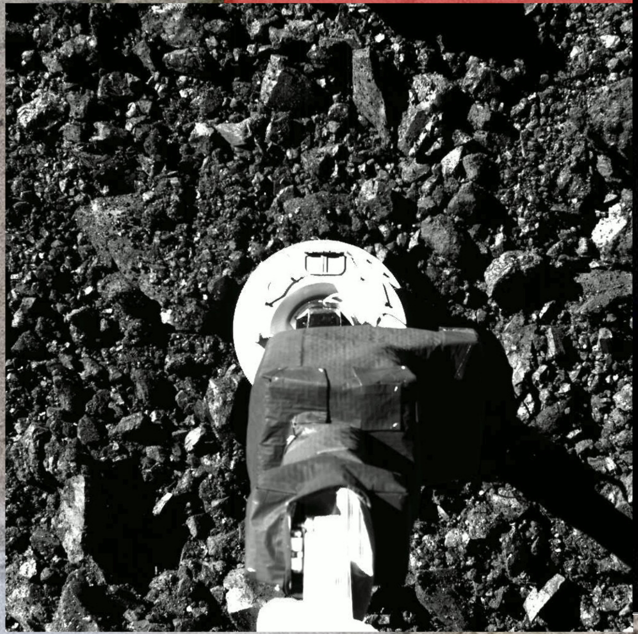
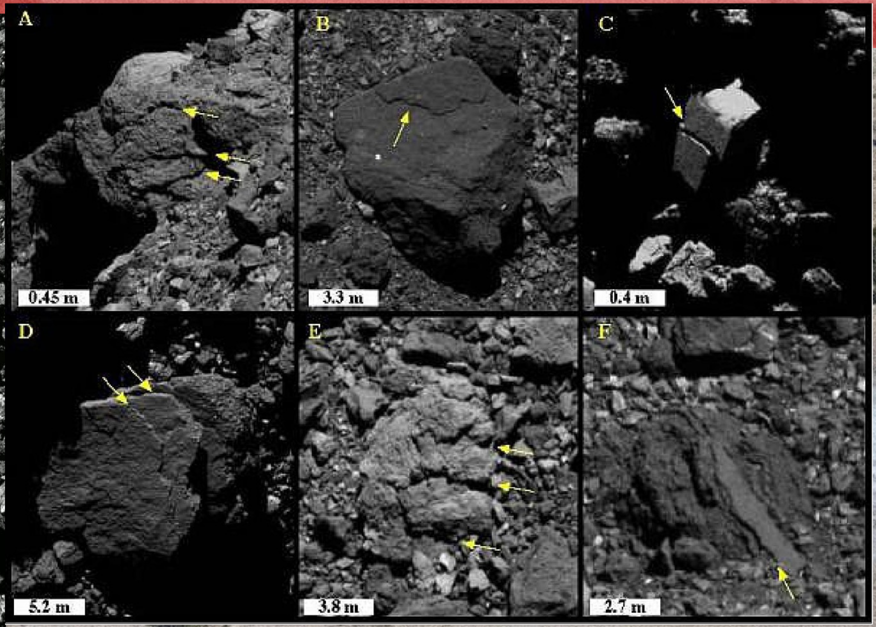
NASA Astrobiology Program Update

David Grinspoon
Senior Scientist for Astrobiology Strategy
ExoPAG
January 7, 2024

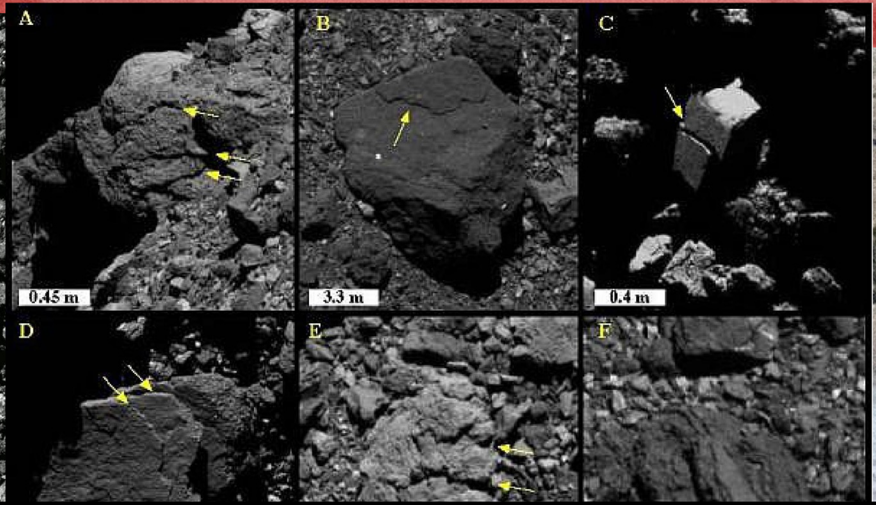
An exciting time for Astrobiology!

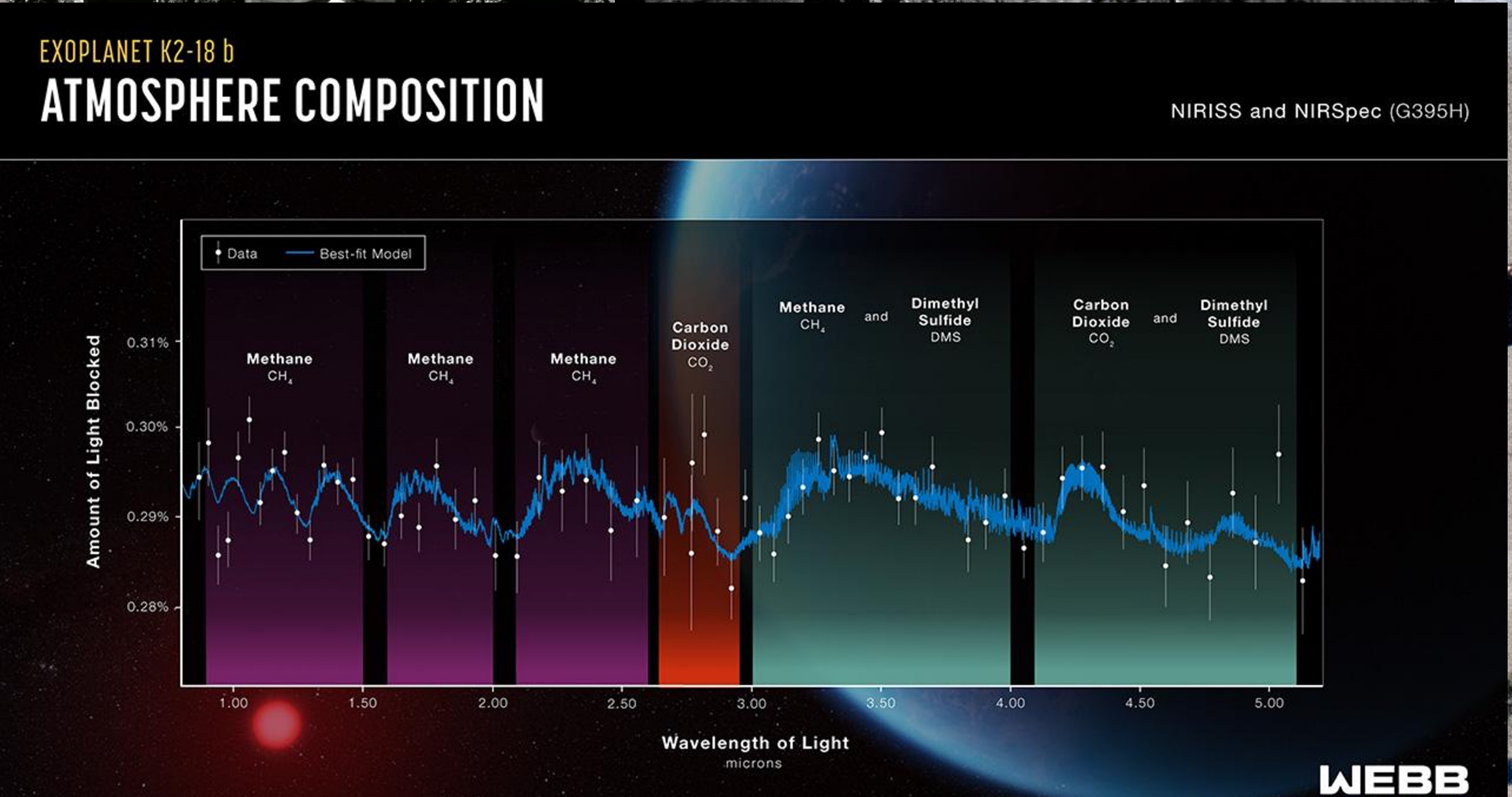
An exciting time for Astrobiology!



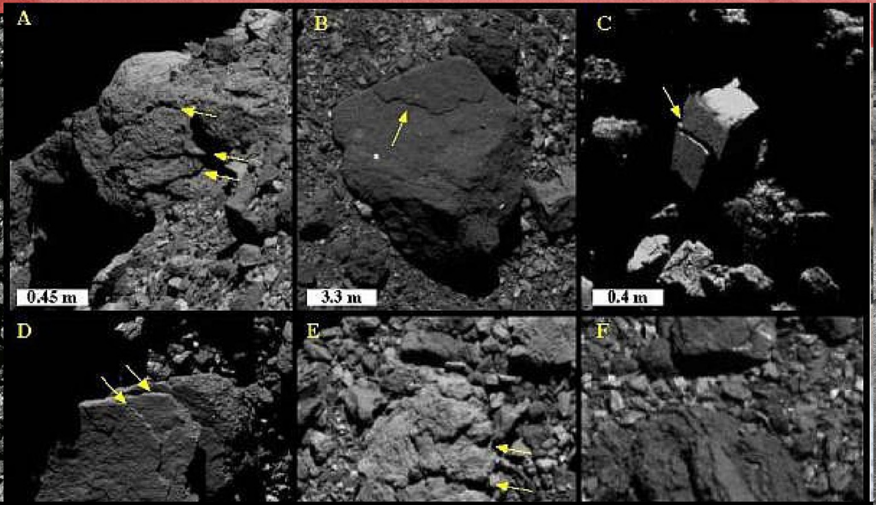


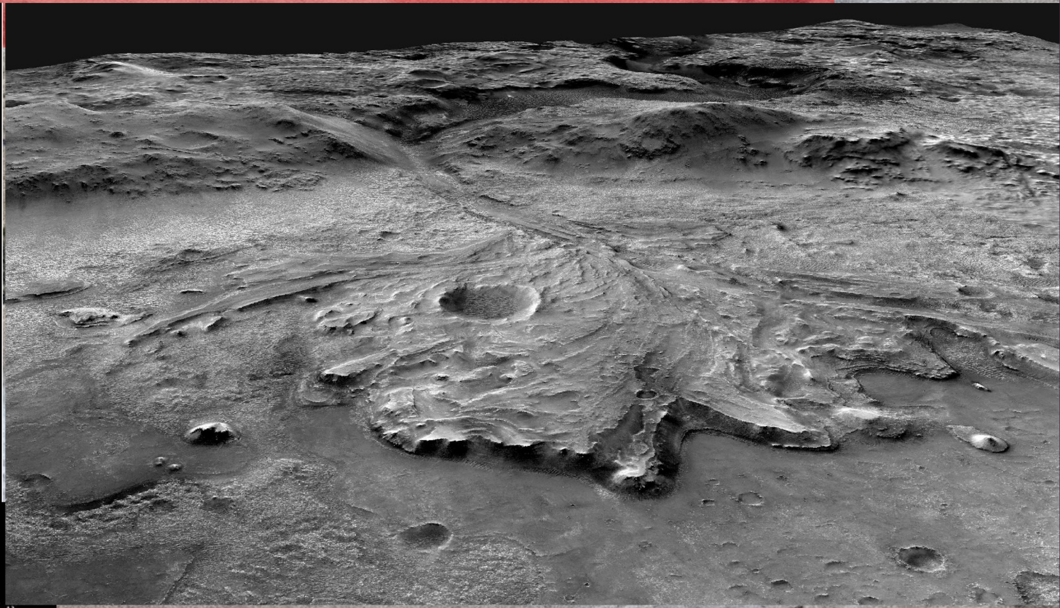
An exciting time for Astrobiology!

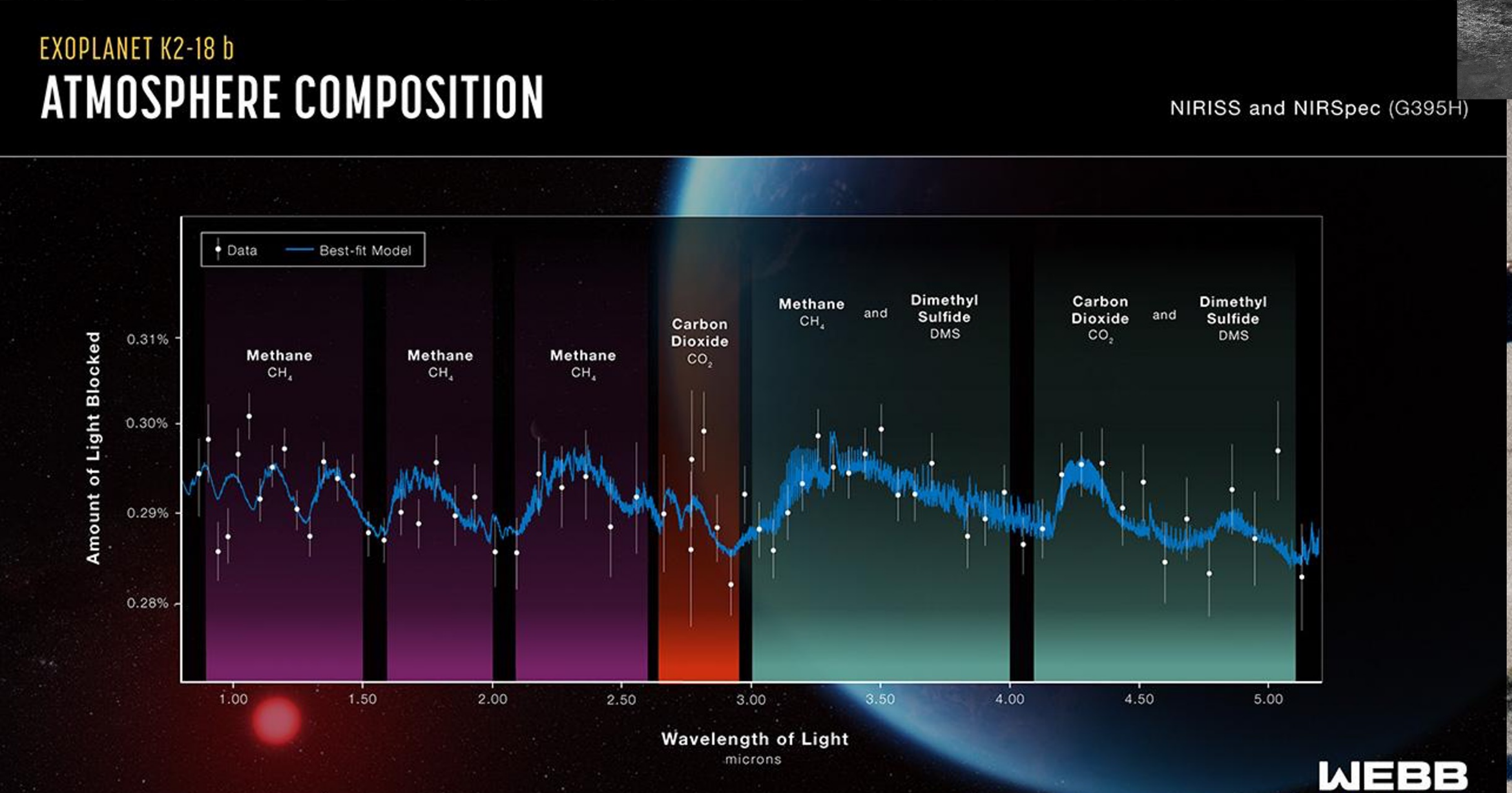




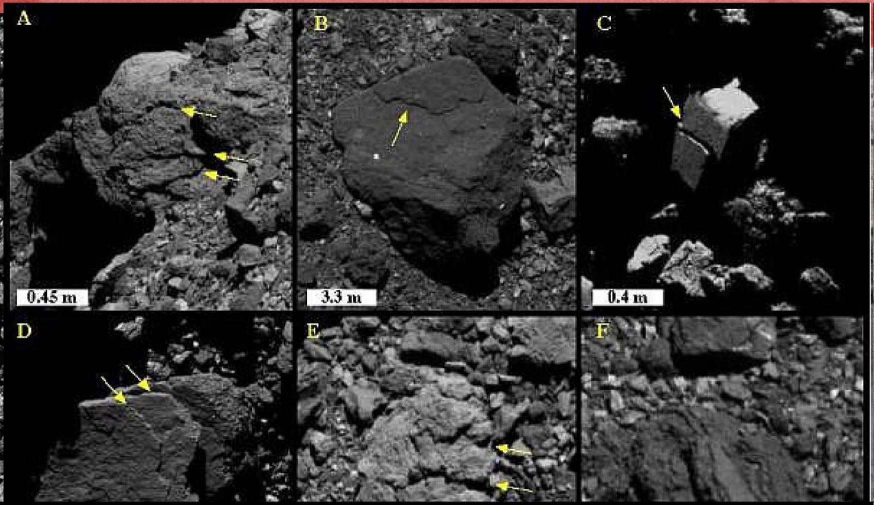
An exciting time for Astrobiology!

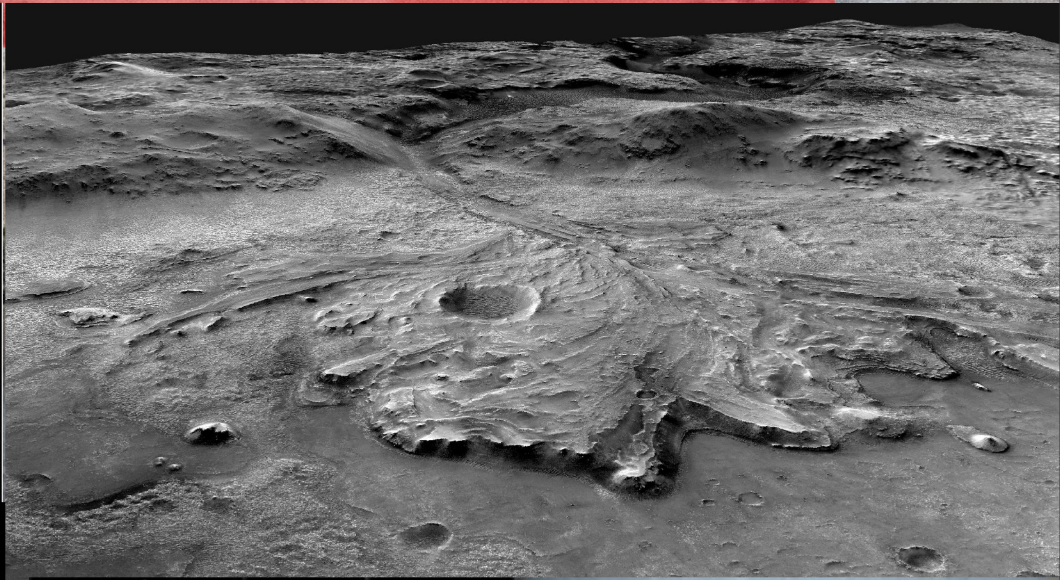


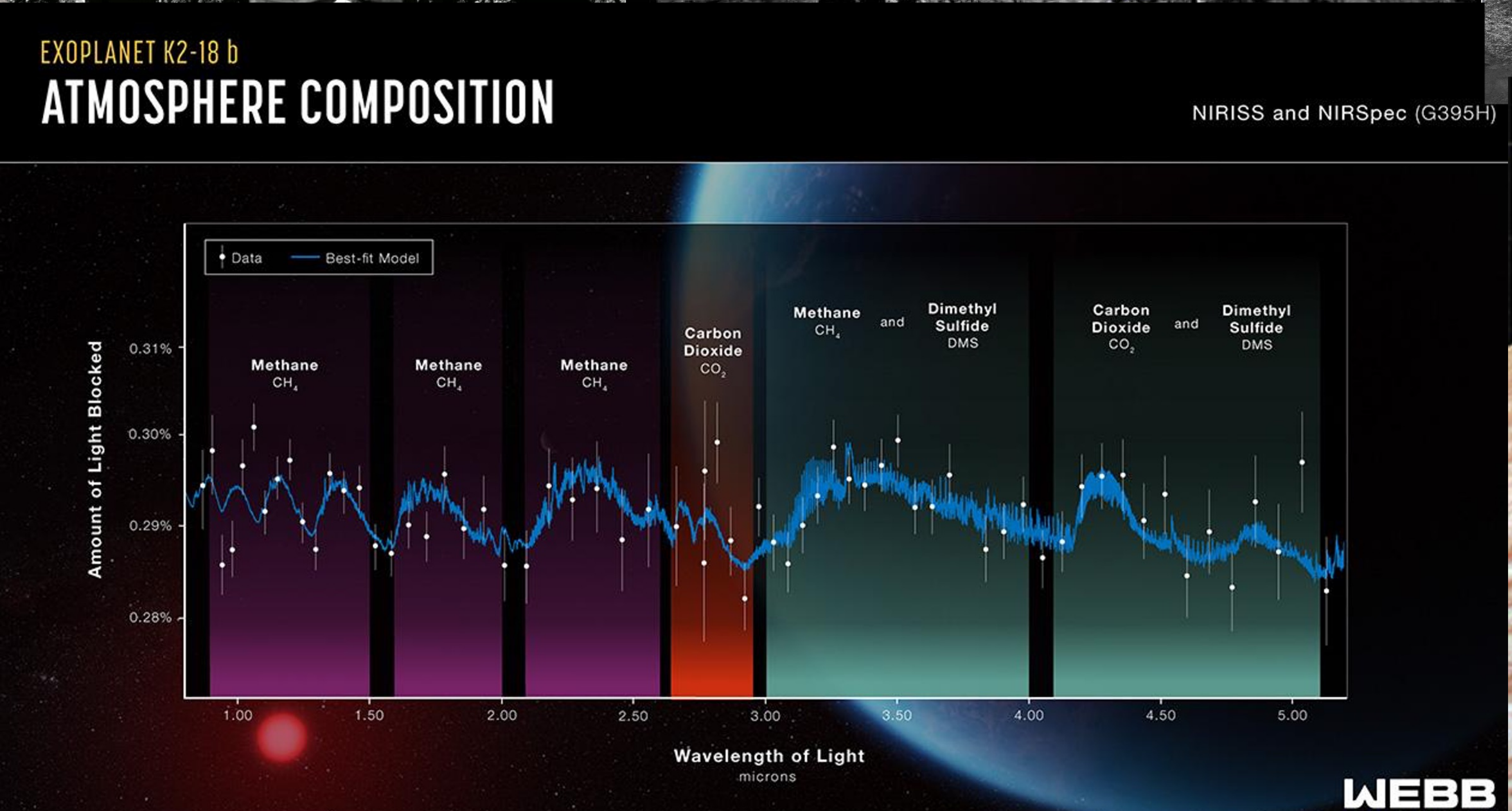


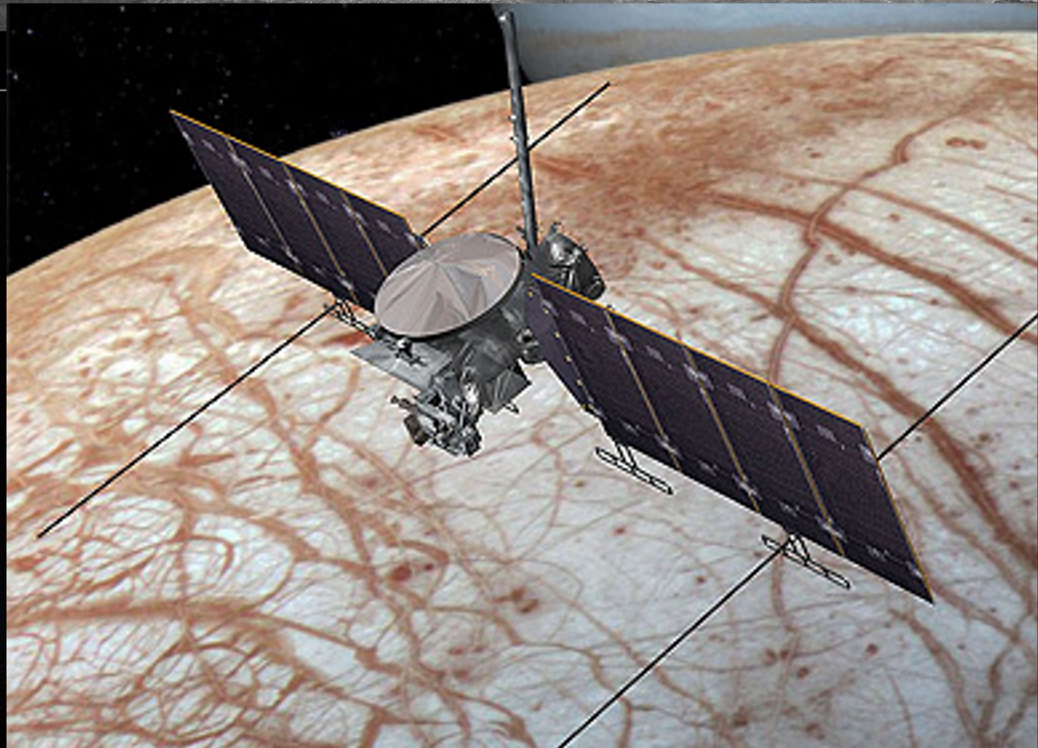


An exciting time for Astrobiology!









New AB program leadership

Senior Scientist for Astrobiology Strategy (David Grinspoon):

“Up and out”
Expand the astrobiology program within NASA and beyond.

Program Scientist for Astrobiology (Lindsay Hays)

“Down and in”
Manage existing research programs.

Deputy Program Scientist for Astrobiology (Becky McCauley Rench)

Research Coordination Networks

The Nexus for Exoplanet System Science

nexss.info

To investigate the diversity of exoplanets and to learn how their history, geology, and climate interact to create the conditions for life, dedicated to the study of planetary habitability.

From Early Cells to Multicellularity

lifercn.org

To understand how life and the Earth coevolved, focused on key innovations in the transition from early cells to multicellularity.

The Network for Life Detection

nfold.org

To advance life detection strategy and capability and catalyze interdisciplinary collaborations for research and technology objectives.

The Network for Ocean Worlds

oceanworlds.space

To advance comparative studies to characterize Earth and other ocean worlds across their interiors, oceans, and cryospheres; to investigate their habitability; to search for biosignatures; and to understand life—in relevant ocean world analogues and beyond.

Prebiotic Chemistry and Early Earth Environments

prebioticchem.org

Investigate the delivery, synthesis, and fate of small molecules under the conditions of the Early Earth, and the subsequent formation of proto-biological molecules and pathways that lead to systems harboring the potential for life.

NExSS

NASA's Nexus for Exoplanet System Science:

HQ Reps

Mary Voytek (PSD)
Richard Eckman (ESD)
Doug Hudgins (APD)
Jared Leisner (HPD)

Co-Leads

Daniel Apai (U. Arizona)
Dawn Gelino (IPAC/NExScI)
Victoria Meadows (U. Washington)
Shawn Domagal-Goldman (GSFC)

NExSS NASA Postdoc

Jessica Noviello (GSFC)

→ 2023-2024 →

HQ Reps

Hannah Jang-Condell* (APD)
Lindsay Hays (PSD)
Richard Eckman (ESD)
Doug Hudgins (APD)
Jared Leisner (HPD)

Co-Leads

Ofer Cohen (U. Massachusetts, Lowell)
Hilairy Hartnett (Arizona State U.)
Linda Sohl (Columbia/NASA GISS)
Rob Zellem (JPL/Caltech)

NExSS NASA Postdoc (until 2/2024)

Jessica Noviello (GSFC)

NExSS Goals: Achieved by Interdisciplinarity

- **Study planetary habitability and the search for life on exoplanets**

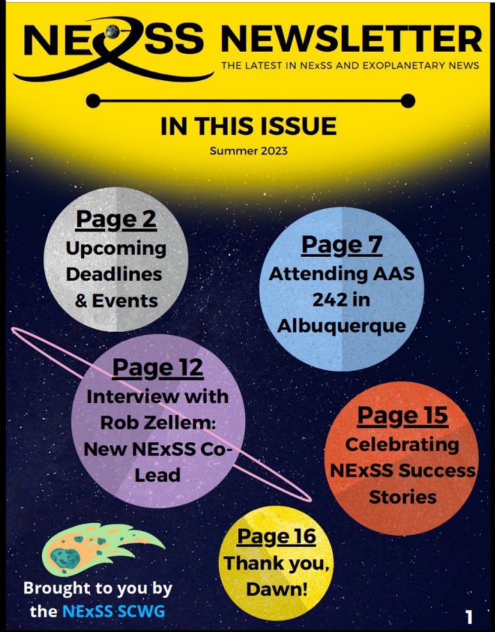
- **Answer fundamental questions related to planet formation,evolution,diversity , habitability, and signs of life**

- **Membership is open to *any* scientists working in NExSS science areas**

NExSS: Bringing the Community Together

NExSS builds community and advances our science with:

- **Interdisciplinary, inter-RCN Workshops and Conferences,** e.g. HabWorlds, Biosignatures, exoplanetary space weather, Technoclimes, EiOBY
- **Collaborative Exoplanet Observing Communities,** e.g., JWST ERS proposals, TRAPPIST-1 JWST Community Initiative, community contributions to Astro2020, OWL 2022 Decadal Surveys
- **Science Working Groups,** e.g. intermodel comparisons, habitability quantification, technosignatures and science communications
- **Quarterly Steering Committee (PI) meetings, Slack Workspace w/ working group/early career channels**
- **NExSS Newsletter, Website,**



CUISINES model intercomparisons

website: nexss.info

The CHAMPs Team

Consortium on Habitability and Atmospheres of M-dwarf Planets

Overarching Science Question

- Can M-dwarf planets support life, and if so, how do we best observe and characterize them?

Four Core Tasks

M-dwarf Planetary Processes

M-dwarf Planetary Atmospheres

M-dwarf Star-Planet Interactions

M-dwarf Exoplanet Observations

Deliverables from one task are used as inputs into the next tasks

JWST observations will yield quantitative constraints that feed back into models

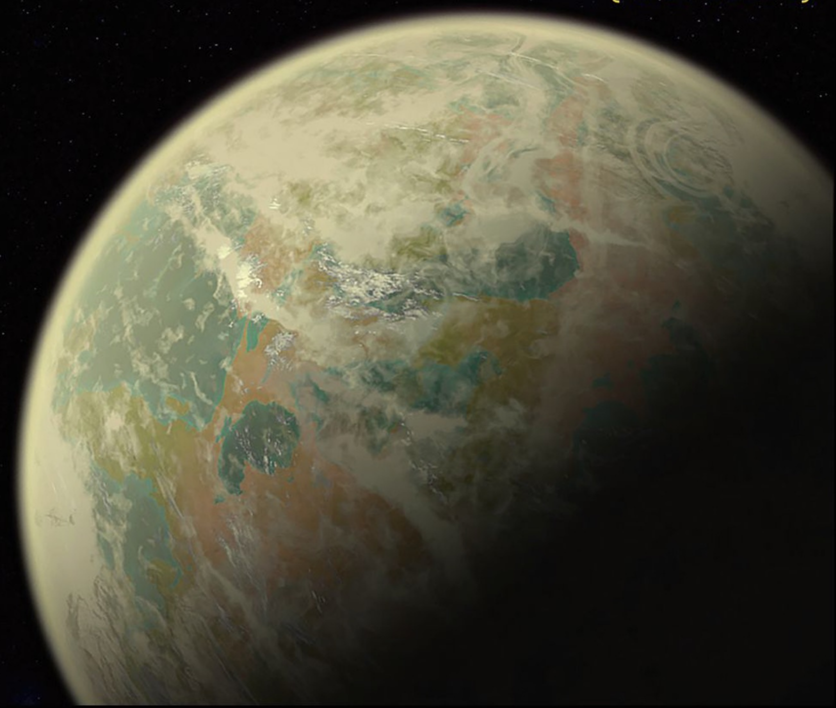
CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN

Strange New Worlds:

Characterizing Nearby M-dwarf Habitable Zone Planets

Program PI
Kevin Stevenson
(Johns Hopkins APL)

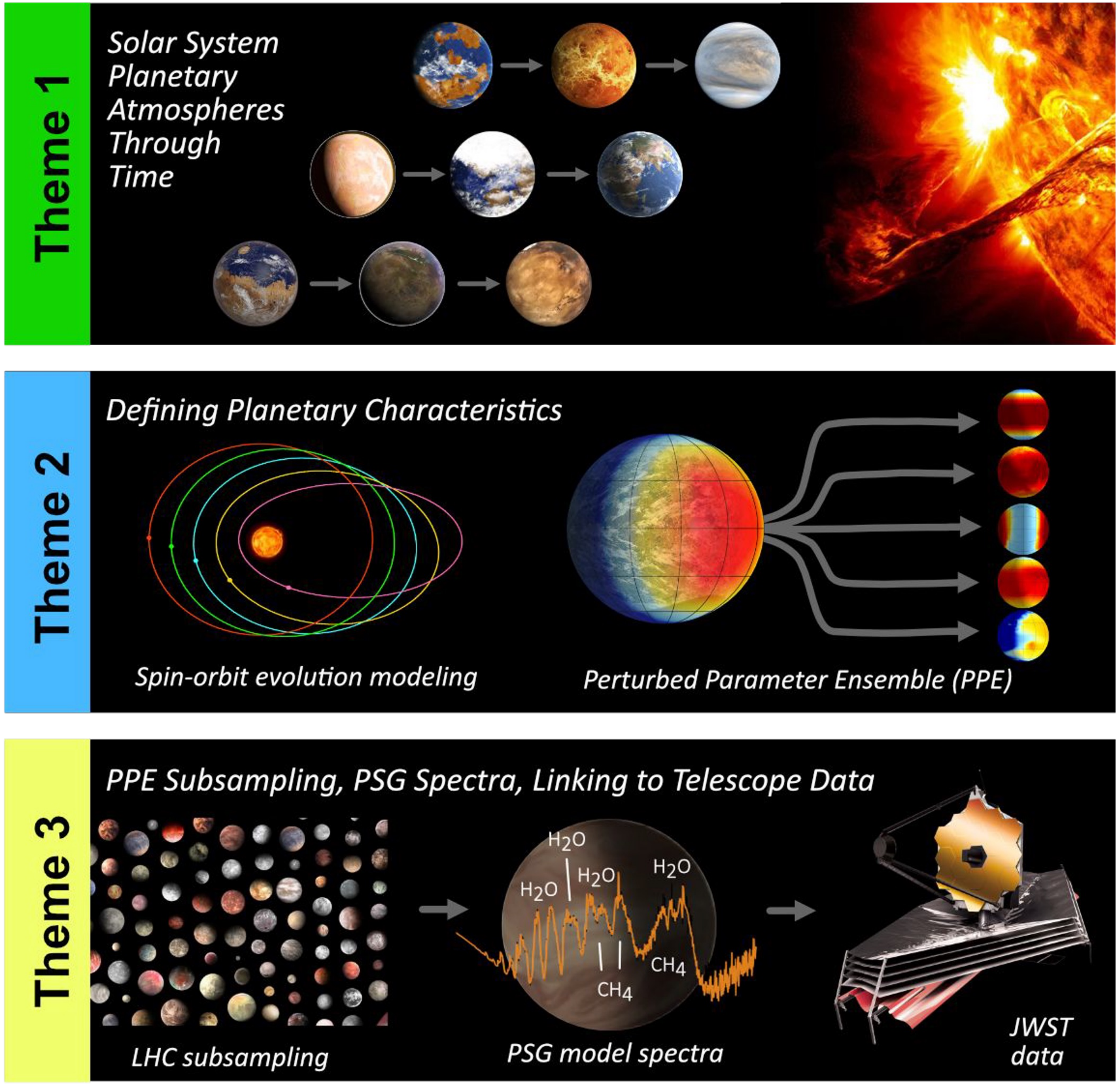
Science PI
Ravi Kopparapu
(NASA GSFC)

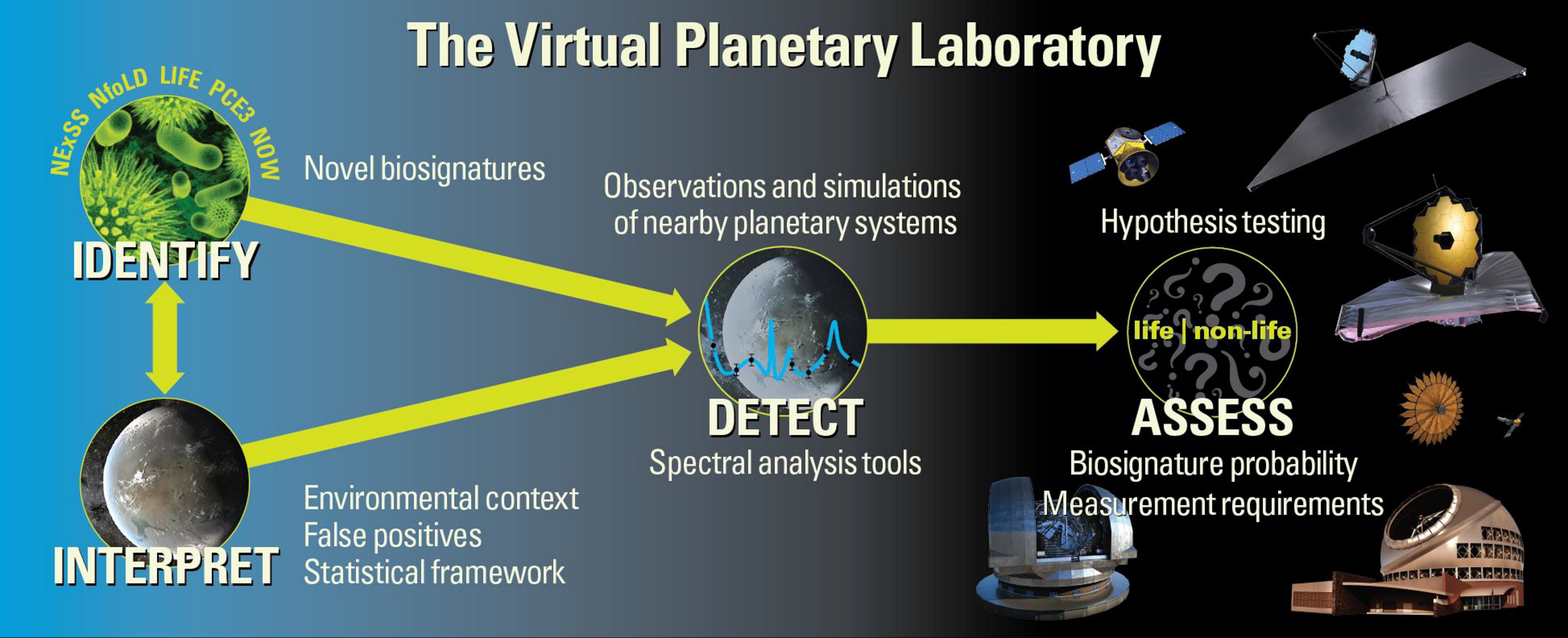


Habitability Space: Exploring a New Frontier via Climate Models & Planetary Statistics

Michael Way

Goddard Institute for Space Studies ROCKE-3D Team





The VPL team focuses on the search for life on exoplanets, and will:

- create a "network of networks" with five RCNs to **identify** novel biosignatures in the context of early Earth environments
- understand environmental context and develop statistical frameworks to **interpret** biosignatures
- obtain JWST observations and simulate observations of planetary systems to **detect** terrestrial planetary characteristics, and
- use simulations and frameworks developed in the **identify**, **interpret** and **detect** tasks to **assess** to how well we can discriminate a living from a non-living local solar neighborhood using 25 HZ planet spectra from the Habitable Worlds Observatory.

Retention of Habitable Atmospheres in Planetary Systems

PI: Dave Brain (CU Boulder)

How do the properties of a planet and its host star influence its ability to retain an atmosphere?

Objective 1: Compute inputs for atmospheric escape for an ensemble of star-planet scenarios

stellar EUV, stellar wind and magnetic field

Objective 2: Improve and link models for atmospheric escape from any planet

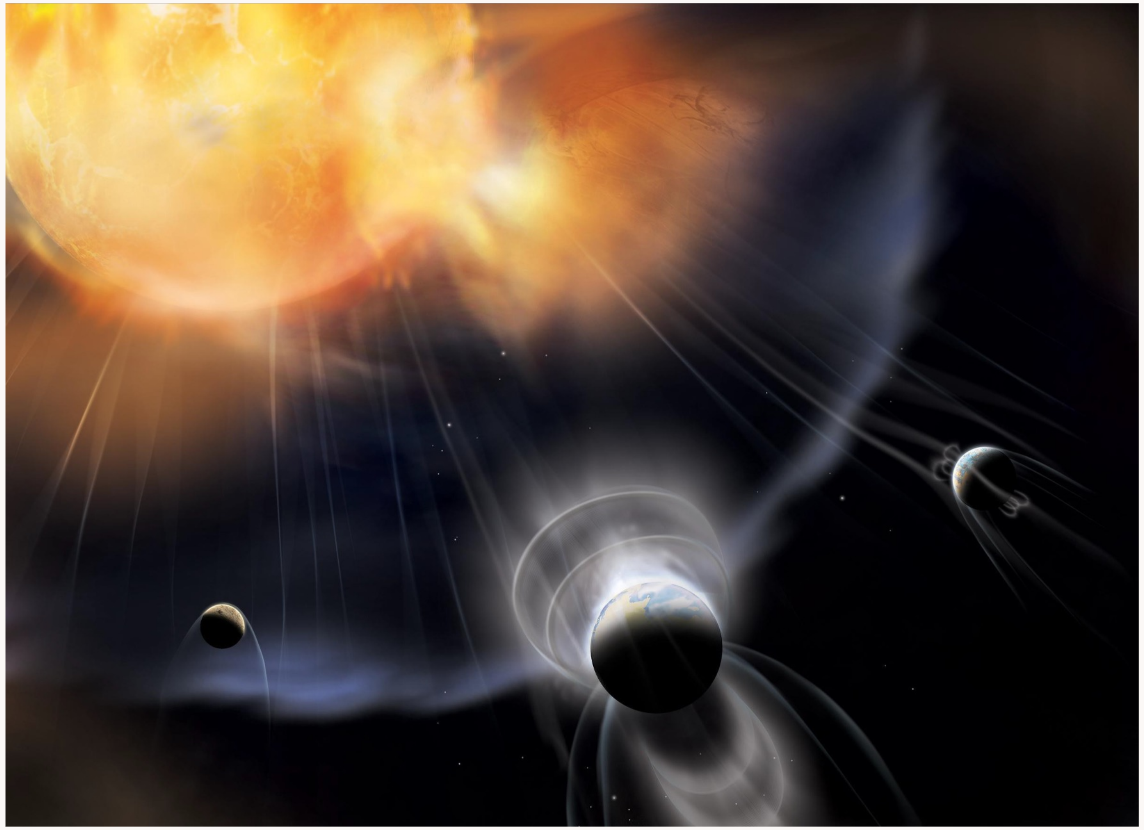
12 redundant models for upper atmosphere and escape

Objective 3: Construct a multi-dimensional model library for atmospheric escape

public web interface to entire library and synthesis

Objective 4: Apply the model library to understand the connection between atmospheric escape, habitability, and observations

Atmospheric lifetimes, scaling laws, transit predictions



Professional Advancement Workshop Series (PAWS)

- For early-career researchers to explore different career paths and hone new skills
- Space to network and learn together
- **Open to all members of the RCNs within the NASA Astrobiology Program**
- Fully virtual, monthly meetings
- Resources and recordings hosted on the PAWS webpage and NExSS YouTube
  - https://nexss.info/paws/

Aaron Gronst

PAWS Team

Lead: Jessica Noviello
NExSS NASA Postdoctoral Management Fellow

Co-leads: Shawn Domagal-Goldman (NASA GSFC) and Melissa Kirven-Brooks (NASA Ames Exobiology Branch & the NASA Astrobiology Program)

Example of Inter-Divisional Research Potential:

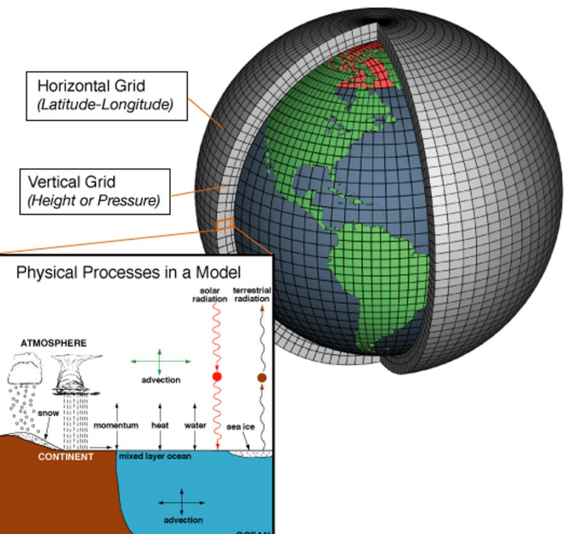
Was Venus the first habitable world of our solar system?

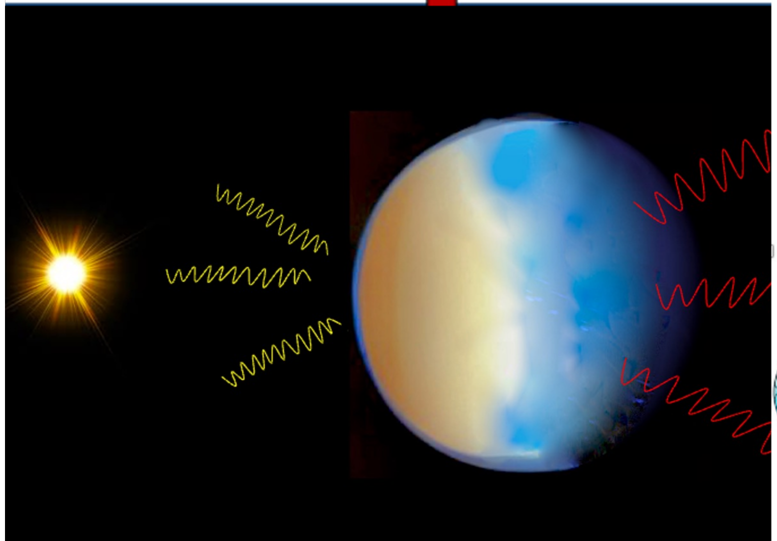
M. J. Way[1,2], Anthony D. Del Genio[1], Nancy Y. Kiang[1], Linda E. Sohl[1,3], David H. Grinspoon[4], Igor Aleinov[1,3], Maxwell Kelley[1], and Thomas Clune[5]

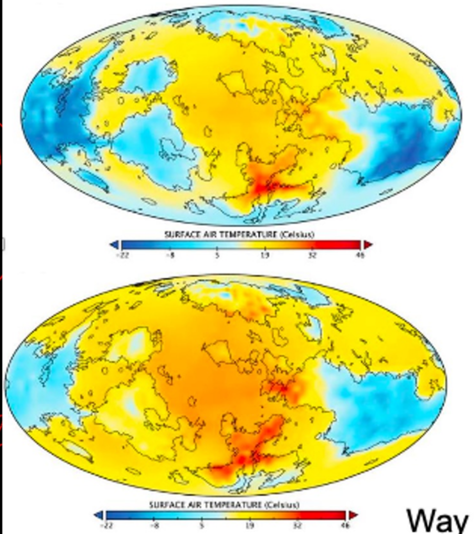
[1]NASA Goddard Institute for Space Studies, New York, New York, USA, [2]Department of Astronomy and Space Physics, Uppsala University, Uppsala, Sweden, [3]Center for Climate Systems Research, Columbia University, New York, New York, USA, [4]Planetary Science Institute, Tucson, Arizona, USA, [5]Global Modeling and Assimilation Office, NASA Goddard Space Flight Center, Greenbelt, Maryland, USA

Abstract Present-day Venus is an inhospitable place with surface temperatures approaching 750 K and an atmosphere 90 times as thick as Earth's. Billions of years ago the picture may have been very different. We have created a suite of 3-D climate simulations using topographic data from the Magellan mission, solar spectral irradiance estimates for 2.9 and 0.715 Gya, present-day Venus orbital parameters, an ocean volume consistent with current theory, and an atmospheric composition estimated for early Venus. Using these parameters we find that such a world could have had moderate temperatures if Venus had a prograde rotation period slower than ~16 Earth days, despite an incident solar flux 46–70% higher than Earth receives. At its current rotation period, Venus's climate could have remained habitable until at least 0.715 Gya. These results demonstrate the role rotation and topography play in understanding the climatic history of Venus-like exoplanets discovered in the present epoch.

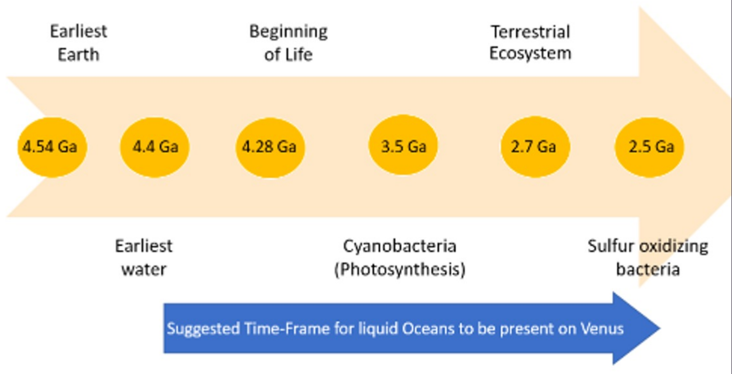
- Tools from Earth Science
- Data from Planetary & Helio
- Tested with future planetary missions
- Results relevant for Exoplanets, future space telescopes, etc.



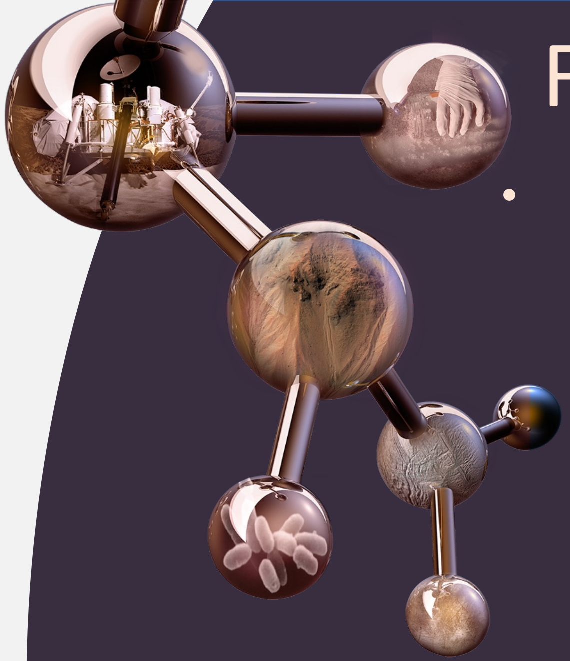




Way et al. 2016



Neira et al. 2018

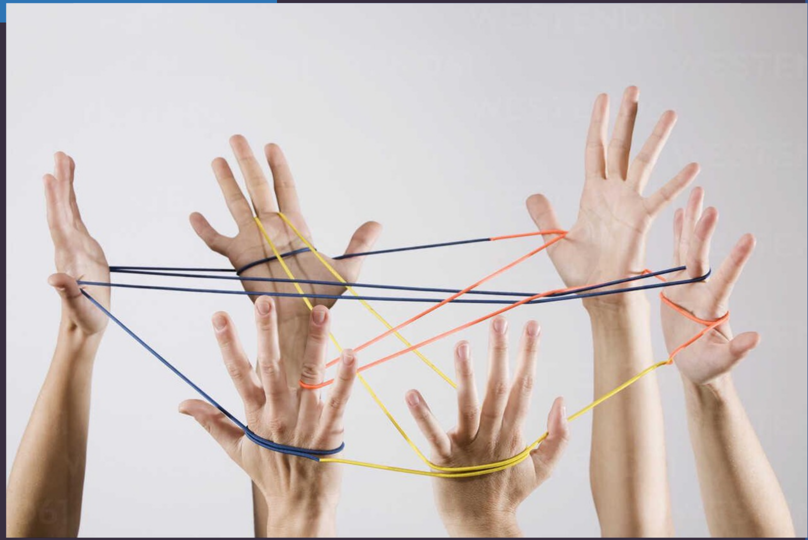


Future Directions:

(1/2)

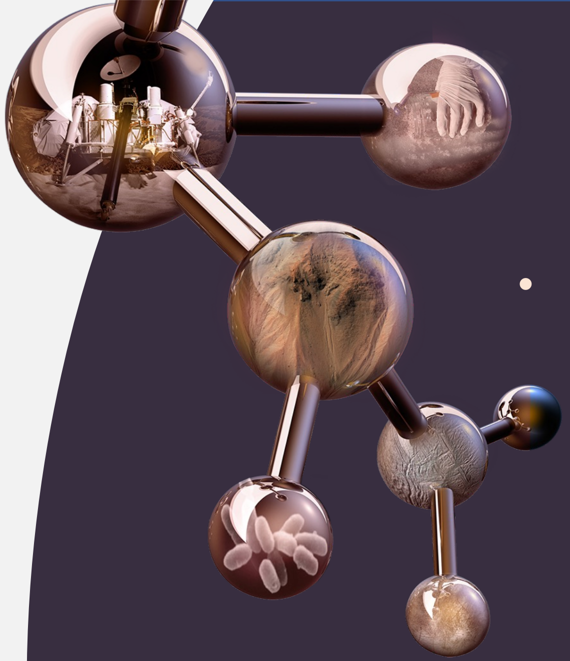
- Increased cross-divisional & cross-directorate activity in Astrobiology at NASA.

The current divisional structure within the Science Mission Directorate largely predates the discovery of exoplanets and significant placement of the search for life as a cross-cutting theme for NASA science.



Goal: Raise visibility of astrobio program, increase connectivity. Look to bolster existing activities with new models for support of interdisciplinary, cross-divisional research projects.

- Interagency programs. (NSF, USGS, NIH…)
- Revitalized international connections & collaborations.
- Public/private partnerships.
- Role in missions.



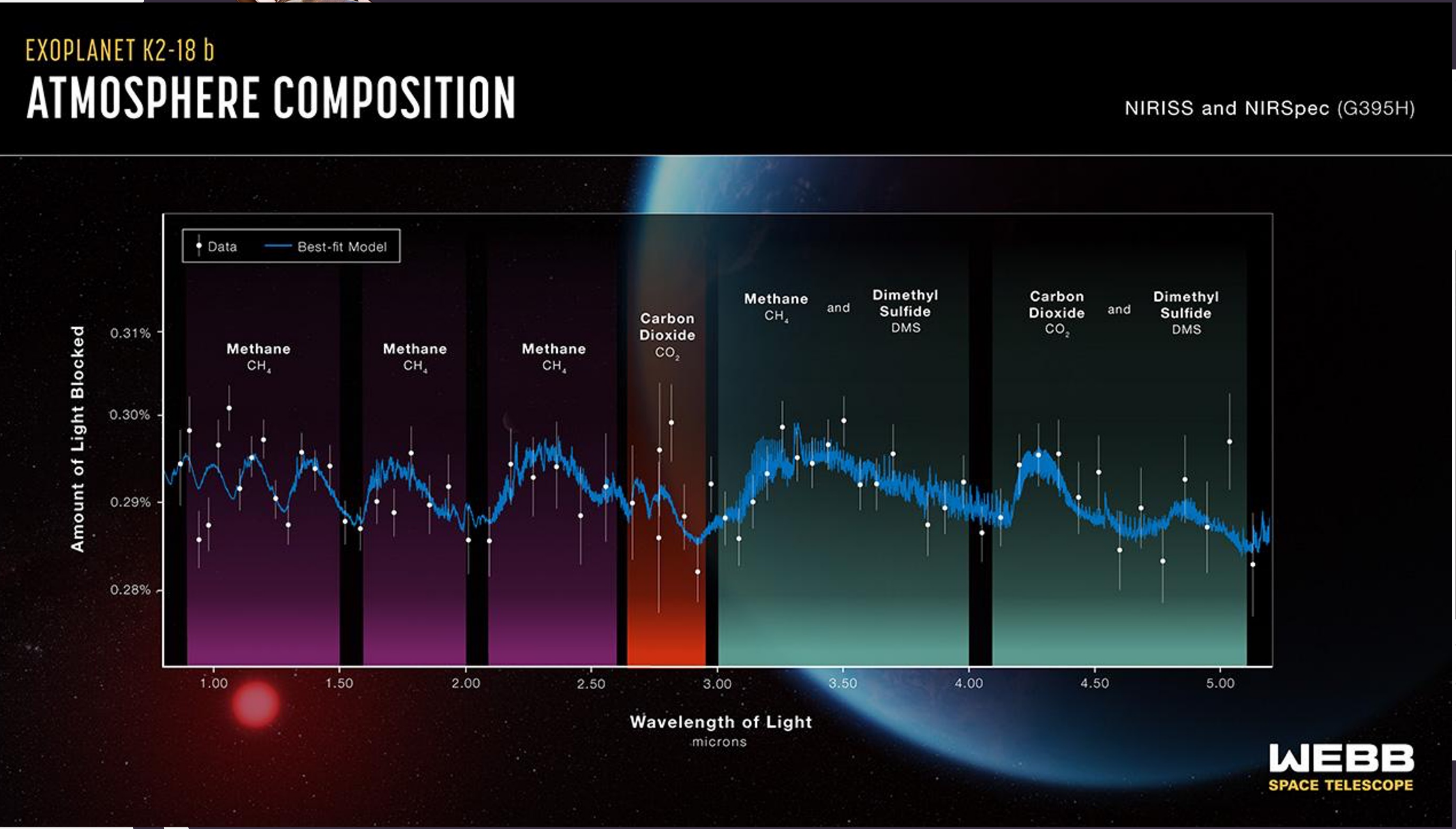
Future Directions: (2/2)

- Post discovery planning/imagining
  – communication.
  -- science.

If we succeed in “finding life” that is not the end but a new beginning for Astrobiology.
Comparative planetology -> comparative biospheres, biochemistries, etc.
What would that science look like?

- Astrobiology & global sustainability/Anthropocene/ future of ife/technosignatures
- Transformative potential of new technologies: AI, machine learning, networked smallsats…
- Ethical issues in fieldwork, exploration

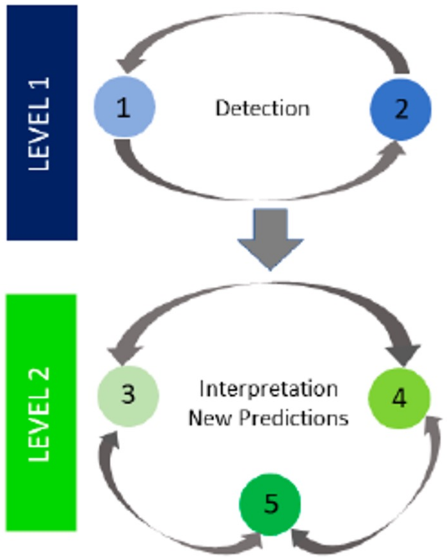
Communication Challenges



Webb Discovers Methane, Carbon Dioxide in Atmosphere of K2-18 b

This artist's concept shows what exoplanet K2-18 b could look like based on science data. K2-18 b, an exoplanet 8.6 times as massive as Earth, orbits the cool dwarf star K2-18 in the habitable zone and lies 120 light-years from Earth. A new investigation with NASA's James Webb Space Telescope into K2-18 b has revealed the presence of carbon-bearing molecules including methane and carbon dioxide. The abundance of methane and carbon dioxide, and shortage of ammonia, support the hypothesis that there may be a water ocean underneath a hydrogen-rich atmosphere in K2-18 b.
Illustration: NASA, CSA, ESA, J. Olmsted (STScI), Science: N. Madhusudhan (Cambridge University)

Standards of Evidence



Question 1: Have you detected an authentic signal?
Have you authenticated your signal, and is it statistically significant? Have you ruled out artifacts from the measurement, pre-processing and/or analysis process that might mimic a real signal?

Question 2: Have you adequately identified the signal?
Have you adequately ruled out other potential sources for this signal? For example, have you ruled out contamination in the environment, or other real phenomena that could produce a similar signal?

Question 3: Are there abiotic sources for your detection?
Is it likely that there is a current or past environmental process, other than life, that could be producing this signal? Have you ruled out these potential false positives for the biosignature?

Question 4: Is it likely that life would produce this expression in this environment?

Given what we know about the likely environment that an organism is operating in, or would have operated in, does it make physical and chemical sense that life would produce this potential biosignature?

Question 5: Are there independent lines of evidence to support a biological (or non-biological) explanation?
Are there other measurements that provide additional evidence, or allow you to predict and execute follow-on experiments, that will help discriminate between the life or non-life hypotheses?

CDSLU: Communicating Discoveries in the Search for Life in the Universe

Overview

If astrobiologists discover evidence of life beyond the Earth, how should these findings be shared with the public? Which communication strategies and techniques would best support public understanding of findings that are likely to be complex and highly specialized? Astrobiology faces a fundamental tension between the implications of finding evidence of biology or biological processes elsewhere in the universe, and explaining how observations or experiments used to accumulate that evidence will be subject to uncertainty and controversy. How might scientists and science communicators navigate this tension and communicate effectively about this uniquely compelling but challenging research?

This virtual workshop organized by NASA's Astrobiology Program (NAP) will bring together astrobiologists, science journalists, science communicators, and science content creators for a series of presentations, conversations, and activities aimed at building a greater shared understanding of the challenges and opportunities for each group that such an event might present. By creating a space to exchange perspectives, experiences, professional realities, and foster relationships between scientists and science communicators we hope to explore mutually-beneficial and socially responsible paths towards communicating the discovery of extraterrestrial life.

Summary

This virtual workshop will bring together the astrobiology and science communication communities to exchange perspectives about the potential discovery of life beyond Earth. Through a series of presentations, conversations, and activities the workshop will explore mutually-beneficial and socially responsible paths towards communicating the discovery of extraterrestrial life and creating a lasting community of shared interest.

Virtual Workshop Session Details

Kickoff webinar: Friday February 23, 11am to 12 pm EST

Day 1: Friday March 1, 11 am to 1 pm EST

Day 2: Monday March 4, 11 am to 2 pm EST

Day 3: Wednesday March 6, 11 am to 3 pm EST

Astrobiology Strategy 2025

We are starting to plan an activity to formulate a new Astrobiology Strategy

A decade since the previous one.

Much has happened :
-New Decadal Surveys
-Exoplanets (discovery that Trappist-1 has multiple planets in potentially HZ)
-JWST, Roman, HWO
-Concrete evidence of habitable early environments on Mars,
-Dragonfly selection
-Tremendous progress in understanding biology and environmental evolution of early Earth

Include post-discovery science strategy?

Worth looking more than 10 years ahead?
20 years from now: Hopefully, samples back from many targets, HWO will be operating, perhaps we'll be planning a fleet of next generation telescopes, perhaps we'll have found multiple biosignatures (or not).
What laboratory & analytical techniques might we have access to?
What will our science look like?


Questions?

Assessment of NASA's
Nexus for Exoplanet System Science Initiative

Assessment Team Members and Affiliations

Mark Marley (co-Chair)
University of Arizona

Nicolle Zellner (co-Chair)
Albion College and NASA HQ

Bradley Burcar, NASA Goddard Space Flight Center

Ofer Cohen, University of Massachusetts Lowell

Colin Goldblatt, University of Victoria

Tiffany Kataria, Jet Propulsion Laboratory

Quinn Konopacky, University of California, San Diego

Kathleen Mandt, Johns Hopkins Applied Physics Laboratory and NASA Goddard Space Flight Center (starting April 24, 2023)

Larry J. Paxton, Johns Hopkins University Applied Physics Laboratory

Margaret Tolbert, University of Colorado, Boulder

Nicholeen Viall, NASA Goddard Space Flight Center

Ex Officio Members
Lindsay Hays (NASA Headquarters)
Eric Mamajek (Jet Propulstion Laboratory)

The Assessment Team found that NExSS has been broadly successful in achieving many of its goals and has contributed positively to the advancement of the field. Specifically NExSS succeeded in fostering new connections resulting in new science investigations and is particularly valuable for early career scientists. True to its charter to inform NASA space observatory observations, NExSS sparked important JWST ERS and Cycle 1 programs. The Assessment Team also identified areas in which NExSS might be improved in the future. The stated goals and actual operational processes of NExSS are somewhat complex and are difficult to convey crisply. The Assessment Team itself had to frequently return to questions of management and organization to seek clarification. Likewise the selection process and roles for various levels of leadership are not always fully transparent. Currently the representation of investigators from various NASA Divisions is not uniform with Astrophysics and Heliophysics being particularly over and under-represented, respectively. Greater attention to recruitment and streamlining the process of joining the network could improve program diversity. Finally, the Assessment Team found that the all-volunteer model for NExSS leadership and the overall lack of support for process (e.g., handling email lists) has not scaled well with the growth of NExSS.

Astrobiology Research Programs

- C.5 Exobiology (PO: Lindsay Hays)
  - Aim is to understand the origin, evolution, distribution, and future of life in the Universe. Research is centered on the origin and early evolution of life, the potential of life to adapt to different environments, and the implications for life elsewhere.
- C.14 Planetary Science and Technology Through Analog Research (PSTAR) (PO: Becky McCauley Rench)
  - This program solicits proposals for investigations focused on exploring the relevant environments on Earth in order to develop a sound technical and scientific basis to conduct astrobiological research on other Solar System bodies.
- C.20 Interdisciplinary Consortia for Astrobiology Research (ICAR) (PO: Lindsay Hays)
  - Proposals that describe a multi-million dollar, five-year project with an interdisciplinary approach to a single, compelling question in astrobiology. For projects larger than the scope of the individual research programs, but within the scope of the Research Coordination Networks.
- F.4 Habitable Worlds (HW) (PO: Becky McCauley Rench)
  - Aim is to use knowledge of the history of the Earth and the life upon it as a guide for determining the processes and conditions that create and maintain habitable environments and to search for ancient and contemporary habitable environments and explore the possibility of extant life beyond the Earth.