Meeting Summary

ExoPAG/COPAG Joint Session on Big Telescopes in Space
Space Telescope Science Institute, Baltimore, April 26, 2010

The ExoPAG and COPAG held a joint meeting at Space Telescope Science Institute on April 26, 2011 to discuss future large UV/visible/near-IR space telescopes that could conceivably follow JWST and that could meet the needs of both the exoplanet and UVOIR astronomical communities. Thinking about such a telescope has been motivated by the Astro2010 Report, in which technology development for a New Worlds Observer mission was given the highest priority amongst medium class missions and the development of detectors, coatings and optics for a future UVoptical telescope was recommended.

Several presentations were given during the first part of the meeting. These are posted on the ExoPAG webpage at:

http://exep.jpl.nasa.gov/exopag/exopagCopagJointMeeting/

Following an introduction by STScI Director Matt Mountain, the next two talks focused on science goals for the ExoPAG and COPAG. Jim Kasting gave the ExoPAG perspective. The science goal here is crystal clear: We want to find and spectroscopically characterize rocky planets orbiting in the habitable zones of nearby stars. An existing, detailed set of science goals for such a mission was produced for the TPF-C (Terrestrial Planet Finder—Coronagraph) study that was carried out in 2005-06. The report from that study is available on the NASA Planetquest website:

http://planetquest.jpl.nasa.gov/TPF/tpf_index.cfm

The ExoPAG is in the process of redefining these science goals, as discussed further below (see Recommendations). *Importantly, a 4-m telescope is considered to be the minimum aperture that would allow this science goal to be achieved.* The constraint comes partly from the need for high (60 mas) angular resolution and partly from the need to collect enough photons to form a spectrum within a reasonable amount of time, *e.g.*, one week. This sets a firm lower bound on the size of the proposed space telescope, and clearly from purely a planet characterization standpoint, larger aperture is better. How much better still needs to be discussed and quantified properly.

COPAG science goals were presented by Marc Postman. A large UVOIR telescope having a wavelength coverage similar to that of Hubble (e.g., 100 nm – 1.8 μm) could be used for a wide range of astrophysical investigations. Prominent amongst them is understanding how galaxies assemble and evolve, determining the properties of the intergalactic medium and its evolution with time, and observing how stars of all types, including those that may harbor planets with life, interact with the interstellar medium. Larger telescopes than Hubble or JWST have distinct advantages in making significant progress in these areas. Key advances could be made with a telescope with a 4-meter-diameter aperture with a large field of view and fitted with high-efficiency UV and optical cameras/spectrographs, possibly operating at shorter wavelengths than HST. However, the increased angular resolution and light collecting power of 8m+

telescopes would provide access to environments and classes of objects that are beyond the reach of these other observatories (*e.g.*, distant quasars, galactic nuclei and bars at moderate redshifts, main sequence turnoff in galaxies beyond the Local Group, and interstellar/intergalactic regions in the low-redshift universe). In addition, as Hubble has taught us, there are likely to be many unanticipated discoveries with such an observatory, and the potential for such capability in the post-JWST era should not be underestimated. For these reasons, some segments of the COPAG community would like to see the next UVOIR telescope be considerably larger than 4-m in aperture, if appropriate technology investments can be identified now to control the cost of such a telescope. This may require a segmented primary mirror, depending on the availability of launch vehicles and fairings in the next decade.

The science talks were followed by two talks on technology needs. Charley Noecker presented the ExoPAG perspective. The fundamental choice to be made concerns the type of coronagraph—external (occulter) or internal coronagraph. Among the internal coronagraphs, several different options exist: Lyot, PIAA (pupil remapping), shaped pupil, visible nuller, and optical vortex. Importantly, most (but not all) of these internal coronagraphs may require a monolithic mirror to avoid diffraction from the edges of a segmented primary. So, there may be a potential conflict with the desire for a very large (e.g., 8-m) primary if it needs to be segmented. Pupil mapping schemes and visible nullers may be compatible with segmented primaries, and previous studies should be revisited in light of recent and future technology developments.

Ken Sembach then talked about UVOIR technology needs from the COPAG perspective. Prominent amongst these was the need to increase the quality of ultraviolet and optical detectors and to study new mirror coatings and coating procedures. Significant gains in throughput can be achieved in both areas, particularly at ultraviolet (<200 nm) wavelengths. Significant detector advances (*e.g.*, lower read noise, active pixel readout, higher quantum efficiency, larger format, radiation hardness) should be achievable this decade with strategically deployed funding. Advances in optical coatings may be more difficult, but atomic layer deposition and other techniques hold considerable promise. Al+MgF_2 and Al+LiF are the present-day coatings of interest if one wants reflectivity at ultraviolet wavelengths, but these coatings still pass only 60-70% of the light at each reflective surface. While they are not as reflective as silver at longer wavelengths, they do offer a broader bandpass (including optical-UV). The coatings may need to be applied exceptionally smoothly in order to be compatible with a high-contrast internal coronagraph.

The afternoon portion of the meeting was spent discussing these issues and making plans for how to proceed. This resulted in a set of recommendations:

<u>Recommendations</u>

1. First, and most importantly, cooperation between ExoPAG and COPAG is essential if we wish to have the 2020 Decadal Survey select a large UVOIR telescope. Continued joint meetings, perhaps in the form of joint sessions at the Winter AAS meetings, would be a good way to pursue this goal.
2. Both groups should pursue the study of two different types of representative missions:
    a. A 4-m aperture monolithic telescope with an internal coronagraph of some sort. The coronagraph must be capable of achieving a contrast ratio of 10^{-10} or better in order to find exoEarths. It would need to operate at an inner working angle of ~2 λ/D in order to satisfy the exoplanet science requirements.

A possible alternative to this architecture, which could be studied at the same time, would be an 8×3.5 m monolithic telescope, similar to that studied in the 2005-06 TPF-C study. This telescope could achieve the same angular resolution while operating at 4 λ/D. As Charley Noecker emphasized in his presentation, the requirements on wavefront stability are greatly relaxed if one operates at a larger inner working angle, as would happen in this design.

b. An 8-m aperture segmented telescope that relies on an external occulter to achieve the high contrast needed to find an exoEarth.

Note that these two architectures do not have to be mutually exclusive. One could imagine an 8-m segmented mirror that included at least one 4-m monolithic segment. One could potentially include a somewhat lower resolution internal coronagraph attached to this segment and simultaneously fly an occulter to get the extremely high contrast ($<10^{-10}$) needed to find exoEarths.

3. As a corollary to recommendation 2, both groups need to define a set of science goals that could be achieved with such observatories. The goals will clearly be somewhat different for the 8-m telescope than for the 4-m. These science goals need to be defined as early as possible, preferably in time to provide guidance for the money devoted to technology in NASA's next budget proposal (so, by September, 2011).
4. We may want to set up some joint telecons within the next few months to help define these science goals and to keep the two PAGs in touch with each other.