ExoPAG Report

NAC Astrophysics Subcommittee Meeting
April 16-17, 2013
Scott Gaudi
(ExoPAG EC Chair)

Objective.

In June 2009, NASA formed the *Exoplanet Exploration Program Analysis Group* (ExoPAG), responsible for soliciting and coordinating community input into the development and execution of NASA's Exoplanet Exploration Program (ExEP). The ExoPAG serves as a community-based, interdisciplinary forum for analysis in support of activity prioritization and for future exploration.

- Articulate the key scientific drivers for exoplanet research.
- Evaluate the expected capabilities of potential ExEP missions for achieving the science goals of the program.
- Evaluate ExEP goals, objectives, investigations, and required measurements **on the basis of the widest possible community outreach**.
- Articulate focus areas for needed mission technologies.
- Identify related activities that enhance the ExEP mission portfolio such as ground-based observing, theory and modeling programs, and community engagement.

Activities prior to June 2012.

- EC chaired by Jim Kasting up until June 2012.
- The ExoPAG had 5 meetings and one joint CoPAG/ExoPAG meeting between January 2010 and January 2012.
  - These meetings were well attended, with about 70-80 people at the winter meetings and 50-60 in the summer.
- The primary topic of discussion was planning for a future flagship-class direct imaging mission.
  - Joint meetings/discussions with COPAG about a large optical/UV space telescope.

New Direction.

- In response to exoplanet community input, and new budget realities, the ExoPAG EC chose to revise its focus.
- In particular, subsequent ExoPAG activities have been aimed at:
  - Expanding the inclusiveness of NASA's Exoplanet Exploration Program to the wider exoplanet community, beyond the past focus on future flagship missions in space.
  - Considering novel ways in which NASA can address exoplanet research in the short term.
- Goal: To develop a unified and coherent exoplanet roadmap with community consensus, focusing on areas where NASA can contribute.

Current EC Membership.

- EC as of April 2013:

Scott Gaudi (*Chair)*	Ohio State
Aki Roberge	NASA Goddard
Tom Greene	NASA Ames
Charley Noecker	JPL
Lisa Kaltenegger	MPIA
Alycia Weinberger	Carnegie Institute
Dave Latham	Harvard Smithsonian
Peter Plavchan	Caltech/NexSci
Remi Soummer	Space Telescope Sci. Inst.
Jonathan Fortney	U.C. Santa Cruz
Wes Traub (*Ex officio)*	JPL
Doug Hudgins (*Ex officio)*	Headquarters
James Kasting (*Ex officio)*	Penn State

Activities since July 2012.

- Two meetings:
  - ExoPAG 6, October 13+14, Reno, NV
  - ExoPAG 7, January 5+6, Long Beach, CA
- Monthly EC Telecons
- One SAG completed.
- One SAG rebooted.
- One new SAG created.

ExoPAG 6.

- October 13+14, Reno, NV
  - Weekend prior to the 44th DPS Meeting.
- First meeting with this broader focus in mind.
- Questions addressed:
  - What is the landscape of current and future missions?
    - Kepler, JWST, WFIRST, NRO, medium-scale direct imaging.
  - What do we need to characterize exoplanets?
    - Mini-workshop on exoplanet characterization.
  - What is the current and future role of precision RV for exoplanet detection?
    - Mini-workshop on the future of PRV.
- Talks available online:

  http://exep.jpl.nasa.gov/exopag/exopag6/agenda/

ExoPAG 7.

- January 5+6, Long Beach, CA
  - Weekend prior to the 221st AAS meeting.
- Second meeting with this broader focus in mind.
  - Goal: continued to gather broad community input.
- Addressed the questions:
  - What is the landscape of current and future instruments and missions?
  - What do we need to characterize host stars?
  - What is the future role of precision RV for exoplanet detection?
  - What are the goals for the next decade in exoplanets? (Talks by Geoff Marcy, Dave Charbonneau, Doug Lin)
- Talks available online:

http://exep.jpl.nasa.gov/exopag/exopag7/agenda/

WFIRST+C Discussion at ExoPAG 7.

- Scheduled talk from David Spergel on AFTA, but…
- Brief summary of AFTA SDT activities up to that point.
- Group discussion:
  - "Does the community endorse putting a coronagraph on AFTA/WFIRST, even if it means forgoing some future technology development opportunities and/or other small-scale direct imaging missions?"
- Unanimous yes!

Future.

- ExoPAG 8
  - Originally June 1+2 – Victoria, BC (with IAU 299 meeting) – cancelled.
  - Now October 5+6 – Denver, CO (with DPS meeting) – pending approval
- SAG activities.
- New EC members.

Summary of SAGs.

- Two completed SAGs, four active SAGs, three defunct SAGs
- SAG1: Debris Disks & Exozodiacal Dust - Aki Roberge
  - Report completed; paper published in PASP, 2012, 124, 799-808
- SAG2: Potential for Exoplanet Science Measurements from Solar System Probes - Dave Bennett and Dan Coulter
  - Completed, no report. Topic explored in detail at Kavli Institute workshop, Santa Barbara CA, May 2010
- SAG4: Planetary Measurements Needed for Exoplanet Characterization - Lisa Kaltenegger
  - Draft report completed, final report delivered by ExoPAG 9.
- SAG5: Exoplanet Flagship Requirements and Characteristics- Charley Noecker, Tom Greene
  - Final report complete, subject to APS approval.
- SAG8: Requirements and Limits of Future Precision Radial Velocity Measurements - Dave Latham, Peter Plavchan
  - First presentations at ExoPAG 6 and 7
  - Report started, final report by ExoPAG 9?
- SAG-9: Exoplanet Probe to Medium Scale Direct-Imaging Mission Requirements and Characteristics - Rémi Soummer
  - Announced and official charter sent on 3/7/2013.

SAG5:

Exoplanet Flagship Requirements and Characteristics

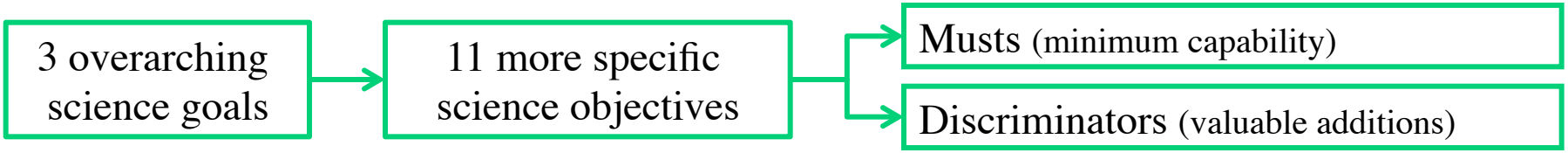
Charley Noecker, Tom Greene

SAG5 Final Report.

Charley Noecker and Tom Greene, Co-chairs
Marie Levine, Facilitator.
~ 60 scientists, technologists, engineers

- Goal: Develop strawman science requirements for direct imaging
  - Groundwork for Astro2010 mid-decade technology downselect
  - Structured to support making comparisons and decisions
- Parameters:
  - Considered both Coronagraph and Starshade designs
  - Considered a 2020+ "flagship" imaging mission
- Methodology:
  - Communication via emails, yahoo group, telecons, ExoPAG meetings.
  - Coordination with COPAG -> initiated effort to define a shared space telescope for exoplanets and UV-opt astrophysics
  - COPAG's flagship definition is consistent with ours
- Results: Established a framework of Science Goals, Objectives, and Musts & Discriminators
  - Emphasized terrestrial planets, but other science goals are included in key Discriminators
  - Did not assign scoring
  - Several requirement values are TBR, pending better knowledge
- Final Report delivered at ExoPAG 7, posted to arXiv:
  - **"NASA ExoPAG Study Analysis Group 5: Flagship Exoplanet Imaging Mission Science Goals and Requirements Report," Greene, Noecker et al., http://arxiv.org/abs/1303.6707.**

Unusual Framework for Requirements.



- **Musts** correspond to traditional minimum science requirements, but can include technical or programmatic constraints
- **Discriminators** are a new way to handle Baseline and Goal/ Stretch requirements
  - Phrased to be independent of mission architecture
- **Allows fair comparison of different mission concepts with very different strengths and weaknesses**
- Worked with SAG 4 (exoplanet characterization) and SAG 1 (exozodi requirements)
- COPAG has agreed to formulate their requirements in this framework
  -> Selection of one mission concept based on the union of both sets of criteria

Science Goals (Top Level).

- **Goal 1:** **Determine the overall architectures** of a sample of nearby planetary systems. This includes determining the numbers, brightnesses, locations, and orbits of terrestrial to giant planets and characterizing exozodiacal dust structures in regions from habitable zones to ice lines and beyond.
- **Goal 2:** **Determine or constrain the atmospheric compositions** of discovered planets, from giants down to terrestrial planets. Assess habitability of some terrestrial planets, including searching for spectral signatures of molecules and chemical disequilibrium consistent with the presence of life. Determining or constraining surface compositions of terrestrial planets is desirable but is not strictly required.
- **Goal 3:** Determining or constraining **planetary radii and masses are stretch goals** of this mission. These are not strictly required. However, measuring radii and masses would provide a better understanding of detected planets, significantly increasing the scientific impact of this mission.

Science Objectives (condensed).

1. Detect terrestrial planets
2. Measure orbital parameters
3. Obtain multi-band photometry
4. Confirm planets and distinguish among them (motions & colors)
5. Determine or constrain planet masses if possible
6. Spectroscopic characterization of terrestrial planets
7. Detect giant planets
8. Spectroscopic characterization of giant planets
9. Measure location and extent of dust disks
10. Detect and measure substructures in dusty disks to infer planets
11. Understand the evolution of circumstellar disks: pre-planetary to debris

Musts and Discriminators.

- Specific, quantitative goals.
- Described in detail in draft report.
- For example:
  - M1: Able to detect an Earth twin at quadrature in a Solar System twin at a distance of 10 pc.

SAG8:

Requirements and Limits of Future Precision Radial Velocity Measurements

Peter Plavchan, Dave Latham

SAG 8 Goals.

Key science questions:

- **What are the near-term, medium-term, and long-term needs for Doppler measurements to support NASA science objectives – how many stars of what magnitudes and spectral types?**
- What are the astrophysical limitations on radial velocity precision for measurements of nearby stars?
- How does this precision vary as a function of stellar type and wavelength?
- What are the implications of these limitations for new ensemble survey science goals and for finding the nearest low-mass exoplanets for future characterization?

Programmatic questions:

- What are the benefits or disadvantages of increased investment in telescope time (and for which class of telescope)?
- What competitive opportunities exist in the short and long term in the context of existing and planned US and European facilities?
- How should we prioritize increased investment in existing telescope resources versus investment in new, dedicated facilities and/or technology development for precision calibration/stabilization?

Instrument/technical questions:

- What approaches can improve radial-velocity instrumental precision to the astrophysical limits?
- What can be done to increase the efficiency and sensitivity of radial-velocity facilities?
- What potential exists for red/near-infrared radial velocity precision?

Discussion at ExoPAG Meetings.

ExoPAG 6 “Mini Workshop”:

- Peter Plavchan, Overview & SAG Goals
- Dave Latham, Kepler Followup + HARPS-N
- Andy Szentgyorgyi, G-CLEF
- Phil Muirhead, General PRV / High-Res Requirements
- Suvrath Mahadevan, NIR RVs + HPF
- Valeri Makarov, Limits of RV Precision

ExoPAG 7 talks:

- Peter Plavchan, Overview & SAG Goals
- Andreas Quirrenbach – CARMENES
- Dave Charbonneau – M-dwarfs: The Fast Track to Inhabited Exoplanets
- Dave Latham – The Case of Alpha Cen B

SAG 8 Stats and Tentative Consensus Points.

Status of Report:

- some draft text has been written.
- Revisions in progress before we'll move to a wider circulation for comments and additions.

Primary Points:

- Precision RVs are firmly in the systematic noise regime.
- Alpha Cen B b is the nearest known exoplanet to our Sun, and represents a non-incremental advance with the RV technique.
- Recent announcements and Bayesian analysis such as Tuomi et al. 2013 are intriguing but deserve further validation and scrutiny. Important question for the community: how will we "confirm" statistical exoplanets and/or validate this statistical approach?
- There is a rich ensemble of planned instrumentation in both the visible and NIR. RV technology development is a hotbed of activity, but running into cost-constraints.
- The number of observations (for binning) and illumination stability matter, but both the gas cell and instrument stabilization approaches are successful and complementary.
- **Dedicated facilities with stable instrumentation focused on a small number of targets with high cadence is critical.**
- Visible/NIR efforts are optimally designed for HZ surveys and complementary in targets.
- The next generation of NIR PRV instrumentation will be competitive with the current generation of optical PRV instrumentation.
- SMF spectrographs are a novel new instrumentation technique.
- **Stellar "noise" is a signal, and methods exist to mitigate the limitations of stellar jitter, with activity indicators and wavelength dependence critical to this analysis.**
- **RVs are soundly supported by Astro 2010.**
- **Precision RVs are a necessary element for TESS follow-up.**

SAG9:

Exoplanet Probe to Medium Scale Direct-Imaging Mission Requirements and Characteristics

Rémi Soummer

SAG9 Charter.

The ExoPAG Study Analysis Group 9 (SAG-9) will:

- **Define metrics** by which the science yield of various exoplanet probe-scale to medium-scale direct-imaging mission designs can be compared and evaluated in order to facilitate a well-informed decision process by NASA.
- **Focus on smaller mission sizes** that can be considered on shorter timescales than a flagship, with a particular emphasis on missions with probe-scale costs (under $1B).
- **Build on the methodology developed by SAG-5** (Exoplanet Flagship Requirements and Characteristics), defining science goals, objectives and requirements, further detailed into "Musts" and "Discriminators".
- **Establish the minimum science thresholds** ("Musts") for such missions, and develop quantitative metrics to evaluate the marginal performance increase beyond the threshold science using "Discriminators".

Key questions for SAG-9.

- What is the minimum threshold science to justify an exoplanet probe-scale direct imaging mission?
- What are the additional science goals that can be used as "discriminators" to evaluate science performance beyond the minimum thresholds?
- What are the possible achievements from the ground by plausible launch date, and overlapping the expected mission lifetime?
- What quantitative metrics for these "discriminators" can we provide to help define the weighting process to be used in the comparison of mission concepts?

Complementarity of STDTs & SAG-9.

- STDTs will be looking at technology needs associated with two different direct detection architectures, and then developing two design reference missions (one based on each architecture) that could realistically be accomplished for <$1B.

- SAG-9 will be developing the tools by which the scientific merit of these—or any other exoplanet direct detection mission concept — could be assessed.

Ongoing SAG-9 work.

- Bi-weekly telecons (first meeting 4/3/13)
- Currently assembling useful documentation e.g. SAG-5, ASMCS reports (PECO, ACCESS, EPIC)
- Group will start by investigating topics including:
  - RV science by expected mission launch and during mission
  - Ground based coronagraphic science by mission launch and during mission (GPI/SPHERE/SUBARU, ELTs)
  - JWST high contrast
  - Disk science
  - Define example science cases and interesting “pushpins” for the probe/medium scale

Suggestions for New SAGs.

- SAG10?: Requirements for Characterization of Exoplanet Atmospheres
  - Previous SAGs have focused on habitable planets.
  - What do we need to know about exoplanet atmospheres for the full diversity of planets?
    - Physics of Planetary Atmospheres
    - May inform our understanding of the atmospheres of SS planets.
    - May inform our understanding of the atmospheres of habitable planets.
- SAG11?: Required preparations for the WFIRST microlensing survey
  - Define the observational and theoretical work is needed to plan and optimize the WFIRST microlensing survey, and determine the expected science yield (including habitable planets).
  - Define the requirements to extract final science productions from the microlensing survey (i.e., data reduction pipeline, analysis pipeline, auxiliary observations, etc.)
  - Suggested by Jennifer Yee and Andrew Gould

New EC Members.

- Members rotating off:

Charley Noecker	JPL
Alycia Weinberger	Carnegie Institute
James Kasting (*Ex officio)*	Penn State

- Candidates for the two new positions were solicited in the usual way.
- 20 nominees were evaluated by Doug Hudgins, Larry Petro, and Scott Gaudi.
- Subject to APS approval, three were chosen to replace the members rotating off, based on topical and institutional considerations.

Nick Cowan	Northwestern
Amy Lo	Northrop-Grumman
Gene Serabyn	JPL

- Although this is one more full member than is rotating off, the additional of Cowan was considered sufficiently valuable to warrant increasing the size of the EC by one.