The Nexus for Exoplanet System Science

https://nexss.info

Natalie Batalha, Andrew Rushby (NASA ARC)
Shawn Domagal-Goldman (NASA GSFC)
Dawn Gelino (NExSCI)
Tony Del Genio (NASA GISS)
Mary Voytek (NASA HQ)

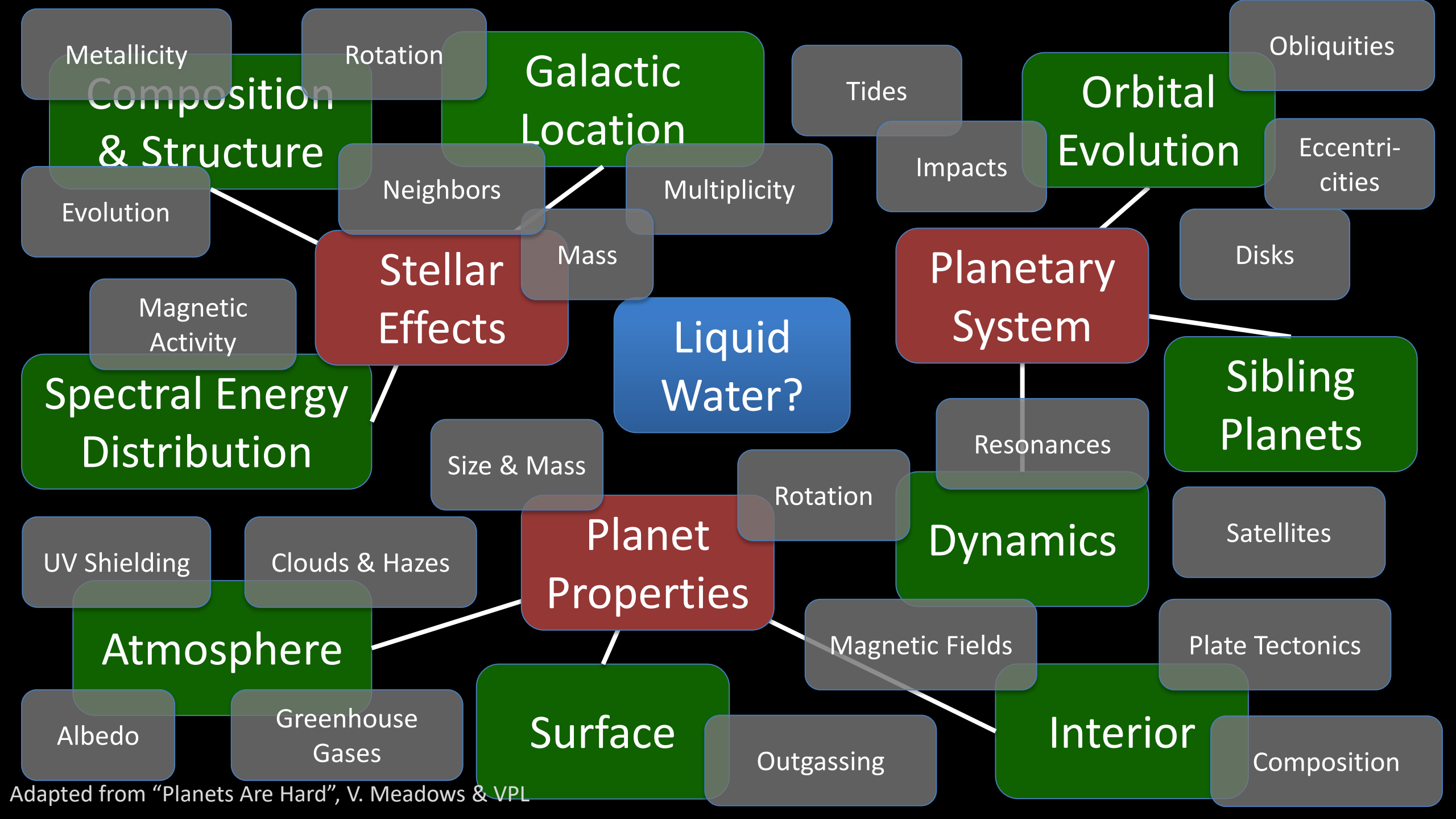
What is NExSS?

- A research coordination network dedicated to the study of planetary habitability and the search for life on exoplanets.

- A NASA cross-division initiative bringing astrophysicists, planetary scientists, Earth scientists, and heliophysicists together to yield a “systems science” approach to the effort.

Scientific goals of NExSS

- Investigate the diversity of planets
- Understand how planet history, geology, and climate interact to create the conditions for life
- Put planets into an architectural context as stellar systems built over time by dynamical processes and sculpted by stars
- Use experience from solar system (including Earth) history to identify where habitable niches are most likely to occur and which planets are most likely to be habitable
- Leverage NASA investments in research and missions to accelerate discovery and characterization of potential life-bearing worlds



Adapted from “Planets Are Hard”, V. Meadows & VPL

Strategic Objectives

- To further our joint strategic objective to explore exoplanets as potentially habitable and inhabited worlds outside our solar system.
- To establish common goals across divisions in SMD including Planetary Science (PSD), Heliophysics (HPD), Earth Science (ESD) and Astrophysics (APD)
- To leverage existing Programs in SMD to advance the field of Exoplanet Research, specifically research in comparative planetology, biosignature and habitat detection, and planet characterization.
- To establish a mechanism to break down the barriers between divisions, disciplines, and stove piped research activities.

Pilot Program

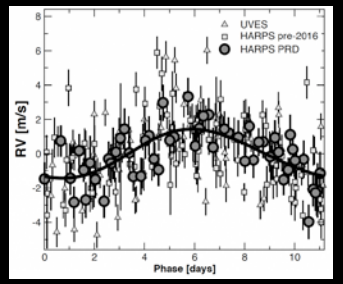
- Initiated in 2015
- Leveraged selections from existing FY15 ROSES NRAs and CANs
- 18 PIs selected from NAI, XRP, ATP, ADAP, Living With a Star proposal calls were invited to become part of the pilot project
- No new research funds as a result of joining NExSS
- NExSS teams are responsible for organizing community-wide activities that reach well beyond NExSS team members

Inaugural NExSS Teams

D. Fischer
A. Jensen
J. Graham

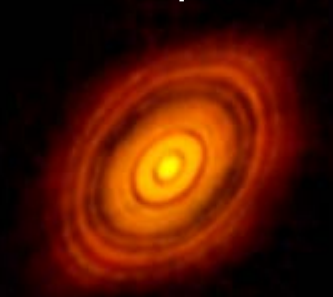
Exoplanet Detection

E. Ford
D. Deming
J. Wright



Exoplanet Characterization

N. Turner
H. Jang-Condell
D. Apai

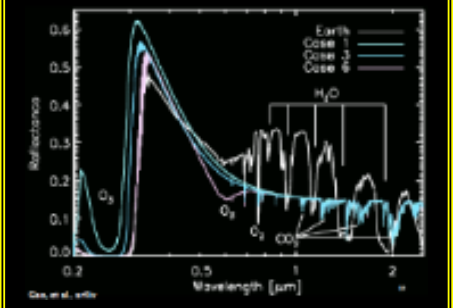


Disks & Planet Formation

<u>HQ reps:</u>
Mary Voytek (PSD)
Doug Hudgins (APD)
Jared Leisner (HSD)
Richard Eckman (ESD)
Shawn Domagal-Goldman

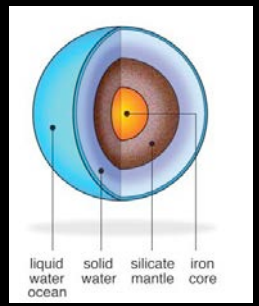
<u>Co-leads:</u>
Natalie Batalha
Dawn Gelino
Tony Del Genio

Management



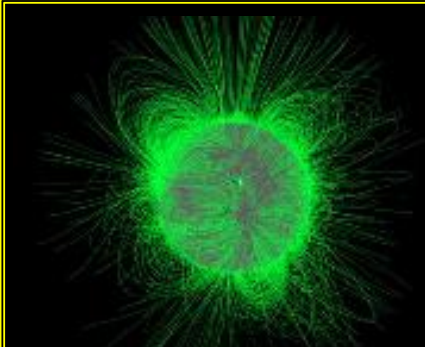
H. Imanaka

Laboratory Astrophysics



B. Moore
J. Fortney

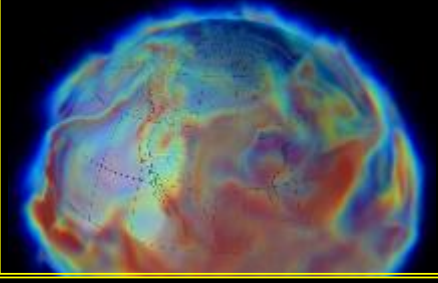
Planetary Structure and Evolution



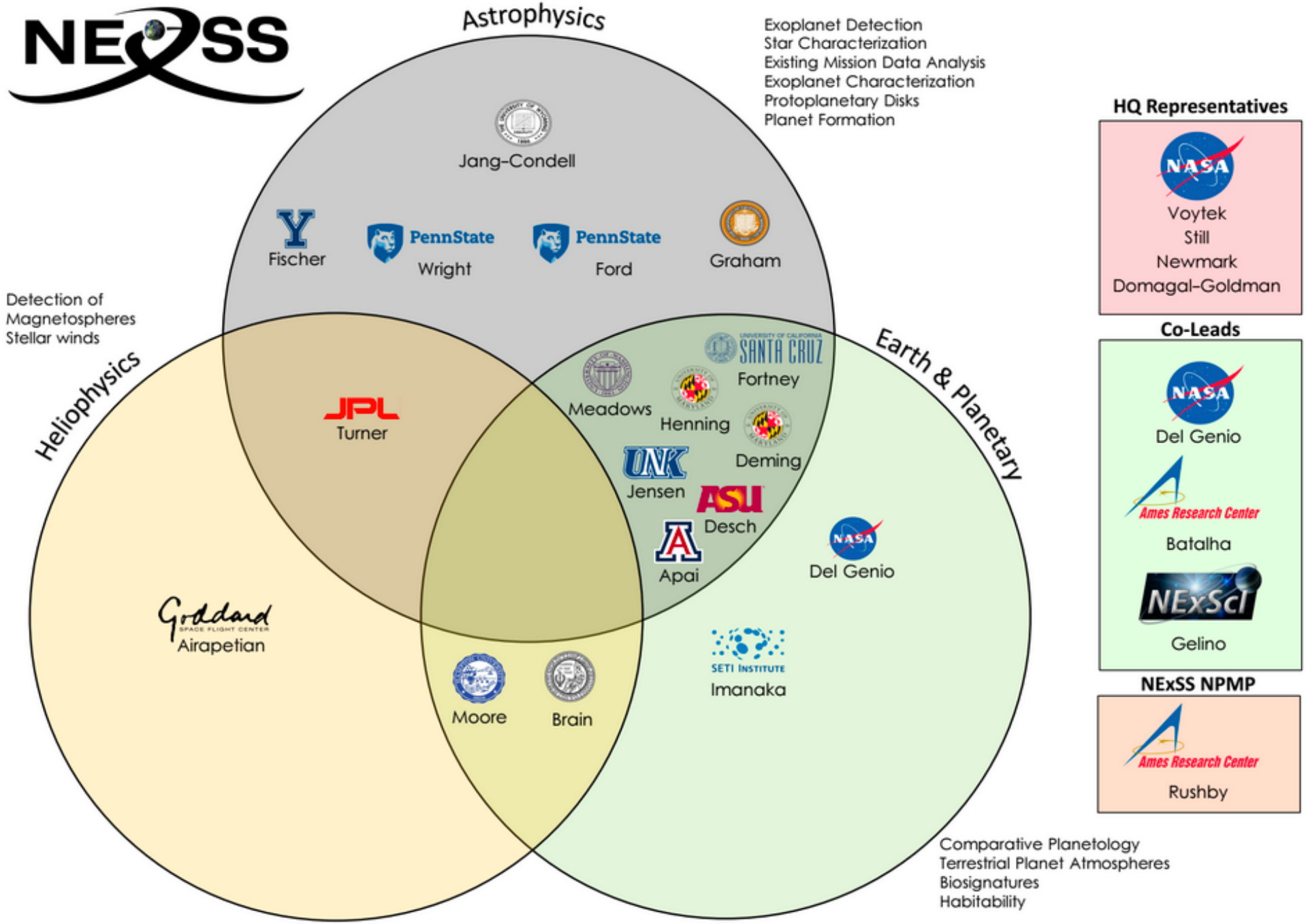
V. Airapetian
D. Brain

Space Weather

W. Henning
S. Desch
V. Meadows
T. Del Genio



Planetary Habitability


NExSS
Astrophysics
Exoplanet Detection
Star Characterization
Existing Mission Data Analysis
Exoplanet Characterization
Protoplanetary Disks
Planet Formation
Jang-Condell
Fischer
PennState
Wright
PennState
Ford
Graham
Detection of
Magnetospheres
Stellar winds
Heliophysics
Earth & Planetary
JPL
Turner
Meadows
Henning
SANTA CRUZ
Fortney
Deming
UNK
Jensen
ASU
Desch
Apai
Del Genio
Goddard
SPACE FLIGHT CENTER
Airapetian
Moore
Brain
SETI INSTITUTE
Imanaka
Comparative Planetology
Terrestrial Planet Atmospheres
Biosignatures
Habitability
HQ Representatives
NASA
Voytek
Still
Newmark
Domagal-Goldman
Co-Leads
NASA
Del Genio
Ames Research Center
Batalha
NExScI
Gelino
NExSS NPMP
Ames Research Center
Rushby

Activities

- White Papers
- Workshops Without Walls
- Community Working Groups
- Steering Committee Meetings
- Webinars
- Interdisciplinary Postdocs
- Public Outreach
- New Collaborations
- ExoPAG Participation & Leadership
- Habex/LUVOIR/OST Concept Studies

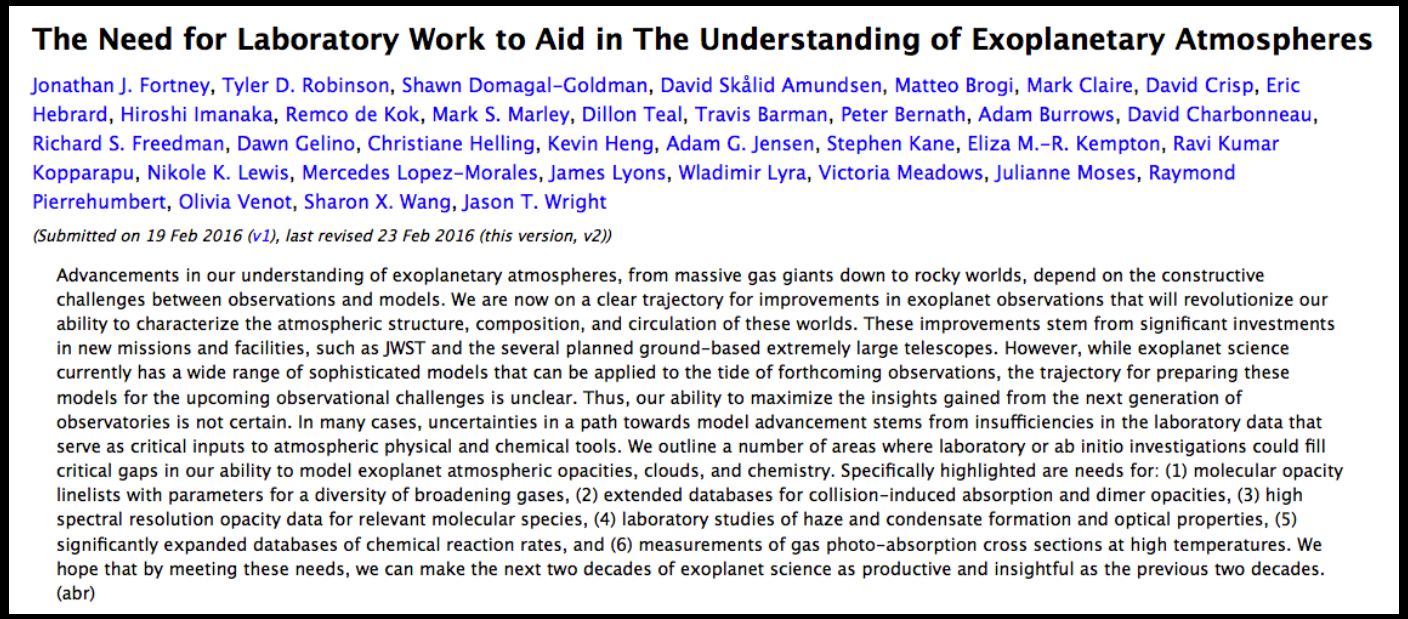
Fostering Communication & New Collaborations

Highlight: Exo-Mineralogy

- Three NExSS groups with complimentary expertise: planetary interiors (geophysicists), surface geologists (geochemists), and exoplanet detection & characterization (astronomers).
- Goal: determine the size and composition of dust from the planets orbiting these stars; compare this to the dust grains expected to be shed from disintegrating planets, based on our surface petrology and dust condensation models.
- Forming a new discipline: exo-mineralogy

Community White Papers

- Science & Technology Gaps: identification of areas needing substantive work to support goals related to the study of planetary habitability.
- Decadal Review Planning: supporting strategic planning efforts leading to heightened readiness for decadal reviews



The Need for Laboratory Work to Aid in The Understanding of Exoplanetary Atmospheres

Jonathan J. Fortney, Tyler D. Robinson, Shawn Domagal-Goldman, David Skålid Amundsen, Matteo Brogi, Mark Claire, David Crisp, Eric Hebrard, Hiroshi Imanaka, Remco de Kok, Mark S. Marley, Dillon Teal, Travis Barman, Peter Bernath, Adam Burrows, David Charbonneau, Richard S. Freedman, Dawn Gelino, Christiane Helling, Kevin Heng, Adam G. Jensen, Stephen Kane, Eliza M.-R. Kempton, Ravi Kumar Kopparapu, Nikole K. Lewis, Mercedes Lopez-Morales, James Lyons, Wladimir Lyra, Victoria Meadows, Julianne Moses, Raymond Pierrehumbert, Olivia Venot, Sharon X. Wang, Jason T. Wright

(Submitted on 19 Feb 2016 (v1), last revised 23 Feb 2016 (this version, v2))

Advancements in our understanding of exoplanetary atmospheres, from massive gas giants down to rocky worlds, depend on the constructive challenges between observations and models. We are now on a clear trajectory for improvements in exoplanet observations that will revolutionize our ability to characterize the atmospheric structure, composition, and circulation of these worlds. These improvements stem from significant investments in new missions and facilities, such as JWST and the several planned ground-based extremely large telescopes. However, while exoplanet science currently has a wide range of sophisticated models that can be applied to the tide of forthcoming observations, the trajectory for preparing these models for the upcoming observational challenges is unclear. Thus, our ability to maximize the insights gained from the next generation of observatories is not certain. In many cases, uncertainties in a path towards model advancement stems from insufficiencies in the laboratory data that serve as critical inputs to atmospheric physical and chemical tools. We outline a number of areas where laboratory or ab initio investigations could fill critical gaps in our ability to model exoplanet atmospheric opacities, clouds, and chemistry. Specifically highlighted are needs for: (1) molecular opacity linelists with parameters for a diversity of broadening gases, (2) extended databases for collision-induced absorption and dimer opacities, (3) high spectral resolution opacity data for relevant molecular species, (4) laboratory studies of haze and condensate formation and optical properties, (5) significantly expanded databases of chemical reaction rates, and (6) measurements of gas photo-absorption cross sections at high temperatures. We hope that by meeting these needs, we can make the next two decades of exoplanet science as productive and insightful as the previous two decades. (abr)

Highlight: Lab Work for Understanding Exoplanet Atmsopheres

Fortney et al. 2016 arXiv: 1602.06305

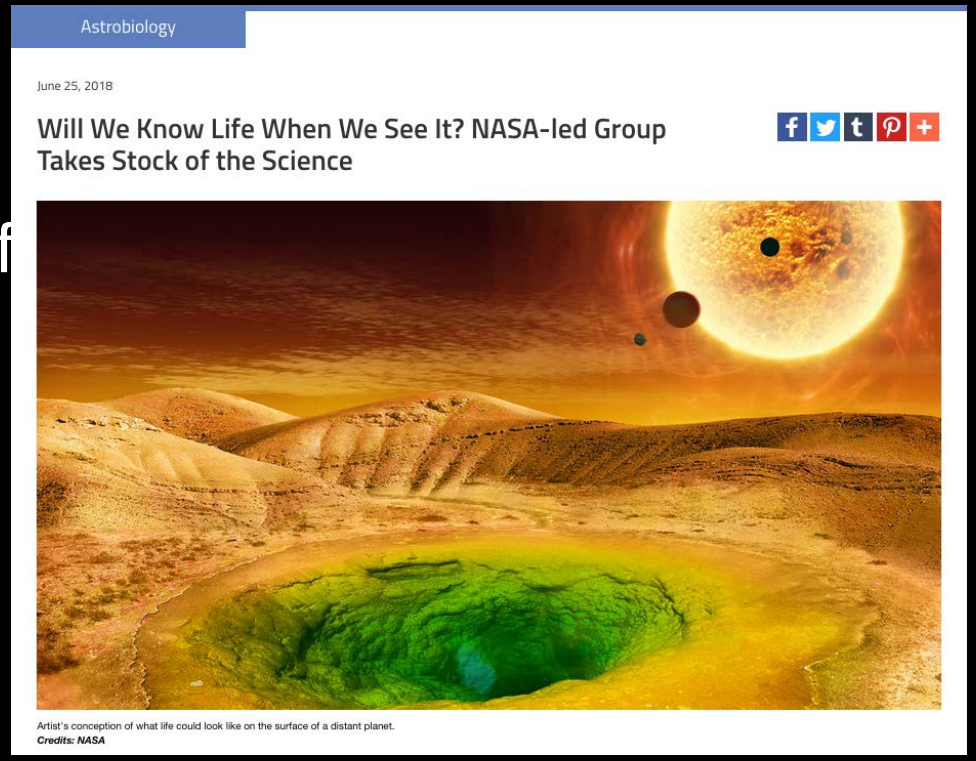
- Topics raised by NExSS team members
  - Pressure-induced line broadening parameters (self- , foreign)
  - Optical properties of particles, haze formation
  - Reaction rate constants
  - Photo-absorption cross-sections at high T
  - Lab spectroscopy of continuum absorption
  - Oxygen absorption by early magma ocean
- NASA Astrophysics R&A program (ROSES 2016 & 2017): “highlights the timeliness of Laboratory Astrophysics proposals pertaining to JWST”

Workshops Without Walls

1) Upstairs Downstairs: Consequences of Internal Planet Evolution for the Habitability and Detectability of Life on Extrasolar Planets
   - Tempe, AZ, Feb. 17-19 (led by PSD)
   - Joint NExSS-NAI-NSF effort, in-person + virtual participation
   - Winter school for students/postdocs
2) Exoplanet Biosignatures Workshop Without Walls
   - Seattle, WA, July 27-29. 2016 (led by PSD, ASD)
   - Joint NExSS-NAI-ExEP effort
   - Summative State of the Research to be published
3) Approaching the Stellar Astrophysical Limits of Exoplanet Detection (partner)
   - Aspen, CO, Aug 28 – Sep 18, 2016
   - Joint NExSS & Aspen Center for Physics , Penn State
4) Impact of Exoplanetary Space Weather on Climate & Habitability
   - New Orleans, LA, Nov 29 – Dec 2, 2016
5) Extreme Precision Radial Velocities III (partner)
   - Penn State, PA, Aug 14 – 17, 2017
6) NASA Technosignatures Workshop
   - Houston, TX, Sep 26 – 28, 2018

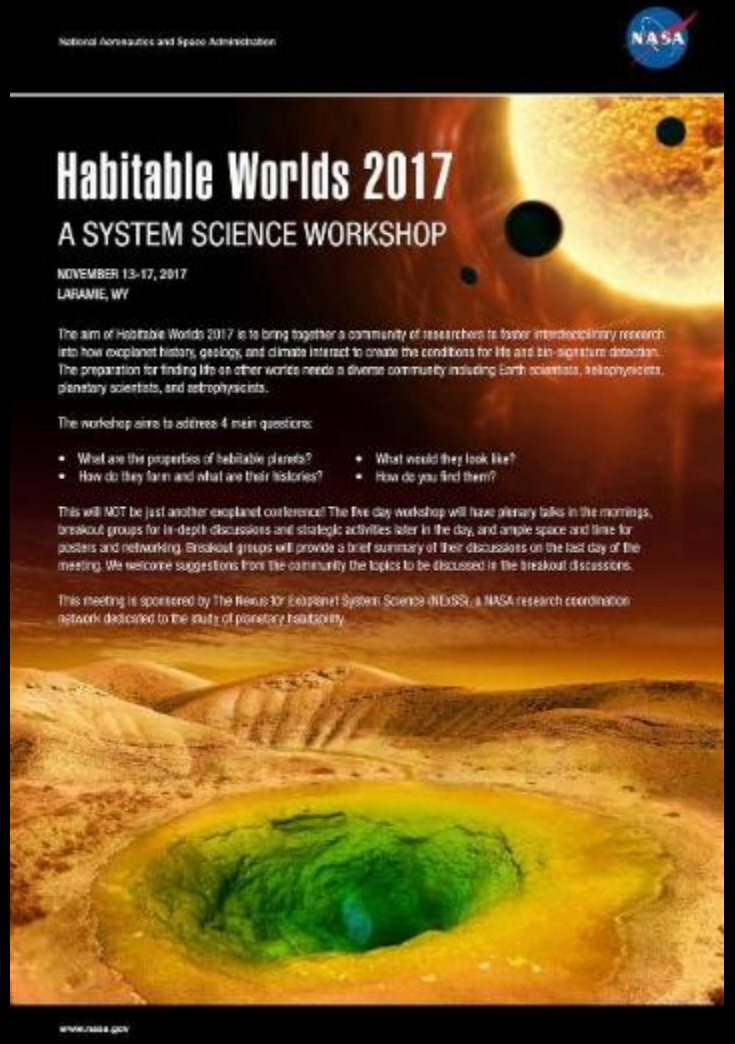
Highlight: Exoplanet Biosignatures WwW

- Seattle, WA, July 27-29. 2016
- Five papers developed from breakout sessions:
  1. Review of Remotely Detectable Signs of Life
  2. Understanding Oxygen as a Biosignature in the Context of Its Environment
  3. A Framework for Biosignature Assessment
  4. Future Directions
  5. Observational Prospects
- Post-workshop, ab Prospects wide discussion and feedback
- Executive summary submitted to NAS-Astrobiology committee



NASA Web Feature
June 25, 2018

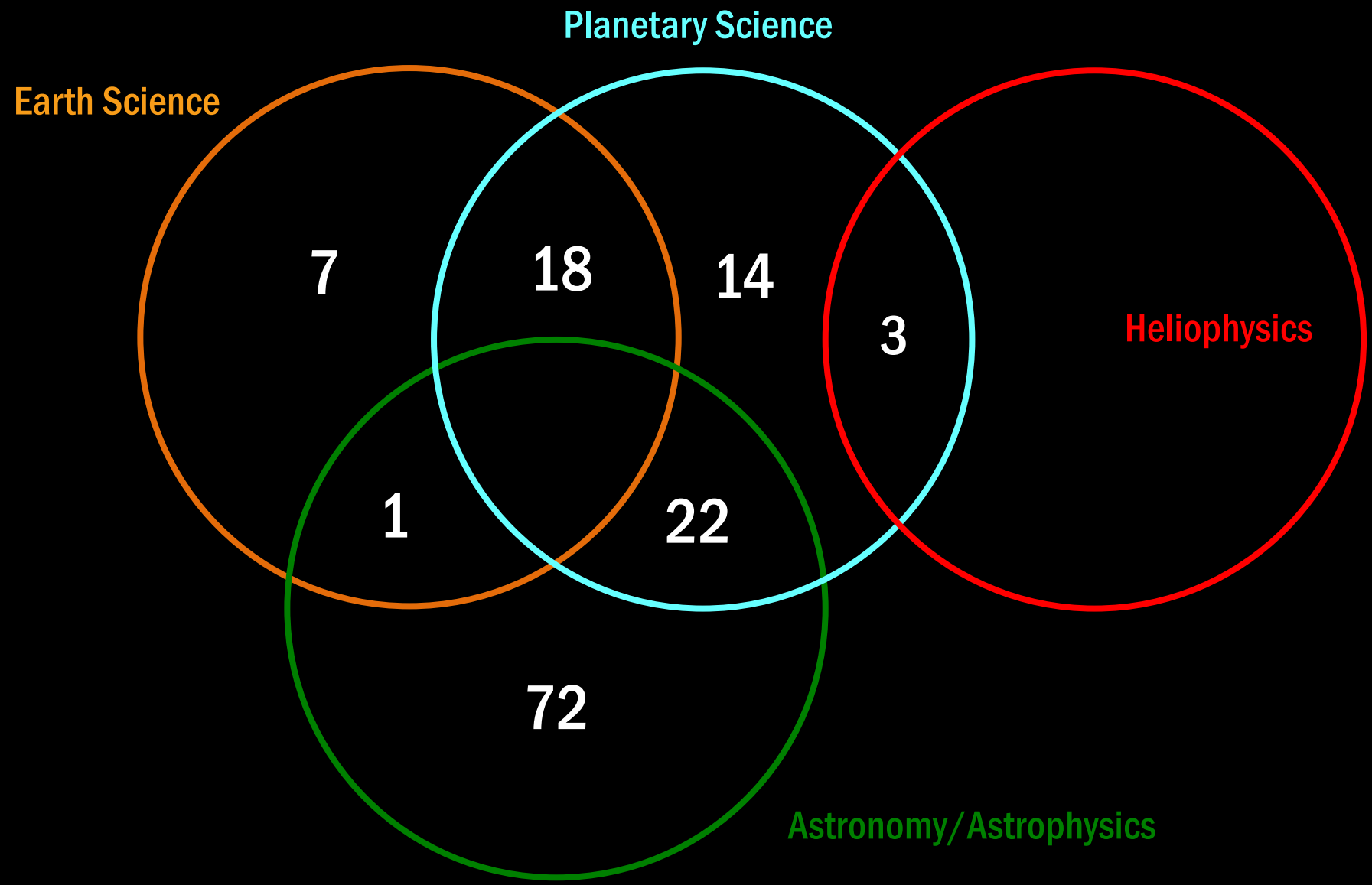
Habitable Worlds 2017: A System Science Workshop



- Laramie, Wy., November 13-17 2017
- First NExSS Conference
- NExSS (57) & non-NExSS (85) attendance
- Emphasis on breakouts, panels, hacks.
- Live-streaming of talks and some breakouts
- Balanced contributions from astro, planetary, earth, and helio

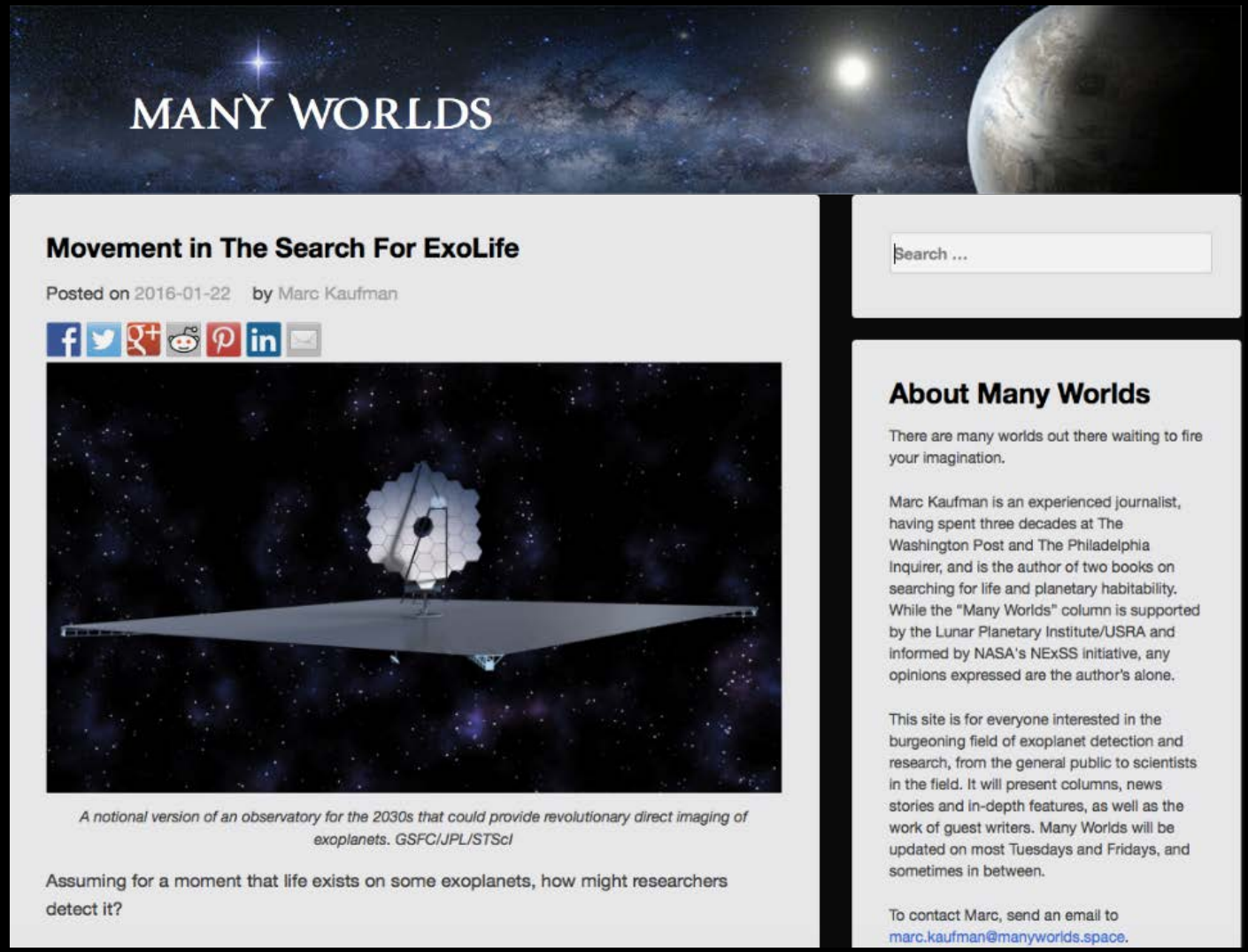
Diversity of Expertise*

*Roughly grouped from abstracts/Google Scholar/chats over coffee



72 Astro
63 All else

Public Awareness



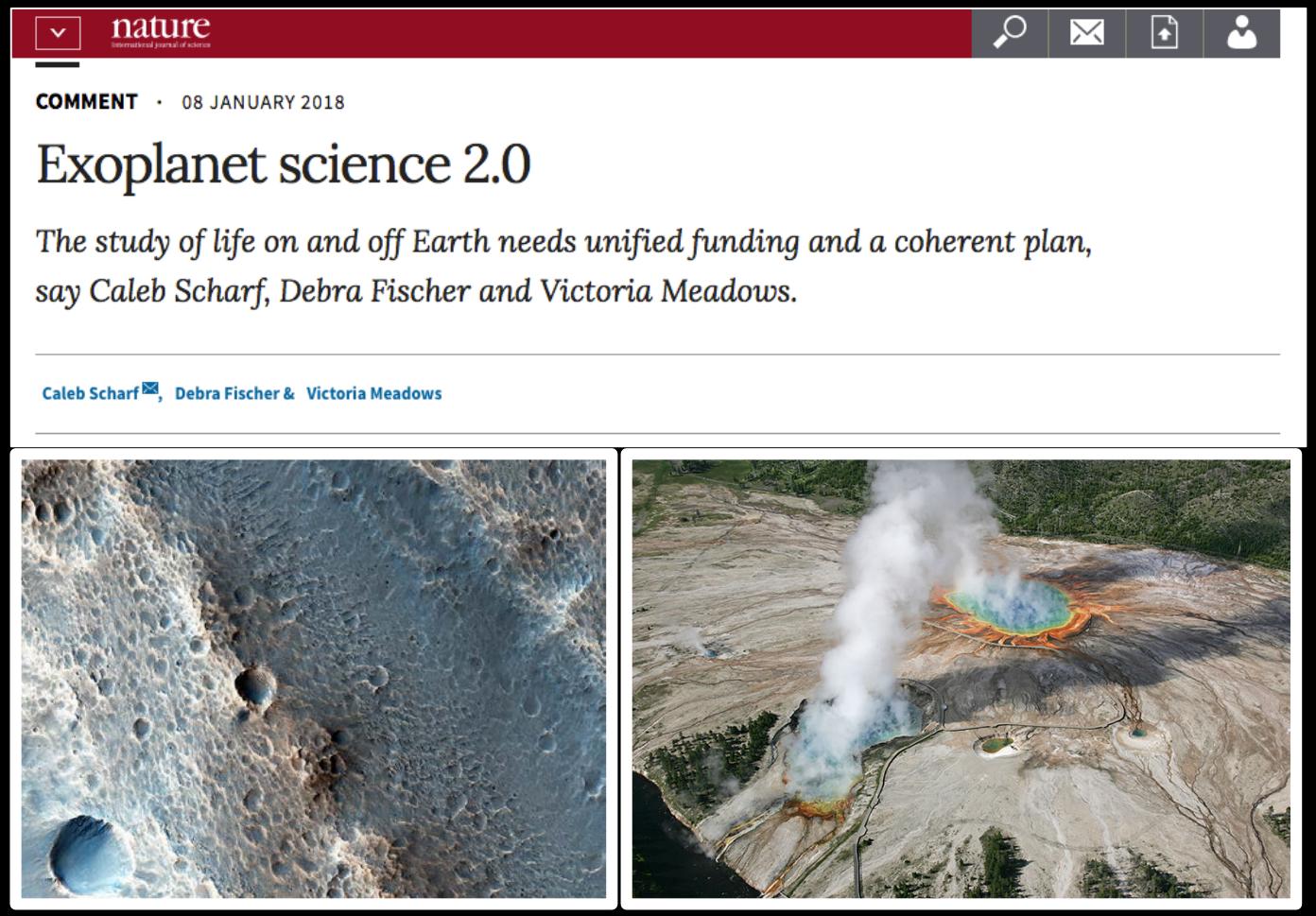
Many Worlds Blog:

URL: manyworlds.space
Facebook: @nexssmanyworlds

Contributors:

Marc Kaufman
Elizabeth Tasker

Highlight: Nature Commentary, Jan 2018



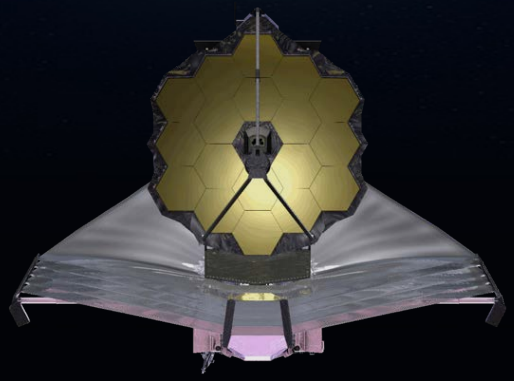
Scharf, Fischer, Meadows 08 Jan 2018

"Now that answers about life's universality are finally within reach, funding agencies and scientists must step up. In our view, the field needs a systems-science approach focused on interactions — between galactic environments, planet formation, orbital dynamics, heliophysics, atmospheres, hydrospheres, cryospheres, geospheres, biospheres and magnetospheres — rather than on components in isolation. This would extend Earth-systems science to encompass other types of planet and ecosystem."

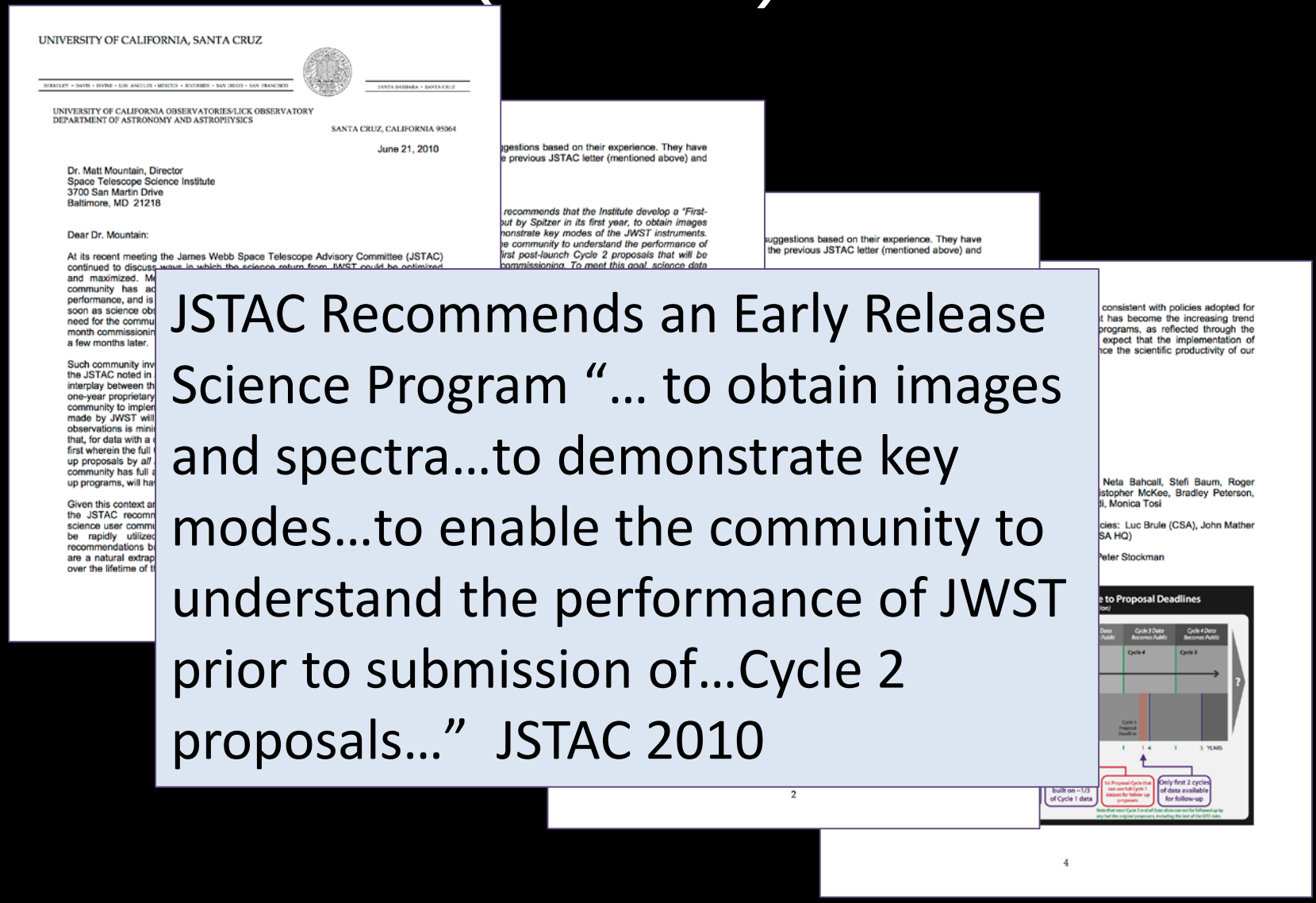
Community Working Groups

TRANSITING EXOPLANETS WITH JWST:

Community Efforts for Early Release Science



JWST Advisory Committee (JSTAC)


UNIVERSITY OF CALIFORNIA, SANTA CRUZ

UNIVERSITY OF CALIFORNIA OBSERVATORIES/LICK OBSERVATORY
DEPARTMENT OF ASTRONOMY AND ASTROPHYSICS
SANTA CRUZ, CALIFORNIA 95064

June 21, 2010

Dr. Matt Mountain, Director
Space Telescope Science Institute
3700 San Martin Drive
Baltimore, MD 21218

Dear Dr. Mountain:

At its recent meeting the James Webb Space Telescope Advisory Committee (JSTAC) continued to discuss ways in which the science return from JWST could be optimized and maximized.

JSTAC Recommends an Early Release Science Program "… to obtain images and spectra…to demonstrate key modes…to enable the community to understand the performance of JWST prior to submission of…Cycle 2 proposals…" JSTAC 2010

Highlight: ERS Working Group

- Initiated October 2016 by NExSS
- Formed Executive Committee: Fortney, Lopez-Morales, Line, Knutson, Sing
- Open invitation announced via ExoPAG
- Over 100 scientists responded to call
- NExSS facilitated:
  - Online training, virtual meetings, discussion boards
  - An open science environment
  - Strategic planning & preparatory HST observing campaigns
  - Democratic decision-making processes
  - ERS Proposal Submission (8/18/2017)

104 Team Members & Growing

Alam Munazza K.
Angerhausen Daniel
Barrado David
Batalha Natalie M.
Batalha Natasha E.
Bean Jacob L.
Benneke Björn
Berta-Thompson Zachory K.
Blecic Jasmina
Bouwman Jeroen
Bruno Giovanni
Carone Ludmila
Carter Aarynn L.
Casewell Sarah L.
Chapman John W.
Crossfield Ian J.M.
Crouzet Nicolas
Cubillos Patricio E.
Decin Leen
Demory Brice-Olivier
Desert Jean-Michel
de Val-Borro Miguel
de Wit Julien
Dragomir Diana
Drummond Benjamin
Endl Michael
Espinoza Nestor
Evans Thomas M.
Fortney Jonathan J.
Fraine Jonathan D.
France Kevin
Gao Peter
García Muñoz Antonio
Garland Ryan
Gibson Neale P.
Gizis John E.
Goyal Jayesh M.
Greene Thomas P.
Harrington Joseph
Heng Kevin
Henning Thomas K.
Hong Yucian
Hu Renyu
Ingalls James G.
Iro Nicolas
Irwin Patrick G. J.
Kataria Tiffany
Kendrew Sarah
Kempton Eliza M.-R.
Kilpatrick Brian M.
Knutson Heather A.
Kreidberg Laura
Krick Jessica
Lagage Pierre-Olivier
Lahuis Fred
Leconte Jeremy
Lendl Monika
Lillo-Box Jorge
Line Michael R.
Lines Stefan
Lopez-Morales Mercedes
Lothringer Joshua D.
Louden Tom
Madhusudhan Nikku
Mancini Luigi
Mandell Avi M.
Mansfield Megan
Marchis Franck
Marley Mark S.
May Erin M.
Mayne Nathan
Molliere Paul
Morello Giuseppe
Morley Caroline V.
Moses Julianne I.
Nikolov Nikolay
Palle Enric
Parmentier Vivien
Rauscher Emily
Redfield Seth
Roberts Jessica E.
Rocchetto Marco
Rogers Leslie A.
Roudier Gaël
Schlawin Everett
Shkolnik Evgenya L.
Showman Adam P.
Sing David K.
Southworth John
Spake Jessica J.
Stevenson Kevin B.
Swain Mark R.
Teske Johanna C.
Todorov Kamen O.
Tremblin Pascal
Tsiaras Angelos
Tucker Gregory S.
Venot Olivia
Waalkes William C.
Wakeford Hannah R.
Waldmann Ingo P.
Weaver Ian
Wheatley Peter J.
Zellem Robert T.
YOUR NAME HERE

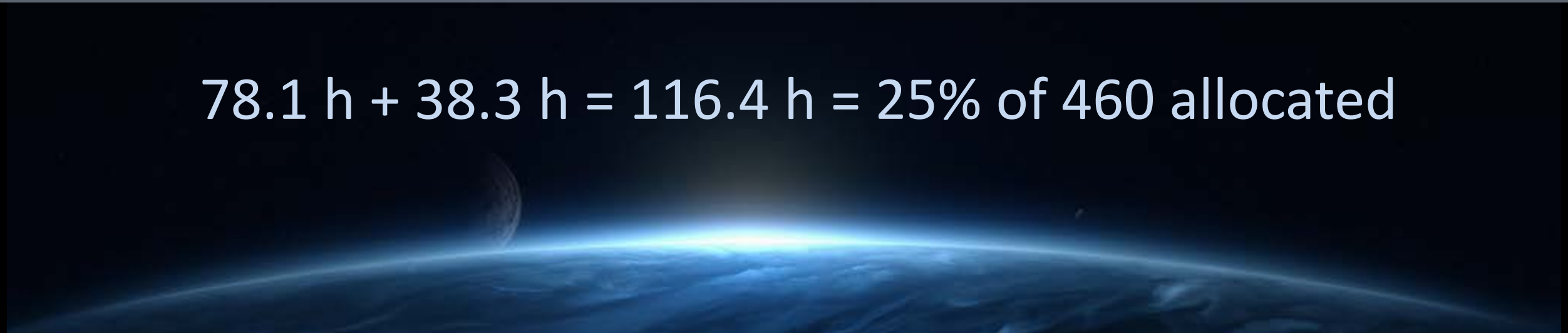
JWST Early Release Science Awards

1309	IceAge: Chemical Evolution of Ices during Star Formation	McClure (Amsterdam)	Stellar Physics
1324	Through the Looking GLASS: A JWST Exploration of Galaxy Formation and Evolution from Cosmic Dawn to Present Day	Treu (UCLA)	Galaxies and the IGM
1328	A JWST Study of the Starburst-AGN Connection in Merging LIRGs	Armus (CalTech)	Galaxies and the IGM
1334	The Resolved Stellar Populations Early Release Science Program	Weisz (UC Berkeley)	Stellar Populations
1335	Q-3D: Imaging Spectroscopy of Quasar Hosts Analyzed with a Powerful New PSF Decomposition & Spectral Analysis	Wylezalek (ESO)	Massive Black Holes and their Galaxies
1345	The Cosmic Evolution Early Release Science (CEERS) Survey	Finkelstein (Austin)	Galaxies and the IGM
1349	Establishing Extreme Dynamic Range with JWST: Decoding Smoke Signals in the Glare of a Wolf-Rayet Binary	Lau (CalTech)	Stellar Physics
1355	TEMPLATES: Targeting Extremely Magnified Panchromatic Lensed Arcs and Their Extended Star Formation	Rigby (GSFC)	Galaxies and the IGM
1364	Nuclear Dynamics of a Nearby Seyfert with NIRSpec Integral Field Spectroscopy	Bentz (Georgia State)	Massive Black Holes and their Galaxies

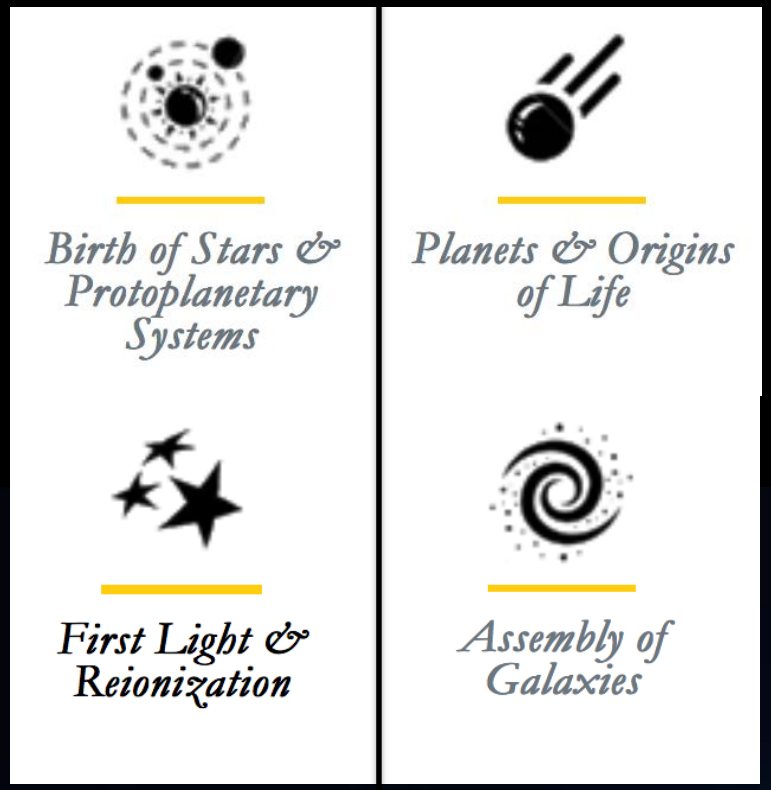
JWST Early Release Science Awards

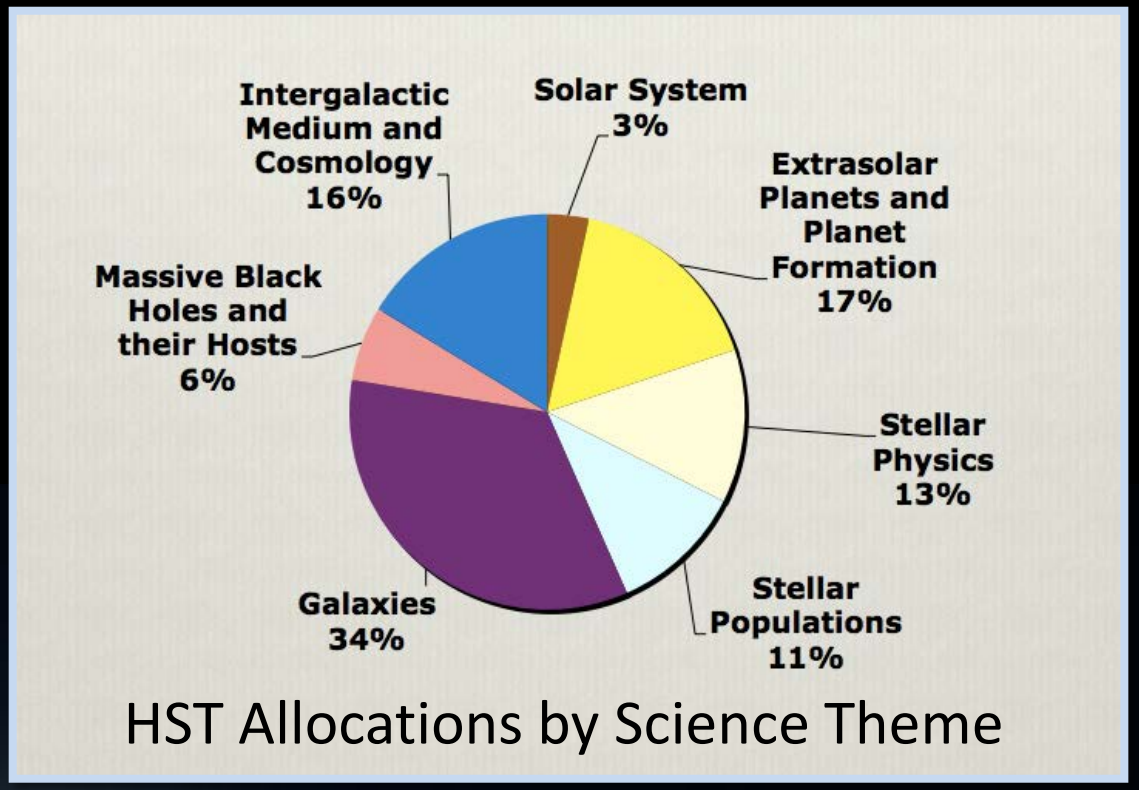
1366	The Transiting Exoplanet Community Early Release Science Program	Batalha (NASA ARC), Bean (Chicago), Stevenson (STScI)	Planets and Planet Formation
1373	ERS observations of the Jovian System as Demonstration of JWST's Capabilities for Solar System Science	de Pater (Berkeley)	Solar System
1386	High Contrast Imaging of Exoplanets and Exoplanetary Systems with JWST	Hinkley (Exeter), Skemer (UCSC), Biller (Edinburgh)	Planets and Planet Formation

78.1 h + 38.3 h = 116.4 h = 25% of 460 allocated



Increase Over Past Allocation Levels





HST Allocations by Science Theme

Measures of Success

- Investigators carry out and propose interdisciplinary research through new collaborations
  - e.g. Exo-Mineralogy
- Produces a plan for utilization of current space telescopes
  - ERS Working Group
- Spawns ideas for new and exciting missions
  - STDT participation
- Identifies new targeted technologies needed not yet reported elsewhere
  - Lab Astro Gap List White Paper
- Contributes to decadal review efforts for both PSD and APD
  - NExSS white papers submitted to NAS-Astrobiology & Exoplanets
- Enhances International engagement
  - Invited lectures; travel awards to international conference; 46% participation in ERS working group

NAS-Astrobiology White Papers

Life Beyond the Solar System:

- Exoplanet Properties as Context for Planetary Habitability (Batalha et al.)
- Observation and Modeling of Exoplanet Environments (Del Genio et al.)
- Space Weather and its Impact on Habitability (Airepetian et al.)
- Remotely Detectable Biosignatures (Domagal-Goldman et al.)

NAS-Exoplanet White Papers

- NExSS PI’s contributed to 44 of 76 white papers
- 9 of the 18 PI’s served as first author of a white paper
- 10 of the white papers were specifically motivated by NExSS or enabled by cross-disciplinary interactions (see papers by: Henning, Airapetian, Batalha, Fortney, Wright, DelGenio, Graham, Apai, Domagal-Goldman, Barnes)

Positive Programmatic Impacts

E.4 HABITABLE WORLDS

NASA's Habitable Worlds Program includes elements of the Astrobiology Program, the Mars Exploration Program, the Outer Planets Program (all in the Planetary Science Division) and Exoplanet research in the Astrophysics Division. A common goal of these programs is to identify the characteristics and the distribution of potentially habitable environments in the Solar System and beyond.

2018 NRA, Section 2.12

Although Exobiology does not solicit proposals specifically aimed at habitability, PIs of proposals selected for funding from this program element that cover a research topic related to the habitability of, or search for life on, exoplanets (for example, conditions for the emergence of life) are eligible to be part of the Nexus of Exoplanet System Science (NExSS). Relevance to NExSS is not an evaluation criterion for proposals to this Program element. Eligibility for participation in NExSS does not indicate that additional funding will be provided.

Future: New Membership Selection

- Drawn from 2017 ROSES program selections
- Broadly relevant to planetary habitability science
- Identified by NASA HQ Program Scientists (envision self-identifying check-box in the future as part of proposal submission process)
- Membership on Steering Committee defined by period of performance

Backup Slides