Exoplanet Program Analysis Group Report
Astrophysics Subcommittee Meeting
October 4, 2016

Alan Boss
(ExoPAG Chair)

ExoPAG EC Membership

Alan Boss (Chair)	Carnegie Institution
Daniel Apai	University of Arizona
Rus Belikov	NASA Ames Research Center
David Ciardi	NASA Exoplanet Science Institute
Shawn Domagal-Goldman	NASA Goddard Space Flight Center
Tiffany Glassman	Northrup Grumman Aerospace Sys.
Dimitri Mawet	Jet Propulsion Laboratory
Tyler Robinson	University of California, Santa Cruz
Maggie Turnbull	Global Science Institute
Lucianne Walkowicz	Adler Planetarium
Scott Gaudi (Past Chair, Ex officio)	Ohio State University
Martin Still (Ex officio)	NASA Headquarters
Karl Stapelfeldt (Ex officio)	Jet Propulsion Laboratory
Erik Mamajek (deputy to KS)	Jet Propulsion Laboratory

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

Active Study Analysis Groups (SAGs)

Year	SAG	Title	Lead
--	12	Scientific potential and feasibility of high-precision astrometry for exoplanet detection and characterization (planned completion Jan. 2017)	Bendek
--	13	Exoplanet Occurrence Rates and Distributions (planned completion early 2017)	Belikov
--	14	Characterization of Stars Targeted for NASA Exoplanet Missions	Stassun
--	15	Exploring Other Worlds: Observational Constraints and Science Questions for Direct Imaging Exoplanet Missions	Apai
--	16	Exoplanet Biosignatures	Domagal-Goldman
--	17	Community Resources Needed for K2 and TESS Planetary Candidate Confirmation (new)	Ciardi & Pepper
--	18	Metrics for Direct-Imaging with Starshades (new)	Glassman & Turnbull
--	19	Exoplanet imaging signal detection theory and rigorous contrast metrics (proposed here)	Mawet & Jensen-Clem

ExoPAG Study Analysis Groups (SAGs) Overall Status

- 7 SAGs finished work with final report online
- 7 SAGs actively working
- 2 SAGs nearing completion in early 2017:
- SAG 12 on exoplanet astrometry (Bendek)
- SAG 13 on exoplanet demographics (Belikov)
- 1 new SAG is proposed:
- SAG 19 on direct imaging/coronagraph metrics – Dimitri Mawet & Rebecca Jensen-Clem, Co-Chairs

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

Science Goals

We seek to answer 3 broad questions:

1) What are known remotelyobservable biosignatures, the processes that produce them, and their known nonbiological 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 October 2016, invite review and commentary from the community, and submit final SAG report by March 2017.

PROPOSED 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 onsky datadriven 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.

ExEP Technology Needs and Prioritization Process

ID	Activity	Date
1	Technology Needs Input Window Opens	06/08/16
	Email to the ExoPAG: Technology Gap Lists, Input Forms, process explanation	
	Presentation at June ExoPAG	06/12/16
2	Technology Window Closes	08/26/16
3	Prioritization Criteria Concurred by the ExEP	09/15/16
4	Technology Gaps Prioritized by the ExEP	10/20/16
5	Technology Gap Lists Inform TDEM Amendment	mid-Nov
	Technology Amendment released through NSPIRES	mid-Dec
6	ExEP Technology Plan Appendix Updated and Posted	12/22/16
	Presentation at Winter ExoPAG	01/02/17
7	TDEM Proposal Deadline	03/17/17
8	TDEM Awards Selected	Aug 2017

- Enabling technologies only (vs. enhancing) - requires ExEP iteration with community members
- PCOS/COR Technology team involved in every step; ExEP involved in their prioritization process

Technology Needs and Prioritization Process

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1	Technology Needs Input Window Opens	06/08/16
	email all three PAGs: Technology Gap Lists, Input Forms, process explanation	
	presentation at June ExoPAG	06/12/16
2	Technology Window Closes	08/26/16
3	Technology Gap Selection and Prioritization Criteria Peer Review	09/08/16
	Selection and Prioritization Criteria Review by Independent Review Board convened by ExoTAC	09/21/16
4	Technology Gaps Assessed and Prioritized by the ExEP	10/10/16
	Technology Gap Assessment and Prioritization Reviewed by Independent Review Board convened by ExoTAC	10/20/16
5	Technology Gap Lists Inform TDEM Amendment	mid-Nov
	Technology Amendment released through NSPIRES	mid-Dec
6	ExEP Technology Plan Appendix Updated and Posted	12/22/16
	Presentation at January ExoPAG	01/02/17
7	TDEM Proposal Deadline	03/17/17
8	TDEM Awards Selected	Aug 2017

ExoPAG Future Activities

- Continue monthly ExoPAG EC telecons
- Continue work of seven active SAGs – 12, 13, 14, 15, 16, 17 and 18
- Begin work of new SAG 19 (if approved)
- Continue to provide assistance to Far-IR/Origins STDT about exoplanet science (but no new SAG)
- Review ExEP Technology Gap List planning
- Hold ExoPAG 15 meeting prior to AAS winter meeting: January 2-3, 2017 in Grapevine, TX
- Joint PAG session with P. Hertz, Large Mission STDTs, and ESA L3 (LISA) mission reports

APS Action Requested by ExoPAG EC

- PROPOSED SAG 19 – Exoplanet Imaging Signal Detection Theory and Rigorous Contrast Metrics (Dimitri Mawet and Rebecca Jensen-Clem, Co-Chairs) – approve charter?
- Charter was circulated to the APS prior to this meeting

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 early 2017: estimates of occurrence rates

SAG 14: Characterization of Stars Targeted for NASA Exoplanet Missions (Keivan Stassun, Chair, and TESS coI 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 in preparation.

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

NEW 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)

NEW 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)?