Science Interest Group #1: Virtual Town Hall

June 2, 2015

Scott Gaudi

(SIG#1 Chair)

Meeting structure.

Tuesday June 2

- 2:00–2:30 Introductory talk (this).
- 2:30 Discussions
  - Joint PAG reports?
  - How do we define the missions?
  - How do organize the STDTs?
  - Add/subtract missions?
  - Probes?

The Future of Exoplanets.

- Opportunity:
  - The next 20 years of exoplanets science can be transformative and history-making.
- Challenge:
  - We want to maximize this opportunity.

Goal of SIG#1.

- Address this challenge, and maximize the opportunity via strategic planning.
- In order to achieve this goal, we must develop a compelling vision to accomplish this science:
  - Our peers must be persuaded.
  - Our stakeholders must be persuaded.
  - Developed in time.
  - Robust to positive disruptive science
  - Doable within technology and funding constraints.

Positive Outcomes.

- Having a community vision going into the next decadal survey will improve the chances that our priorities will be executed and/or highly ranked.
- This will also facilitate coordinated efforts to attract other sources of support (industry, philanthropy, entertainment, international).

Defining a successful outcome.

- What does a successful outcome of the SIG activity look like?
  - The SIG identifies a holistic, broad, unified, and coherent plan for exoplanet exploration, focusing on areas where NASA can contribute.
  - Recommendation includes Science (“why”), Measurements (“what”), and Missions/Ground Instruments/ Programmatics (“How”)
  - Enthusiastically supported by ExoPAG, NASA Centers, community.
  - (Response to Paul Hertz’s charge by October 2015)
  - SIG1 preliminary report completed by end of 2015 (?).

NASA's Charge to the PAGs.

"I am charging the Astrophysics PAGs to solicit community input for the purpose of commenting on the small set [of large mission concepts to study], including adding or subtracting large mission concepts."

ExoPAG's Response to Paul's Large Mission Charge.

- The ExoPAG had already initiated the process of building consensus for an "Exoplanet Roadmap" through the SIG #1 activities.
- The ExoPAG will respond to Paul's charge under the auspices of this SIG.

Detailed Charge, Part 1.

1. Each PAG, under the leadership of its Executive Committee, shall broadly solicit the astronomy and astrophysics community for input to the report in an open and inclusive manner.
   - To accomplish this, each PAG is empowered to envision and use its own process.
2. Each PAG will consider what set of mission concepts should be studied to advance astrophysics as a whole; there is no desire for mission concepts to be identified as "belonging" to a specific Program or PAG.
   - Each PAG shall keep the number of large mission concepts in the set as small as possible.
   - Each PAG is specifically charged to consider modifications and subtractions from the small set, and not just additions.
3. Each PAG shall produce a report, where it shall comment on all large mission concepts in its small set of large missions, including those in the initial small set and those added or subtracted.
   - The PAGs may choose to work together and submit coordinated or joint reports.

Detailed Charge, Part 2.

4. Each PAG may choose to have a face-to-face meeting or workshop I in developing its report; said meeting may be scheduled in proximity to an existing community meeting or conference.
5. Although there is no page limit for the report, each PAG shall strive to be succinct.
6. Each PAG shall submit its report in writing no later than two weeks prior to the Fall 2015 meeting of the NAC Astrophysics Subcommittee (meeting schedule not yet known).

How are we going to accomplish this?

1. Define the challenge.
2. Define the goal.
3. Brainstorm.
4. Evaluate Feasibility/Risk/Opportunity
5. Develop Recommendation
6. Celebrate!

Structuring the Plan.

- Why?
  - What are the big questions/inquiry areas in exoplanets?
- What?
  - What measurements do we need to make to answer these questions?
- How?
  - What telescopes/"instruments"/missions/ technology do we need to make these measurements?
- When?
  - What is the timeline for making these measurements and developing these technologies and missions?

Timeline for STDTs.

- 2015:
  - Identify a small set of candidate large missions to study
  - PAG reports due by October 2015 APS meeting.
- 2016–2019:
  - Initiate studies.
  - Conduct studies.
  - Identify technology requirements
  - Deliver results to decadal survey.

Timeline/Meetings for Hertz Charge (completed).

- *January 2014: Initial discussion at ExoPAG 9.
- March 2014: APS approves SIG #1.
- *June 2014: Brainstorming session at ExoPAG 10.
- *January 2015: Brainstorming session at ExoPAG 11, Paul's charge.
- *February 2015: First dedicated SIG #1 Meeting, brainstorming & consensus building.
- March 10 COPAG Virtual Town Hall
- *March 19, 2015: Joint PAG EC meeting.
- April 11-14 2015, Am. Phys. Soc. (Baltimore) - PhysPAG
  - SIGs and PCOS mini-symposium

Timeline/Meetings for Hertz Charge (future).

- June 2, 2015 – ExoPAG Virtual Town Hall
- *June 3-5, Far-IR Workshop (Caltech) – COPAG
- Early Summer 2015- COPAG Virtual Town Hall
- *June 13-14, ExoPAG #12 (Chicago) - ExoPAG
  - Half to full day to be spent on charge (2nd day)
- *June 25-25, UV/Vis SIG Meeting, Greenbelt, MD – COPAG
- *July 1 panel discussion during the HEAD meeting (Chicago) – PhysPAG
- July 14, 2015 – ExoPAG Virtual Town Hall
- August 2015 – COPAG Virtual Town Hall
- *August 7, Joint PAG Splinter Session at IAU, 1-5pm
- August 18, 2015 – ExoPAG Virtual Town Hall
- July-September 2015: writing, circulating, finalizing report(s?).
- October 2015: Deliver report to Hertz (two weeks before the APS)

Inputs to date.

- Talks, brainstorming, and discussion at ExoPAGs 9, 10, 11.
- NASA Astrophysics Roadmap.
- Solicited (and unsolicited) input from a several dozen members of the community.
- COPAG White Papers

SIG #1 Meeting
Collated Suggestions

Suggestions
how: can we construct candidate list for target list (from RV, or do we need astrometry)
how: dedicated precision radial velocity instrument on 10m-class telescope
how: false positives (strategy for screening)
how: high-resolution UV spectrograph instrument with capabilities much greater than HST.
how: Optical and IR spectroscopic instruments on Spitzer, JWST, and future large space missions
how: probability of a rocky planet in HZ actually being habitable (define as potentially habitable)
how: TPF-I as a capstone mission
how: transit characterization mission
how: understand the astrophysical limits of precision radial velocity, high resolution, large aperture, optical + near-IR
how: unresolved Doppler shift spectra?
how: what are the true capabilities for ground-based VLTs for direct imaging?
how: what is Eta_Earth? Or at least assume for mission designs
how: what will ELTs do for HZ earths orbiting M stars?
how: yield goal (how many stars do we need to look at)
how: 2015 is too early to be presuming anything about mission size, narrow down after considering all of the options
how: a large ($8B-$10B) mission will be dead on arrival for 2020-2030, due to "JWST hangover", need to consider alternatives
how: a mission must do direct spectroscopy of earth analogs to be relevant when launched, need to start now for US leadership role
how: boost R&A grants by a factor of ~3
how: bring in planetary scientists
how: Can we sell a mission that doesn't look for and characterize Earth-like planets?
how: consider aperture as metric for comparison with other science
how: convince the entire community (get observing time)
how: dedicated exoplanet Explorer ($300-$400M) program every few years, allows one to be nimble
how: develop a consensus program with a modest flagship plus modest “Probe” class options
how: develop a menu of options of increasing costs and capabilities: occulter for WFIRST/AFTA -> 4-m class -> 12-16-m class.
how: direct imaging mission: go as big as possible, without creating a budget crises (starving R&A)
how: direct imaging mission: where to set the bar for the minimum justifiable science, is that affordable?
how: discuss with COPAG
how: don't put all our eggs in the "spectra of Earth-twin" to sell a mission
how: don’t constrain the budget too much early on (let the science lead, then marshal resources to that goal)
how: even a dedicated mission can be tuned to various science programs, and incorporate other science goals
how: exoplanet community must unite behind WFIRST-AFTA + coronagraph
how: Far IR surveyor, LUVOIR surveyor, Habitable Exo-planet Imaging Mission, X-ray surveyor
how: go for big goal, or make sure you also harvest all of the low hanging fruit (how do you prioritize)
how: how do we allocate observing time between science objectives?
how: how do we not become a non-fractured community?
how: how to avoid mission creep (assess needs)
how: how to get mission selected (engage entire community early on)

SIG #1 Meeting
Collated Suggestions

how: large DI mission questions: launch vehicle? UV+coronagraph compatibility? Starshade viable, and demonstrable?
how: major missions: have to demonstrate that they are capable of a broad range of science
how: make sure the dedicated technology advances other (broader) science
how: maximize probability of actually flying a mission
how: national or agency priority (get buy in from entire agency)
how: need an intermediate mission category ($500M - $1B), enable an image-based astrometry or transit spectroscopy mission?
how: not realistic to do spectroscopy of exo-Earths using an internal coronagraph
how: probes are cost-capped, not science constrained
how: put all of our eggs in one basket for a large flagship mission, or study more affordable 2-4m missions
how: serving the entire community, time needs, yield goal
how: support theoretical models on planet formations, atmospheres, climate, bio-signatures, etc.
how: technology for 10^-10 contrast imaging with segmented apertures appears unlikely to be ready in time for Astro2020
how: viability: technology, multiple communities, other science mission can do
how: what missions do we recommend for technology development
how: when is the next flagship mission?
what: K2,TESS, PLATO, GAIA: precision radial velocity follow-up
what: earth analogs: R=100 spectroscopy, 30 magnitude objects, 0.2” from a 5th magnitude star.
what: find Rosette stone planets that tie together the different characterization techniques
what: fundamental parameters of the star (ages)
what: get orbits of the planet (eccentricity), ensure they stay in HZ, etc.
what: host star parallaxes, astroseismology
what: how much risk do we accept when searching for habitable planets
what: is Kepler + WFIRST a good enough survey, or do we need an other mission?
what: look at planets that are not habitable (is the census from WFIRST and Kepler enough)
what: mass loss rates from exoplanet host stars
what: Measure compositions of exoplanet atmospheres, build robust codes to understand the physical and chemical processes
what: measurements of the UV, extreme-UV, and X-ray
what: need spectra of stars (UV), for stellar environment
what: need UV measurements of planetary systems
what: planet formation imager? Mid- to far-IR for young systems
what: precision RV census and masses of planets orbiting the closes FGKM stars for potential HZ targets for DI mission
what: tie habitable planets to those with direct imaging (M-dwarfs); be smart about what has been done from transit searches
what: to understand climate, need mid IR (to confirm habitability and surface temperature)
what: wavelengths do we absolutely have to have, for habitability, and what Resolution
why: Are specific exoplanets habitable?
why: are we alone?
why: characterize exoplanets and solar system planets: interiors, compositions, radii, bulk metallicity, P-T profile, magnetic fields
why: characterizing systems (not just a single planet), Exo-Zodi, dynamics, disks, holistic understanding of the full planetary system
why: comparative planetology

SIG #1 Meeting
Collated Suggestions

why: demographic measurements of planets, host stars and host environments
why: Eta_* other planet types (not just Earths) (Hot Earth, super-Earth, etc.) Get also from WFRIST and Kepler
why: Exo-planet science also doesn't end with a single spectra of an Earth-twin
why: go smaller and smaller, ultimately characterize, biology
why: how do exoplanets form?
why: how do planet system form? (formation and evolution, this is part of cosmic origins)
why: how does planet atmosphere depend on star, formation, evolution
why: language: use broader language than Earth-twin, or planet. Use planetary system, characterize Earth-like planets, etc.
why: leverage from diversity (need to characterize more than just a bunch of Earths)
why: properties of host stars: demographics, masses, radii, ages
why: put Earth in context, not just search for Earth-twin
why: search for habitable conditions is primary, and actually finding Earth-like comes after
why: synergy with planetary science
why: understand all planets as a species
why: understand atmosphere is important to understand habitability (chemistry and processes)
why: understand habitability planets as a system (geology, integration of the entire planet)
why: understanding exoplanets in general in order to inform our understanding of habitable zone planets
why: what are exoplanets like?
why: what are the architectures of multi-planet systems?
why: what are the demographics of moons, belts, cometary systems, and protoplanetary debris disks?
why: what are the environments of planets in the universe and over cosmic time?
why: what happens to habitable planet when star goes off main sequence
why: what is habitability mean (not just Earth-like), what are the implications for bio-signatures
why: what planets are out there?
why: where is the closest habitable, earthlike zone planet?

SIG #1 Stand-alone Meeting

- February 10+11, 2015 at JPL.
- Roughly 45 people attended in person and remotely.
- Talks, break-out sessions, brainstorming and group discussions.
- Afternoon of February 11 devoted to Paul's charge.
- Consensus building.
  - Start the process of developing a consensus on Whys and Whats.
- Define path forward.
  - Identify questions and topics for future discussions.

Takeaways from SIG #1 Meeting.

1. There was a general consensus that a broad range of apertures and architectures for direct imaging missions should be studied, encompassing both the nominal concepts of the HabEx and LUVOIR missions.

2. There were discussions about how the STDT or STDTs that study these direct imaging missions should be organized. There was a diversity of opinions as to whether there should be completely separate teams for HabEx and LUVOIR (including separate science and design teams), or a joint science team with two design teams, or one science and one design team.

3. There was discussion about whether we should attempt to prioritize the various direct imaging mission concepts, or whether we are even capable prioritizing those missions.

Goals for this meeting.

- Continue brainstorming process.
  - New missions? Ideas for organization?
- Consensus building.
  - Start the process of developing a consensus.
- Define path forward.
  - Identify roadblocks, questions and topics for future discussions.

NASA's Charge to the PAGs.

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Initial list of missions.

Taken from NASA Roadmap (Surveyors) and Decadal Survey (HabEx)

- Far IR Surveyor
- Habitable-Exoplanet Imaging Mission
- UV/Optical/IR Surveyor
- X-ray Surveyor

Far-IR Surveyor.

- A) 4-6m filled aperture, single-dish, cold
- B) 10m+ segmented
- C) 10m+ equivalent interferometric system
- Imagers, spectrographs

HabEx.

- 4-8m monolith
- Needs ~10^{-10} contrast
- Coronagraph, wavelength of 0.5-1.0 micron
- and/or starshade, wavelength of 0.25-1.0 micron
- Camera
- IFU, R=70 spectrum of 30 mag exoplanet
- 1” FOV
- Optimized for exoplanets, but other uses of instruments possible
- L2 orbit or Earth-trailing

Large UVOIR Surveyor

- 8-16m (likely segmented, obscured primary)
- HST-like bandpass (91nm – ~2 microns)
- Suite of imagers/spectrographs
- Need ~10^{-10} contrast for planet imaging (coronagraph and/or starshade), less contrast for other studies

X-ray Surveyor

- Angular resolution better than 1”
- 3 sq. m effective area
- High-resolution spectroscopy (few thousand) over a broad band
- FOV ~ 5’
- Wavelength range ~0.1-10 kev

Constraints.

- Technological.
- Financial.
- Programmatic.
- Social. I suggest: let's solve this one!

Suggested Topics of Discussion.

- Joint PAG Reports?
- Should we add any missions?
- Should we subtract/merge any missions?
- Should we study the full range of exoplanet DI architectures?
- How should we organize the STDTs for these missions?
- What non-exoplanet science can be done with smaller apertures (e.g., for HabEx)?
- What roles do the Far-IR and X-ray Surveyors play in exoplanet science?
- What about probes?

Requests:

- Let's be careful to distinguish facts from opinions and speculations.
- Let's focus on possibilities and solutions, rather than shooting down other people's ideas.
- Participate!
- Be generous: to each other, to the process, to facilitator (me!)
- Have fun!

Reference Material.

- http://cor.gsfc.nasa.gov/copag/rfi/
- https://exep.jpl.nasa.gov/exopag/decadal/
- http://pcos.gsfc.nasa.gov/physpag/

Organizing the STDTs for HabEx and LUVOIR.

- Separate or joint STDTs?
- Strong opinions on both sides.
  - "I am strongly of the opinion that NASA should proceed with studies of BOTH a "LUVOIR" mission and a "HABEX" mission
  - "…we strongly endorse study of a merged mission concept that simultaneously addresses the scientic goals of the exoplanet and the UVOIR communities."

Possible solutions.

- Wish to avoid duplication of effort and to maximize exoplanet community unity through shared exoplanet purpose, tools, science and technology
- The breadth of technologies required may not allow for thorough study by one STDT.
- Separate STDTs may lead to fracturing of the community:
- Solution: carefully and closely coordinated efforts:
  - ~1-2 shared exoplanet scientists on STDTs
  - Periodic meeting overlap, as was done effectively on 2 probe studies
  - Program-funded exoplanet analysis support to both STDTs/Design Teams via a small, dedicated, Exoplanet Working Group (eXWG): common tools, assumptions, figures of merit, technology evaluation
  - Similar to that same function performed effectively on the ACWG.
- These and similar steps will go a long way to maximizing effort and unity.

ExoPAG Report to Paul Hertz Regarding Large Mission Concepts to Study for the 2020 Decadal Survey

August xx, 2015

Authors

Joint PAG Executive Summary