Biological and Physical Sciences Research in Space:

NSF's Mathematical & Physical Sciences Directorate

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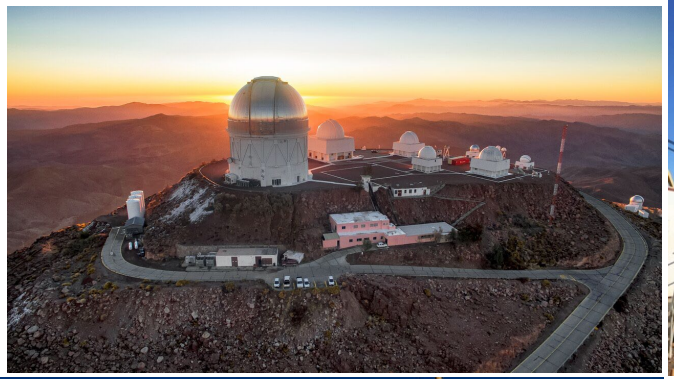
Division of Astronomical Sciences

4 May 2022



MPS: NSF's Directorate for Mathematical and Physical Sciences

- Division of Astronomical Sciences (AST)
- Division of Chemistry (CHE)
- Division of Materials Research (DMR)
- Division of Mathematical Sciences (DMS)
- Division of Physics (PHY)

AST: Division of Astronomical Sciences

- Scientific Overlap with NASA/Science Mission Directorate
  - Astrophysics Division
  - Planetary Sciences
  - Heliophysics
- Recent joint participation in Decadal Surveys for each area
- Scientific Overlap/Partnership with other NSF Divisions
  - Habitable Worlds
  - Space Weather
  - Space Domain Awareness
  - Electromagnetic Spectrum Management
  - Precision Measurement, Data Centers
  - Determination of Atomic/Molecular/Plasma Parameters

AST: Programs and Opportunities

- "Astronomy & Astrophysics Research Grants" program (AAG)
  - Flexible, Responsive, Comprehensive;
  - Must demonstrate astronomical context, and perhaps explain why proposal is not better suited to support from a NASA program
- Advanced Technology and Instrumentation programs
- Access to major facilities
  - Open to all through competitive telescope allocation process
- Coordinated observations common; may support campaigns
  - MultiWavelength, MultiMessenger, Time Domain
- Examples of interagency partnerships
  - NN-Explore (NASA/APD); GONG (NOAA); VLBA (USNO)

NSF Center for Chemical Evolution (CCE, NSF-1504217/1004570)

- CCE is a $40M research center jointly supported by the Center for Chemical Innovation (CCI) Program in the Division of Chemistry at NSF and the Astrobiology Program at NASA;
- CCE aims to understand the **chemical origins of biopolymers**, with the aims of identifying the molecules and processes necessary for the formation of polymers with the ability to evolve function, which led to better understanding of the chemical origins of life;

CHE also supports research in space, directly or indirectly, through core research programs, both theoretical and experimental astrochemistry research and chemical instrument development for space exploration.

Sequence Evolution of Protein-like Molecules in Early-Earth Puddles

Jay G. Forsythe (College of Charleston), Anton S. Petrov, W. Calvin Millar, Sheng-Sheng Yu, Ramanarayanan Krishnamurthy (TSRI), Martha A. Grover, Nicholas V. Hud, and Facundo M. Fernández (Georgia Tech)
NSF-NASA Center for Chemical Evolution [PI: Nick Hud; CHE-1504217]

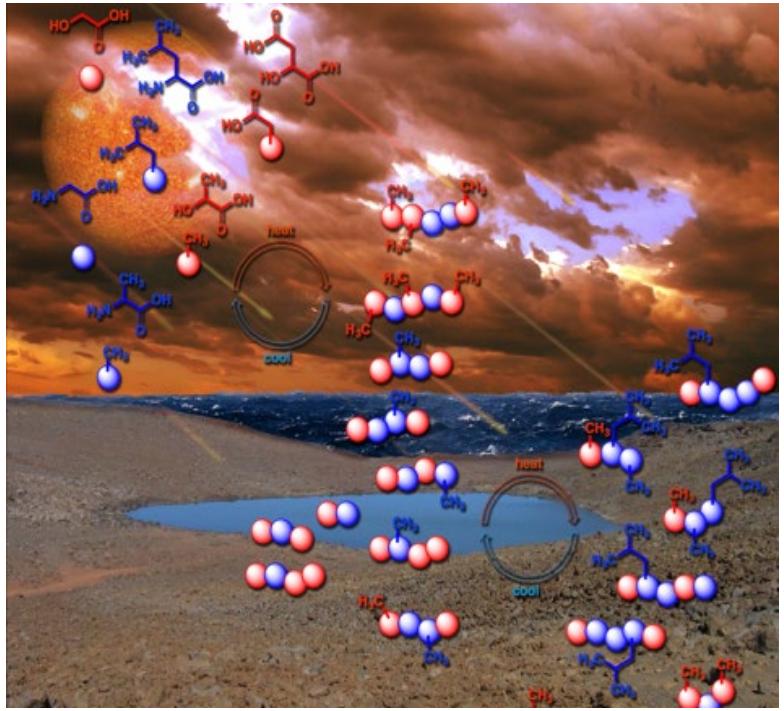


Photo credit: Scripps Research Institute (CA).

Proteins are large molecules used by all life on Earth. It is found that a unique type of peptides –depsipeptides-- likely represent the oldest ancestors of proteins in pools of water on the early Earth.

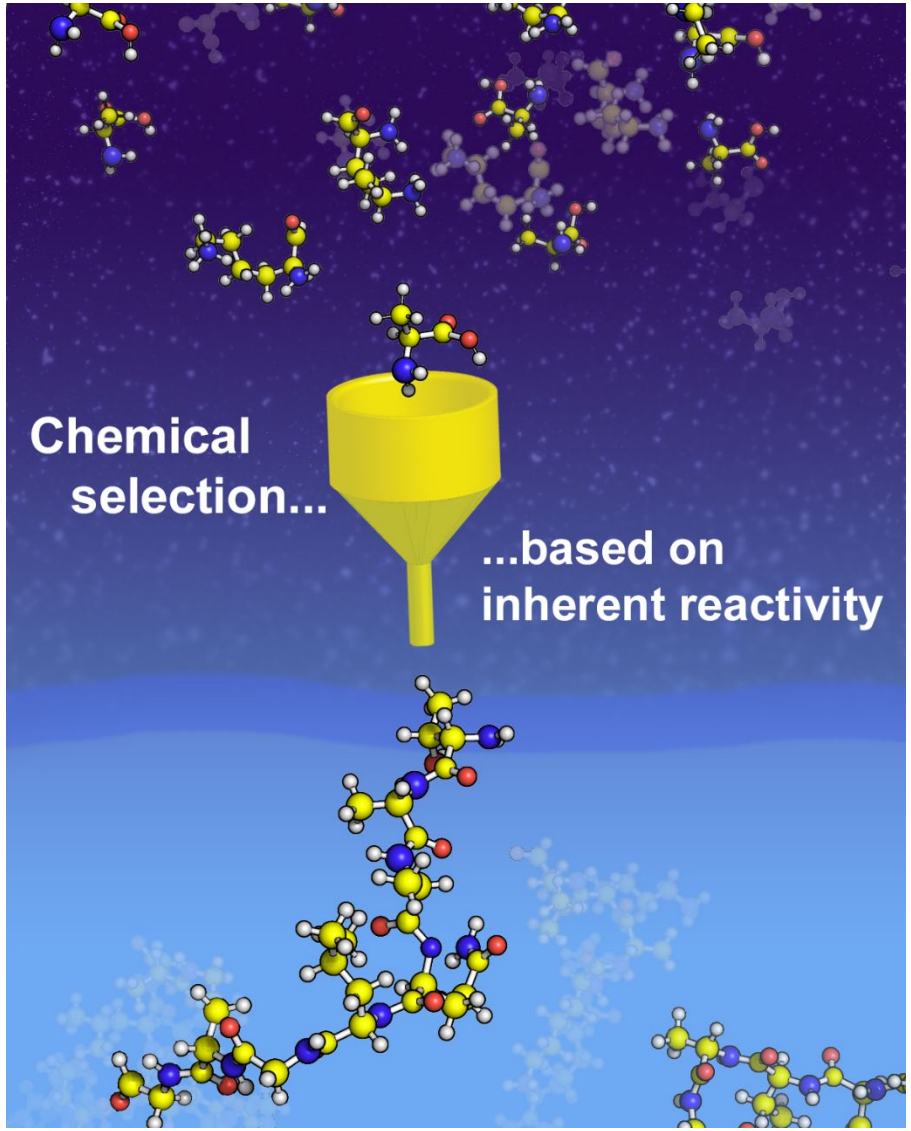
• In this study, the researchers developed a new, power analytical tool to analyze hundreds of different depsipeptide sequences produced in a process mimicking day and night environment of early Earth. Their results suggest that depsipeptides were ubiquitous on the early Earth. (Forsythe et al. *Proc. Natl. Acad. Sci. USA* 2017, 114(34):E7652-E7659).

• In addition to help NASA's search for life on other planets and their moons, research on depsipeptides have multiple uses in other fields. For example, a number of nature-inspired pharmaceuticals and certain drug delivery systems are depsipeptides.

• The new technology developed for this research project may be applied to other fields as well, such as studying peptides related to brain functions and diseases.

Clues to the Prebiotic Selection of Life's Building Blocks

Luke Leman (TSRI) and Loren Dean Williams (Georgia Tech)
NSF-NASA Center for Chemical Evolution [PI: Nick Hud; CHE-1504217]



The NSF-NASA Center for Chemical Evolution investigates plausible pathways for the formation of life's building blocks and informational polymers, such as DNA, RNA, and proteins.

On the prebiotic Earth, there would have been a complex mixture molecules that could react with each other - a 'primordial soup'. How did certain types of molecules come to dominate the landscape of early chemical evolution on the path to life? For example, how were the amino acids used in life today selected during the earliest phases of evolution?

Our study found that certain positively-charged amino acids more readily polymerize into peptides than other amino acids. Intriguingly, the most efficient amino acids were those found in peptides and proteins of living organisms. This finding suggests that certain amino acids were selected during the origin of life based on inherent reactivity advantages over other available amino acids.

Frenkel-Pinter M *et al.* (2019) Selective incorporation of proteinaceous over nonproteinaceous cationic amino acids in model prebiotic oligomerization reactions. *Proc Natl Acad Sci U S A*. 116 (33) 16338-16346

NASA-NSF Cooperation on Complex Plasma Research in Space

- NASA and NSF have had a robust partnership to support US PIs' research on complex plasmas under microgravity in cooperation with international partners

  - Plasma Krystal – 4 (PK-4): joint ESA/DLR – Roscosmos experimental facility, launched 29 October, 2014.
  - Conversations about mutual interest in supporting science investigations on the facility by US PIs began in the spring of 2015.
  - "NASA/NSF Partnership on Science of Dusty Plasmas: Utilizing the PK-4 Facility on board the International Space Station" – Research Announcement released in May 2016 -- a funding opportunity with award duration of up to 4 years.
  - Award announcements made in the spring of 2017 with projects now in extension periods wrapping up their work.

NASA-NSF Cooperation on Complex Plasma Research in Space

National Aeronautics and Space Administration
NASA Headquarters
Space Life and Physical Sciences Research and Applications Division
300 E ST SW
Washington, D.C. 20546-0001

The National Science Foundation
Directorate for Mathematical and Physical Sciences (MPS)
Directorate for Geosciences (GEO)
Office of International Science and Engineering (OISE)
4201 Wilson Blvd
Arlington, VA 22230

Research Opportunities in Fundamental Physics

NASA/NSF Partnership on Science of Dusty Plasmas
Utilizing the PK-4 Facility on board the International Space Station

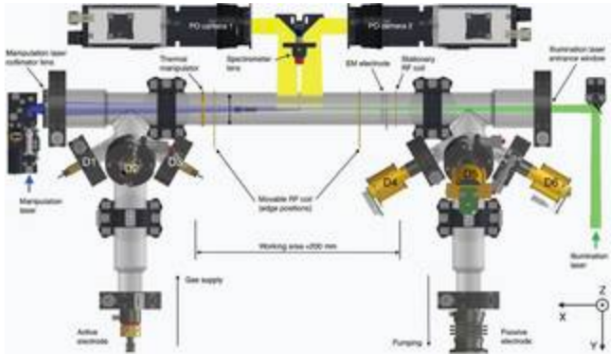
NASA/NSF Research Announcement

Catalog of Federal Domestic Assistance (CFDA) Number: 43.003

NNH16ZTT002N NASA/NSF Research Announcement
Issued: May 18, 2016
Proposals Due: August 19, 2016

NASA and NSF Select 6 Proposals for Dusty Plasma Investigations

NASA's Physical Sciences Research Program and the National Science Foundation (NSF) will fund 6 proposals to investigate dusty plasmas, a state of plasma that contains microparticles in addition to electrons, ions, and neutral gas. Four of the projects will be flight investigations that will be performed under microgravity conditions on the joint ESA (European Space Agency) and the Russian space agency, Roscosmos, Plasma Kristall-4 (PK-4, launched 29 Oct 2014) experimental facility on board the International Space Station. Two of the projects will be ground investigations related to the PK-4 experiments and potential follow-on microgravity experiments in the field of dusty plasma physics.

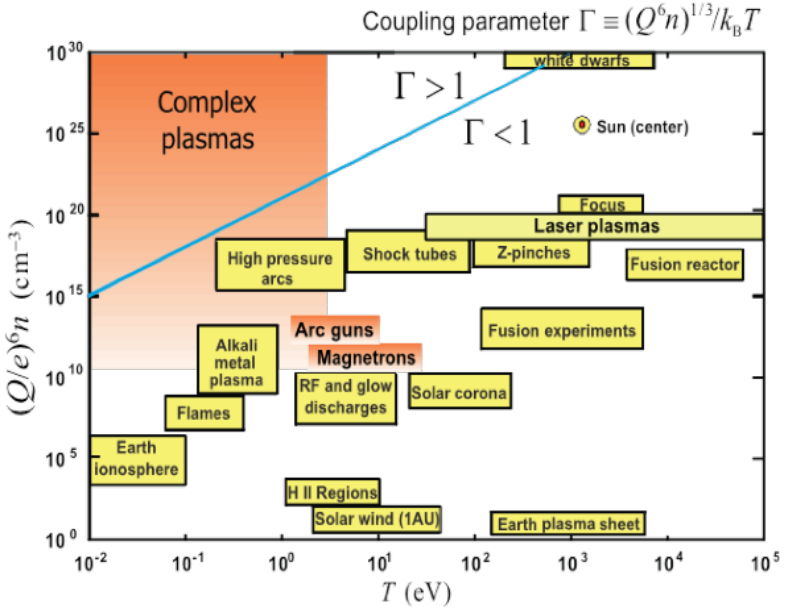


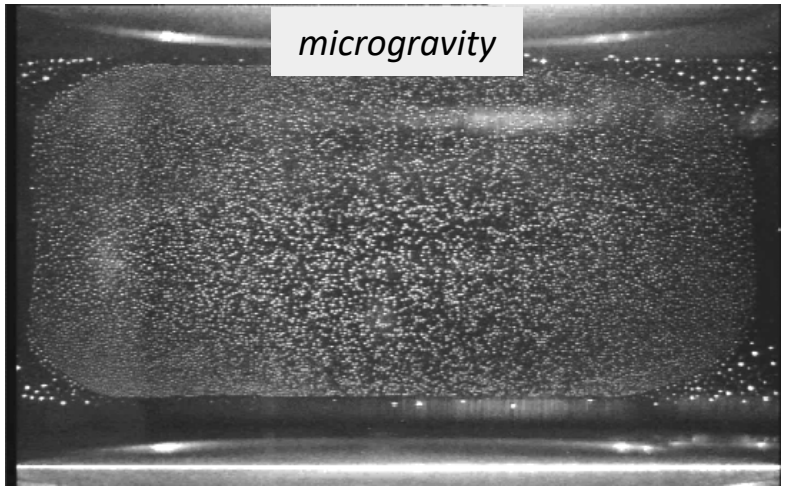
Hardware schematic for the joint ESA-Roscosmos Plasma Kristall-4 (PK-4) facility the selected flight investigations will use to perform their experiments aboard the International Space Station.
Credits: Pustylnik et al. Review of Scientific Instruments 87, 093505 (2016)

See https://www.nasa.gov/feature/nasa-and-nsf-select-6-proposals-for-dusty-plasma-investigations

NASA-NSF Cooperation on Complex Plasma Research in Space

- We are looking forward, with ongoing discussions about future cooperation and potential next generation complex plasma facilities in space
  - DLR (lead), NASA, NSF, and ESA have been supporting a Science Definition Team for COMPACT -- COMplex PlAsma facility, since 2020.
  - An MOU between the parties on future cooperation regarding COMPACT is under development

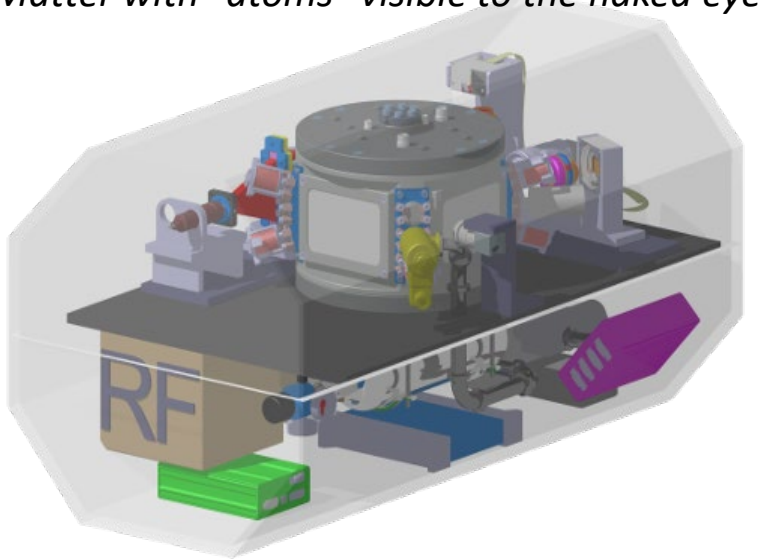




Images courtesy of COMPACT Science Definition Team

COMPACT – COMplex PlAsma faCiliTy

Matter with "atoms" visible to the naked eye



Engineering Research in Microgravity to Benefit Life on Earth

- NSF's partnership with the Center for the Advancement of Science in Space (CASIS) jointly supports engineering research
  - Provides access to a unique microgravity research environment onboard the International Space Station (ISS) National Lab
  - Enables researchers to answer research questions that can't really be addressed elsewhere

Since 2016, NSF has invested $16 million in ~30 projects

Transport Phenomena Research
onboard the ISS to Benefit Life on Earth

- Topics include:
  - Fluid dynamics
  - Particulate and multiphase processes
  - Combustion and fire systems
  - Thermal transport processes
  - Nanoscale interactions

- NSF investment up to $3.6 million in the current solicitation (22-539) for up to 9 awards (up to 4 years and $400K each)

Tissue Engineering and Mechanobiology Research onboard the ISS to Benefit Life on Earth

- Topics include:
  - Models of tissues and organ systems for the development and testing of medical interventions
  - Systems that integrate living and non-living components for improved diagnosis, monitoring, and treatment of disease or injury
  - Advanced biomanufacturing of three-dimensional tissues and organs
  - Multiscale mechanics approaches across molecular, cell, tissue, and organ domains
  - Influence of in vivo mechanical forces on cell and matrix biology of tissues and organs

- NSF investment up to $1.2 million in the current solicitation (22-535) for up to 3 awards (up to 3 years and $400K each)

Launch in Summer 2021

ISS NATIONAL LABORATORY®
CENTER FOR THE ADVANCEMENT OF SCIENCE IN SPACE

Tissue Engineering in Space Could Treat Age-Related Muscle Loss on Earth

AUGUST 9, 2021

A preflight photo of the BioCell bioreactor for housing engineered muscle developed in collaboration with BioServe Space Technologies.

Image courtesy of the Palo Alto Veterans Institute for Research

Joint Support from NSF and CASIS

NSF Support

- Fundamental and translational research
- Preparation of experiments for execution onboard the ISS
- Collaboration with service providers as necessary
- Preliminary analysis to conduct the experiment
- Analysis and interpretation of data
- Broad dissemination of results

CASIS Support

- Assistance in translating ground-based experiments and technologies into an appropriate ISS certified hardware solution
- Costs for translation of the proposed experiments to flight experiments onboard the ISS (via CASIS cooperative agreement with NASA)
- Costs for use of existing flight hardware and facilities of commercial implementation partners