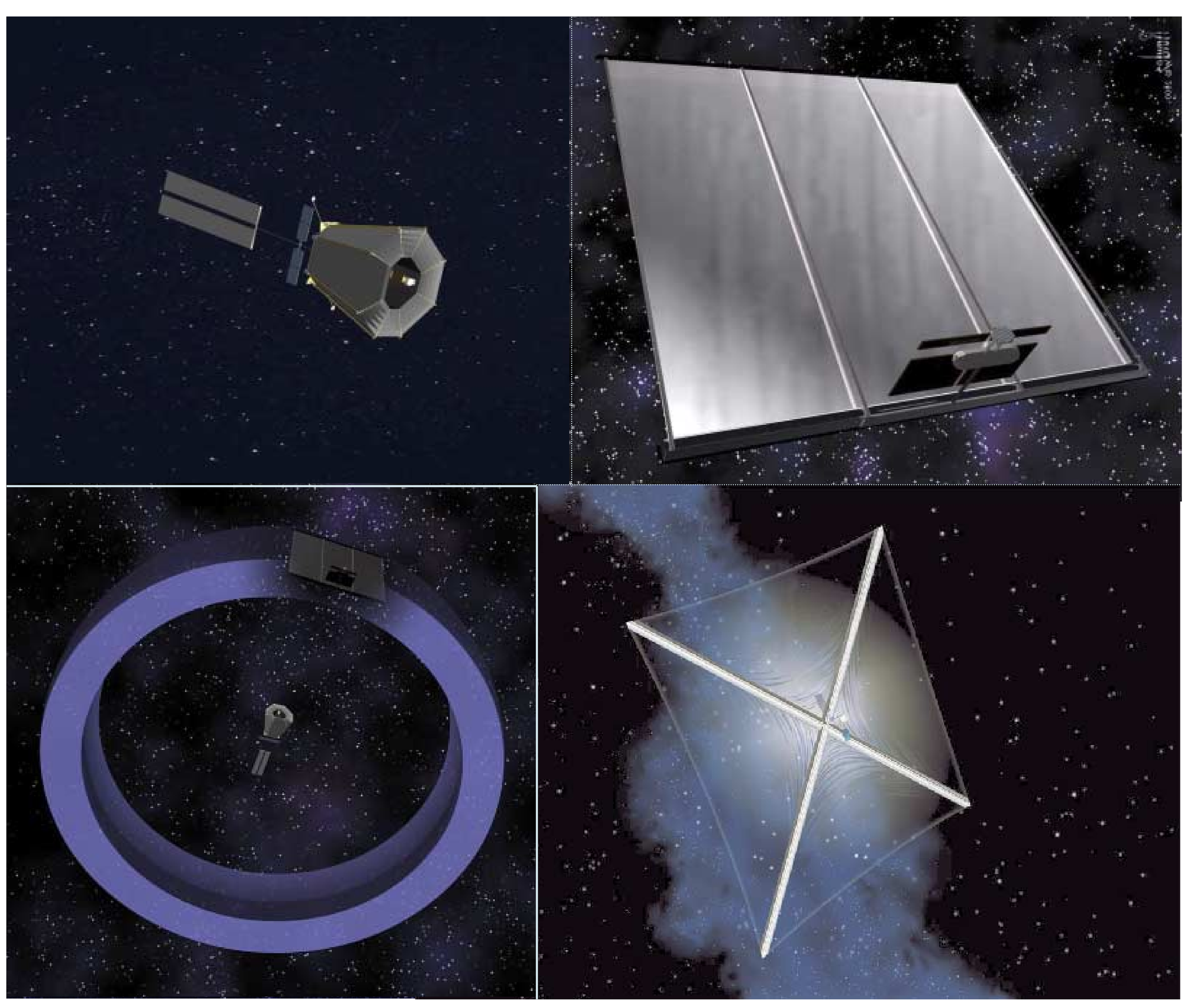
Are External Occulters Useful for TPF-C?

Abstract: Studies indicate that the reduction of incident star light provided by even simple opaque external occulters can decrease the requirements on wave-front quality for TPF-C. An external occulter can provide leverage towards TPF technology development risk reduction and higher technology readiness levels in critical systems. As important, an external occulter may enhance the science obtainable by TPF-C.

Authors: I. J. E. Jordan, A. B. Schultz (CSC/STScI), H. M. Hart (CSC/JHU), R. G. Lyon (NASA/GSFC), G. Starkman, C. Copi (CWRU), F. Bruhweiler, P. C. Chen (GSFC/CUA/IACS), R. A. Woodruff (LMMSC), D. A. Fraquelli, M. Kochte (CSC/STScI), K. P. Cheng (CSU Fullerton)



TPF-C straw man observatory (upper left), simple opaque occulter (upper right), and gradient transmission occulter (lower right) are among design bases for designing an optimum occulter to work compatibly with TPF-C. Occulter operations (conceptually at lower left--not to scale) are compatible with TPF-C observing constraints: both are used in the quadrature ring.

Why add an external occulter?

- Better science.
- Insurance against on-orbit coronagraph underperformance.
- Insurance against launch slippage if unable to converge on pre-feasibility/critical design contrast goals.

In this poster, we discuss only how science quality may be increased.

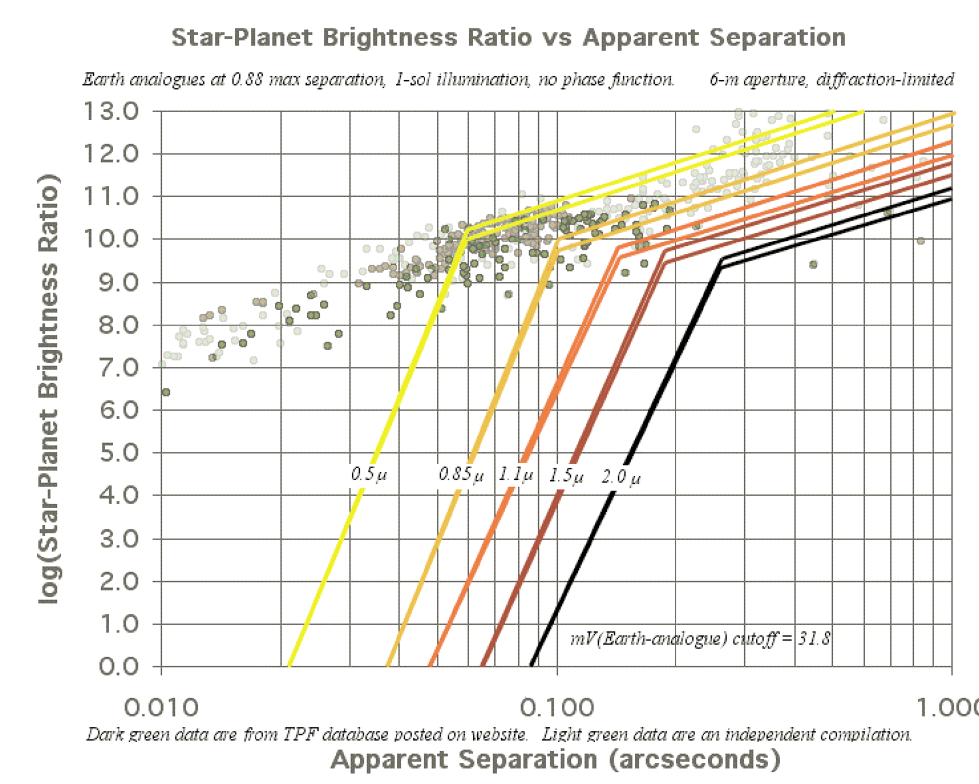
Alignment:	At least two possibilities exist for alignment sensing require only the telescope and occulter: 1. Oversampled focal plane imaging or 2. photometric aperture-plane null sensing.
Target Rates:	4-6 SEP occulters match TPF-C goals. Simplest occulter design requires one additional launch to TPF-C's Delta IV H.
Occulter Design:	Range of architectures, higher-lower complexity, all make TPF-C perform better science.
Launchability:	4 (or 6) simple occulters is practical.
Operations:	Semi-autonomous occulter with quantitative decision-based algorithms . "Augmented" normal science operations. Compatible with at least some coronagraph/mask designs.
Engineerability:	At least simplest occulters can be built now. Alignment sensing and control must be validated.

How can TPF-C Science improve?

Suppression of starlight before it reaches the telescope aperture provides a direct contrast performance gain. Consider some 1st-order arguments as demonstration.

Below is a graphical comparison of star-planet brightness ratio goals for TPF-C with Earth-analogues placed around TPF-C "shortlist" stars. The plot shows Earth-analogues around TPF short-list stars without orbital phase effects modeled (dark green circles) along with other nearby stars (faint green circles).

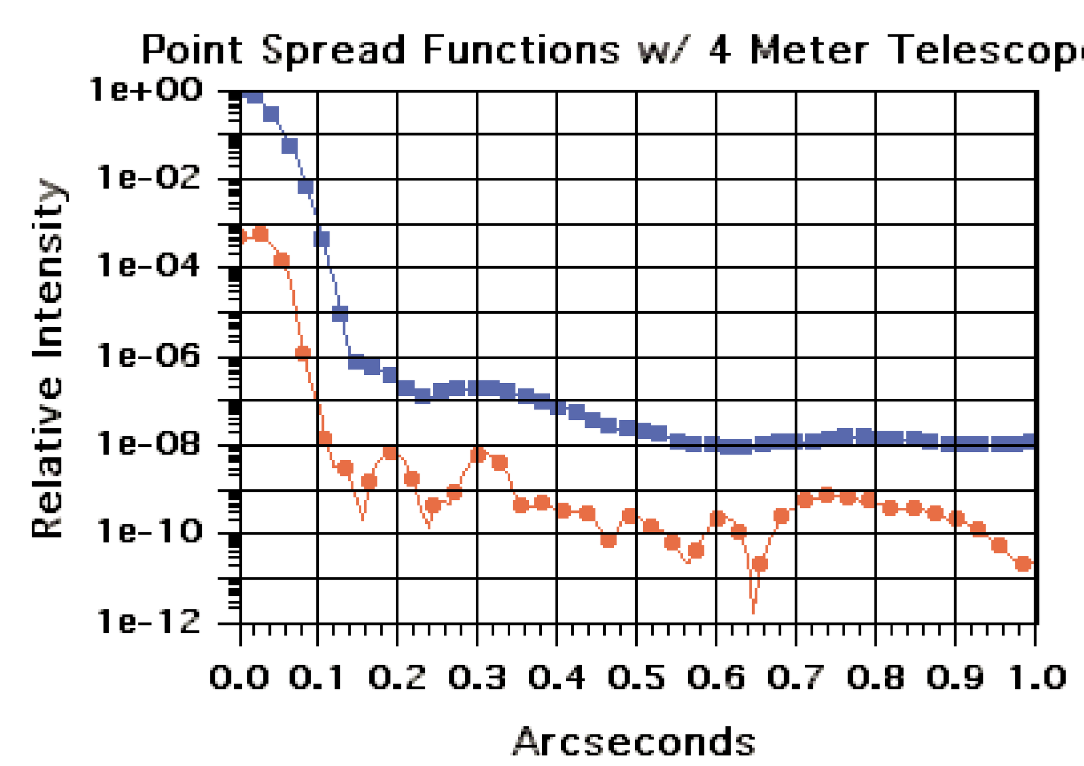
Their placement on the graph conforms with the following specific straw man mission parameters: 95% completeness in 6 visits to each target distributed over 2 years, 6-metre working-axis elliptical coronagraph.



Over-plotted model curves are for perfect optical performance of a 6-metre mirror. The closely spaced pairs of curves for 5 wavelengths show the 10^{10} star-planet brightness ratio goal met at 0.5 μ (lower) and 0.85 μ (upper).

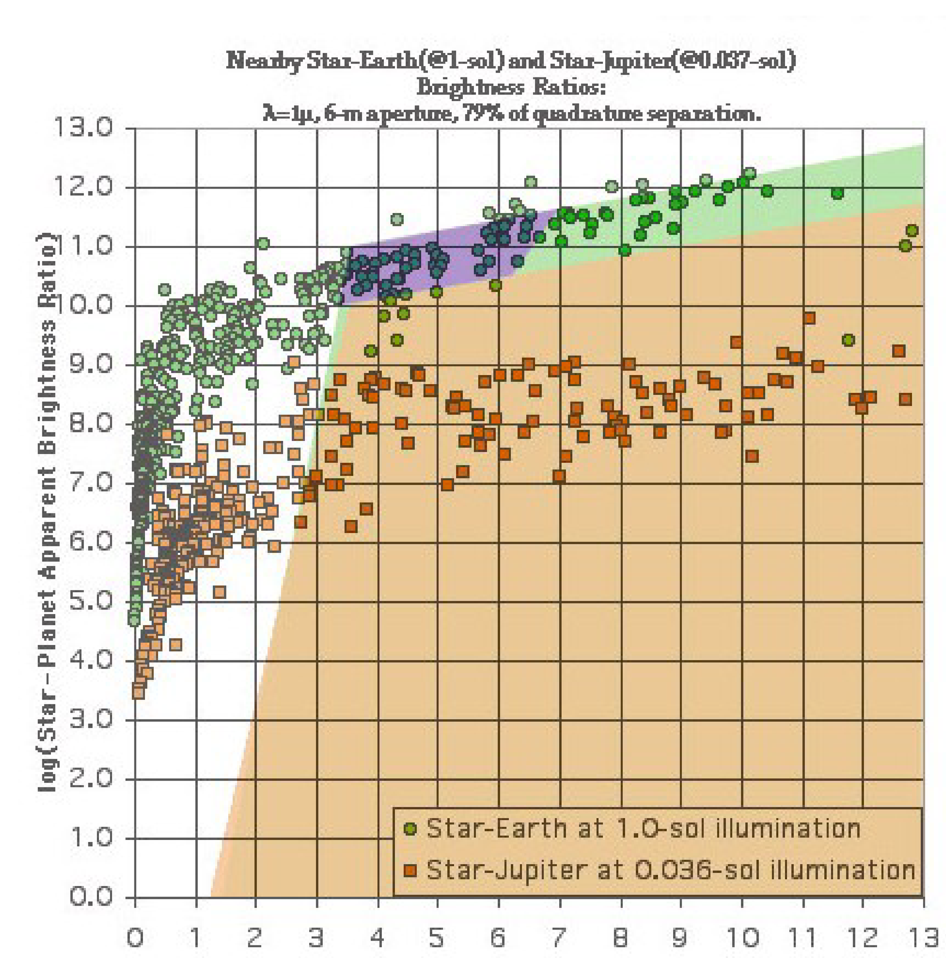
Realistic large angle limits would be much flatter than shown Airy falloff as the PSD of residual wave front error at large λ/D overwhelms the ideal PSF.

Next, consider the benefit offered by an external occulter. From a separate study of a matched apodized square aperture telescope plus opaque rectangular occulter, it was found that an order of magnitude or more reduction in field brightness was achieved with lower wave front quality at the focal plane. (q.v. graph below).



The plot at left shows cross-sections through two PSFs. The upper (blue) curve is of a Sonine-apodized square aperture with wave-front error of ~ λ/1,000. The lower (red) curve is for the same system with ten-times *worse* (λ/100) wave-front quality, with a simple opaque occulting screen 14-metres across, 40,000 km away (Fresnel number = 10 at 0.5 μ).

Below, the straw man TPF-C Earth-analogue (green circles) discovery space is re-plotted as in the graph at top (except plotted log-linear) and shaded (tan) at only one wavelength (1-μ). Assuming a simple factor of 10 gain in light suppression (rough average from graph above), the extended discovery space for TPF-C with an external occulter is shaded (green). The gain in the blue region depends strongly on compatibility of the occulter and coronagraph/DM designs. Deeper nulling with suitably matched occulting screens could extend the discovery space upward even more.



Although inner working-angle of the system is not improved dramatically, improvement in starlight suppression may allow a significant increase in the number of terrestrial-sized planets to be studied--and at longer wavelengths.

References for the work in this poster may be found in the conference proceedings package and in publications and group URL links at http://www.umbras.org .