Response to Call for White Papers for Universe Roadmap

Free-Flying External Occulting Screens

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1 External Occulting Screens: A Better Way to Image Earth-like Planets.

External occulters – free-flying spacecraft carrying an occulting screen and other necessary equipment – positioned in front of space telescopes, with apertures as small as 4-m, provide a highly competitive means to obtain high-contrast, high-resolution imaging and spectroscopy of extrasolar Earth-like planets orbiting nearby stars. Our studies have shown that telescope systems using external occulters can achieve the required high contrast ($\geq 10^{10}$ in light suppression) imaging at small angular separations. This capability is well within what can be achieved with available technology, which implies both a low-cost mission and development time. If a decision were made today, an Earth-finding mission could be launched by the end of the decade.

2 The Evolving Occulter Concept

Numerous investigators, beginning with L. Spitzer and R. Danielson in the early 1960s, have highlighted the advantages that external occulters can provide in yielding the stellar light suppression needed to image Jupiter-like and Earth-like planets at visible wavelengths (1962). In the mid-1990's and early part of this decade, Copi and Starkman(1998, 1999, 2000) and Schultz *et al.* (1999, 2000, 2002, 2003) explored the utility and presented more details on mission design and operation. This was pursued in the TPF preliminary architecture review (TPF 2002a), where it was shown that occulters and a space telescope could accomplish the full TPF mission of both identification and spectroscopic characterization of Earth-like planets. The free-flying occulter architecture offered great system utility at relatively low cost (TPF 2002b). Other external free-flying screen mission concepts are being studied. The New Worlds Observer, a NIAC-funded study of a free-flying pinhole, essentially an inverse occulter, being performed by Cash *et al.* (2003), appears to be a practical approach to extrasolar planet studies.

The big benefit of any external occulter-telescope design is that most of the contaminating starlight never enters the telescope. This leads to definite advantages over other options for planet-finding missions: 1) The concept eliminates the need for super-smooth mirrors, 2) It allows for much simpler associated instruments, 3) The simpler design implies reduced design, manufacturing, and testing costs, 4) The overall design is less sensitive to polarization, and 5) The concept is less demanding in terms of formation flying.

3 Light Suppression

To achieve the required light suppression of the central star, the Copi and Starkman design employed a 70-m diameter occulter, placed approximately 70-100 thousand km from an 8-m class telescope. The occulter design was apodized by smoothly varying the transmissivity of the screen from fully opaque at the center to as transparent as possible at the edges.

Schultz *et al.* showed that a simpler unapodized, smaller occulter, at 10-20 thousand km, can reduce the amount of starlight entering the telescope by several orders of magnitude. This significantly reduces the optical wavefront and amplitude quality requirements levied on the telescope. Modeling shows that a $\lambda/100$ rms (HST quality) mirror plus an occulter has 10-100 times better light suppression in the near wings of the PSF than a $\lambda/1000$ rms mirror alone. Additional light suppression can be accomplished using off-the-shelf coronagraphic designs.

4 Mission Design

A free-flying external mission has at least two spacecraft: a space telescope and at least one external occulter craft. The occulter craft would have its own propulsion system, navigation and communication capability to support movement and placement of the light-blocking screen. The occulter craft would be positioned in front of the telescope, blocking a target star's light from reaching the telescope–but not that of a close, faint companion such as an an extrasolar planet.

The system may be operated at the Earth-Sun Lagrange Point (L2), or in an Earth-trailing orbit. To minimize the screen reflection, observations utilizing the occulter are confined to a ring-shaped region symmetric about the Sun/Anti-Sun line through the telescope. Current formation flying concepts can be enhanced in a straightforward way to enable occulter operation.

Drift along the telescope-target line-of-sight (TTLOS) changes the apparent size of the screen and position of the screen edge, a negligible problem during observations. Drift perpendicular to the TTLOS causes changes in the diffraction pattern and must be controlled to the 10-500 cm range.

The occulter craft can use solar electric propulsion, a technology demonstrated by the Deep Space 1 mission, to maneuver and transit from one target to the next and to maintain formation control. An occulter craft will require significant time (5-20 days depending on angular separation) to travel between target observation stations. The duty cycle for observations requiring the occulter can be improved by adding other occulters to the system. Alternatively, the duty cycle could be considered an opportunity to employ the accompanying large aperture telescope for other science.

References

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