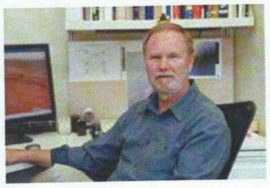
"Astrobiology and Life Beyond Earth"
April 8-9, 2016
Conference Schedule

Conference Description: How life originated on Earth and whether life exists elsewhere in the universe are two of the most fundamental and inspiring unanswered questions in science. Recent discoveries of amino acids and other building blocks of life in comets and asteroids suggest that the ingredients for life are abundant and widely distributed in the solar system. The discovery of water in the atmospheres of planets outside our solar system suggests that there are many places in the universe where life could possibly arise. This conference brings together world-class researchers in the field of Astrobiology to discuss issues related to the search for life in our galaxy as investigated in diverse environments ranging from planets, asteroids, and comets in our own solar system to planets around other stars and the disks of gas and dust from which they formed.

Schedule for Friday, April 8

Mars Session:



9:15-10:15: "Early Mars: Warm, Wet, and Habitable"
Dr. Ray Arvidson
James S. McDonnell Distinguished University Professor
Washington University

Abstract: Analysis of remote sensing and in-situ data collected by Mars orbiters and the rovers Spirit, Opportunity, and Curiosity show that during early Martian history the planet supported rivers, alluvial fans, deltas, lakes, and playas. Steam-charged volcanic explosions were common, with consequent deposition of ash, together with aqueous alteration in hydrothermal systems. Impact events produced craters and liberated ground water, leading to extensive alteration of rim and wall rocks. Many of these ancient environments would have been habitable for microbial systems. The presentation will include an overview of evidence for warm, wet conditions, and focus on a few examples for which orbital and rover-based observations have been be used to generate detailed models for ancient warm, wet, and habitable conditions.

10:45-11:45: "The Martian Environment: The potential for Current Life and Habitability of the Red Planet"

Dr. David Horne
Assistant Teaching Professor
Department of Physics & Astronomy
University of Missouri – St. Louis

Abstract: This presentation will give an overview of the current state of Mars atmospheric and geological research with respect to the search for conditions/environments which may harbor life or evidence of past life on the red planet. This discussion will also assess the probability of Mars successfully supporting a human expedition based on our current state of knowledge on the presence of key volatiles both in the atmosphere, above and below the surface

Exoplanet Session:

12:30-1:30: "The Age of Exoplanets: From First Discoveries to the Search for Living Worlds"

Dr. Avi Mandell
Research Scientist
NASA Goddard Space Flight Center

Abstract: In 1995 a pair of Swiss scientists stumbled onto the first clear evidence of a planet around another star. Since then, the pace of discovery has been nothing short of spectacular. We now know of thousands of planetary systems, many with multiple planets and some that strongly resemble our own Solar System. But we are only now approaching a time when we can begin the search for the Holy Grail of Exoplanets: a planet displaying clear signs of a living biosphere and possibly an intelligent species. In this talk I will take a tour through the highlights of the last twenty years of exoplanet discoveries, and then describe how we are preparing the next generation of telescopes to begin a search for habitable worlds and eventually life among the stars.

1:30-2:30: "The Golden Age of Exoplanet Discovery"

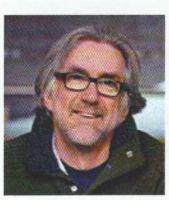
Dr. Peter Plavchan
Assistant Professor
Department of Physics
Missouri State University

Abstract: Over 1800 exoplanets have been confirmed to orbit other stars over the past 25 years. This revolution in our understanding of our Universe is driven by a multitude of advances in data analysis techniques and engineering to achieve unprecedented precision and accuracy. I will provide an overview of the several different methods we use to detect these distant exoplanets, and what we've learned from our discoveries about our Universe. I will conclude with describing exoplanet research projects at Missouri State University.

Schedule for Saturday, April 9

Icy Bodies Session:

9:15-10:15: "Astrobiology of Icy Ocean Worlds: Habitability and Habitancy"



Dr. William McKinnon, Professor
Department of Earth and Planetary Science
Washington University

Abstract: One of the signature results of NASA's exploration of the Outer Solar System has been the realization that icy worlds can and do contain internal oceans, sometimes maintained by tidal heat. The most internally active of these, Europa and Enceladus, have been studied in detail, and their oceans are in direct contact with their respective rocky cores. So not only may such oceans be habitable, but thermodynamic gradients at their ocean/core interfaces provide opportunities for the origin and maintenance of life. Ocean waters vent to space from Enceladus and may do so from Europa; in Enceladus' case *Cassini* has directly sampled "plume" particles and vapor, while Europa is the focus of a new, major NASA mission.

10:45-11:45: "A Woesian View of the Origin and Evolution of Life on Earth"

Dr. Rachel Whitaker, Associate Professor
Microbiology and Institute for Genomic Biology
University of Illinois

Comet Session:

12:30-1:30: "From Comets to Interdisciplinary Science"

Dr. Boncho Bonev, Research Associate
NASA Goddard Space Flight Center
Catholic University of America

Abstract: The emergence of the terrestrial biosphere may be linked to delivery of water and prebiotic organic matter from objects like asteroids, comets, meteorites, and interplanetary dust roughly within the first billion years of Earth's history. A major challenge to astrobiology is to test this possibility and to evaluate the relative contributions from various classes of small bodies. This is a highly interdisciplinary effort, which requires investigating the origin and the reservoirs of water and prebiotic matter in various space environments as well as the transport mechanisms responsible for the hypothesized delivery of the building blocks of life on the young Earth. An important element in this effort is measuring the chemical composition of the volatiles (ices) stored in the nuclei of comets during the formative stages of our solar system. This talk will show how compositional studies of cometary volatiles are placed in context of understanding the evolution of volatile matter in the early solar system and the possibility for exogenous delivery of the building blocks of life to early Earth. The talk will also highlight how an ongoing cutting edge research in cosmogony and astrobiology is successfully integrated into undergraduate education.

1:30-2:30: "The Comet-Disk Connection: Could Comets have Delivered the Ingredients for Life?"

Dr. Erika Gibb
Professor and Chair
Department of Physics & Astronomy
University of Missouri – St. Louis

Abstract: Planets form in the mid-planes of disks of gas and dust (protoplanetary disks) around young stars. However, these regions are hidden from our view. Comets are remnants from the planet formation process in the outer solar system where the giant planets formed. They were gravitationally scattered by the forming gas giant planets into their current reservoir of either the Oort Cloud or Kuiper Belt. The Oort Cloud is a spherical distribution of comets located ~10,000-50,000 AU from the Sun and the Kuiper Belt is a flattened distribution just beyond the orbit of Neptune. Since their formation nearly 4.5 billion years ago, comets have been frozen in their respective reservoirs, preserving a record of the chemical composition and processing of the early solar system. On issue in interpreting comet compositions is that they may be an end product of a variety of processes that took place during the early solar system. Chemical models of protoplanetary disks may be able to provide key insights in interpretation of comet compositions. This talk will discuss how chemical modeling and cometary observations are being used to address key astrobiological questions.

The Comet-Disk Connection: Erika Gibb April 9, 2010

Could comets have delivered the Ingredients for Life?

very primitive prebiotic compounds; ammonia, methane, water

Warm Molecular Layer in Protoplanetary Disk – nice spot protected from radiation where lots of molecules can exist in gaseous form – Could these migrate to the midplane where planets or comets are forming?

– midplane is difficult to directly observe b/c can't see through dense dust

Earth was too close in (too warm) in the protoplanetary disk for water to condense at formation.

We must have gotten our water from comets from the outer solar system, past the ice line, thrown in by the forming gas giants of the outer solar system.

Comets: closest to pristine, retain volatiles, represent midplane volatile abundance in the disk during planet formation

Assumption: comet compositions have not changed much since their formation

Anatomy: nucleus not usually visible, bright coma, dust trail, gas or ion trail)

Comets have a range of levels of composition among those observed some enriched, some depleted, varying by compound/element

~~Some~~ comets may be peices of multiple comets that stuck together, further complicating as parts have different composition

D/H (HDO / H_2O) ratio to try to answer if Earth's water came from Comets

Need more data! Sample more than 10-13 comets! 10^8? comets in Oort cloud Kepler's 2nd?

Other isotopes analysed for origin determination: Heavy Noble Gases

Future Work:

Disks – just beginning to determine molecular component and location to test disk models (ISSI) midplane, not surface

"The Late Veneer"

Comets – midplane abundances during planet formation? Models indicate mixing is necessary to explain formations (crystalline silicates)

Microbial Origin and Evolution of Life on Earth April 9, 2010

Rachel J. Whitaker, Carl R. Woese institute for Genomic Biology

Earth is a Microbial World – few organisms aren't, they live everywhere

they could live without us; we could not live without them

Timeline of early microbe evolution: starts w/ universal common ancestor

Last Eukaryote Archea Common Ancestor:

Highly reduced / no molecular oxygen "LEACA"

ARCHEA distinct from both BACTERIA and EUKARYOTES

Chemotrophic primary productivity without light

Anoxygenic Phototrophic Bacteria (Anoxic Earth Atmosphere (N_2 CO_2 CH_4)

Origin of cyanobacteria ↓ Earth is slowly Oxygenated

Origin of Eukaryotes ↓

Algal Diversity O_2 ↓

Shelly invertebrates

Vasclar plants

Mammals

Humans

} Quickly

How to find oldest life?

Bacteria / Archea

Proposition from Carl Wilkes to Crick: look for "molecular fossils" in DNA

look at Ribosomal RNA – everything has it

Last Universal common Ancestor had everything required for <u>Translation</u>

Transcription, Genome Replication and Chromosomal Structures diverge into LEA~~KA~~CA & Bacteria; Cell shows full divergence among 3 branches

metabolism vastly diverse; Redox couples – harvest energy from difference in ~~energy~~ electron potential, electron transport chain makes a proton gradient

<u>ATPase</u> – makes ADP into ATP, found all over tree of life – everything has it

Earth began at 4.5 bya, last common ancestor at 3.5 bya – 1 billion years to produce 'advanced' cellular structures/processes: ATPase & Translation

Woese C.R: "communal evolution" took place before the Progenote

everything evolved together; possibly symbiosis, chlorophyll, mitochondria or sharing RNA

Darwinian evolution as we think of it is ~~mostly~~ vertical descent which is different

"supermolecular aggregates" with communal sharing of genetic material

(macromolecular)

This communal evolution is still going on today & can be studied

Viruses move genetic material around and affect evolution too... new fronteir for research

Ocean Worlds   Bill McKinnon   April 9, 2010

2012 key "Europa Science Questions" → Journal Astrobiology

Europa, Ganymede, Callisto — all have oceans, all in ~~lots~~ resonant orbits w/ Jupiter
small   Big   Big

→ ocean evidence: tides, repulsion of Jupiter's Magnetic field (salt water → conductivity than ice)

"chaos region"

Enceladus, Titan   protoplanetary disk
tiny   Big   ~~Mean~~ formin/ TW Hydrae from ALMA
satellites planets, secondary disk around growing planet

★ Heat from interior keeps water liquid in outer solar system (Triton, Pluto, Kupier Belt)
"what is chirality?" — me   liquid water THEORETICALLY possible

Red discoloration — ~~????~~ Iron oxide, sulfates, Archae bacteria? ?????

Brown discoloration — leading candidates hydrated sulfates

Eruptions on Europa — pons — possibly brine from interior

Thera & Thrace macula geologically active regions?

Tidal "kneading" contributes to maintanence of liquid ocean layer
possibly enough energy for interior volcanism??

Europa goes through cool phases and warm phases

Chondrites contain lots of stuff including CHNOPS — confirmed on Europa

we assume this kind of stuff must be on Europa too

Enceladus — causes "E ring" of ~~dust~~ around Saturn
water ice, rock on the inside
also in a resonance with the next moon out → liquid, active
tidal forces show ice is free/rocking! Journal Icarus

Plumes! 200 km/second of water & other stuff spewing out

Heating/activity concentrated at South Pole (salty ~~sea~~ ocean beneath ice?)

"Tiger Stripes" interesting feature in this region

characteristics warmth activity plumes   Spectroscopy of plumes includes organics (2008)
concentration factor of 10 "it's a stew down there"

Roth et al 2014, Science → Europa Plumes?? much harder to detect

Future MISSION: Europa "Clipper" — Explore & Assess Habitability

Possible lander? Solar Powered (25% less sunlight) & RADAR antennas for MAPPING OCEAN FLOOR

Comets   Boncho P. Bonev   April 9, 2016

Intro
- to Interdisciplinary Science
- Cutting Edge Research and Education - combine/integrate
- Physics Education 300 year old curriculum
- as if History of Physics is same as Physics
- Argument: Teach science, not history of science

Comets formed early in the history of the solar system

Comets are Diverse - tails, nuclei, COMPOSITION may contain material made even before the birth of the solar system

Hyakutake Hale-Bopp Lemmon

Pan-STARRS

Ion Tail, Dust tail can stretch millions of km

* Those are "fossils" from the early solar system

Comets are different

Spectroscopy for analysis of composition tells us more than just imaging

Cometary Nucleus - mostly water ice & dust
- irregular shape

☆ also contain traces of prebiotic molecules e.g. ammonia (precursor of amino acids)
how are these synthesized in a space environment

solar UV radiation photo dissacociates parent molecules into daughter fragments

gases dust, ions create tail

Q's: - why is the Earth wet?
- How did life originate on Earth?

Hypothesis: Cometary Bombardment of Early Earth (LHB

Mauna Kea Observatory - Hawaii (High, Dry conditions ideal)

Did comets bring water to Earth? (compare comet water w/ Earth water)

prebiotic molecules? maybe microscopic ~~planet~~ cometary dust

Comets likely contributed - but what is the weight? affect a lot/little?

maybe also some water/prebiotics from asteroids, meteorites

examine isotopes of Hydrogen
ratio of normal water to heavy water