



SCIENCE QUESTIONS FOR DIRECT IMAGING MISSIONS

SAG15 PROGRESS REPORT

Dániel Apai

Steward Observatory and Lunar and Planetary Laboratory, University of Arizona
Earths in Other Solar Systems Team / NASA NExSS



SAG15 Charge

In SAG15 we will 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 ($\sim 2,000$ K). For each question we will study and describe the type and quality of the data required to answer it.



SAG15 Charge

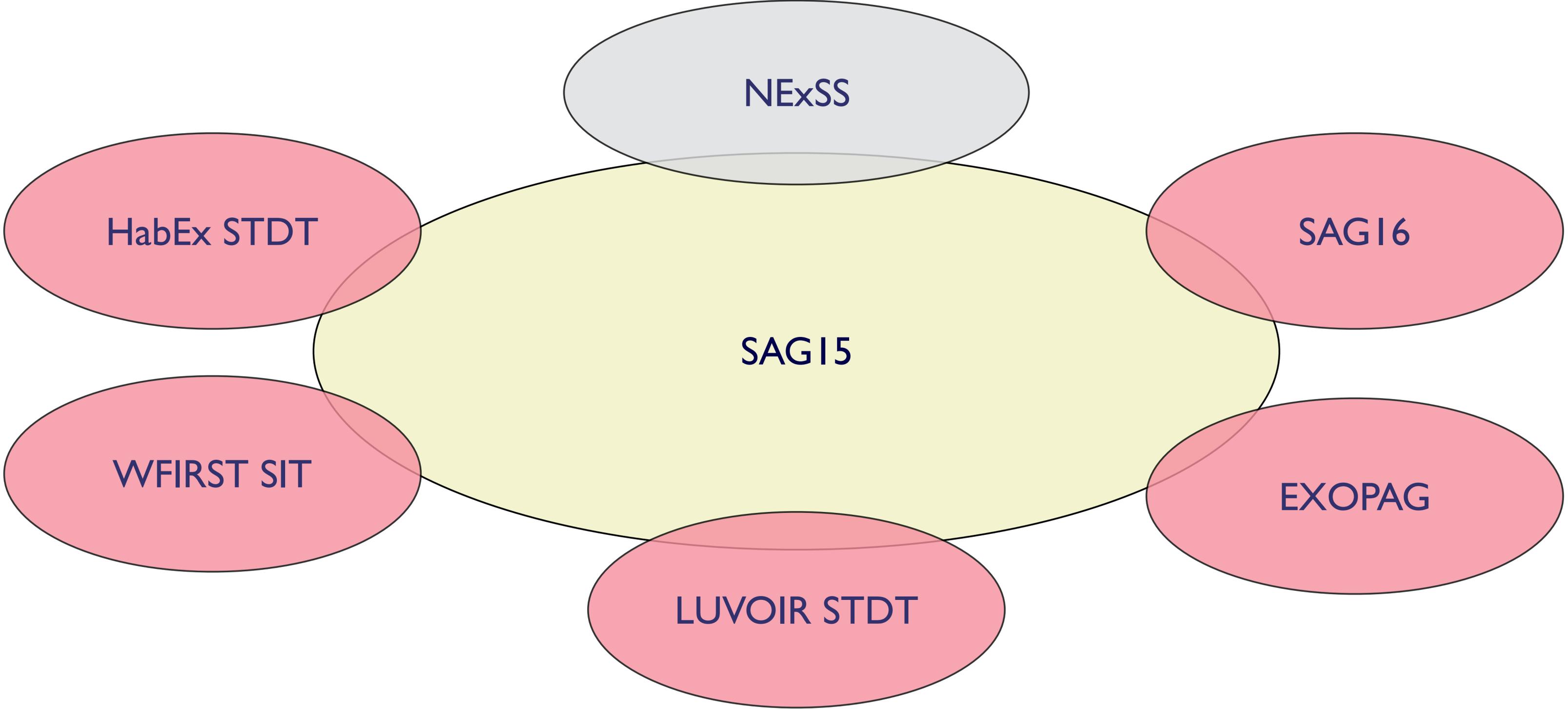
What is not included:

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



Uses of the Report

- 1) STDT 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.





The SAG15 Team

SAG15 Membership

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

Members:

Travis Barman, University of Arizona

Alan Boss, Carnegie DTM

James Breckenridge, Caltech

David Ciardi, IPAC/Caltech

Ian Crossfield, University of Arizona

Nicolas Cowan, McGill University

William Danchi, NASA GSFC

Shawn Domagal-Goldman, NASA GSFC

Caroline Morley, Lick Observatory

Glenn Schneider, University of Arizona

Nicolas Iro, University of Hamburg

Stephen Kane, San Francisco State University

Theodora Karalidi, University of Arizona

James Kasting, Penn State University

Ravikumar Kopparapu, NASA GSFC

Patrick Lawrence, IPAC/Caltech

Avi Mandell, NASA GSFC

Mark Marley, NASA Ames

Michael McElwain, NASA GSFC

Nikku Madhusudhan, Cambridge University

Charley Noecker, JPL

Peter Plavchan, Missouri State University

Aki Roberge, NASA GSFC

Leslie Rogers, University of Chicago

Adam Showman, University of Arizona

Arif Solmaz

Philip Stahl, NASA MSFC

Karl Stapelfeldt, JPL

Mark Swain, JPL

Margaret Turnbull, SETI Institute

SAG15 Website: <http://eos-nexus.org/sag15>

31 OFFICIAL MEMBERS;

INPUT FROM ANOTHER 22 NEXSS MEMBERS



The SAG15 Website

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



This page provides status reports and documents in support of the development of the [EXOPAG](#) Study Analysis Group 15: Science Goals from Direct Imaging Missions.

The SAG15 study is led by [Daniel Apai](#) (University of Arizona). The SAG15 team is charged with studying high-level science questions that can be answered by direct imaging studies of exoplanets and identifying the type and quality of data these studies require. The SAG15 study does not focus on any particular telescope architecture or observational method, but on the fundamental science questions.

This page provides a summary of the SAG15 study and status updates. The SAG15 study is voluntary and open to all members of the exoplanet, EXOPAG, NExSS communities.

If you would like to contribute to SAG15 or have comments/questions on the draft report, please, email to Daniel Apai (apai@arizona.edu).

SAG15 Report Drafts:

[SAG15 Report Draft High Level Science Questions - May 30](#)

[SAG15 Report Draft High Level Science Questions - May 29](#)

[SAG15 Report Draft High Level Science Questions - May 28](#)

[SAG15 Report Draft High Level Science Questions - May 9](#)

[SAG15 Report Draft High Level Science Questions - April 25](#)

[SAG15_Report Draft_High Level Science Questions - April 5](#)

[SAG15_Report Draft_Report_Feb5-2016](#)

SAG15 Telecon Slides and Telecon summaries:

[SAG15_Telecon3_Minutes](#) (April 6, 2016)

[SAG15 Telecon 2 slides](#) (Apai, March 2, 2016) [SAG15 Telecon 2 Minutes](#)

[SAG15 Telecon 1](#) (Dec 2015) [SAG15 Telecon 1 Minutes](#)

SAG15 Supporting Documents:

[SAG15 Charter](#)

[ADS Library for SAG15-related publications](#)



Content and Organization of the Report

High-level Science Questions



Observables



Required Data Type/Quality



Status

Approved in October 2015

SAG15 Team (31 members)

Six Telecons (Dec, Feb, Mar, Apr, May, June)

Timeline, Products, Process defined

Interactions / Connections with Other Groups

Draft report in development (30 pages)

List of Science Questions and Brief Science Cases



Science Questions on Exoplanetary System Architectures & Population	Importance
A1. What is the diversity of planetary architectures? Are there typical classes/types of planetary architectures? How Common are Planetary Architectures resembling the Solar System?	
A2. What are the distributions and properties of planetesimal belts and eco-zodiacal disks in exoplanetary systems and what can these tell about the formation and dynamical evolution of the planetary systems?	
Science Questions on Exoplanet Properties	Importance
B1. How do rotation periods and obliquity vary with orbital elements and planet mass/type?	
B2. Which rocky planets have liquid water on their surfaces?	
B3. What are the origins and composition of clouds and hazes in ice/gas giants and how do these vary with system parameters?	
B4. How do photochemistry, transport chemistry, surface chemistry, and mantle outgassing effect the composition and chemical processes in terrestrial planet atmospheres (both habitable and non-habitable)?	
Science Questions of Evolution and Processes that Change Exoplanets	Importance
C1. What processes/properties set the modes of atmospheric circulation and heat transport in exoplanets and how do these vary with system parameters?	
C2. What are the Key Evolutionary Pathways for Rocky Planets?	
C3. What types/which planets have active geological activity, interior processes, and /or continent-forming/resurfacing processes?	



Next Steps

Soliciting Further Community Feedback on Science Questions

Determining Data Types for Each Science Question

Focused Literature or Original Studies to Determine Data Quality

Solicit Community Input in Support of STDTs

Next Milestone: Advanced Draft Ready by Sep 2016



Summary

- SAG15 underway, on track
- Target date for completion Spring 2017
- Report + refereed publication is foreseen
- Input from 50+ scientists
- Channels to STDTs, WFIRST, SAG16