Working Together to Find Life in the Universe: NASA's Nexus for Exoplanet System Science

https://nexss.info

Dr. Dawn Gelino

Deputy Director, NExScI

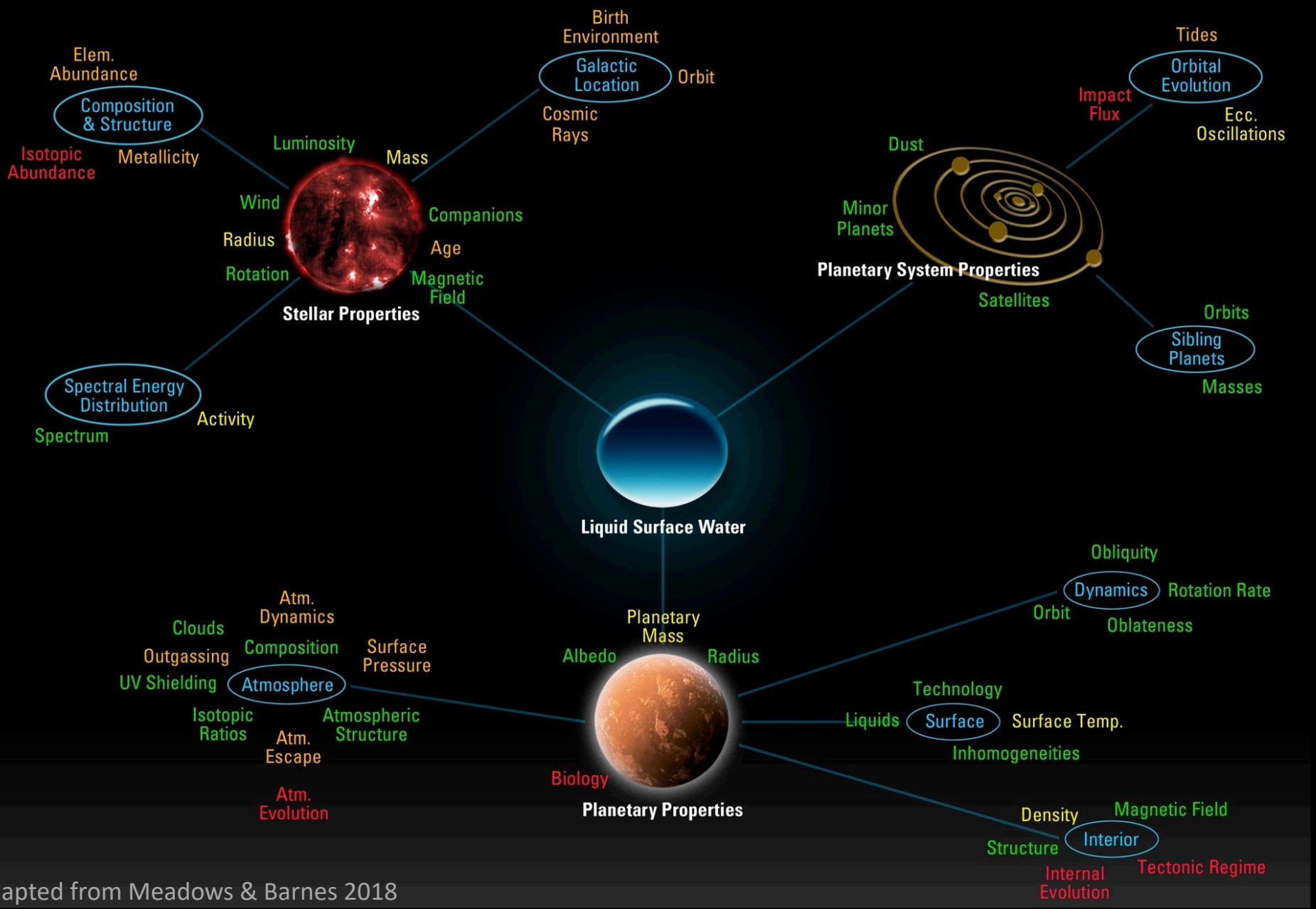
What is NExSS?

- An interdisciplinary 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 bring a "systems science" approach to this problem
- A way to leverage NASA investments in research and missions to accelerate discovery and characterization of potential life-bearing worlds, and to break down barriers between SMD divisions
- Now one of the five ICAR programs

HQ Reps:
Mary Voytek (PSD)
Richard Eckman (ESD)
Doug Hudgins (APD)
Jared Leisner (HPD)
Shawn Domagal-Goldman

Co-Leads:
Tony Del Genio (GISS)
Dawn Gelino (Caltech/JPL)
Vikki Meadows (UW)

Why is NExSS Needed?



Adapted from Meadows & Barnes 2018

Exoplanet studies are inherently interdisciplinary, and by working together, we can work more efficiently to answer one of humanity's oldest questions:

Are we alone?

History/Basics

- Leverage selections from successful ROSES teams
- 2015: 17 PIs selected from NAI, XRP, APT, ADAP, and Living With a Star proposal calls were invited by NASA HQ program scientists to become part of the pilot project
- Unprecedented coordination between ALL 4 divisions of NASA's Science Mission Directorate (Astrophysics, Earth Sciences, Heliophysics, Planetary Sciences)
- Teams receive 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
- Fall 2018: New teams were added as 3 year award teams rolled off --> 34 teams
- Both Astrobiology and Exoplanet NAS 2018 study reports supported NExSS-like collaborations and activities
  - As a result, more ROSES calls (Habitable Worlds and XRP) are interdivisional!

Activities

- Telecons
- Workshops Without Walls
- Community Working Groups
- Webinars
- Affiliate Program
- Public Outreach: Manyworlds.space
- White Papers
- Postdoc Opportunities
- New Science Collaborations
- ExoPAG Participation & Leadership
- HabEx/LUVOIR Leadership

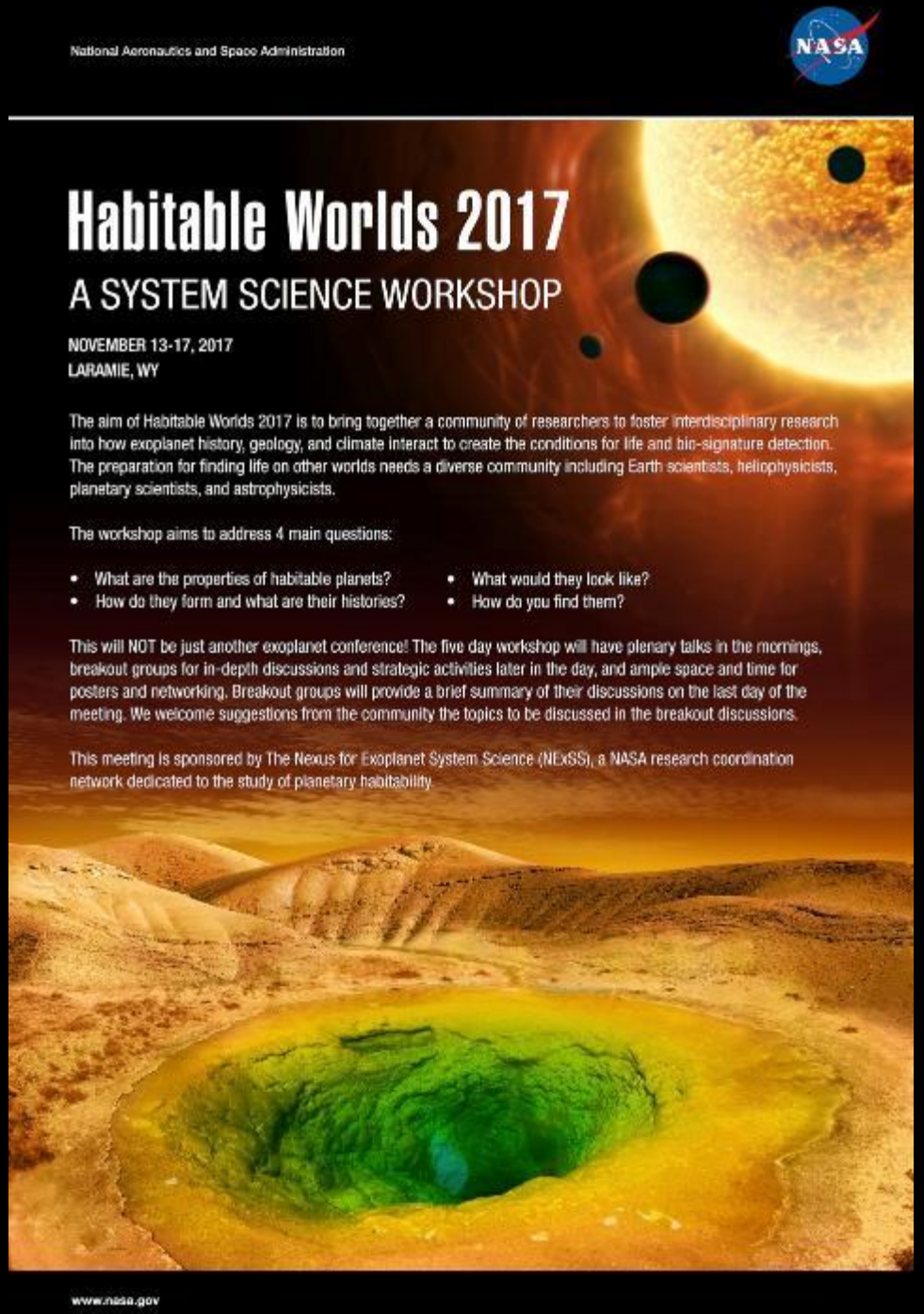
NExSS Goals & Activities

1. Investigators carry out and propose interdisciplinary research through new collaborations
   - After NExSS was initiated, the Habitable Worlds program saw an increase in exoplanet proposals from NExSS-engaged PIs who had not previously proposed to Exobiology/NAI
   - Several proposals from NExSS PIs, Co-Is, and collaborators submitted to Exoplanet Research Program and Topical Workshops Program. One grant awarded to two new, collaborating researchers that developed the idea for the proposal at the NExSS “Upstairs-Downstairs” Winter school
   - New insights and collaborations in Exo-Mineralogy arose as a result of a workshop between astronomers and solid earth scientists
2. Develop programs for using existing space telescopes/NASA facilities to advance NASA science objectives
   - JWST Early Release Science working group (WG) lead by NExSS as a NExSS activity
   - 2 proposals submitted by NExSS PIs and collaborators as a result of NExSS WG won 23% of the allotted ERS time

3. Makes important contributions to science cases for future flight missions
   - STDT Leadership and significant participation in LUVOIR/HabEx/OST mission concept studies by NExSS members
   - Discussion on the STDTs impacted by NExSS led research and panelist experience
   - NExSS biosignatures workshop provided comprehensive state of the field publications, and developed a community vision for biosignature assessment strategies for future missions and mission concepts
4. Identifies new targeted technologies needed but not yet reported elsewhere
   - "Laboratory Astrophysics Gap List" White Paper, Fortney *et al.* 2016, identified needed studies to increase the list of informative wavelengths and enhance our ability to interpret spectra
5. Provides and increases cross-divisional inputs to decadal review efforts for PSD and APD
   - 4 NExSS white papers submitted to NAS Astrobiology Strategy Study and 7 to the Exoplanet Exploration Study
   - NExSS asked to present to both the NAS Astrobiology and Exoplanet Strategy study committees, and both recommended NExSS-like activities for the long-term
   - 15 Astrophysics Decadal 2020 papers led by NExSS PIs, with team members and PIs on many more
6. Enhances US leadership of international cross-disciplinary exoplanet researchers
   - 46% participation in JWST Early Release Science working group was international researchers
   - NExSS Directory developed at the request of International attendees to NExSS workshops

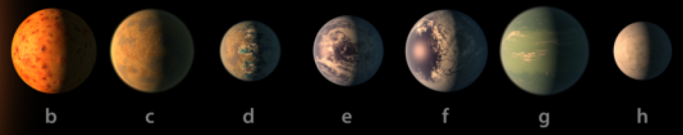
Positive Programmatic Impacts

- E.4 Habitable Worlds (ROSES 2017)
  - 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, PSD) and Exoplanet research in the Astrophysics Division (APD). A common goal of these programs is to identify the characteristics and the distribution of potentially habitable environments in the Solar System and beyond.
  - Now cross-divisional for PSD and APD
- E.3 XRP (ROSES 2018 amended)
  - This program is now interdivisional for ALL 4 SMD Divisions (APD, PSD, HPD, ESD)!!
  - Now encourages observational, archival, and theoretical investigations focused on the detection of *technosignatures*, as a direct result of the Technosignature Report sent to HQ from the workshop
    - ADAP (D.2) now accepts technosignature study proposals
- NASA Postdoctoral Program (2017)
  - 2 NExSS-specific NPPs awarded to postdocs working with both a large and small NExSS group



NExSS Activities in the Works:

- Workshops
  - Exoplanets in our Backyard (Houston, Feb 2020, APD & PSD PAGs)
  - Habitable Worlds 2 (Early 2021, joint w/AAS)
  - 1D & 3D GCM Model Comparison Workshop (2021/22)
  - Magnetic Field Affects on Habitability (2021/22)
- Webinars
- PSD Decadal Preparation
- Science Working Groups
  - Exoplanet/Solar System Synergies
  - Interior/Atmosphere exchange
  - Atmospheric Escape and Evolution
- Communications Working Group
  - Inter-team, Science Community, HQ
  - Science Nuggets, Opportunities, Knowledge Exchange
- More involvement from early career scientists
  - NPP opportunity
- New Slack Workspace – *anyone* can join our slack!
  - New Working Group Channels
  - New Early Career Channel
- Connections Across RCNs



The TRAPPIST-1 JWST Community Initiative

- The TRAPPIST-1 planets likely provide the best opportunities for JWST characterization of terrestrial planetary atmospheres
- The T-1 JWST CI is a community effort to ensure the coordination and optimization of the study of TRAPPIST-1 with JWST
- Board: Victoria Meadows, Michaël Gillon, Eric Agol, Adam Burgasser, Drake Deming, René Doyon, Jonathan Fortney, Laura Kreidberg, James Owen, Frank Selsis
- Goals include:
  - Providing communication channels between interested scientists (NExSS website, Slack channel)
  - Coordination with instrument/GTO + ERS teams
  - Global sharing of all relevant information + data with minimal proprietary period
  - Well-structured sequential observing/proposal strategy, and planning for a possible Legacy Program
  - Supporting ground-based observations (TTV, activity, radial velocity, etc)
- ANYONE is free to join/support (contact Vikki or Michaël, or sign up on the NExSS website)!

NExSS

Current NExSS PIs


Airapetian


Henning


Wright

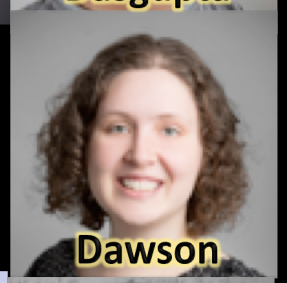

Del Genio

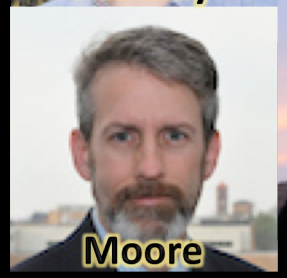

Jensen


Dasgupta

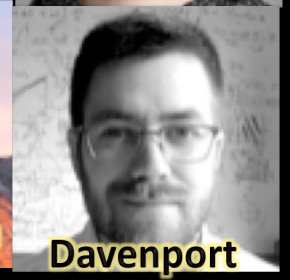

Fortney


Andrews


Dawson


Moore

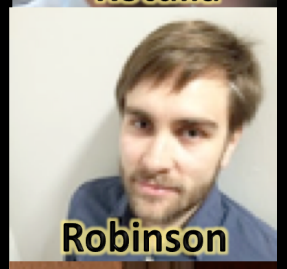

Charbonneau


Davenport


Kotulla


Stassun


Rieker


Robinson


Weinberger


Schlichting


Mandell


Reinhard


Shields


Shim


Brandt


Jang-Condell

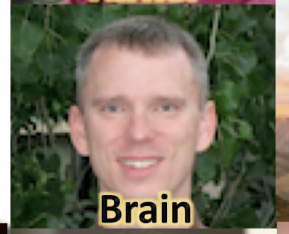

Apai


Dong


Turner


Desch


Haghighipour


Brain


Kalas

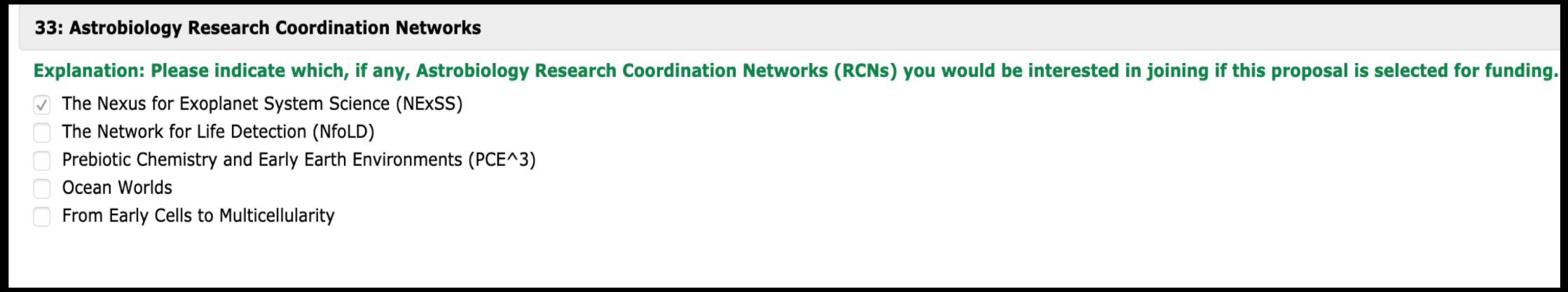

Kane


Christiansen


Meadows

How can YOU get involved with NExSS?

- Submit proposals though relevant ROSES calls
  - XRP (PSD, APD, HPD, ESD)
  - Exobiology, Habitable Worlds, ICAR (PSD)
  - ADAP, ATP (APD)
  - Living With a Star (HPD)



33: Astrobiology Research Coordination Networks

Explanation: Please indicate which, if any, Astrobiology Research Coordination Networks (RCNs) you would be interested in joining if this proposal is selected for funding.

- [x] The Nexus for Exoplanet System Science (NExSS)
- [ ] The Network for Life Detection (NfoLD)
- [ ] Prebiotic Chemistry and Early Earth Environments (PCE^3)
- [ ] Ocean Worlds
- [ ] From Early Cells to Multicellularity

How can YOU get involved with NExSS?

- Contribute to workshop planning activities
  - Currently in early planning for Habitable Worlds 2 in 2021
- Join our Slack Workspace! (https://nexss.slack.com/)
- Check out our Affiliate Program!
  - An *affiliate* refers to a non-member person, group, or organization whose research interests, goals, and vision are aligned with those of NExSS, and who are, have recently been, or would like to be, actively participating in NExSS activities (workshops, conferences, virtual seminars, white papers, working groups etc.)
  - The affiliate association is intended to facilitate cooperation, local and international collaboration, engagement and open communication between the affiliate party and the NExSS network in order to assist in the delivery of NExSS' stated outcomes regarding advancing exoplanet science research
  - http://nexss.info/about/nexss-affiliates/

Thanks!

https://nexss.info
@nexssinfo

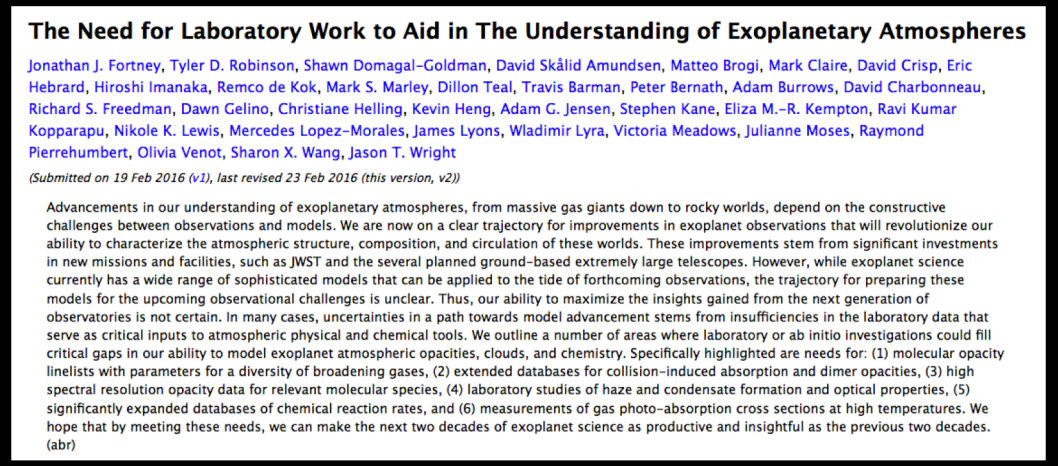
Backup

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

White paper: Laboratory Work for Understanding Exoplanet Atmsopheres (led by J. Fortney)

- NASA Astrophysics R&A program (ROSES 2016): “highlights the timeliness of Laboratory Astrophysics proposals pertaining to JWST”
- Topics raised by NExSS team members
  - Pressure-induced line broadening parameters (self- , foreign)
  - Optical properties of particles, haze formation
  - Reaction rate constants
  - Photoabsorption cross-sections at high T
  - Lab spectroscopy of continuum absorption
  - Oxygen absorption by early magma ocean
- White Paper: arXiv: 1602.06305



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)

Workshops Without Walls

- Upstairs Downstairs: Consequences of Internal Planet Evolution for the Habitability and Detectability of Life on Extrasolar Planets
  - Tempe, AZ, Feb. 17-19, 2016 (led by PSD)
  - Joint NExSS-NAI-NSF effort; Including a winter school for students/postdocs
- Exoplanet Biosignatures Workshop Without Walls
  - Seattle, WA, July 27-29. 2016 (led by PSD, APD)
  - Joint NExSS-NAI-ExEP effort; Summative State of the Research published 5 papers in *Astrobiology Journal*
- Approaching the Stellar Astrophysical Limits of Exoplanet Detection
  - Aspen, CO, Aug 28 – Sep 18, 2016 (led by APD)
  - Joint NExSS & Aspen Center for Physics, Penn State
- Impact of Exoplanetary Space Weather on Climate & Habitability
  - New Orleans, LA, Nov 29 – Dec 2, 2016 (led by HSD)
- NASA Technosignatures Workshop
  - Houston, TX, LPI, Sep 26 – 28, 2018 (led by APD); Technosignatures Report sent to HQ

Focus: Exoplanet Biosignatures WwW

- Seattle, WA, July 27-29, 2016
- Five papers developed from breakout sessions:
  - 1) *Exoplanet Biosignatures: A Review of Remotely Detectable Signs of Life*
  - 2) *Exoplanet Biosignatures: Understanding Oxygen as a Biosignature in the Context of Its Environment*
  - 3) *Exoplanet Biosignatures: A Framework for Their Assessment*
  - 4) *Exoplanet Biosignatures: Future Directions*
  - 5) *Exoplanet Biosignatures: Observational Prospects*
- Post-workshop, community-wide discussion and feedback enabled by NExSS online infrastructure: https://nexss.info/groups/ebwww/
- Published in an *Astrobiology Journal* special edition

Transiting Exoplanets with JWST: Community Working Group for Early Release Science

- Working Group Initiated December 2016
- Discussion Boards, Office Hours, Weekly Telecons
- 101 Registered Members
- NOI Submitted 3/7/2017
  - 81 Team Members: 52 Co-I, 29 Collaborators
  - 33 (of 81) ESA
  - 2 (of 81) Canada
- Proposal submitted 8/18/2017

MANY WORLDS

www.manyworlds.space

Posted on 2016-04-25 by Marc Kaufman

Leave a comment

Breaking Down Exoplanet Stovepipes

The search for life beyond our solar system requires unprecedented cooperation across scientific disciplines. NASA's NExSS collaboration includes those who study Earth as a life-bearing planet (lower right), those researching the diversity of solar system planets (left), and those on the new frontier, discovering worlds orbiting other stars in the galaxy (upper right). (NASA)

About Many Worlds

There are many worlds out there waiting to fire your imagination.

Marc Kaufman is an experienced journalist, having spent three decades at The Washington Post and The Philadelphia Inquirer, and is the author of two books on searching for life and planetary habitability. While the "Many Worlds" column is supported by the Lunar Planetary Institute/USRA and informed by NASA's NExSS initiative, any opinions expressed are the author's alone.

This site is for everyone interested in the burgeoning field of exoplanet detection and research, from the general public to scientists in the field. It will present columns, news stories and in-depth features, as well as the work of guest writers. Many Worlds will be updated at least once a week.

To contact Marc, send an email to marc.kaufman@manyworlds.space.

NExSS

Public Outreach:

Science writers Marc Kaufman and Elizabeth Tasker blogs about NExSS related research

ExoPAG SAG15 and SAG16 Reports

1. The SAG15 Team and Contributors

Chair: Dániel Apai, University of Arizona (apai@arizona.edu)

Authors:

Travis Barman, University of Arizona
Alan Boss, Carnegie DTM
James Breckinridge, Caltech
Ian Crossfield, UC Santa Cruz
Nicolas Cowan, McGill University
William Danchi, NASA GSFC
Eric Ford, Pennsylvania State University
Anthony del Genio, NASA GISS, NExSS
Shawn Domagal-Goldman, NASA GFSC, NExSS
Yuka Fujii, NASA GISS, NExSS
Renyu Hu, Jet Propulsion Laboratory
Nicolas Iro, University of Hamburg
Stephen Kane, San Francisco State University
Theodora Karalidi, University of Arizona
Markus Kasper, ESO
James Kasting, Penn State University
Thaddeus Komacek, University of Arizona
Ravikumar Kopparapu, NASA GSFC, NExSS
Patrick Lowrance, Caltech/IPAC
Nikku Mad
Eric Mama
Avi Mande
Mark Marl
Michael Mc
Caroline M
William Mc
Ilaria Pascu
Peter Plavc
Aki Roberg
Glenn Schn
Adam Shov
Margaret T

Major Contributors:

Dániel Apai, University of Arizona
Nicolas Cowan, McGill University
Anthony del Genio, NASA GISS, NExSS
Shawn Domagal-Goldman, NASA GFSC, NExSS
Yuka Fujii, NASA GISS, NExSS
Renyu Hu, Jet Propulsion Laboratory
Stephen Kane, San Francisco State University
Theodora Karalidi, University of Arizona
Markus Ka
Thaddeus I
Ravikumar
Eric Mama
Avi Mande
Mark Marl
Caroline M
Leslie Roge

SAG15 Website with up-to-date draft and relatec

http://eos-nexus.org/sag15/

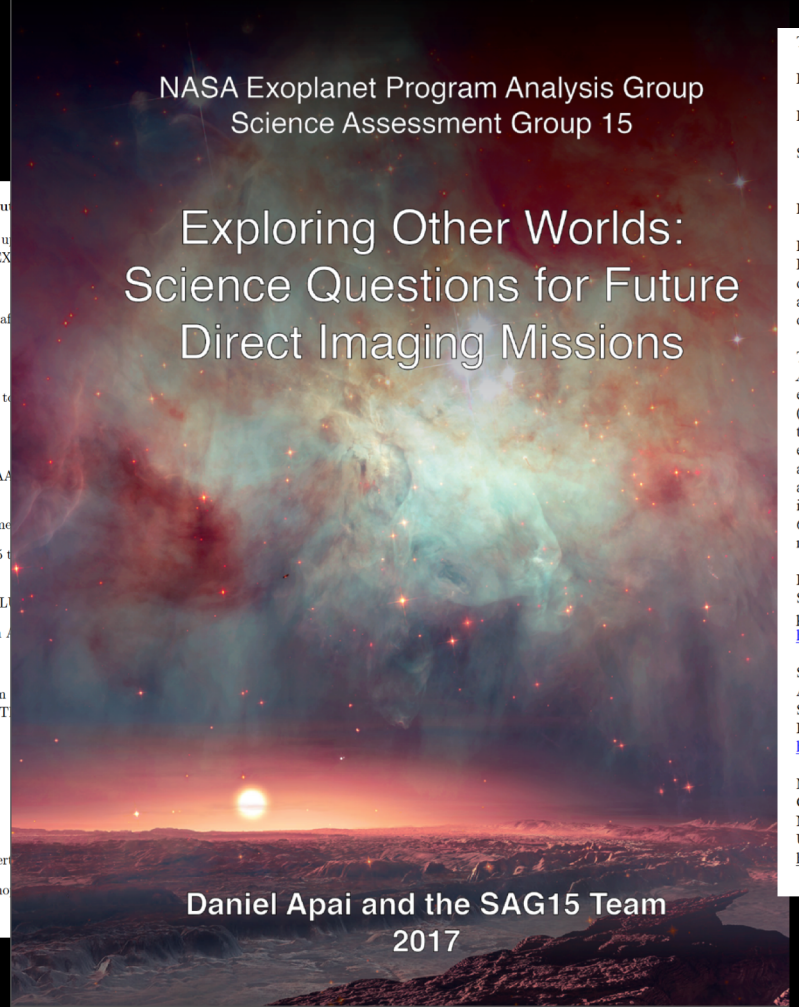
B. Methods of Collecting and Organizing Inpu

Updates: Throughout the project the SAG15 team has provided u
tion on the report's status and next steps to different constituents (EX
EC, NExSS, exoplanet community, STDTs) via the following channels:

- The SAG15 website always containing the up-to-date report draf
relevant documents
- Monthly telecons open to anyone in the exoplanet community
- Minutes of most telecons were circulated on the SAG15 mailing list t
abreast of the progess
- Emails sent to the NExSS group and EXOPAG groups
- Status updates provided to the EXOPAG community at every AA
the project
- Presentation/hackathlon session during the NExSS Face-to-Face me
- Representatives of the LUVOIR and HabEx STDTs on the SAG15 t
telecons
- The up-to-date version of the SAG15 report was shared with the L
- A brief presentation by Marley at the LUVOIR STDT meeting in A
the progress of SAG15

Soliciting Input: SAG15 has solicited and collected input from
stituents (EXOPAG, EXOPAG EC, NExSS, exoplanet community, ST
following channels:

- Presentations at the EXOPAG/AAS meetings
- Presentations to the NExSS community
- Emails sent to the NExSS group and EXOPAG groups
- Targeted emails soliciting input from scientists with required exper
- Input collected from the NExSS Biosignatures and SAG16 worksho



To: Exoplanet Program Analysis Group (ExoPAG) Executive Committee

From: ExoPAG Study Analysis Group (SAG) 16 Co-Chairs

Date: 18 June 2018

Subject: ExoPAG SAG 16 Topic: Exoplanet Biosignatures

Dear ExoPAG Executive Committee:

Below and attached please find a summary of the products from the SAG 16 Topic: Exoplanet Biosignatures Workshop Without Walls (EBWWW). The EBWWW encompassed a series of online and in-person activities, with participation from the international exoplanet and astrobiology communities, tc
detection of life on planets ot

These activities culminated
Astrobiology to be published
executive summary (Kiang
(Schwieterman et al., in pres
the contextual knowledge req
et al., in press); 4) a gener
available data in a formal qu
al., in press); 5) identificatio
incorporate other conceptual
6) a review of the upcoming
needed to search for exoplan

Kiang, N.Y., Domagal-Gold
Schwieterman, E.W., Walk
planetary era. *Astrobiology*,
https://www.liebertpub.com/

Schwieterman, E.W., Kiang,
Arney, G.N., Hartnett, H.E.,
S.I., Grenfell, J.L., Hegde,
Biosignatures: A Review of I
https://www.liebertpub.com/

Meadows, V.S., Reinhard, C
Goldman, S.D., Lincowski,
N., Deitrick, R., Lyons, T.W
Understanding Oxygen as a B
https://www.liebertpub.com/

Catling, D.C., Krissansen-Totton, J., Kiang, N.Y., Crisp, D., Robinson, T.D., DasSarma, S., Rushby, A., Del Genio, A., Bains, W., Domagal-Goldman, S., 2017. "Exoplanet biosignatures: A framework for their assessment," *Astrobiology*, 18(6). https://www.liebertpub.com/doi/10.1089/ast.2017.1737

Walker S. I., Bains W., Cronin L., DasSarma S., Danielache S., Domagal-Goldman S., Kacar B., Kiang N. Y., Lenardic A., Reinhard C. T., Schwieterman, E.W., Shkolnik, E.,L., Smith, H.B. (2017). "Exoplanet Biosignatures: Future Directions," *Astrobiology*, 18(6). arXiv preprint 1705.08071.
http://arxiv.org/abs/1705.08071

Fujii, Y. , Angerhausen, D., Deitrick, R., Domagal-Goldman. S., Grenfell, J.L., Hori, Y. , Palle, E., Siegler, N., Stapelfeldt, K., Rauer, H. (2017). "Exoplanet Biosignatures: Observational Prospects," *Astrobiology*, 18(6). arXiv preprint 1705.07098.
https://arxiv.org/abs/1705.07098

In addition, two white papers were submitted to the National Academies of Sciences Astrobiology Science Strategy and Exoplanet Science Strategy panels.

Domagal-Goldman. S., et al. (2018) Life Beyond the Solar System: Remotely Detectable Biosignatures. This is a white paper that was submitted to the National Academies of Sciences Study: Astrobiology Science Strategy for the Search for Life in the Universe.
https://arxiv.org/abs/1801.06714

Domagal-Goldman. S., et al. (2018) Life Beyond the Solar System: Remotely Detectable Biosignatures. This is a white paper that was submitted to the National Academies of Sciences (NAS) Study on an "Astrobiology Science Strategy for the Search for Life in the Universe," and to another NAS study on an "Exoplanet Science Strategy." The NAS Exoplanet Science Strategy white paper is appended to this report.

Sincerely,

Shawn Domagal-Goldman, Nancy Kiang, Niki Parenteau

Selected Webinars

- 15Jun01: Identifying Missing Experimental Data, Fortney (UCSC), Imanaka (ARC), Anbar (ASU)
- 15Jul24: Biomarkers and their relation to the surface and test surface, Domagal-Goldman (GSFC), Anbar (ASU), Desch (ASU)
- 15Dec10: Protoplanetary Disks, Jang-Condell (UWyo), Turner (JPL)
- 16Feb16: Earths in Other Solar Systems, Apai (UA), Mulders (UA)
- 16Mar17: Mission to Young Earth 2.0, Airapetian (GSFC), Desch (ASU)
- 16Apr14: The Living, Breathing Planet, Moore (Hampton), Gronoff (Langley)
- 16Jun09: Exoplanet Unveiled, Graham (UCB)
- 16Jul14: Characterizing the Habitable Zone Planets of Kepler Stars, Fischer (Yale), Ford (PSU)
- 16Aug18: Statistical Characterization of the Atmospheres of Kepler's Small Planets (Deming (UM) & Exoplanetary Exospheres Jensen (U. Nebraska Kearney))
- 16Sep12: Rocky Planet Habitability, DelGenio (GISS)
- 17Feb23: New TRAPPIST-1 Planets, Agol (UW)

Examples of cross-discipline research by NExSS teams

- Disintegrating exoplanet dust tails as a potential window on the composition of planet interiors
- Geochemical constraints on habitability and detectability of biotic O_2 on aquaplanets
- Space weather effects on atmospheric loss for planets orbiting M-stars
- Bayesian framework for biosignature assessment
- Climate model reassessment of the moist greenhouse HZ inner edge