P, and Mo-containing enzymes used in nitrate assimilation and denitrification. The biomass compositional ranges in all treatments match those measured in YNP communities; however, their compositions within these ranges seem to depend on major nutrient supply.

**MD04** **3:45**

RESPONSES TO ENVIRONMENTAL STRESSES WITHIN THE PHYLUM ROTIFERA

BRANDE L. JONES, *Georgia Institute of Technology.*

This work examines both common and unique paths for responses to environmental stresses among different environments and species (extremophiles vs. non extremophiles). Common responses between divergent species suggest that the response mechanisms initially evolved over an extended period and have been preserved over time. Diapausing embryos (resting eggs) from brachionid rotifers are able to withstand desiccation and thermal stress. Resting eggs can remain viable for decades, and develop normally once placed in a permissive environment that allows for hatching, growth and development. The exact mechanisms of resistance are not known, although several molecules have been suggested to confer protection during desiccation and thermal stress.

In this study, we have identified by mass spectrometry two thermostable proteins, LEA (late embryogenesis abundant) and VTG (vitellogenin-like), found exclusively in the resting eggs of Brachionus manjavacas. This is the first observation that LEA proteins may play a role in thermostability and the first report of a VTG-like protein in the phylum Rotifera. These proteins exhibited increased expression in rotifer resting eggs when compared to amictic females. Our data suggest the existence of alternate pathways of desiccation and thermal resistance in brachionid rotifers.

**MD05** **4:00**

UNVEILING THE RESPONSE OF BIOLOGICAL SYSTEMS UNDER SIMULATED PLANETARY AND SPACE CONDITIONS

GABRIEL ARAUJO, FABIO RODRIGUES, and DOUGLAS GALANTE,
*Brazilian Synchrotron Light Laboratory.*

The bacterium Deinococcus radiodurans is one of the most resilient organisms known, setting the boundaries to the presence of life in many extreme conditions. By means of the Simulation Chamber of Planetary and Space Environments at the University of So Paulo, and an extreme-UV beamline at the Brazilian Synchrotron Light Laboratory, these microorganisms can be exposed to accurate recreations of extraterrestrial environments. For a Mars surface simulation, the parameters controlled include the low pressures, low temperatures and ultraviolet radiation present on the planet. The (astro)biologically relevant information is taken from these experiments by different methods. Counting of colony forming units, the traditional approach, is limited to only measuring the survival of the cells (its ability to continually multiply). For a more in-depth study of damage mechanisms at subcellular levels, specific probes are applied and whole populations can be tested, cell by cell, by flow cytometry techniques. The results show that radiation down to the UV-C region is the main inactivation factor in unshaded locations on Mars, and desiccation due to its thin atmosphere affects mainly the outer membranes. Simulations of interplanetary space aimed to assess the effects of vacuum-ultraviolet on cells. These shorter wavelengths caused substantial loss of viability, membrane damage and intracellular oxidative stress. It is planned to apply, in future experiments, the same set of methodologies to other organisms of interest.

**MD06** **4:15**

BIOLOGICAL EXTRACTION OF METALS AND MATERIALS USING A SYNTHETIC BIOLOGY APPROACH

JESICA URBINA-NAVARRETE and LYNN J. ROTHSCHILD, *NASA Ames Research Center.*

Biomining, which uses microbes to aid in metals extraction, is common practice in the mining industry. Approximately 25% of Cu produced in the world is extracted by microbially-mediated oxidation of low-grade ores that could otherwise not be mined. Traditional mining techniques use extreme heat and chemical compounds to separate and purify metals whereas biological extraction methods occur at ambient temperatures and pressures. Recent work by Urbina-Navarrete et al., 2013, has shown that microbes can significantly increase the yield of metals (Fe, Al, Ti, and trace metals) released from basalts (volcanic rocks) similar to those found on the moon and Mars. To enable efficient development of facilities and infrastructure for long-duration space or settlement missions, we propose using microbially-mediated in situ extraction of metals from planetary surfaces. The extracted metal oxides, Fe and Cu in particular, can be used as feedstock for 3D metal printers that are currently being developed for use in space. 3D metal-printing techniques are being pioneered for applications in space exploration by engineers at NASA Marshall Space Flight Center through the use of selective laser melting (SLM). This technology has most recently been used to build rocket components, with complex geometry and dimensional accuracy beyond that possible with traditional fabrication methods. The combined approaches of biomining and additive manufacturing technologies allow for an economically feasible alternative to traditional mining and manufacture. This approach can transform NASA mission design and as well as have an immediate impact on the processing efficiency of limited geological resources on Earth.

# ME. POSTER SESSION

## MONDAY, JULY 28, 2014 – 4:45 P.M.

**Chair: BRADLEY BURCAR, Rensselaer Polytechnic Institute**

### ME01

MICROBIAL EPS-MEDIATED CRYSTALLIZATION OF LOW-TEMPERATURE DOLOMITE IN A HYPERSALINE LAKE: A POTENTIAL BIOSIGNATURE

MINGLU LIU and HUIFANG XU, *University of Wisconsin-Madison.*

Dolomite crystallization in Deep Springs Lake has been proved by our laboratory experiments to have tight association with microbial mediation, they might have a potential as an indirect bio-signature in the search for evidence of life in the rock record, potentially will be able to represent or preserve biological activities, and have a tremendous astrobiological importance.

The biomass in Deep Springs Lake is dominated by Halorhabdus (the major archaea), and Halobacteroides halobius (the major bacteria). These micro-organisms live between sediment mud and top sulfate salt layer. In order to understand the roles of microbes in mediating dolomite precipitation, we use the biomass collected from Deep Springs Lake in California in dolomite precipitation systems.

The experimental results indicate that disordered dolomite can be synthesized at low temperature using the biomass collected from Deep Springs Lake. The bacterially derived extracellular polymeric substances (EPS) might play a crucial role in dolomite precipitation. They can be strongly adsorbed on Ca-Mg carbonate surfaces through hydrogen bonding, and weaken the chemical bonding between Mg and water molecules, which enhances Mg incorporation into carbonate, therefore contribute to the growth of disordered dolomite.

XRD patterns of synthesized HMC (high-magnesium calcite) and disordered dolomite demonstrate that there is a positive relationship between biomass concentration and mole percent of $MgCO_3$ in the precipitates. No dolomite precipitates in solutions without biomass. Temperature and $Mg^{2+}/Ca^{2+}$ ratio from initial solution also have crucial effects on synthesized dolomite. EDS results demonstrate Mg:Ca ratio of precipitates could be as high as 45% under room temperature and 60% under 40°C. SEM images indicate most of synthesized HMC and dolomite grew on the surface of calcite seed crystals. TEM images show dolomite nano-crystals with low-angle grain boundaries among them.

**ME02**

TOWARDS A COMPUTATIONAL MODEL FOR METHANE PRODUCING ARCHAEUM

PIYUSH LABHSETWAR, JOSEPH PETERSON, JEREMY ELLERMEIER, PETRA R. KOHLER, ANKUR JAIN, TAEKJIP HA, WILLIAM W. METCALF, and ZAIDA LUTHEY-SCHULTEN, *University of Illinois at Urbana-Champaign.*

Methanogen M. acetivorans, an anaerobic archaeum is capable of metabolizing several organic compounds to generate methane. Here we report progress towards its complete computational model of the. We characterized size distribution of the cells using differential interference contrast microscopy, finding them to be ellipsoidal with mean length and width of 2.9 $\mu$m and 2.3 $\mu$m, respectively, when grown on methanol and 30% smaller when grown on acetate. We used the single molecule pull down (SiMPull) technique to measure average copy number of the Mcr complex and ribosomes. A kinetic model for the methanogenesis pathways based on biochemical studies and recent metabolic reconstructions for several related methanogens is presented. In this model, 26 reactions in the methanogenesis pathways are coupled to a cell mass production reaction that updates enzyme concentrations. RNA expression data (RNA-seq) measured for cell cultures grown on acetate and methanol is used to estimate relative protein production per mole of ATP consumed. The model captures the experimentally observed methane production rates for cells growing on methanol and is most sensitive to the number of methyl-coenzyme-M reductase (Mcr) and methyltetrahydromethanopterin:coenzyme-M methyltransferase (Mtr) proteins. A draft transcriptional regulation network based on known interactions is proposed which we intend to integrate with the kinetic model to allow dynamic regulation.

**ME03**

INTERSPECIES $H_2$ TRANSFER AND $H_2$ COMPETITION AMONG THERMOPHILES IN DEEP-SEA HYDROTHERMAL VENTS

BEGUM TOPCUOGLU and JAMES F. HOLDEN, *University of Massachusetts.*

Hydrogen gas is predicted to be too low to support the growth of thermophilic methanogens in many basalt-hosted deep-sea hydrothermal vent systems. Yet, these organisms can be found at low concentrations at these sites. $H_2$ in hydrothermal fluids is not the only source of $H_2$ in hydrothermal vent systems. Hyperthermophilic anaerobic heterotrophs produce $H_2$ that can be used as the sole source of their electrons for growth by methanogens and sulfur reducers. Thermococcus sp. strain ES1 is a hyperthermophile that produce $H_2$ when grown on maltose and tryptone without sulfur. The thermophilic methanogen Methanothermococcus sp. strain BW11 and the thermophilic, autotrophic sulfur reducer Desulfurobacterium sp. HR11 each grow in co-culture with strain ES1 in the absence of added $H_2$. The goal of our study is to define the kinetics of $H_2$ consumption and growth by Methanothermococcus and Desulfurobacterium and determine the outcome of competition for $H_2$ between these organisms. Understanding $H_2$ syntrophy and competition over biogenic $H_2$ in a system that is energy-limited is crucial to modeling the biogeochemical impact of thermophilic chemoautotrophs in hydrothermal vents.

**ME04**

THERMALLY INDUCED CHEMISTRY OF METEORITIC COMPLEX ORGANIC MOLECULES: A NEW THERMAL-DIFFUSION MODEL FOR THE ATMOSPHERIC ENTRY OF METEORITES

CHRISTOPHER N. SHINGLEDECKER, *University of Virginia.*

It has been known for several decades that meteorites can contain a rich variety of complex organic molecules (Kvenvolden et al. 1971, PNAS, 68, 2). This research is an attempt to gain a better insight into the thermal conditions experienced by these molecules during atmospheric entry inside meteorites. In particular, we wish to understand possible chemical processes that can occur during entry and that might have had an effect on the types of prebiotic species that were delivered in this manner to the early Earth. A simulation was written to model heating by the shock generated during entry, given some atmospheric parameters and an entry angle, and the subsequent thermal diffusion inside the body of a meteorite. Experimental data (Opeil et al. 2010, Icarus, 208, 449) were used for the thermal parameters of several types of meteorites, including iron-nickel and several classes of chondtites. A Sutton-Graves model of stagnation-point heating was used to calculate peak surface temperatures and a standard two-dimensional thermal diffusion formula was used. Temperature gradients were generated for all of the classes of meteorite studied by Opeil et al. Results from the simulation agree with experiment (Sears 1975, Modern Geology, 5, 155) on the depth of pyrolytic temperature penetration to an average depth of approx. 1 cm. Non-pyrolytic warming over pre-entry temperatures penetrates further to approx. 4 cm, showing that the majority of the body remains quite cold. These results support the findings that extraterrestrial delivery is a viable option for prebiotic molecular "seeding" of a planet. Observed differences in D/L ratios of amino acids found in fragments of the same parent body may be explainable partly in terms of a racemization during entry caused by differential warming of the exterior and whetted surface prior to breakup during entry.

**ME05**

CLUMPED ISOTOPES IN CARBONATES AS A POTENTIAL BIOSIGNATURE

NICHOLAS LEVITT, HUIFANG XU, and CLARK JOHNSON, *University of Wisconsin - Madison.*

Non-equilibrium fractionation of oxygen and carbon isotopes associated with biomineralization has been studied for decades. Early investigators studying isotopic fractionation involving carbonates quickly recognized biogenic non-equilibrium fractionation or so called "vital effects". These isotopic signatures preserved in carbonates have the potential to serve as a robust biomarker if fully understood and characterized. The recently developed method of "clumped isotopes" analysis has opened a new dimension of stable isotope forensics that can be used in tangent with traditional isotope geochemistry. Study of clumped isotopes involves quantification of the preferential bonding between rare stable isotopes (e.g., $^{13}C$ to $^{18}O$) in multiply substituted isotopologues as compared to stochastic bonding predicted for that chemical compound or mineral lattice. Early work on biogenic calcite, aragonite, and apatite utilizing clumped isotopes has revealed fractionation and clumping relationships that do not seem to be consistent with many inorganically precipitated carbonates or theoretical calculations.

Calcite has been synthetically formed using chemostat synthesis whereby seed crystals are used to constrain mineralogy and precipitate rate. This method is also used to maintain constant solution conditions such as saturation index and pH. This approach can provide new insights into fractionations associated with $CO_2$ degassing utilized in previous synthetic carbonate precipitation experiments and is also utilized to directly explore the relationship between precipitation rate and $^{13}C$–$^{18}O$ bond ordering in dissolved inorganic carbon (DIC) versus solid carbonate.

Recent developments in the understanding of $H_2O$–$CO_2$–carbonate system equilibrium and kinetic fractionations associated with carbonate precipitation requires a critical reassessment of $^{13}C$–$^{18}O$ bond formation in carbonates and their relationship to the DIC system. A thorough understanding of conditions affecting $\Delta 47$ of inorganic carbonates is imperative for the understanding of vital effects as biomarkers as well as interrogating carbonates for clues to development of early life on Earth and continued investigation of extraterrestrial bodies using clumped isotopes.

**ME06**

PROBING ACTIVITY AND COMPANIONSHIP OF M-DWARF STELLAR SYSTEMS THROUGH LIGHT CURVES

YUTONG SHAN, *Harvard University.*

In the early days of exoplanet exploration, star spots and jitter were considered nuisances to the detection and characterization of planets. One would painstakingly model or qualify anomalies and excess noise in transit and radial velocity curves towards removing their effects and uncovering the true underlying planetary signature. Stupendous improvement in photometric data quality by space missions the likes of Kepler (and soon K2, PLATO and TESS), have inspired us to look beyond the planets, triggering a revival of attention on the host stars. Exquisite light curve precision and continuous monitoring allow us to investigate the properties and activities of these stars reflected in the very apparent variabilities we once tried to rid – in unprecedented detail.

Chromospheric activity manifested as star spots imposes notable effects on stellar photometry, modulating the light curve signal in a periodic fashion regulated by the rotation rate. These periodicities may be spotted in frequency transforms of the light curve, a technique recently applied to tasks ranging from probing stellar rotational properties/scaling relations (e.g. gyrochronology) to sensing multiplicity in unresolved systems in the Kepler field. I forward-model these rotational modulations from stellar spot and system simulations to study the detectability of distinct rotation periods via Fourier-domain methods. I plan to statistically constrain the multiplicity rate of field M-dwarfs, a rich albeit poorly-understood class of stars around which we have the best chance of finding habitable worlds. The study will also aide in the characterization of circumbinary planetary systems, whose exotic insolation and dynamical environment powers paradigm-shifts about the habitable zone.

**ME07**

INVESTIGATING THE REACTIONS BETWEEN OH AND CO USING THE MATRIX ISOLATION TECHNIQUE: IMPLICATIONS FOR PLANETARY AND INTERSTELLAR CHEMISTRY

KAMIL STELMACH, YUKIKO YARNALL, FEREDUN AZARI, and PAUL COOPER, *George Mason University.*

Water and carbon monoxide (CO) are basic molecular building blocks that are found in both planetary surfaces and in the interstellar medium. The HOCO radical is formed in the reaction between OH and CO that has led to speculation that carbonic acid ($H_2CO_3$) may be formed in irradiated $H_2O$ and CO ices via HOCO as an intermediate. We have performed experiments using the matrix isolation technique to investigate the species formed in these reactions. Among the species formed, we have identified an OC-HOCO complex that was recently identified in the gas-phase using rotational spectroscopy. The present work is the first identification of this complex using infrared spectroscopy and is confirmed by comparison to quantum calculations and isotopic substitution. Experiments using $CO/H_2O/Ar$ gas mixtures were subjected to a 60 W microwave discharge and deposited on a KBr substrate at 6 K. The resulting molecules were identified using Fourier Transform Infrared (FTIR) spectroscopy. The implications for forming the OC-HOCO complex in both planetary and interstellar ices are discussed.

**ME08**

DETERMINING SIGNATURES OF MICROBIAL LIFE IN DIFFERENT ENVIRONMENTS USING MICROBIAL FUEL CELLS

BONITA LAM, AARON NOELL, and KENNETH NEALSON, *University of Southern California.*

The detection of chemical and physical signatures of microbial life on Mars or other solar system bodies is likely to remain controversial because of the challenge to distinguish these signatures from those produced by abiotic processes. For any successful life-detection mission it is essential to send instruments aimed at generalized in-situ life detection of extant life to complement the chemical and physical analyses taking place. We are working towards developing microbial fuel cells (MFCs) as life-detection instruments to measure microbial metabolism.

Microbial metabolism is a universal characteristic of life. Metabolism involves electron flow (redox) reactions among organic or inorganic substrates, which can be detected via chemical or electrical means. Changes in oxidation state can be investigated using electrochemical techniques such as fuel cells, which measure electrical current produced by redox reactions. Environmental samples from habitable niches should contain everything necessary to produce current flow, i.e., catalysts (microorganisms) and fuel (nutrients). MFCs can also probe for starving and/or inactive organisms in less habitable areas by artificially adding a fuel to drive growth.

We used half-cell setups with a three-electrode system to determine abiotic and biotic signatures in standard potting soil. Carbon felt electrodes were poised at a potential of 400 mV and consistent sampling of current was measured at the electrode throughout our experiments. More current was generated in half-cells with potting soil compared to the sterilized control. Other experiments were done using sterilized potting soil with the addition of a model microorganism, Shewanella oneidensis at different cell densities. The addition of fewer cells leads to greater current indicating microbial growth is constrained by resources, so less can be more for detection purposes. We are currently expanding our work with the half-cells to test soils and sediments from extreme environments (e.g. Atacama Desert, deep ocean subsurface) along with Mars simulant soils.

**ME09**

WARMING EARLY MARS WITH $H_2$ AND $CO_2$

NATASHA BATALHA and JAMES KASTING, *Pennsylvania State University.*

A recent study by R. Ramirez et al. (Nature Geosci., 2013) demonstrated that an atmosphere with 1.3-4 bar of $CO_2$ and water, in addition to 5-20% $H_2$, could raise the mean surface temperature of early Mars above the freezing point of water. This is thought to be necessary in order to produce enough rainfall (or snowfall) to carve the Martian valleys. Volcanic outgassing could in principle, have generated both $CI_2$ and $H_2$. Mars' mantle is highly reduced, however, and so carbon was probably outgassed as CO and $CH_4$, rather than as $CO_2$. Furthermore, much of the $H_2$ in Mars' early atmosphere could have come from outgassed $CH_4$ and $H_2S$. We will use a 1-D photochemical model to see how efficiently CO, $CH_4$, and $H_2S$ are converted to $CO_2$ and $H_2$. Previous work by K. Zahnle (JGR, 2008) suggests that CO, rather than $CO_2$, might become the dominant carbon-containing gas in such an atmosphere. This possibility will also be investigated.

**ME10**

DOMAIN 0: THE CENTRAL CORE OF THE ANCESTRAL RIBOSOME

KATHRYN LANIER, JESSICA BOWMAN, and LOREN WILLIAMS, *Georgia Institute of Technology.*

The Center for Ribosomal Origins and Evolution recently proposed a revised secondary structure and domain architecture of the Large Subunit rRNA, in which the folded rRNA is organized around a central core called Domain 0. The other six LSU domains are rooted to Domain 0, which is conserved across phylogeny and establishes the entrance and early elements of exit tunnel. Domain 0 provides a supporting scaffold for the catalytic function of the peptidyl transferase center (PTC), cradling the A-site and P-site of Domain V. Domain 0, when isolated from the rest of the ribosome, is hypothesized to fold autonomously and assemble spontaneously with specific ribosomal components. The folding of isolated Domain 0 and its assembly with other ribosomal components has been characterized through computation, in vitro and yeast three-hybrid assays. Assembly has been evaluated through electrophoretic mobility shift assays (EMSA). With EMSA we have demonstrated that Domain 0 specifically binds to particular rPeptides that have crucial interactions with the PTC, independent of other, and perhaps more modern, ribosomal proteins and RNAs. EMSA results allow us to determine approximate dissociation constants of the significant rRNA-rPeptide complexes. The ultimate goal of this project is to determine if catalytic activity is observed when Domain 0 associates with the PTC and specific rProteins. This assembly process would serve as a model of the most ancient functioning ancestral ribosome to date.

**ME11**

USING MICROFLUIDICS TO EXPLORE ADAPTATION AND EVOLUTION OF ESCHERICHIA COLI UNDER CONSTRAINT ENVIRONMENTAL CONDITIONS

LANG ZHOU, REINALDO ALCALDE, RODERICK MACKIE, ISAAC CANN, BRUCE FOUKE, and CHARLES WERTH, *University of Illinois at Urbana-Champaign.*

The adaptation and/or evolution of microorganisms are of considerable interest in natural and engineered environments. In most prior studies, microbial adaptation and evolution were evaluated in batch systems. In nature, however, concentration gradients exist, and microbes can adapt or evolve in the concentration niches that best their physiology. This enhances diversity, and potentially favors adaptation and/or evolution in response to environmental stress. Further knowledge of these phenomena is critical for understanding the nature, speed and likelihood of evolution. In our study, microfluidics has been used to simulate physical and chemical heterogeneous microenvironments existing in nature and explore adaptation and evolution of E. coli K12 to an antibiotic concentration gradient. Fluorescence experiments are being conducted to confirm gradients in the microfluidics. Antibiotic gradients are being established to evaluate stress response to E. coli. We anticipate that the results will support the idea that mutations occur in response to the stress. Further conclusions will be drawn after use of genomic and transcriptomic techniques to track microbial response to information exchange, metabolism and biochemistry. The research is part of a NASA Astrobiology Institute project entitled "Towards Universal Biology: Constraints from Early and Continuing Evolutionary Dynamics of Life on Earth." We will try comprehending the results and figure out if the mechanisms contribute to the evolution and development of early life.

**ME12**

EVOLUTION OF THE RIBOSOME AT ATOMIC RESOLUTION

NICHOLAS A. KOVACS, *Georgia Institute of Technology.*

The origins and evolution of the ribosome, 3-4 billion years ago, remain imprinted in the biochemistry of extant life and in the structure of the ribosome. We have mapped ribosomal size onto the phylogenetic tree. Processes of ribosomal RNA (rRNA) expansion onto the ribosome can be observed by comparing three-dimensional rRNA structures of bacteria (small), yeast (large) and metazoans (even larger). Differences in ribosomes across species reveal that rRNA expansion segments have been added to rRNAs without perturbing the conformation and interactions of the pre-existing core. Here we show that rRNA growth occurs by a limited number of mechanisms that include branching of a pre-existing trunk helix or elongation of a helix. rRNA additions can leave distinctive atomic resolution fingerprints, which we call insertion fingerprints. Observation of insertion fingerprints in the conserved structures of rRNAs of various sizes, are constrained to the outer regions of the LSU, and are remote from the peptidyl transferase center (the PTC, Fig. 2). The locations of the expansions of S. cerevisiae and H. sapiens are indicated by arrows on the secondary structures in Figure 2. In general, rRNA expansion does not perturb the common core or other ancestral rRNA: essentially all conserved core.

**ME13**

THE EFFECTS OF VISCOSITY ON NUCLEIC ACID ASSEMBLY: A POSSIBLE SOLUTION TO STRAND INHIBITION

CHRISTINE HE, *Georgia Institute of Technology - Center for Chemical Evolution.*

Nucleic acid replication is a fundamental process in living systems, but understanding its prebiotic origins has been an elusive problem. While extant life utilizes complex molecular machinery to carry out nucleic acid replication in a step-wise fashion, a major challenge in the origins of life field is identifying a simpler, prebiotic replication mechanism. A significant bottleneck in demonstrating continuing rounds of replication is a phenomenon known as strand inhibition, where the thermodynamic and kinetic favorability of forming a long duplex prevents separation of the single-strands for sufficient time to allow monomer/oligomer binding and ligation.

We propose addressing the problem of nucleic acid strand inhibition by employing highly viscous solvents to control the reannealing rates of long templates and monomers/oligomers. In a viscous environment, DNA mobility is slowed in a length-dependent manner, so that long DNA strands (such as template and product strands) can be kinetically trapped, slowing their reannealing. Meanwhile, monomers or short oligomers can diffuse faster and bind to their complementary targets on the templates. We hypothesize that tuning of viscous solvents, combined with thermal cycles, can be used to drive sustained rounds of nucleic acid self-replication.

In this work, we show that viscous solvents provide a highly effective, controllable means of tuning DNA hybridization. The experimental parameter space is mapped using large scale, methodic characterization of solvent properties as well as DNA thermodynamics and hybridization kinetics in these solvents. Additionally, we have demonstrated that in viscous solvents, the reannealing rate of a gene-length DNA duplex is slowed by many orders of magnitude, allowing binding of complementary oligomers and ligation into a copy strand.

**ME14**

CHARACTERIZATION OF MICROBIAL Fe(III) OXIDE REDUCING COMMUNITIES IN CHOCOLATE POTS HOT SPRINGS, YELLOWSTONE NATIONAL PARK

NATHANIEL W. FORTNEY, ERIC E. RODEN and ERIC S. BOYD, *University of Wisconsin-Madison.*

Previous research into the microbial community at Chocolate pots hot spring (CP), Yellowstone National Park (YNP) has identified it as harboring an abundant assemblage of organisms supported by dissimilatory iron reduction (DIR). Previous most probable number (MPN) enumerations and enrichment culture studies confirmed the presence of endogenous microbial communities that reduced native CP Fe(III) oxides. Enrichment cultures demonstrated sustained DIR coupled to acetate and lactate oxidation through repeated transfers over ca. 450 days. Bacterial sulfate reduction to sulfide, and abiotic oxidation of sulfide by ferric oxide, was determined to not contribute extensively to DIR. To identify putative populations involved in DIR activity, we extracted genomic DNA from enrichment cultures for 16S rRNA gene pyrosequencing. Results indicated that DIR enrichment culture sequences were closely affiliated with the well known Fe(III) reducer *Geobacter metallireducens.* Additional taxa included relatives of sulfate reducing bacterial genera *Desulfohalobium* and *Thermodesulfovibrio*; amendment of enrichments with molybdate, an inhibitor of sulfate reduction indicates they are not involved in DIR. A metagenomic analysis of enrichment cultures is underway in anticipation of identifying genes involved in DIR and thermotolerance. Current studies are aimed at interrogating the *in situ* microbial community at CP. Core samples were collected along the flow path at CP and subdivided into 1 cm depth intervals. A parallel study investigated *in vitro* microbial DIR in sediments collected from three of the coring sites. DNA was extracted from samples from both studies for 16S and metagenomic sequencing in order to obtain a more detailed understanding of the vertical and longitudinal distribution of microbial taxa throughout CP than was previously undertaken. These studies will provide insight into the coupled geochemical-microbial system, demonstrating how genomic properties change with depth and distance in a Fe-rich, neutral pH geothermal environment.

**ME15**

3-DOMAIN TREE VERSUS EOCYTE TREE AND HISTONES

AMANDA DICK and J. PETER GOGARTEN, *University of Connecticut.*

The question of archaeal monophyly is central to eukaryogenesis and is under debate. Ancient gene duplications, protein concatenations, and the fossil record tend to support archaeal monophyly, paraphyly, and are ambiguous on the subject, respectively. More evidence is required to determine the phylogenetic affinity of Archaea and the most likely scenario for eukaryogenesis. Circumstantial evidence in support of archaeal monophyly can be derived from proteins that exhibit long branches along the eukaryotic stem.

The histone family is present in both Archaea and Eukaryotes. There are four homologous histone subunits present in all Eukaryotes and divergence occurred prior to the diversification of Eukaryotes, making them a good choice in the study of eukaryogenesis. Ordinarily, protein phylogenies are examined to determine branching order, but the extreme sequence divergence and short sequence lengths within the histone family make alignments between subunits difficult and branching order unreliable. Branch lengths, as calculated using maximum likelihood in phyml, were used to determine support for archaeal monophyly. Long branches were observed along the stem of eukaryotic subunits, indicating that either Eukaryotes have undergone a long period of evolution, or have an increased evolutionary rate, possibly due to a change in function. Eukaryotic branch lengths are expected to be significantly shorter than archaeal branch lengths if Eukaryotes arose from within the Archaea, but not if Eukaryotes and Archaea are sister taxa. Branches within a eukaryotic histone subunit are long compared to the archaeal out-group, which is evidence for copious eukaryotic evolution and indirect support for archaeal monophyly.

**ME16**

A MICROBIAL IRON SHUTTLE IN A REDOX-STRATIFIED OCEAN 2.9 BILLION YEARS AGO

BREANA M. HASHMAN, BRADLEY M. GUY, NICOLAS J BEUKES, BRIAN L. BEARD, and CLARK M. JOHNSON, *University of Wisconsin-Madison.*

In the search for the first 'whiff' of atmospheric oxygen, the possibility of a Mesoarchean ephemeral oxidation is debated. While a muted Mass Independent Fractionation of Sulfur (MIF-S) signal first sparked the hypothesis of an ephemeral oxidation (Ono et al. 2006), a subsequent detailed investigation suggested this geochemical signature was a product of increased continental weathering, rather than atmospheric oxygen (Guy et al. 2012). However, new data in the form of Cr isotopes and Se concentrations has once again suggested the presence of atmospheric oxygen in the Mesoarchean (Crowe et al. 2013; Large et al. 2014).

To add clarity to this debate, pyrite Fe isotope compositions from the well-preserved Witwatersrand Supergroup were determined from a variety of lithologies representing a range of depositional settings. The data suggests a link between Fe isotope composition and depofacies, where $\delta^{56}$Fepyrite are lighter in more distal settings than in proximal settings. Additionally, Fe concentrations of lithologies increase from proximal to distal settings. This negative correlation between $\delta^{56}$Fepyrite and Fe bulk-rock concentration is indicative of a benthic Fe shuttle, where dissimilatory iron reduction (DIR) produces isotopically light iron which escapes from the shelf and is transported and trapped in a deeper anoxic basin settingresulting in lighter Fe isotope ratios and iron enrichment in distal depofacies. These data not only demonstrate an active Mesoarchean microbial iron cycle, but also imply the presence of oxygenated surface waters, since a Fe shuttle requires a redox boundary in the water column in order to trap the reactive Fe. This model would assuage the apparent discrepancies in the ephemeral oxidation debate; An oxic Mesoarchean environment would support the Cr and Se studies (Crowe et al. 2013; Large et al. 2014), while also providing a mechanism for the MIF-S diluting increased continental sulfate flux suggested by Guy et al. (2012).

**ME17**

UNDERSTANDING STRESS-INDUCED MICROBIAL EVOLUTIONARY MECHANISMS VIA MICROFLUIDIC CELLS

REINALDO ALCALDE, LANG ZHOU, ISAAC CANN, ROD MACKIE, BRUCE FOUKE, and CHARLES WERTH, *University of Illinois at Urbana-Champaign.*

Natural environments have the ability to establish physical and chemical heterogeneous microenvironments that are advantageous in microbial mutagenesis. It is our objective to find evidence of stress-induced mutations, in contrast to random mutagenesis, and ask whether this is a major driving force in the evolution of cellular life. Previously, microfluidic cells were used to explore antibiotic resistance of Escherichia coli. The gradients established in the device, triggered rapid response and resistance towards the antibiotic stress within 10 hours. In this study, strategically chosen Archaea (e.g., Methanosarcina acetivorans) are to be subjected to heterogeneous environmental stresses in a microfluidic cell. A wide range of chemical and physical stresses, such as those found in natural environments (e.g., geothermal hot spring communities), will be simulated in the cell; crucial in providing information on how the natural system gives rise to the evolution and development of microbial communities. Genomic and transcriptomic technology will be implemented to track the microbial response (i.e., information exchange, metabolism and biochemistry). Fluorescence experiments are being conducted to confirm gradients in the microfluidic cells. Antibiotic gradients are being established to evaluate cellular stress response. Time-lapsed microscopy is being implemented to analyze microbial response in real time. This study can prove beneficial in understanding the origins of life and assessing forms of life elsewhere in the universe, addressing NASA Astrobiology Roadmap objectives 5.1 and 6.2.

**ME18**

ECOLOGICAL RESPONSE AND ISOTOPIC VARIABILITY DURING EARLY PALEOGENE HYPERTHERMALS

ROSS H. WILLIAMS, SABINE MEHAY, SURYENDU DUTTA, and ROGER E. SUMMONS, *Massachusetts Institute of Technology.*

The search for life outside of our planet often relies upon the principal that life elsewhere will be fundamentally similar to life as we know it here on Earth. However, it is also important to consider how any life can persist or alter in the face of extreme changes in environments. The early Paleogene period provides us with a useful analog for a warmer Earth punctuated by periods of intense, rapid warming termed hyperthermals. The most prominent of these events is the Paleocene-Eocene Thermal Maximum (PETM), where global temperatures have been estimated to increase 6°C on the order of 20,000 years. To better understand the ecological effects of such extreme events, samples belonging to the early Cenozoic from the Canadian High Arctic as well as lignite mines from the Northwestern India have been analyzed for biomarker content and isotopic variability. Due to the geographic separation of these formations these results can provide a comparative study about how life in two different climatic regimes may respond to drastic changes in temperature.

**ME19**

TRACE ELEMENTS IN QUARTZ OF THE JACK HILLS METACONGLOMERATE

M.R. ACKERSON, N.D. TAILBY, and E.B. WATSON, *Rensselaer Polytechnic Institute.*

The trace-element chemistry of Hadean zircons from the Jack Hills metaconglomerate (Eranondoo Hill, W74 site) has broadened our understanding of the early earth. Despite the importance of these samples, little work has been done on the chemistry and history of W74 quartz, which dominates the mineral assemblage[1]. Recent advances in interpreting quartz trace-element chemistry provide a means to gain new insights into the origin and history of quartz in the metaconglomerate and its relation to the Hadean zircons. In this study we present chemical and petrographic evidence that quartz of the Jack Hills metaconglomerate has undergone pervasive recrystallization since deposition. We observe no chemical or petrographic evidence for primary magmatic quartz.

Quartz dominates both pebbles and matrix at W74, both of which show petrographic evidence of dynamic recrystallization and grain boundary migration. The unit is also cut by post-depositional quartz veins, which are undeformed. LA-ICPMS analyses of matrix quartz and >40 individual pebbles demonstrate uniformly low Ti content. Ti-in-quartz thermometry[2] (assuming a $TiO_2 = 1$ and $P \sim 4$ kbar) yields an average pebble quartz temperature of 346 °C and an average matrix quartz temperature of 401 °C. Post-depositional quartz veins record a temperature of 344 °C. These temperature estimates conform with accessory mineral observations of regional greenschist-grade metamorphism.

Trace-element analysis of the quartz provides an additional means of evaluating the history of the Jack Hills. If quartz in the Jack Hills was derived from igneous or high-grade metamorphic activity and remained unaltered throughout its geologic history, the quartz would contain elevated levels of several trace-elements (Ti, Al, Li). However, low abundances of these trace elements in the quartz supports the notion that the majority of quartz has undergone pervasive post-depositional recrystallization at greenschist facies conditions.

[1] Menneken et al. (2010) MinMag 75, 1455.
[2] Thomas et al. (2010) Contrib Mineral Petrol 160, 743-759.

**ME20**

SIMS $\delta^{18}O$ MICROANALYSIS OF THE STRELLEY POOL CHERTS AT THE TRENDAL LOCALITY IN THE PILBARA CRATON OF WESTERN AUSTRALIA. INSIGHT INTO FLUID SOURCES, ALTERATION, AND PALEOENVIRONMENTAL CONDITIONS

JAKE N. CAMMACK, JOHN W. VALLEY, REINHARD KOZDON, MIKE J. SPICUZZA, and AARON J. CAVOSIE, *Rensselaer Polytechnic Institute.*

SIMS $\delta^{18}O$ Microanalysis of the Strelley Pool Cherts at the Trendal Locality in the Pilbara Craton of Western Australia. Insight Into Fluid Sources, Alteration, and Paleoenvironmental Conditions.

Abstract: This study conducts in-situ SIMS measurements of $\delta^{18}O$ to investigate microtextural trends of quartz and carbonates from the 3.4 Ga Strelley Pool Chert at the Trendall locality (SPC-TL) in layers with quartz and carbonate cemented stromatolites within the Pilbara Craton, Western Australia. Using transmitted light microscopy and SEM (BSE & CL) this study describes several quartz and carbonate textures and generations. Voids are frequently rhombohedral and are often associated with micro-mesocrystalline quartz. Occasional 2-8 $\mu$m dolomites are encased by microcrystalline quartz. Megacrystalline vein quartz (Mqv) and associated meso-megacrystalline quartz crystals, are often in proximity to 4-200 $\mu$m dolomite and calcite and frequently contain 2-4 $\mu$m dolomite. Chalcedonic quartz is locally associated with fractures, and some voids along with calcite. Sparry quartz overgrowths are observed in the voids and fractures of many samples. Petrography on thin sections of stromatolitic samples reveals 4 distinct quartz and carbonate generations: (1) dolomite and calcite in stromatolitic layers (2) quartz veining parallel to stromatolitic layering (3) Mqv crosscut by (4) Mqv associated with calcite and dolomite overgrowths on carbonates within these veins. SIMS $\delta^{18}O$ data reveals bimodal isotopic zonation between quartz textures.

Quartz overgrowth textures in cherts within voids and fractures have $\delta^{18}O$ ranging from 25 to 30‰, while other quartz textures have $\delta^{18}O$ from 16 to 19.5‰VSMOW. These data provide evidence of bimodal zonation reflecting unique temperatures, timing, and fluid sources of different quartz varieties. Although the timing of the overgrowth textures is under investigation, Paleogene low temperature surface alteration may be responsible for quartz overgrowth textures in voids and fractures. Other quartz textures may be formed from hydrothermal silicification, diagenesis, or a later resetting event in the SPC-TL.

**ME21**

UNDERSTANDING HOW CHEMICAL CONSTRAINTS SHAPE EVOLUTION THROUGH COMPUTATIONAL MODELING OF CHEMICAL NETWORKS

HARRISON B. SMITH, JASON RAYMOND, and SARA WALKER, *Arizona State University.*

Across all domains of life, amino acids carry out important biological functions, acting as chemical messengers, metabolites, and nutrients. However, out of the hundreds of natural and synthesized amino acids, only 22 are incorporated as building blocks of proteins. Given that laboratory research (such as the Miller-Urey experiment) has demonstrated that considerably more than 22 amino acids should have been created in prebiotic environments, why do contemporary organisms utilize only a small subset of amino acids in proteins? Similarly, how do early stage biochemical processes, such as evolving amino acids synthesis pathways, select the chemistries that end up getting incorporated into their own functionality? In order to help answer these questions, we are constructing a computational chemical reaction network. For our purposes, the chemical reaction network is defined by a set of initial substrates and mutable enzymes that enable reactions between the substrates. Because the enzymes mutate, they are forced to compete with each other to maintain functionality and maximize catalytic rates amongst an evolving set of chemical substrates. This tournament-style competition between enzymes will help predict the enzyme functionality and chemical products that should emerge in our network. Preliminary results, including enzyme functionality and chemical products, generated from first order simulations of early amino acid synthesis will be presented.

**ME22**

NUTRIENT AVAILABILITY IN THE ARCHEAN OCEAN

HILLARY EMICK, *Arizona State University.*

In the period leading up to the Great Oxidation Event, ancestral cyanobacteria underwent rapid metabolic evolution. Their metabolic innovations include oxygenic photosynthesis and nitrogen fixation. My research focuses on the elements required for the enzymes required for these reactions and their abundance in the Archean ocean. I am examining abundance of key elements in drill cores obtained from the Pilbara Craton in W. Australia.

**ME23**

RECONSTRUCTION OF ANCIENT MICROBIAL BIODIVERSITY AND METABOLISM FROM FOSSIL TRAVERTINE

ABIGAIL ASANGBA, *University of Illinois at Urbana-Champaign.*

A virtually unexplored frontier in the study of life in extreme environments is the extraction of genetic and environmental information directly from microbes entombed in calcium carbonate ($CaCO_3$) crystals in the geological record. An environmental metagenomic study has been initiated to systematically track the fate of microbial gene sequences, lipids and other biomarkers during the fossilization and diagenesis of Pleistocene terrestrial hot-spring travertine in Yellowstone National Park and the Pamukkale region of Turkey. The Mammoth Hot Springs corridor of Yellowstone contains thermal springs (73°C) that are actively and rapidly (mm's/day) precipitating travertine, as well as a complete time-series of travertine deposits that extend back to the Pleistocene (∼33 ka). Comparative samples have been collected from quarries in the Denizli Basin (700-900 ka). The goal is to quantitatively track the preservation of these biomolecules through geological time, across specific sequences of down-flow travertine depositional facies and use this information to accurately reconstruct the identity, activity and ecology of the ancient microbes and their hot-spring environments. Analyses are being conducted of biomarkers extracted from bulk rock (cm's in diameter) as well as micro-drilled samples ($\mu$m in diameter). Each travertine sample is first being quantitatively screened (optically and geochemically) to determine the extent and fabric of water-rock alteration. Biomass has been successfully extracted from 10 $\mu$m-diameter fluid inclusions in primary crystals, as well as inter-crystalline deposits, and is undergoing metagenomic sequencing.

**ME24**

SELF-ASSEMBLY OF TITAN THOLINS IN ENVIRONMENTS SIMULATING TITAN'S LAKES

JUN KAWAI, *FfAME.*

Titan, the largest satellite of Saturn, has a thick atmosphere containing nitrogen and methane. A variety of organic compounds have been detected in the atmosphere, most likely produced when atmospheric gases are exposed to ultraviolet light, electrons captured by the magnetosphere of Saturn, and cosmic rays. The Cassini / Huygens probe showed that the average temperature on the surface of Titan is 93.7 K, with lakes of liquid ethane and methane. Sub-surface mixtures of liquid ammonia and water may also be present. We have synthesized complex organic compounds (tholins) by exposing a mixture of nitrogen and methane to plasma discharges, and investigated their interactions with several different liquids that simulate Titans liquidosphere. We found that coacervates formed when tholins were extracted in non-polar solvents followed by exposure to aqueous ammonia solutions. The results suggest that coacervates can self-assemble in Titans liquidosphere which have the potential to undergo further chemical evolution. Similar processes are likely to occur in the early evolution of habitable planets when tholin-like compounds undergo phase separation into microscopic structures dispersed in a suitable aqueous environment.

**ME25**

PROBING THE ORIGINS OF CATALYSIS WITH A DEOXYRIBONUCLEIC ACID (DNA) SYSTEM

RACHEL GYSBERS, KHA TRAM, JIM GU, and YINGFU LI, *McMaster University.*

Life would not exist in the absence of catalysis. Indeed, the RNA World model for the origin of life hinges on the capabilities of ribonucleic acid to encode information and perform catalysis (i.e. self-replication). Previously, functional nucleic acids such as ribozymes and deoxyribozymes (DNAzymes) have been isolated using the process of in vitro selection. This method is typically performed by isolating a catalytically active molecule from a large random library. This project employs a novel perspective; rather than a random library, a known, non-functional sequence is utilized. Using in vitro selection, this known sequence is gradually evolved into a functional catalyst by solely allowing the existence of sequences that acquire mutations to enhance their function. The objective of this project is to exploit the properties of DNA to act as a proxy system for the origins of prebiotic chemistry by isolating a functional catalyst from a previously non-catalytic sequence. This may assist in understanding the origin of life. Additionally, this project will contribute to the understanding of in vitro selection as a means of molecular evolution.

**ME26**

ELECTRIC CABLE BACTERIA AND SIGNATURES OF LIFE

ANJA BAUERMEISTER, *Department of Civil and Environmental Engineering, Rensselaer Polytechnic Institute, Troy, NY*; JEFF SCHRAMM, *Department of Biology, Rensselaer Polytechnic Institute, Troy, NY*; and YURI GORBY, *Department of Civil and Environmental Engineering and Department of Biology, Rensselaer Polytechnic Institute, Troy, NY.*

Electric cable bacteria are organisms of the family Desulfobulbaceae that exhibit a novel method of electron transport and metabolism. Cells form conductive filaments that function like electric wires, transferring electrons over distances of more than 1 cm from deep sulfidic sediments to oxygen or other electron acceptors near the soil/water interface. Electron transfer from depth at rates that far exceed diffusion limited processes generates characteristic profiles of pH that can significantly influence geochemical reactions and products, leading to distinct mineralogical profiles that are unlikely to be created by abiotic means. Carbonate dissolution at depth, and formation of carbonate and metal oxide crusts at the sediment/water interface are signature features of electric cable bacteria in marine sediments. Our research seeks to address the possible contributions of cable bacteria to preserving evidence of life in the rock record. We hypothesize that aqueous and sediment geochemistry, such as ion concentration, will impact stratification of minerals mediated by cable bacteria. Therefore, sampling will take place along salinity gradients of marine estuaries such as the Hudson River.

By studying these organisms our goal is to elucidate a novel mechanism of energy transfer and its impact on the geological record that can be directly applied to subsurface life exploration and potentially expand the boundaries of what is considered a suitable environment for life.

**ME27**

PREBIOTIC PHOSPHORYLATION ON THE EARLY EARTH

MAHEEN GULL and MATTHEW A. PASEK, *School of Geoscience, University of South Florida, 4202 E Fowler Ave, Tampa FL 33620.*

The synthesis of organophosphates from organic reagents and a phosphorus source is a key step in prebiotic chemistry, especially if RNA was one of the first biomolecules in life. Phosphorus minerals must have acted as the ultimate phosphate source for this chemistry. In our study, we present how phosphorus would have incorporated on the early Earth. Phosphorus (P) plays a vital role as it is a key biologic element. However, a big question still remains as to how P was incorporated into the first biomolecules. In our extensive studies we studied the prebiotic phosphorylation reactions by using water as a solvent and some other potentially prebiotic solvents such as deep eutectic solvents (choline chloride and urea 1:2) [1]. We attempted prebiotic phosphorylation reactions by using various P minerals including apatite, whitelockite, monazite, struvite, monetite and meteoritic mineral SC (or its synthetic analogue $Fe_3P$ as well as P salts such as $NaH_2PO_4$, or $Na_2HPO_4$ [1-3]. We attempted to phosphorylate organics such as glycerol, uridine, adenosine, and glucose. By using these sources we attempted two parallel routes to study phosphorylation reactions occurring in both aqueous and non-aqueous solvents. The recent discovery of phosphite in Archean rocks suggests that it is likely that the meteoritic mineral schreibersite (SC thereafter) may have provided reduced P that would corrode into water and generate inorganic P [4]. It was found that SC corrodes and reacts with an aqueous solution of glycerol at 65–70 °C to form glycerol phosphates and also releases reactive inorganic P species such as orthophosphate, hypophosphate, phosphite etc. However, unlike SC when similar reaction was tried with apatite, whitelockite, monazite, struvite and monetite the formation of glycerol phosphate was below detection limit. Alternatively, we also attempted prebiotic phosphorylation reactions in the deep eutectic solvent with various P sources and different organics and obtained yields of organophosphates ranging from 10-99% [1].

[1] Gull, M.; Zhou, M.; Fernandez, F. M.; Pasek, M. A. Prebiotic Phosphate Ester Syntheses in a Deep Eutectic Solvent. J. Mol. Evol. 2014, 78, 109-117.
[2] Gull, M.; Pasek, M. A.. Is Struvite a Prebiotic Mineral? Life 2013, 3(2), 321-330.
[3] Gull, M.; Pasek, M. A. Role of Phosphorus Minerals in the Origin of Life on Earth. American Geophysical Union, Fall Meeting 2013, abstract #P31B-1795.
[4] Pasek, M. A., Harnmeijer, J. P., Buick, R., Gull, M. & Atlas, Z. Evidence for reactive reduced phosphorus species in the early Archean ocean. Proc. Natl. Acad. Sci. USA. 2013, 110, 10089-10094.

**ME28**

MICROMETEORITE MATERIAL COLLECTION FROM OUTER SPACE AND ASTROBIOLOGICAL CHARACTERIZATION OF MICROBIA BY THE UPR-NASA ROCKSAT-X TEAM

REBECA RIVERA et al., *University of Puerto Rico.*

The UPR-NASA RockSat-X team has developed micrometeorite detection and collection systems with the aim of gathering specimens from a meteor trail, as well as biological sampling systems that can compile microbial material from the high altitudes of the thermosphere. During the August 2013 rocket flight the team had a successful impact detection performed by piezoelectric sensors coated with nanodiamonds, a novel nanolayer capable of withstanding the harsh environments of the outer layers of our atmosphere. This years piezoelectric sensors will also be covered with another well-known durable film, graphene, intended to provide protection. The experiment also involves particle collection by means of a Polymide Aerogel (PA) developed and supplied by NASA Glenn Research Center. This year's sampling during flight will be achieved by incorporating an Organic Polymer Collecting Tape (OPCT) combined with the PA, which will enable the capture of microbial material and micrometeorites. A key aspect and main concern of this mission is the avoidance of terrestrial contamination, since our goal is to obtain pristine samples of altitudes between 70km and 160 km. The results retrieved will offer fundamental evidence to the renowned Panspermia Theory. The samples collected will be analyzed in UPR-RP's Nanotechnology and Bioinformatics laboratories for characterization of microbial material using genomics approaches, which will allow the determination of the specific origin of the captured biomaterial. In addition, tests will be carried out to determine the survival rate of microorganisms in extreme conditions such as outer space. Collection of chondritic micrometeorites from space will allow characterization of their organic component without terrestrial contamination. The combination of all data collected delivers insightful information as to the quantity and nature of organic compounds delivered to the early Earth, the building blocks of life.

**ME29**

CREATING AN UNDERGRADUATE ASTROBIOLOGY COURSE FOR NON-SCIENCE MAJOR STUDENTS

PATRICK LATHROP *Marist College.*

# WA. EVOLUTIONARY BIOLOGY

## WEDNESDAY, JULY 30, 2014 – 9:00 A.M.

**Chair: KRISTIN COARI, Rensselaer Polytechnic Institute**

**WA00** **9:00**

WARM-UP TALK

KRISTIN COARI, *Rensselaer Polytechnic Institute.*

**WA01** **9:30**

FOLDING OF ANCIENT RIBOSOMAL RNA UNDER EARLY EARTH CONDITIONS

TIMOTHY K. LENZ, NICK V. HUD, and LOREN DEAN WILLIAMS, *Georgia Institute of Technology.*

RNA-cation interactions are crucial for the folding of large, globular RNA structures, as cations allow negatively-charged phosphate groups to pack closely together. In modern biology, $Mg^{2+}$ is the divalent cation most commonly found interacting with RNA, but recent reports suggest that Fe(II) may have held a more prominent role in the proposed "RNA world". We are exploring the interactions between Fe(II) and a model resurrected ribosomal RNA in order to better understand the folding of large RNAs under simulated early earth conditions. The ribosome is universal to modern biology, and likely fostered a transition from an RNA-centric biology to a protein-based biology well before the last universal common ancestor. Comprehending the folding of the ribosome's RNA components is crucial to understanding the emergence of complex life on earth. We have used chemical footprinting techniques to provide single-nucleotide resolution data on the structure of ribosomal RNA under plausible early earth conditions.

**WA02** **9:45**

VARIATION IN EVOLUTIONARY RATE MODELS IN PROKARYOTES

ANAIS BROWN and FABIA BATTISTUZZI, *Oakland University.*

A chronological framework of life is fundamental to reconstruct the major evolutionary steps of life's development on Earth; from an astrobiological perspective, this can be used to determine unique identifiers for biological processes on other planets. However, while the estimation of timetrees in phylogenetic studies has increased due to improved understanding of evolutionary mechanisms, many questions remain on their accuracy. In particular, effects of basic assumptions, such as the variation in evolutionary rate among branches of phylogeny, need to be further investigated to reduce biases during the time estimation process.

Materials and Methods: We investigated the fit of branch-specific evolutionary rates to autocorrelated (AR) and uncorrelated (RR) rate models using class population and phylum level phylogenies of prokaryotes. Rates were obtained using a model-free method (RelTime) and compared to estimates obtained with another commonly used molecular clock method (MCMCTree) that requires prior rate model assumptions.

Results: We find that rate distributions between prokaryote classes show variable rate change throughout the phylogeny, with no preference for fast or slow rates in specific groups; however, faster rates do seem to accumulate on tip branches. Additionally, we find that rate changes among branches do not follow either of the two commonly used models (AR or RR), suggesting a need for caution when using these assumptions in divergence time estimations. Based on these results, we encourage the use of more straightforward molecular clock methods in order to reduce assumptions. Promotion and development of bioinformatics tools and increased molecular data are allowing for large-scale analyses of large time periods, and more reliable methods for rate and time measurement.

**WA03** **10:00**

INFORMATION HIEARCHIES OF COUPLED LOGISTIC MAPS AS A PROXY FOR EVOLUTIONARY TRANSITIONS

RYAN BROSCH, *Arizona State University.*

Interacting polymers are modeled as a network of coupled logistic maps to study the transition from prebiotic to biotic chemistry. Coupling is done through a tunable global interaction topology. Non-trivial collective behavior is found in discrete time (n+1) vs. (n) return maps between individual polymer populations and between populations and the mean field. It is postulated that information exchange drives monomer to trivial (non-living) polymer to non-trivial (living) polymer transitions. Additional research needed to measure transfer entropy and quantify information exchange.

**WA04** **10:15**

MATHEMATICAL MODEL OF EVOLUTION OF COMPLEXITY

F. JAFARPOUR and N. GOLDENFELD, *University of Illinois at Urbana-Champaign.*

We propose a mathematical model to study the evolution of complexity independent of the medium or chemistry in which it materializes. In this model, we replace most elementary building blocks of chemistry, i.e. molecules, with the abstract concept of agents, and the interaction of these molecules with action of these agents on each other that in return can produce new type of agents. To mathematically model these agents, we can think of each agent as a function. However, the inputs and outputs of these functions are agents that are functions themselves. We hypothesize that this self-referential property is responsible for the open ended growth of complexity and novelty generation in biological systems. To capture this property, we are designing a very simple programming language that is a pure metaprogramming language for itself. Then in our system, each agent will be a program in this language. At every time step, each program attempts to run with its neighbors as inputs, and if terminates successfully, the inputs will be replaced by the resulting program. The goal of this project is to study the possibility of the emergence of evolution of complexity from a dynamical system with the above property starting with an initial condition consisting of only simple objects. If the resulting language is Turing complete, at least every deterministic dynamical system can be modeled by a particular set of programs and a set of rules on the order and frequency of action of those programs on each other. These rules can be based on space-dependent parameters playing the role environmental factors. This establishes a theoretical framework to study the possibility and the conditions under which those dynamical systems cross the inanimate-living boundary.

**WA05** **10:30**

INFRARED SPECTRAL INVESTIGATIONS OF UV IRRADIATED NUCLEOBASES ADSORBED ON MINERAL SURFACES

TERESA FORNARO, *Scuola Normale Superiore of Pisa*; JOHN BRUCATO, *INAF-Astrophysical Observatory of Arcetri*; MALGORZATA BICZYSKO, *CNR-Institute of Chemistry of Organometallic Compounds*; and VINCENZO BARONE, *Scuola Normale Superiore Di Pisa.*

Spectroscopic studies of the effects of UV radiation on biomolecules such as nucleobases in heterogeneous environments are particularly relevant in prebiotic chemistry to unravel the role of minerals in the transformation/preservation of biomolecules in abiotic environments. Studies on the photodegradation of biomolecules adsorbed on minerals have applications also in the life detection context to identify potential biomarkers for future space mission and hence to develop suitable sample-extraction protocols for bioanalytical instruments. Moreover, the characterization of the spectroscopic features of biomolecules-mineral complexes provides a support in remote sensing spectroscopy for detecting organic compounds on planetary surfaces or cometary grains and asteroid surfaces.

In particular, nucleobases are prebiotically relevant molecules to investigate. It is believed that nucleobases might have played a critical role at the dawn of life due to their photoprotective properties. Indeed, several studies on the photodynamics of nucleobases suggest that their structure could have been naturally selected for the ability to dissipate electronic energy through ultrafast photophysical decay.

In this context we will present the results of the infrared spectral analysis of nucleobases adsorbed on magnesium oxide and forsterite minerals irradiated with UV light. Due to the great variety of interactions between the adsorbate and the surface and to complex environmental factors, the results of experimental spectroscopic studies on these kinds of systems are difficult to interpret. Indeed, the intermolecular interactions may deeply influence the vibrational frequencies of the isolated molecules and misleading assignments based on gas-phase data might occur. Therefore a strong synergy between experimental and computational studies is often indispensable for accurate spectroscopic assignments. For this reason we will present some results obtained in the development of a general, reliable and effective computational protocol for analyzing infrared spectra of nucleic acid bases - solid-support complexes.

# WB. LARGE BIOMOLECULES AND THEIR INTERACTION WITH RADIATION AND ENERGETIC PARTICLES

### WEDNESDAY, JULY 30, 2014 – 11:45 A.M.

**Chair: KRISTIN COARI, Rensselaer Polytechnic Institute**

**WB01** **11:45**

NUCLEOBASE PHOSPHORYLATION BY A KINASE RIBOZYME

RAGHAV R. POUDYAL, PHUONG DM NGUYEN, MACKENZIE K. CALLAWAY, and DONALD H. BURKE, *University of Missouri.*

The RNA world hypothesis posits that Ribonucleic Acids (RNA) served as the repository for genetic material and as catalysts during the early evolution of life. In vitro selection of functional nucleic acids has identified multiple kinase ribozymes. All previously published kinase ribozymes phosphorylate either the 5′OH or 2′OH of the RNA backbone, although little else is known about the catalytic mechanisms utilized by most of these ribozymes. The ribose 2′OH is important for many functional RNA molecules for hydrogen bonding, metal ion coordination and self-cleavage. To understand the role of 2′OH in artificial ribozyme 1.140, we uniformly substituted all A, C, G or U nucleotides with 2′F nucleotide analogs, yielding four 2′F-substituted ribozyme constructs. Previous work showed that activity of the all-ribose ribozyme was stimulated by higher pH. The pH dependence of the 2′F- substituted ribozymes was indistinguishable from that of the all-ribose ribozyme. Thus, pH dependence is not related to the deprotonation of 2′OH, as 2′F substituted ribozymes lack 2′OHs. To study the phosphorylated product in more detail, we separated the catalytic and substrate functions into individual polynucleotide chains. Surprisingly, both RNA and DNA substrate strands were phosphorylated by the ribozyme-even though DNA lacks the 2′OH that serves as phosphoryl acceptor in all other known kinase ribozymesestablishing the nucleobase of G2 as the phosphoryl acceptor. In modern metabolism, nucleobase phosphorylation is catalyzed by protein kinases during nucleotide biosynthesis; study of this ribozyme could help us understand mechanisms utilized by kinase ribozymes to catalyze early biosynthetic reactions.

**WB02** **12:00**

CONTROLLING GENE EXPRESSION IN AN RNA WORLD BY mRNA PHOSPHORYLATION

RAGHAV R. POUDYAL, MACKENZIE K. CALLAWAY, and DONALD H. BURKE, *University of Missouri*.

The RNA world hypothesis posits that Ribonucleic Acids (RNA) served as the repository for genetic material and as catalysts during the early evolution of life. Although many RNA enzymes (Ribozymes) with phosphoryl transfer activity (kinases) have been artificially selected from random pools of RNA, but their mode of utilization in the context of RNA world largely remains unexplored. In this study we explore RNA nucleobase phosphorylation by a kinase ribozyme, a chemical modification that could potentially regulate gene expression.

Covalent modifications can have dramatic impact on RNA stability, splicing, degradation and its suitability as a template for replication or translation. Modifications of the backbone or nucleobase of mRNA can thus be an attractive target for artificial gene regulation. Our lab recently discovered a synthetic RNA enzyme that directly phosphorylates the nucleobase of an RNA chain. Initially selected as a self-phosphorylating ribozyme, we show here that it can be dissected into a separate substrate and catalytic strands such that annealed to formed the active ribozyme complex, thereby phosphorylating the substrate strand. The ribozyme can be engineered to phosphorylate novel polynucleotide targets that contain a GGA triplet by changing the internal guide sequence (IGS) of the ribozyme that recognizes the substrate. We used this approach to phosphorylate several 22nt DNA oligonucleotides representing segments of Enhanced Green Fluorescent Protein (eGFP) mRNA using suitably programmed ribozymes. Future studies could potentially reveal a new mechanism of controlling gene expression by Ribozymes through mRNA phosphorylation.

**WB03** **12:15**

REACTIVE OXYGEN SPECIES ARE REQUIRED FOR ENVIRONMENTAL-STRESS INDUCED MUTATIONS

JM MOORE, PC THORNTON, SM ROSENBERG, and PJ HASTINGS, *Baylor College of Medicine.*

Determining the influence that environmental conditions have on mutation rates leads to a better understanding of the mechanisms that shape evolution. To investigate these effects we utilized a well-characterized system that selects for starvation-stress induced mutants in Escherichia coli. Our lab has shown that, through the induction of stress responses, starving E. coli cells switch from high fidelity DNA double-strand break (DSB) repair to mutagenic error-prone repair pathways that result in transiently increased mutation rates under environmentally stressful conditions. In addition to the formation of a DSB, genetic requirements for mutation formation include three stress responses: 1) the general starvation stress response regulated by RpoS, 2) the unfolded periplasmic protein response regulated by RpoE, and 3) the SOS DNA damage response. Also required are the homologous recombination proteins RecA, RecBCD and RuvC, along with error prone DNA polymerases II, IV, and V. We have recently uncovered a novel requirement for reactive oxygen species (ROS). Both the use of exogenous reducing agents bipyridine and thiourea that scavenge intracellular ROS, and constitutive mutants that overexpress ROS detoxifying enzymes result in a reduction of stress-induced mutation (SIM) frequency. Use of a hyperaccurate ribosomal allele that reduces oxidized protein content has no effect on SIM, meaning that ROS are likely required for the formation of mutagenic DNA lesions. A preliminary line of evidence is that deletion of mutM and mutY, which respectively remove incorporated 8-oxoguanine (the primary oxidative DNA lesion) or a misincorporated adenine opposite of 8-oxoG, increase SIM. Experiments are underway to show more rigorously that ROS are required specifically for the formation of oxidative DNA lesions by overexpressing mutM. Together these data show that the endogenous generation of ROS are required for environmental-stress induced mutation, most probably for the formation of oxidative lesions in DNA.

# WC. EARLY EARTH GEOBIOLOGY

## WEDNESDAY, JULY 30, 2014 – 1:30 P.M.

**Chair: BRADLEY BURCAR, Rensselaer Polytechnic Institute**

**WC00** **1:30**

WARM-UP TALK

BRADLEY BURCAR, *Rensselaer Polytechnic Institute.*

**WC01** **2:00**

PHOTO-INTIATED PRODUCTION OF SELF-ASSEMBLED VESICLES: A PLAUSIBLE ORIGIN OF A PRIMITIVE ENCLOSURE

REBECCA J. RAPF, ELIZABETH C. GRIFFITH, RICHARD K. SHOEMAKER, BARRY K. CARPENTER, and VERONICA VAIDA, *The University of Colorado at Boulder.*

Enclosures are a necessary component of life. The search for the emergence of such structures in the origin of life requires two conditions: the existence and/or synthesis of a prebiotically plausible membrane component and spontaneous self-assembly into a stable enclosed structure despite the challenges of a dilute early ocean environment. Here, photons are used as the energetic driver to prompt reaction forming a double-tailed surfactant from a single-tailed one in the water surface region. Then, as the photochemistry proceeds with no perturbation to the system, spontaneous self-assembly into vesicles occurs. These vesicles were further shown to be temporally stable as well as persistent in the presence of magnesium chloride salt. This work illustrates a simple, prebiotically plausible synthesis of a membrane component in aqueous solution at dilute concentrations using the energy provided by the sun, followed by spontaneous self-assembly into stable vesicles. This contributes to the origin and evolution of membranes in protocell structures.

**WC02** **2:15**

THE GEOBIOLOGY OF HIGH-ARCTIC SULFUR SPRINGS

GRAHAM E. LAU, *The University of Colorado at Boulder.*

Massive sulfur deposits borne from sulfide-rich springs form annually on the surface of glacial ice at Borup Fiord Pass on Ellesmere Island in the Canadian High Arctic. These sulfur deposits are of astrobiological interest because, while it is posited that biologically-induced sulfur minerals may be an important target in the search for evidence of past or present extraterrestrial life, many of the physiological and environmental controls on extracellular sulfur biomineralization and preservation are not yet well known. Past and present research on the sulfurous materials and related microbiology of Borup Fiord Pass, including recent results from a field expedition in June of 2014, will be presented. Furthermore, this talk will center on the use of instrumental methods, such as x-ray and Raman spectroscopies, to probe the chemical nature of materials that have been returned from this remote site in the Arctic.

**WC03** **2:30**

Z-RAY VISION: PRECAMBRIAN MICROFOSSILS AND APPLICATIONS TO ASTROBIOLOGY

KIRA N. LORBER and ANDREW D. CZAJA, *University of Cincinnati.*

Detecting physical or chemical evidence of Precambrian life is challenging due to often poor preservation of microorganisms and the relative paucity of well-preserved sedimentary units of the Precambrian (when life originated) compared with the Phanerozoic Eon (when life became more complex). Fossils of ancient microorganisms (microfossils) can provide keys to addressing some fundamental gaps in the knowledge of the origin and early evolution of life on Earth, and may guide how we search for life on other planets.

Early investigations of Precambrian microfossils were limited by currently available technology and therefore many previously described fossil microbes (including those discovered using surface-dependent techniques and acid extractions) have since been reinterpreted as non-biological features with microfossil-like morphologies and/or modern contaminants. Having "Z-ray vision" (the ability to analyze microfossils along the z-axis within a rock sample) allows a more detailed analysis of microfossil morphology and geochemistry.

Here is reported the presence of $\sim 15 - 20$ $\mu$m-wide filamentous structures, interpreted as probable microfossils, in samples collected from the 2.5-billion-year-old Tsineng Member of the Gamohaan Formation in the South African Kaapvaal Craton. Specimens were initially located using transmitted light microscopy with their biologic morphology confirmed using confocal laser scanning microscopy (CLSM). Additionally, the geochemistry of suspect microfossils was studied using Raman spectroscopy/imagery, demonstrating the structure's carbonaceous character.

Rock-penetrating analytical techniques allow microfossils to be studied in situ, in their original, preserved habitat, thus preventing unnecessary alteration of samples. For example, because both Raman and CLSM can capture in-focus images at a variety of optical planes, non-destructively creating three-dimensional images of points of interest within a sample. Such techniques could potentially be used in situ in a planetary setting or applied to studying samples retrieved from future sample-return missions.

**WC04** **2:45**

GEOCHEMISTRY OF THE 1.4 Ga ROPER GROUP, THE EARLY OCEAN AND LIFE

KEVIN NGUYEN, AMY KELLY, GORDON LOVE, CHUNFANG CAI, MEGAN ROHRSSEN, STEVEN BATES, JEREMY OWENS, and TIMOTHY LYONS, *University of California*.

Understanding the nature of the mid-Proterozoic ocean redox is vital to unraveling the apparent biogeochemical stasis that defines an estimated one-billion-year interval and its relationship to the early evolution of eukaryotic life. The true geochemical nature of this "boring billion" remains poorly constrained, and many of the best data have come from the McArthur basin, Northern Territory, Australia. Specifically, black shales from the Roper Group Formation have emerged as one of the best windows to the mid-Proterozoic ocean. These rocks are well dated, minimally metamorphosed, and lie in the middle of this key interval. In addition, paleogeographic data suggests a relative strong connection to the open ocean; therefore conditions in the Roper basin may reflect the redox state of the broader ocean margin.

This research presents a high-resolution geochemical history captured in the samples from the Roper Group obtained by drill core. We have utilized a multi-geochemical proxy approach, which include a high-resolution elemental concentration and isotopes to access the oxygenation spatial-temporal variability of the mid-Proterozoic. Of additional value, these data provide an essential backdrop for organic geochemical study, specifically the search for early organic molecular record of eukaryotic organisms. This will be one of the first Precambrian biomarker studies performed within a strict inorganic proxy context, allowing us to ascertain the nuances of eukaryotic diversification during this time period.

**WC05** **3:00**

ANAEROBIC METHANE OXIDATION COUPLED TO IRON REDUCTION IN AN ARCHAEAN OCEAN ANALOGUE

BENJAMIN C. REED, THOMAS J. DICHRISTINA, FRANK J. STEWART, DAVID A. FOWLE, SEAN A. CROWE, and JENNIFER B. GLASS, *Georgia Institute of Technology.*

Anaerobic methane oxidation (AOM), regarded as one of the earliest forms of metabolism on Earth, is widespread in modern anoxic ecosystems, with significant implications for global carbon cycling. Microorganisms that couple AOM to reduction of nitrate and sulfate have been discovered, and geochemical data suggests that AOM coupled to Fe(III) reduction (Fe-AOM) is also occurring in marine and freshwater environments. Nitrate and sulfate were largely unavailable in Archaean Earth, while Fe(III) and methane were abundant, suggesting that Fe-AOM may have been an important primitive microbial metabolism. Lake Matano, Indonesia is an Archaean ocean analogue with abundant Fe and methane, and extremely low sulfate and nitrate. Fe-AOM is likely a thermodynamically favorable microbial metabolism in Lake Matano's anoxic, Fe(III)-rich sediments. This work aims to isolate the microbes mediating Fe-AOM from Lake Matano sediments through serial enrichment cultures in minimal media lacking nitrate and sulfate with added methane and Fe(III). 16S amplicon sequencing of sediment inocula revealed a high presence of the Fe(III)-reducing bacterium Geobacter as well as a number of Euryarchaeota implicated in AOM including ANME-1 and 2d and methanogenic Methanosarcinales. After 90 days, three layers of Lake Matano sediments each showed high levels of Fe(III) reduction ($\sim$60 – 90 $\mu$M Fe(II) d-1) in the presence of methane compared to no methane and heat killed controls. The stoichiometry of methane consumption coupled to Fe(III) reduction is currently being evaluated. To gain insights into which microbes or microbial consortia may be mediating this process, 16S rRNA gene sequencing is being performed to quantify how community composition changed over the 90 day incubation. Fluorescent in situ hybridization (FISH) will be used to visualize spatial arrangement of the microbial community. This research will explore alternative microbial pathways for carbon and iron cycling under energy-limiting conditions, present on ancient Earth and other planets.

# WD. ISOTOPIC STUDIES

## WEDNESDAY, JULY 30, 2014 – 3:30 P.M.

**Chair: BRADLEY BURCAR, Rensselaer Polytechnic Institute**

**WD01** **3:30**

METHANOGEN SURVIVAL FOLLOWING EXPOSURE TO LOW PRESSURE

R. L. MICKOL and T. A. KRAL, *University of Arkansas.*

The low surface pressure of Mars is one condition that any extant life at the surface or near sub-surface would need to endure. The average surface pressure of the planet is 7 mbar, which increases very gradually at depth. Methanogens are chemoautotrophs in the domain Archaea, which use $H_2$ and $CO_2$ to produce $CH_4$. These organisms are ideal candidates for life on Mars because they are anaerobic and non-photosynthetic (indicating they could exist in sub-surface environments). Four methanogen species (Methanothermobacter wolfeii, Methanosarcina barkeri, Methanobacterium formicicum, Methanococcus maripaludis) were tested for their ability to survive exposure to pressures between 143 mbar and 6 mbar over six experiments. In each experiment, methanogens were grown in their respective anaerobic growth media and pressurized with 200 kPa $H_2$. Twenty test tubes consisting of five replicates for each of the four species were placed into the Pegasus Planetary Simulation Chamber. The chamber was evacuated to $\sim$1 mbar then filled with 80% $H_2$/20% $CO_2$ gas to $\sim$50 mbar and repeated three times to ensure removal of the atmosphere. The chamber was maintained at the desired pressure between 24 – 33°C for the duration of the experiment. After 1 – 2 days, the tubes were punctured to equilibrate the tubes with the atmosphere. Before the tubes were removed, $CO_2$ gas was added to bring the chamber to atmospheric pressure and the tubes were unpunctured. Following removal, 0.5 mL was transferred from each of the original tubes to a transfer tube containing fresh media, and the transfer tubes were pressurized with 200 kPa $H_2$. All tubes were then kept at the methanogens' respective ideal growth temperatures. Growth was monitored via optical density (600 nm) and methane production measured by a gas chromatograph, both before and after the experiment. All methanogen species displayed survival after exposure to low-pressure.

**WD02** **3:45**

STABLE CARBON ISOTOPE FRACTIONATION BY METHANOGENS GROWING ON DIFFERENT MARS REGOLITH ANALOGUES

NAVITA SINHA and TIMOTHY A. KRAL, *University of Arkansas, Fayetteville, AR.*

Methanogenic archaea, which consume $CO_2$ and $H_2$, and produce methane, have been considered models for possible life forms on Mars for a long time. Isotopic fractionation is one of the methods to differentiate between biogenic and abiogenic sources of methane in the martian atmosphere.

Our goal was to investigate the nature of carbon isotope fractionation of methane by four different species, Methanothermobacter wolfeii, Methanosarcina barkeri, Methanobacterium formicicum, and Methanococcus maripaludis, growing on the same $H_2/CO_2$ substrates, but in different microenvironments such as growth-supporting media or Mars regolith analogues (JSC Mars-1, JSC Mars-2, basalt, and montmorillonite).

These four methanogens were cultured on JSC Mars-1, JSC Mars-2, basalt, montmorillonite, and media. After one month, they were transferred into the same microenvironments to reduce the presence of residual micronutrients from the original cultures. The stable carbon isotope fractionation of methane in the headspace gas of the second transfers was measured by a Piccaro Cavity Ringdown Spectrometer G2201-i isotopic $CO_2/CH_4$ in the University of Arkansas Isotope Lab.

The $\delta^{13}CCH_4$ for M. wolfeii in growth-media demonstrated an average of -51.78 permil, but on JSC Mars-1 and montmorillonite showed more negative fractionation, of about -66.17 permil and -68.41 permil, respectively. We found a similar trend with M. barkeri and M. maripaludis.

M. formicicum in media and JSC Mars-1 demonstrated little or no difference in isotopic values but on montmorillonite, it demonstrated more depleted $\delta^{13}CCH_4$ data. Several factors are responsible for the magnitude of fractionation such as the species of methanogens, hydrogen supply, growth phase, temperature, substrate levels, and the isotopic effects of enzymes involved in biosynthetic pathways of methane production. It is crucial to understand the effect of microenvironments on the isotopic signatures of methane produced by methanogens.

The carbon isotope fractionation of methane by these four methanogens growing on JSC Mars-2 and basalt are in progress.

**WD03** **4:00**

THE CARBON ISOTOPE RECORD AND THE RISE OF OXYGEN

JOSHUA KRISSANSEN-TOTTON and DAVID C. CATLING, *University of Washington.*

Organic and inorganic carbon isotope records reflect the burial of organic carbon over geological timescales. Permanent burial of organic carbon in the crust or mantle oxidizes the surface environment by removing reduced carbon. It is sometimes claimed that both organic and inorganic carbon isotope ratios have remained approximately constant throughout Earth's history, thereby implying that the (fractional) flux of organic carbon burial has remained fixed and cannot be invoked to explain the rise of atmospheric oxygen [e.g., 1, 2]. However, the opposite conclusion has been drawn from the same carbon isotope record [3, 4].

To test these opposing claims, we compiled an updated carbon isotope database and performed a much more rigorous statistical analysis of the carbon isotope records than has been done before. We applied both parametric and non-parametric models to the carbon isotope record to quantify trends and mean-level changes in organic carbon burial with associated uncertainties and confidence levels. These analyses allow us to quantitatively determine whether changes in organic carbon can explain the rise of oxygen. The possible mechanisms that control organic burial are also explored. Understanding these controls informs our understanding of biogenic oxygenation in exoplanet atmospheres.

[1] Schidlowski M. (1988) Nature 333, 313.
[2] Holland H. D. (2009) Geochim. Cosmochim. Acta, 73, 5241-5255.
[3] Des Marais D. (1992) Nature 359, 605.
[4] Bjerrum C. J. & Canfield D. E. (2004) Geochem. Geophys. Geosyst. 5.

**WD04** **4:15**

STABLE ISOTOPES OF PERIGLACIAL PALEOSOLS FROM SOUTH AUSTRALIA AND IMPLICATIONS FOR THE CRYOGENIAN SNOWBALL EARTH

JEFF T. OSTERHOUT, GREGORY J. RETALLACK, and BROOKLYN N. GOSE, *University of Cincinnati*.

The Reynella Siltstone near Hallett Cove, South Australia contains late Cryogenian outcrops that have been analyzed for evidence supporting the Snowball Earth hypothesis. Previously considered to represent shallow marine methane seeps, they are also thought to have contributed to the following deglaciation event. In combination with petrographic data, new stable isotope analyses of carbonate in the Reynella Siltstone support the reinterpretation of these samples as periglacial paleosols. The observed correlation between $\delta^{13}C_{carb}$ and $\delta^{18}O_{carb}$ is characteristic of soils and paleosols, and this unique pattern is not compatible with known methane seeps (Figure 1). The array of values and covariance of stable isotopic compositions observed in the Reynella Siltstone at Hallett Cove are unknown for any marine rocks or sediments, providing strong evidence against previous marine explanations. The carbonate within these outcrops instead suggests that the late Cryogenian paleoenvironment was host to subaerial, well-drained soils representing frigid floodplains at equatorial latitudes, and therefore contradicts a global oceanic glaciation. Additionally, these findings negate the idea that methane emissions hastened the end of the Marinoan glaciation.

**WD05** **4:30**

INFLUENCE OF UV ACTIVITY ON THE SPECTRAL FINGERPRINTS OF EARTH-LIKE PLANETS AROUND M DWARFS

S. RUGHEIMER, L. KALTENEGGER, A. SEGURA, J. LINSKY, and S. MOHANTY, *Harvard University*.

A wide range of potentially rocky transiting planets in the habitable zone (HZ) have been detected by Kepler as well as ground-based searches. The spectral type of the host star will influence our ability to detect atmospheric features with future space and ground based missions like JWST, GMT and E-ELT. Particularly the active and inactive M stars are a stellar class, covering a wide range of UV luminosity, that will influence the detectability of habitable conditions. The UV emission from a planet's host star dominates the photochemistry and thus the resultant observable spectral features. Using the latest UV spectra obtained by Hubble as well as IUE, we model Earth-like planets orbiting a wide range of M-dwarfs from M0 to M9 for both active and inactive stars. We also model the UV fluxes reaching the ground. These planets are the first ones that should become available to observations with JWST and E-ELT. A wide range of such targets will soon be identified in our Solar Neighborhood by the 2017 TESS mission.