SAG15 Telecon 1

Exploring Other Worlds: Observational Constraints and Science Questions for Direct Imaging Exoplanet Missions

December 15, 2015

Agenda:

1) Welcome and review of the SAG15 goals

2) Review of the workflow, timeline, and milestones of the SAG15 study

3) Discussion of the content and organization of the report(s)

4) Discussion of the general procedure, format, the products of any sub-studies

5) Initial discussion of the SAG15 questions (highest-level science questions, direct observable)

Name	Email	Affiliation
Daniel Apai (Chair)	apai@arizona.edu	Univ. Arizona
Travis Barman	barman@lpl.arizona.edu	Univ. Arizona
Alan Boss	boss@dtm.ciw.edu	Carnegie DTM
Nicolas Cowan	nicolas.cowan@mcgill.ca	McGill University
Ian Crossfield	ianc@lpl.arizona.edu	Univ. Arizona
Shawn Domagal-Goldman	shawn.goldman@nasa.gov	NASA HQ
Ravikumar Kopparappu	ravikumar.kopparapu@nasa.gov	NASA GSFC
Mark Marley	mark.s.marley@nasa.gov	NASA Ames
Caroline Morley	cmorley@ucolick.org	UC Santa Cruz
Peter Plavchan	plavchan@gmail.com	Missouri State University
Mark Swain	mark.r.swain@jpl.nasa.gov	JPL
Margaret Turnbull	turnbull.maggie@gmail.com	SETI Institute

SAG15 Charter

Future direct imaging missions may allow observations of flux density as a function of wavelength, polarization, time (orbital and rotational phases) for a broad variety of exoplanets ranging from rocky sub-earths through super-earths and neptunes to giant planets. With the daunting challenges to directly imaging exoplanets, most of the community's attention is currently focused on *how* to reach the goal of exploring habitable planets or, more specifically, how to search for biosignatures.

Arguably, however, most of the exoplanet science from direct imaging missions will not come from biosignature searches in habitable earth-like planets, but from the studies of a much larger number of planets *outside* the habitable zone or from planets within the habitable zone that do not display biosignatures. These two groups of planets will provide an essential context for interpreting detections of possible biosignatures in habitable zone earth-sized planets.

However, while many of the broader science goals of exoplanet characterization are recognized, there has been no systematic assessment of the following two questions:
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?

We propose to form SAG15 to identify the key questions in exoplanet characterization and determine what observational data obtainable from direct imaging missions is necessary and sufficient to answer these.

The report developed by this SAG will explore high-level science questions on exoplanets ranging from gas giant planets through ice giants to rocky and sub-earth planets, and — in temperatures — from cold (~200 K) to hot (~2,000 K). For each question we will study and describe the type and quality of the data required to answer it.

For example, the SAG15 could evaluate what observational data (minimum sample size, spectral resolution, wavelength coverage, and signal-to-noise) is required to test that different formation pathways in giant planets lead to different abundances (e.g. C/O ratios). Or the SAG15 could evaluate what photometric accuracy, bands, and cadence is required to identify continents and oceans in a habitable zone Earth-sized or a super-earths planet. As another example, the SAG15 could evaluate what reflected light data is *required* to constrain the fundamental parameters of planets, e.g. size (distinguishing earth-sized planets from super-earths), temperature (cold/warm/hot), composition (rocky, icy, gaseous), etc.

SAG15 will not attempt to evaluate exoplanet detectability or specific instrument or mission capabilities; instead, it will focus on evaluating the *diagnostic power* of different measurements on key exoplanet science questions, simply adopting resolution, signal-to-noise, cadence, wavelength coverage as parameters along which the diagnostic power of the data will be studied. Decoupling instrumental capabilities from science goals allows this community-based effort to explore the science goals for exoplanet characterization in an unbiased manner and in a depth beyond what is possible in a typical STDT.

We envision the SAG report to be important for multiple exoplanet sub-communities and specifically foresee the following uses:
1) Future STD teams will be able to easily connect observational requirements to missions to fundamental science goals;
2) By providing an overview of the key science questions on exoplanets and how they could be answered, it may motivate new, dedicated mission proposals;
3) By providing a single, unified source of requirements on exoplanet data in advance of the Decadal Survey, the science yield of various missions designs can be evaluated realistically, with the same set of assumptions.

Our goal is to carry out this SAG study by building on both the EXOPAG and NExSS communities.

We aim to complete a report by Spring 2017 and submit it to a refereed journal, although this timeline can be adjusted to maximize the impact of the SAG15 study for the ongoing and near-future STDTs and other mission planning processes.

Synergy with a potential future SAG proposed by Shawn Domagal-Goldman: While the SAG proposed here will include studies of habitable zone rocky planets, it will focus on planets without significant biological processes. A future SAG may be proposed by Shawn Domagal-Goldman to explore biosignatures; if such a SAG is proposed, we envision a close collaboration on these complementary, but distinct problems.

We propose to form SAG15 to identify the key questions in exoplanet characterization and determine what observational data obtainable from direct imaging missions is necessary and sufficient to answer these.

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?

The report developed by this SAG will explore high-level science questions on exoplanets ranging from gas giant planets through ice giants to rocky and sub-earth planets, and — in temperatures — from cold (~200 K) to hot (~2,000 K). For each question we will study and describe the type and quality of the data required to answer it.

What is *not* included:

1) Biosignatures (but habitable planets are!)
2) Evaluation of instrument capabilities or advocacy for mission architectures

Uses of the Report:

1) Future STD teams will be able to easily connect observational requirements to missions to fundamental science goals;

2) By providing an overview of the key science questions on exoplanets and how they could be answered, it may motivate new, dedicated mission proposals;

3) By providing a single, unified source of requirements on exoplanet data in advance of the Decadal Survey, the science yield of various missions designs can be evaluated realistically, with the same set of assumptions.

Agenda:

1) Welcome and review of the SAG15 goals

2) Review of the workflow, timeline, and milestones of the SAG15 study

3) Discussion of the content and organization of the report(s)

4) Discussion of the general procedure, format, the products of any sub-studies

5) Initial discussion of the SAG15 questions (highest-level science questions, direct observable)

Tentative Timeline

i) December or January: Initial brainstorming telecon to define process and collect initial ideas
ii) February: a major, 2-3 hour long videocon with brief presentations and in-depth discussion of ideas
iii) March-May: monthly telecons to discuss results and coordinate next steps
iv) June: Major, longer telecon halfway in the process to assess progress and identify steps to answer open questions
v) July-Aug: monthly telecons
vi) Aug/Sep: potential in-person meeting, coordinated with NExSS, focusing on finalizing the advanced draft of the report
vii) Oct-Feb: work on report draft and preparation of a shorter version for a refereed journal as a review article
viii) March/April: current target date for submission

Milestones

2016

Feb 15: List of science questions complete; list of observables complete; necessary sub-studies identified.
June 15: First draft, describing complete set of ideas and topics; preliminary results from sub-studies. Action items for completion
Sep 15: Advanced draft ready, start of finalizing manuscript
Dec   15: Shorter version ready for submission as review paper to refereed journal

2017

Feb 15: Final version of the report circulated
April 15: Submission of the report to EXOPAG and APS

Workflow

1) Emails via email alias: SAG15@as.arizona.edu
2) Team telecons
3) Substudies: smaller teams/individuals lead literature reviews and simple evaluations
4) References via myADS public library: http://adsabs.harvard.edu/cgi-bin/nph-abs_connect?library&libname=SAG15&libid=4fde410a6e
5) Draft - Cloud-based until advanced draft, offline after that https://www.icloud.com/pages/0005vbr_-JmPS6H_ZEkKYnVLQ#SAG15_Draft_Report_versionAA

Agenda:

1) Welcome and review of the SAG15 goals

2) Review of the workflow, timeline, and milestones of the SAG15 study

3) Discussion of the content and organization of the report(s)

4) Discussion of the general procedure, format, the products of any sub-studies

5) Initial discussion of the SAG15 questions (highest-level science questions, direct observable)

Content and Organization of the Report(s)

High-level Science Questions

↓

Observables

↓

Required Data Type/Quality

Content and Organization of the Report(s)

Content and Organization of the Report(s)

Summary of science questions for different types of individual planets.					
	Gas Giant	Ice Giant	Super-Earth	Earth	Sub-Earth
Hot					
Warm					
Cold					

Summary of science questions for populations of planets, i.e. questions that are comparative or statistical in nature.					
	Gas Giant	Ice Giant	Super-Earth	Earth	Sub-Earth
Hot					
Warm					
Cold					

Content and Organization of the Report(s)

Summary of observables for different types of individual planets.					
	Gas Giants	**Ice Giants**	**Super-Earths**	**Earths**	**Sub-Earths**
Hot (>600 K)	Size. Orbit. Gas-phase abundances. Cloud and haze coverage (lon/lat/alt). Cloud evolution. Rotational period. Albedo. Presence of giant satellites.				
Warm (400-600K)					
Cold (<400 K)					

Content and Organization of the Report(s)

Summary of observables and the required data type and data quality					
	Gas Giants	**Ice Giant**	**Super-Earth**	**Earth**	**Sub-Earth**
Absorption feature depth					
Light curve					
Albedo					
Rotation Period	NIR Photometry, Cadence XX/ hr, SNR20				
NIR Colors					

Agenda:

1) Welcome and review of the SAG15 goals

2) Review of the workflow, timeline, and milestones of the SAG15 study

3) Discussion of the content and organization of the report(s)

4) Discussion of the general procedure, format, the products of any sub-studies

5) Initial discussion of the SAG15 questions (highest-level science questions, direct observable)

Sub-studies: General Procedure, Format, Products

1) Sub-studies address particular, well-defined questions
2) Most sub-studies will be based on literature review
3) Some may use existing models or develop toy models
4) Authors of sub-studies and their contributions will be identified in the final document

Agenda:

1) Welcome and review of the SAG15 goals

2) Review of the workflow, timeline, and milestones of the SAG15 study

3) Discussion of the content and organization of the report(s)

4) Discussion of the general procedure, format, the products of any sub-studies

5) Initial discussion of the SAG15 questions (highest-level science questions, direct observable)

Initial Discussion of High-level Science Questions

Example questions:

1) How does the formation process/location of a gaseous planet influence its bulk atmospheric composition?
2) What processes set the density distribution/bulk composition of super-earths?
3) What processes set the atmospheric composition of rocky planets?
4) How does the presence of plate tectonics depend on bulk composition?