Exoplanet Program Analysis Group (ExoPAG) Report

Astrophysics Advisory Committee (APAC) Meeting

July 20, 2017

Alan Boss
(ExoPAG Chair)

ExoPAG EC Membership

Alan Boss (Chair)	Carnegie Institution
Daniel Apai	University of Arizona
David Ciardi	NASA Exoplanet Science Institute
Shawn Domagal-Goldman	NASA Goddard Space Flight Center
Tiffany Glassman	Northrup Grumman Aerospace Sys.
Eliza Kempton	Grinnell College
Dimitri Mawet	Jet Propulsion Laboratory
Michael Meyer	University of Michigan
Tyler Robinson	University of California, Santa Cruz
Chris Stark	Space Telescope Science Institute
Johanna Teske	Carnegie Observatories
Scott Gaudi (Past Chair, Ex officio)	Ohio State University
Martin Still (Ex officio)	NASA Headquarters

Completed Study Analysis Groups (SAGs)

Year	SAG	Title	Lead
2010	1	Potential for Exoplanet Science Measurements from Solar System Probes	Bennett, Coulter
2012	2	Debris Disks & Exozodiacal Dust	Roberge
2013	5	Exoplanet Flagship Requirements and Characteristics	Noecker, Greene
2015	8	Requirements and Limits of Future Precision Radial Velocity Measurements	Latham, Plavchan
2015	9	Exoplanet Probe to Medium Scale Direct-Imaging Mission Requirements and Characteristics	Soummer
2015	10	Characterizing the Atmospheres of Transiting Planets with JWST and Beyond	Cowan
2014	11	Preparing for the WFIRST Microlensing Survey	Yee
2017	12	Scientific potential and feasibility of high-precision astrometry for exoplanet detection and characterization (final presentation at ExoPAG #15, January 2017)	Bendek
	3,4,6,7	[SAG numbers not used]	

Study Analysis Groups Closing Out

Year	SAG	Title	Lead
2017	13	Exoplanet Occurrence Rates and Distributions (close out presented 6/18/17)	Belikov
2017	15	Exploring Other Worlds: Observational Constraints and Science Questions for Direct Imaging Exoplanet Missions (close out presented 6/18/17)	Apai
2017	18	Metrics for Direct-Imaging with Starshades (close out presented 1/2/17)	Glassman & Turnbull

Active Study Analysis Groups (SAGs)

Year	SAG	Title	Lead
--	14	Characterization of Stars Targeted for NASA Exoplanet Missions (on hold)	Stassun
--	16	Exoplanet Biosignatures (5 papers written, final report by August 2017?)	Domagal-Goldman
--	17	Community Resources Needed for K2 and TESS Planetary Candidate Confirmation (close out expected at ExoPAG #17 in January 2018)	Ciardi & Pepper
--	19	Exoplanet imaging signal detection theory and rigorous contrast metrics (in progress)	Mawet & Jensen-Clem

ExoPAG Study Analysis Groups (SAGs) Overall Status

- 8 SAGs finished work (7 with final report online)
- 3 SAGs actively working, 1 on hold
- 3 SAGs now ready to be closed out:
- SAG 13 on exoplanet demographics (Belikov)
- SAG 15 on science questions beyond biosignatures (Apai)
- SAG 18 on star shade metrics (Glassman & Turnbull)

ExoPAG Recent Activities

- Held ExoPAG #16 meeting prior to KepSciCon in Mountain View, CA on June 18, 2017
- Excellent attendance by KepSciCon folks at ExoPAG #16 – about 80 attendees in total
- Held ExEP splinter sessions to "send and receive" at AbSciCon (Mesa, AZ), AAS (Austin, TX), and at KepSciCon (NASA Ames, CA)
- Reasonable numbers attended these splinter sessions: many suggestions were received for expanding ExEP/community communications

2018 Technology Selection and Prioritization Process

ID	Activity	Last year	This year
1	Technology needs input window opens	06/08/16	06/18/17
	email all three PAGs: Technology Gap Lists, input forms, process explanation		06/19/17
	presentation at June ExoPAG	**06/12/16**	**06/18/17**
2	Technology window closes	08/26/16	08/28/17
3	Technology Gap Selection and Prioritization Criteria Review by APD Program Offices	09/08/16	08/25/17
4	Selection and Prioritization Criteria Review by ExoTAC	09/21/16	09/05/17
5	Technology Gap Assessment Review by APD Program Offices	10/07/16	09/18/17
6	Technology Gap Assessment Review by ExoTAC	10/21/16	10/02/17
7	Technology Gap Lists inform TDEM Amendment	mid-Nov	mid-Nov
8	Technology Amendment released through NSPIRES	mid-Dec	mid-Dec
9	ExEP Technology Plan Appendix updated and released	01/02/17	12/01/17
	Presentation at January ExoPAG	01/02/17	01/06/18
10	TDEM Proposal Deadline	03/17/17	03/15/18
11	TDEM Awards Selected	Aug 2017	Aug 2018

ExoPAG Future Activities

- Continue monthly ExoPAG EC telecons
- Finish work of four remaining SAGs – 14, 16, 17, and 19
- Continue to review ExEP Technology Gap List planning process
- Hold ExoPAG #17 meeting prior to AAS meeting in National Harbor, MD in early January, 2018
- ExoPAG #17 to feature a 2-3 hour mini-science symposium on the theme of JWST's role in exoplanet transit spectroscopy

APAC Action Requested by ExoPAG EC

- Accept close out of following three SAGs:
- SAG 13: Exoplanet Occurrence Rates and Distributions (Rus Belikov, Chair)
- SAG 15: Exploring Other Worlds: Observational Constraints and Science Questions for Direct Imaging Exoplanet Missions (Daniel Apai, Chair)
- SAG 18 – Metrics for Direct-Imaging with Starshades (Tiffany Glassman and Maggie Turnbull, Co-Chairs)

Backup Slides

SAG 12: Scientific Potential and Feasibility of High-Precision Astrometry for Exoplanet Detection and Characterization (Eduardo Bendek, Chair)

- **Key questions and goals that this group will address are:**
- **1) What is the scientific potential of astrometry for different precision levels?** Which planet types, confirm planet candidates.
- **2) What are the technical limitations to achieving astrometry of a given precision?** Technical challenges, observational strategies or post processing to improve the astrometry.
- **3) Identify mission concepts that are well suited for astrometry.** Next mission after GAIA that will make exoplanet science possible? What are the requirements for such a mission?
- **4) Study potential synergies with current and future European astrometry missions**. What are the available astrometric facilities to follow-up on GAIA (exoplanet-related) discoveries? Are they sufficient?

SAG 13: Exoplanet Occurrence Rates and Distributions (Rus Belikov, Chair)

Key objectives and questions:

1. Propose standard nominal conventions, definitions, and units for occurrence rates/ distributions to facilitate comparisons between different studies.
2. Do occurrence estimates from different teams/methods agree with each other to within statistical uncertainty? If not, why?
3. For occurrence rates where extrapolation is still necessary, what values should the community adopt as standard conventions for mission yield estimates?

Recent Progress:

- Computation/crowdsourcing of eta tables
- 11 participants submitted tables so far
- Latest estimates of occurrences of potentially habitable planets seem to be converging (at least to a factor of ~2-3), and explanations for discrepancies are starting to clarify
- Expected product in mid 2017: estimates of occurrence rates

SAG 14: Characterization of Stars Targeted for NASA Exoplanet Missions (Keivan Stassun, Chair, and TESS co-I for Target Selection)

[TESS = Transiting Exoplanet Survey Satellite]

SAG 14 has prepared a preliminary analysis of potential benefits of a pre-launch spectroscopic survey of TESS targets:

- Primary TESS goal: discover ***50 Earth-sized transiting planets*** ($R < 4\ R_{Earth}$) ***whose masses can be measured*** by follow-up radial-velocity measurements.
  - Analysis of activity-driven RV jitter in TESS targets shows that, even in most stringent worst-case scenario, TESS is certain to deliver the above mission science requirement.
  - A pre-launch spectroscopic survey of TESS targets could help ensure an even larger yield on the above goal by identifying an even larger sample of low-activity, Doppler stable target stars.
- SAG 14 report is on hold.

SAG 15: Exploring Other Worlds: Observational Constraints and Science Questions for Direct Imaging Exoplanet Missions (Daniel Apai, Chair)

Charge:

1) What are the most important science questions in exoplanet characterization, apart from biosignature searches?
2) What type of data (spectra, polarization, photometry), with what quality (resolution, signal-to-noise, cadence), is required to answer these science questions?

Progress:

- SAG15 underway and on track
- Team, timeline, process, milestones identified
- Up-to-date status and documents: eos-nexus.org/SAG15/
- Currently finishing work on list of high-level science questions
- Target date for completion Spring 2017
- Report + refereed publication are foreseen
- Interactions with WFIRST and Large Mission STDTs important

SAG 16: Biosignatures (Shawn Domagal-Goldman, Nancy Kiang, and Niki Parenteau, Co-Chairs)

Science Goals

We seek to answer 3 broad questions:

1) What are known remotely-observable biosignatures, the processes that produce them, and their known non-biological sources?

2) How can we identify additional biosignatures, and a more comprehensive framework for biosignature assessment?

3) What are the requirements for detecting these biosignatures to different levels of confidence?

A 3-day workshop was held on July 27-29, 2016, along with the NASA Astrobiology Institute (NAI) and the Nexus for Exoplanet System Science (NExSS). Plan is to draft a SAG report and a peer-reviewable paper by mid 2017, invite review and commentary from the community, and submit final SAG report by end of 2017.

SAG 17 – Community Resources Needed for K2 and TESS Planetary Candidate Confirmation (David Ciardi and Joshua Pepper, Co-Chairs)

- SAG 17 will study and enumerate the resources needed by the community to effectively and efficiently validate as many K2 and TESS candidates as possible, and propose methods to allow the community to coordinate and self-organize the process.
- Specific goals of SAG 17 include the following:
- Identify needed follow-up observations for K2 and TESS including but not limited to imaging, spectroscopy, and time-series follow-up
- Identify telescopes, instrument, and financial resources available to the US community
- Identify how archival resources can be utilized (e.g., Gaia)
- Identify how the community can be organized and communication facilitated particularly with regards TESS full frame images, candidate identification, single transiting events, and candidate prioritization.
- Identify needs to ensure efficient and effective characterization with JWST (and WFIRST)
- Identify connections to other SAG efforts (e.g., SAGs 15 and 16)

SAG 18 – Metrics for Direct-Imaging with Starshades (Tiffany Glassman and Maggie Turnbull, Co-Chairs)

- We propose to identify the areas of starshade performance where standardized metrics would be beneficial, and to create rigorous definitions of key terms, data processing techniques, and performance requirements.
- There have been informal definitions of contrast as the amount of residual starlight at the location of an exoplanet of interest and of suppression as the total amount of residual starlight entering the telescope.
- How can contrast or suppression be used as metrics of starshade performance (pros and cons)?
- How should contrast be defined?
- How should suppression be defined?
- What contrast limit is required to detect a planet of a given magnitude at the inner working angle (IWA)?

SAG 19 – Exoplanet Imaging Signal Detection Theory and Rigorous Contrast Metrics (Dimitri Mawet and Rebecca Jensen-Clem, Co-Chairs)

- Go back to the basics of Bayesian Signal Detection Theory (SDT), i.e., H0:signal absent / H1:signal present hypothesis testing.
- Rebuild a solid set of usual definitions used for or in lieu of "contrast" in different contexts, such as astrophysical contrast or ground truth, instrumental contrast used for coronagraph/instrument designs, and the measured on-sky data-driven contrast.
- Identify what we can learn and apply from communities outside our field (e.g. medical imaging: receiver operating characteristic (ROC) curve).
- Define precise contrast computation and ROC curve computation recipes, a new "industry standard".
- Identify how the new metrics and recipes can be used to define confidence levels for detection (H1) and subsequently error bars for photometric, spectroscopic, astrometric characterization.
- Perform a community data challenge before and after applying our proposed set of standardized SDT rules and recipes, and apply lessons learned.