Advancing the Technology of Interferometry: The Tool for Mapping New Worlds

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Perhaps one of the most ambitious long-term goals of the astronomical community is to make visible-wavelength maps of distant exoplanets. In order to make such maps, we need instruments that provide sufficient angular resolution to place multiple pixels across an image of an exoplanet. Traditional single aperture telescopes, however, are impractical for this application. Assuming ten resolution elements (diffraction-limited beams at λ = 500 nm) across the diameter of an earth-sized planet, each resolution element has a linear extent of ~1,300 km. At this resolution, if the planet were Earth-like, it would be possible to distinguish continents from oceans. At a distance of 10 pc, this corresponds to an angular resolution of ~1 marcsec. This level of angular resolution could be achieved with a single aperture telescope with a diameter of ~150km, or with an interferometer with a maximum baseline of ~60 km. Single aperture telescopes of this magnitude are beyond all but the wildest of fantasies; interferometers of this size, while challenging, are within the realm of possibility.

This begs the question: How do we turn the dream of a planet-mapping interferometry mission into a reality? To achieve this ambitious goal, we must push along a broad technological front. Examples of key technologies include: (1) beam combining instruments; (2) formation flying; (3) precision metrology; (4) ultra-stable telescope structures; and (5) algorithms for analysis and interpretation of interferometric data. No fundamentally new technology is required here. Rather, current technologies must be pushed farther to meet the stringent requirements needed for optical interferometry at very long baselines in space.

There is a clear path that will allow us to push these technologies forward, while at the same time creating powerful new scientific capabilities. The first milestone on such a path might be the launch and operation of a space-based, two-element, structurally-connected interferometer operating at long wavelengths. Such an interferometer is within technological reach now, but would push the state-of-the art across nearly all the required technologies, except formation flying. Further milestones would be demonstrated by moving to longer (free-flying) baselines, by moving to shorter wavelengths, or to add collecting telescopes. Advances on any of these three elements would further push the technologies required for the ultimate long-term objective.

This is a very ambitious goal for a science mission, and the path to the goal is likely long and arduous. However, the path itself will provide its own reward. Each step will produce unique and powerful data for astrophysics, ranging from the formation of stars and water-bearing planets (a structurally-connected far-infrared interferometer), to the atmospheres of extrasolar planets (a free-flying mid-infrared nulling interferometer), to images of the event horizon of a black hole (a ~100-m x-ray interferometer). Both these rewards and the ultimate goal motivate the pursuit of this path.