Exoplanet Program Analysis Group Report.

223rd AAS Meeting
Washington, DC

Scott Gaudi
(ExoPAG EC Chair)

EC Membership.

- Current EC members (as of April 2013).

Nick Cowan	Northwestern
Jonathan Fortney	U.C. Santa Cruz
Scott Gaudi (*Chair)*	Ohio State
Tom Greene	NASA Ames
Lisa Kaltenegger	MPIA
Dave Latham	SAO
Amy Lo	Northrop Grumman
Peter Plavchan	Caltech/NexSci
Aki Roberge	NASA Goddard
Gene Serabyn	JPL
Remi Soummer	Space Telescope Sci. Inst.
Doug Hudgins (*Ex officio)*	NASA Headquarters
James Kasting (*Ex officio)*	Penn State
Wes Traub (*Ex officio)*	JPL

Charter.

In June 2009, NASA formed the *Exoplanet Exploration Program Analysis Group* (ExoPAG), responsible for soliciting and coordinating community input into the development and execution of NASA's Exoplanet Exploration Program (ExEP). The ExoPAG serves as a community-based, interdisciplinary forum for analysis in support of activity prioritization and for future exploration.

- Articulate the key scientific drivers for exoplanet research.
- Evaluate the expected capabilities of potential ExEP missions for achieving the science goals of the program.
- Evaluate ExEP goals, objectives, investigations, and required measurements **on the basis of the widest possible community outreach**.
- Articulate focus areas for needed mission technologies.
- Identify related activities that enhance the ExEP mission portfolio such as ground-based observing, theory and modeling programs, and community engagement.

ExoPAG Direction.

Over the past ~2 years, ExoPAG activities have been (more or less) focused on the following general goals:

- Gathering input from the wide cross-section of the exoplanet community on the future of exoplanet research.
- Considering novel ways in which NASA can address exoplanet research in the short term, Includes ground-based research *in support* of current or future missions
- *Maintaining progress* toward eventual goal of a flagship direct imaging mission.

Methods & Activities.

- Solicit community input through ExoPAG meetings.
- Identify questions and inquiry areas.
- If needed, form Study Analysis Groups (SAGs) to address these questions in depth.
  - Chaired by EC members (generally), but comprised of community members.
- Deliver conclusions and community input to NASA through the Astrophysics Subcommittee (APS) of the NASA Advisory Council (NAC).
  - Includes final reports from SAGs.

Recent and Upcoming Developments.

1. WFIRST-AFTA blessed for future study, with coronagraph baselined, coronagraph architectures selected.
2. Science and Technology Definition Teams convened.
3. *Kepler* reaches end of its primary mission; future: primary mission closeout + K2.
4. *Gaia*, *JWST*, *TESS* are imminent.
5. Mid-decadal Review.

Immediate questions.

- What do we need to properly characterize exoplanets (of all types)?
- What are the requirements to support NASA's goals and current and future missions?
  - Observational, technological, theoretical.
  - Including ground-based research, and in particular radial velocity requirements.
- What are the science requirements for small- to medium-scale direct imaging missions?
- Others?

Completed SAGs.

SAG1: Debris Disks & Exozodiacal Dust - Aki Roberge

- Report completed; paper published in PASP, 2012, 124, 799-808

SAG2: Potential for Exoplanet Science Measurements from Solar System Probes - Dave Bennett and Dan Coulter

- Completed, no report. Topic explored in detail at Kavli Institute workshop, Santa Barbara CA, May 2010

SAG5: Exoplanet Flagship Requirements and Characteristics- Charley Noecker, Tom Greene

- Final report complete, subject to APS approval.

Current SAGs, Part 1.

SAG4: Planetary Measurements Needed for Exoplanet Characterization - Lisa Kaltenegger

- Draft report completed.
- Final report delivered at ExoPAG 9.

SAG8: Requirements and Limits of Future Precision Radial Velocity Measurements - Dave Latham, Peter Plavchan

- Presentations at ExoPAG 6, 7 and 8
- Report started.

SAG9: Exoplanet Probe to Medium Scale Direct-Imaging Mission Requirements and Characteristics - Rémi Soummer

- Presentations at ExoPAG 8 and 9.

Current SAGs, Part 2.

SAG10: Characterizing the Atmospheres of Transiting Planets with *JWST* and Beyond - Nick Cowan

- What is the full diversity of planet properties needed to characterize exoplanets?
- Which measurements are needed?
- Will *JWST* be able to characterize habitable planets?
- Which critical measurements will be too expensive or inaccessible to *JWST*)?

SAG11: Preparing for the WFIRST Microlensing Survey – Jennifer Yee

- Identify both mission critical and mission enhancing programs,
- Identify immediate science to come out of each program, as well as the program's direct impact on the WFIRST mission,
- For each proposed program, quantify the improved scientific return for the WFIRST mission,
- Emphasize programs that can be executed using existing (NASA) resources.

ExoPAG 6, 7, 8, 9.

- Since June 2012:
  - ExoPAG 6: October 13-14, 2012, Reno, NV
  - ExoPAG 7: January 5+6, Long Beach, CA
  - ExoPAG 8: October 5+6, Denver, CO
  - ExoPAG 9: January 4+5, Washington, DC.
    - Joint meeting with COPAG.
- (most) Talks available online (or will be soon):

  http://exep.jpl.nasa.gov/exopag/exopag6/agenda/

  http://exep.jpl.nasa.gov/exopag/exopag7/agenda/

  http://exep.jpl.nasa.gov/exopag/exopag8/agenda/

  http://exep.jpl.nasa.gov/exopag/exopag8/agenda/

ExoPAG 6, 7, 8, 9.

- Primary topics/questions addressed:
  - What is the landscape of current and future missions?
  - What are the radial velocity requirements to support NASA's goals and current and future missions?
  - What do we need to characterize exoplanets and their host stars?
  - Update on the progress toward a high-contrast imager in space.
  - What do we need to do to prepare for WFIRST-AFTA exoplanet surveys?
  - What do we need to do to ensure a robust measurement of η_{Earth}?
  - What is the potential of JWST to characterize exoplanets?

What we've learned.

- Need to figure out overlap of RV surveys and ground-based direct imaging surveys with potential future direct imaging (space) missions.
- The frequency of habitable planets is not one number; need to specify distribution functions and/or agree upon a fiducial definition for a habitable planet.
- Continued investment in extracting science from Kepler is both worthwhile and critical.
- Need to figure out what is needed to characterize exoplanets; need to figure out whether or not JWST can characterize habitable planets.
- Need to identify the future roles of astrometry and interferometry.

Toward an Exoplanet 5-10 Year Plan.

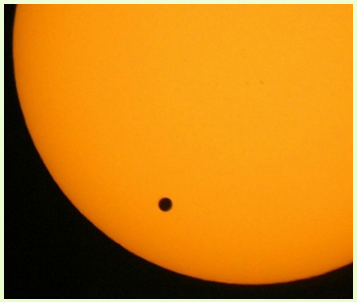
Goal.

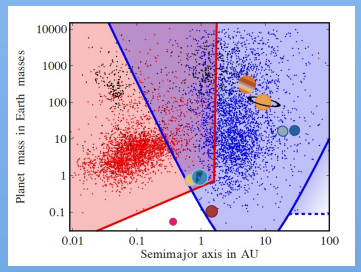
To develop a holistic, broad, unified, and coherent exoplanet roadmap for the next 5-10 years, with community consensus, focusing on areas where NASA can contribute.

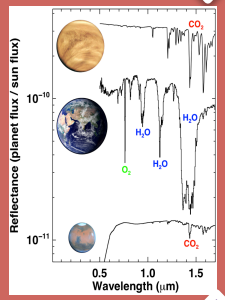
2010-2020	2020-2030	2030-2040

Science Roadmap

- A Complete Exoplanet Statistical Census
- Characterization of a Diversity of Other Worlds
- Our Nearest Neighbors: Surveying Nearby Planetary Systems and Searching for Habitable Climates







Mission Roadmap

- Ground-Based Mission-Supporting Observations
- TESS
- WFIRST+C
- JWST
- HST
- Spitzer
- Kepler
- Transit Char. Mission?
- Astrometry Mission?
- F-DIM: (Flagship Direct Imaging Mission)

Mission Matrix, e.g.

		RV	HST	Spitzer	Kepler	Gaia	TESS	JWST	WFIRST+C	Transit Char. Mission	F-DIM	Astrometry
What is the frequency and diversity of plantary systems? (Demographics)	Obtain a complete statistical census of planets in the Galaxy.				X	X			X			
	Survey the closest planetary systems.	X				X	X		X		X	X
	(Measure the frequency of potentially habitable planets)	X			X				X			
What are the natures of planetary interiors, surfaces, and atmsopheres?	Characterize a diverse set of planetary atmospheres.		X	X				X	X	X	X	
	Characterize exoplanets orbiting the closest stars.		X	X				X	X	X	X	
	(Understand the interiors, surfaces, and atmospheres of Earthlike exoplanets.)							X		X	X	
Is there life on other planets?	Measure the frequency of potentially habitable planets.	X			X				X			
	Understand the interior, surfaces, and atmospheres of Earthlike exoplanets.							X		X	X	
	Find nearby potentially habitable planets.	X					X				X	X
	Discover habitable climates on nearby planets.	X						X			X	
	Search for surface and atmospheric biomarkers.										X	

Technology, other support.

ExoPAG 9.

Broad support (as demonstrated by a show of hands) to continue with this activity and for a Science Interest Group.

Future.

- Continue work on SAGs.
- Form a Science Interest Group (SIG) to coordinate efforts to develop a 5-10 year plan, with approval of APS.
- Work with other PAGs to develop a consistent plan.
- Let us know if you have input, or would like to contribute to these efforts!
- Email me: gaudi@astronomy.ohio-state.edu
- More information on website, including email list:

http://exep.jpl.nasa.gov/exopag/