SAG15 Telecon 3 (April 6, 2016)

Present: *Daniel Apai (DA), Ian Crossfield (IC), Theodora Karalidi (TK), Mark Swain (MS), Patrick Lawrence (PL), Phil Stahl (PS), Stephen Kane (SK)*

<u>Agenda:</u>
1) Brief progress update and summary of last telecon; STDTs
2) Overview of the first draft list of science questions
3) General discussion of the questions; are we missing anything important?
4) Discussion of questions A2, A4, A5, C2
5) Identifying volunteers for providing input on the questions
6) Next telecon info

Daniel Apai (DA): Based on the previous two telecons and input received via emails, over the phone, and in person I compiled an initial draft of the high-level science questions. The initial draft is available on the SAG15 website (http://eos-nexus.org/sag15/), along with all other relevant documents.

In this telecon I would like to discuss the following topics:
1) Are we missing any important questions?
2) Are the questions accurate in their current forms and, if not, what changes are necessary?

Therefore I would welcome your comments on the entire list of questions and then on four individual questions we did not have time to address in our last telecon. Note, that questions are grouped in three categories (A, B, C), reflecting whether they address planet populations, individual planets, or processes. Questions within each category are also numbered; please, refer to the PDF file for the list.

Draft List of Science Questions, as appeared in SAG15 Draft Report 4/6/16

Science Questions on Exoplanetary System Architectures & Population	Importance
A1. What is the diversity of planetary architectures? Are there typical classes/types of planetary architectures?	
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?	
A3. Are there natural classes of exoplanets and if so, what are these?	
A4. How Common is the Solar System?	
A5. What are typical formation/evolution pathways for 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 and how do these vary with system parameters?	
B4. Which planets have large continents and oceans?	

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?	

Discussion:

Mark (MS): The current questions do not seem to cover the role of photo- and transport-based atmospheric chemistry? These have special significance in temperate planets and are important for understanding biosignatures and recognizing whether an atmosphere is in equilibrium vs. in non-equilibrium. We could include a question related to mantle-atmosphere connection.

DA: Very good point. How should we phrase this question?

Stephen Kane (SK): This is closely related to biosignatures and detection of life, but I am unclear on the connection between SAG15 and SAG16?

DA: Good question. SAG16 is focusing on biosignatures and their interpretation, but not on the planetary/abiotic atmospheric context. SAG15 includes habitable zone Earth-like planets and habitability signatures, but not planets that have been transformed by life. SAG15 will provide a context for SAG16 in terms of how habitable planets can be characterized and what is their diversity, e.g., in terms of internal properties, atmospheric composition, processes.

Ian Crossfield (IC): I agree with Mark that the questions should to include atmospheric composition.

Patrick Lowrance (PL): I would propose the following question "What are the Origins and Compositions of Atmospheres and Hazes and Clouds?" This seems to include the various components (atmospheric composition, processes, clouds, hazes). Answering this question may help identifying false positive biosignatures.

SK: For different types of planets different questions are appropriate. We could constrain a 2D grid/matrix connecting questions to planet types.

[additional discussion on what different aspects should be included]

IC: I would propose that we phrase the question as "What are the Atmospheric Compositions and Key Absorbers in Different Atmospheres?"

This would allow us to connect different types of atmospheres and study them in a general context.

DA: I like both suggestions, but I think there is an advantage of separating planets to non-habitable vs. habitable planets, as the methods and questions could be different (non-continuous spectrum) and the former provide a context for SAG16 and biosignature searches.

PL: We have to be careful with the use of the "habitable" adjective, as the boundaries of the HZ will depend on models and may not be fully and correctly characterized for individual systems.

DA: I agree; my point is that it is more practical to address rocky planets broadly similar to Earth separately from planets that are significantly different and that cannot be considered habitable.

MS: Suggested B5: How do photochemistry, transport chemistry, surface chemistry, and mantel outgassing effect the composition and chemical processes in terrestrial planet atmosphres?
MS: I also liked Ian's suggestion also - it was broader than what I have above.

DA: I would suggest to move on the rest of the questions. Based on the input I will come up with a suggested draft question or questions.

Input on A2:
IC: This question will not only be addressed by a direct imaging mission, but will be addressed by other, earlier facilities. We should address synergies with ALMA, LBTI, JWST; these may actually answer the question.

DA: I agree. We should identify what contributions are expected from the earlier facilities and what are the unique/important contributions, if any, of a direct imaging mission for this question.

Input on A4:
DA: This is a question that came up several times, but our previous discussion was inconclusive; I am concerned that the question is not

specific enough. What properties are important to be Solar System—like? What matters here?

SK: This is a really hard question. How similar other systems have to be to be similar to Sol System? We are we speaking about distributions of properties. To narrow this down we could ask "How common are Jupiter analogs?"
If we include this question, it should be very specific.

IC: We could define similarities based on the planets' mass, separation, and atmospheres.
PL: We may ask "Is the Solar System's planetary architecture common?"
IC: This question may not be relevant for a future direct imaging mission — will WFIRST/microlensing or Kepler have already answered this?

SK: RV survey are also providing important constraints. RV is now increasingly able to detect long-period giant planets.
IC: GAIA should also provide a good census of jupiters.

MS: I agree that the range of planet masses/orbits will be pretty well surveyed. However, not necessarily the planetary architectures: different methods can detect different planets in different systems. Surveying planetary architectures requires a high-level of completeness in a larger set of systems over a broad range of periods and planet masses; this is not well addressed by the piece-meal approach the variety of ongoing and future surveys provide. We need sensitive observations for planetary systems and this could be uniquely provided by a future direct-imaging mission.

SK: Questions A4 and A5 can be combined.
PL: You can't observe formation and evolution.

DA: I would be fine with dropping A5 altogether - any objections?

Question C2: What are the Key Evolutionary Pathways for Rocky Planets?
IC: What does evolution mean in this question?

DA: This question is based on one suggested by Nick Cowan, which aims to answer the range of different evolutionary paths a planet may follow, and the role of chance in planetary evolution. Nick sent a few sentences on this which is included in the document; in part he had in mind the example of Earth and Venus and that, although presumably starting as similar planets, they evolved very differently.

SK: The evolution is perhaps understood as "Atmospheric evolution". However, there are lot of important differences between Earth and Venus beyond their location in the Solar System: their rotational periods and magnetic fields are very different.
We should make it clear that the focus is on fundamental, important parameters. We could rephrase the question as *"What are the first order effects that determine evolutionary pathways?"* Perhaps just irradiation is important, but maybe also composition, etc.

IC: This question could also be rephrased to link more specifically to observables, i.e., *What are the effects of rotation rate, mass, etc. on the rocky planet evolutionary pathways?*

DA asked for volunteers to contribute text/discussion to the individual questions.

<u>Volunteers:</u>
Ian Crossfield: Question A4
Stephen Kane: B1, B5 - 2D grid

This summary is based on DA's notes; for corrections or clarifications please email to apai@arizona.edu .

Based on the discussion captured above DA has revised the report. The up-to-date reports are posted on the SAG15 website: http://eos-nexus.org/sag15/