Enhancing NGST Science: UMBRAS

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Abstract: We present a preliminary free-flying occulter design using existing technology to move in formation with NGST, *the Umbral Mission Blocking Radiating Astronomical Sources* (UMBRAS). The purpose of the occulter is to reduce and redistribute light entering NGST. UMBRAS enhances the contrast between faint objects and bright sources allowing planet searches by imaging within a few tenths of an arcsecond of nearby stars. The occulting spacecraft would range from thousands to tens of thousands of kilometers from NGST using solar electric propulsion. Operational constraints for UMBRAS are compatible with NGST. Observing rates between a few dozen and a hundred targets per year with mission lifetimes of 2-6 years are achievable.

1. What is UMBRAS?

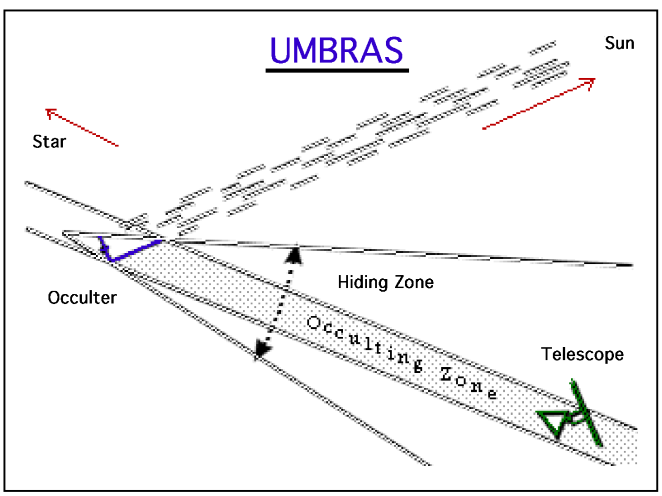

Figure 1: Relative placement (not to scale) of the occulter, target, telescope, and sun are shown.

UMBRAS (*Umbral Mission Blocking Radiating Astronomical Sources*) is a spacecraft designed to interpose itself between a space-based telescope and bright astronomical targets. In addition to blocking light from the target, light in the PSF is redistributed and better contrast at small angular separations is achieved for faint objects. More powerful planet searches around nearby stars are possible, and other science goals can be enhanced.

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2. What can UMBRAS achieve?

Studies on the effectiveness of occulters at reducing light from a star have been done by various groups [1-10]. Figure 2 shows an example at 1.6 microns for various sized occulters. UMBRAS-sized occulters reduce total intensity by factors of 10-100, depending upon telescope-occulter separation. Our study assumed a centred, square occulter with an 8-metre telescope. Detailed analysis shows that light reduction is not uniform across the field. The occulter produces its own diffraction pattern depending upon occulter shape, size and distance. As a result, there are localized regions where the amount of light in the field is far below average.

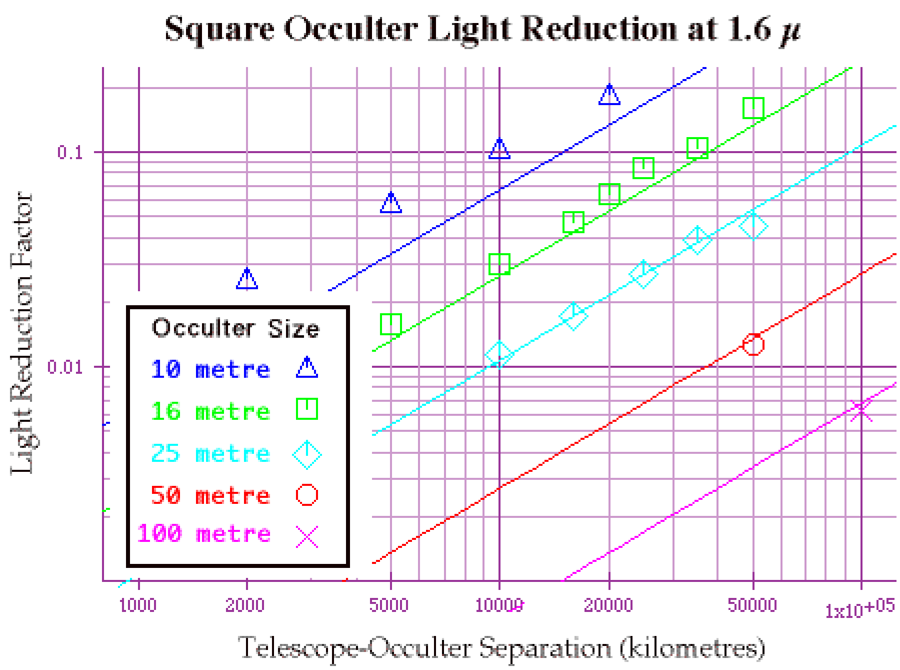

Figure 2: Lines are Copi & Starkman's [9] theoretical aperture independent Nulling factor. Data points are the result of Schroeder's numerical simulation of average light reduction over a centered, circular 8-metre aperture.

3. What might UMBRAS look like?

The preliminary design for SPIDER (Solar-Powered Ion-Driven Eclipse Rover) employs a 16 x 24 metre unfurling multi-layer insulation (MLI) occulting screen (q.v. Figure 3). During observing a shack-roof screen-shade prevents sunlight from falling directly on the occulting screen. SPIDER maintains a fixed orientation during observing with attitude control system (ACS) thrusters mounted on the bus and propulsion boom. A design enhancement using an interlaced telescoping Screen-and-Shade (extending in the y-direction, as in Figure 3) to create a 30-metre wide occulting screen appears possible.

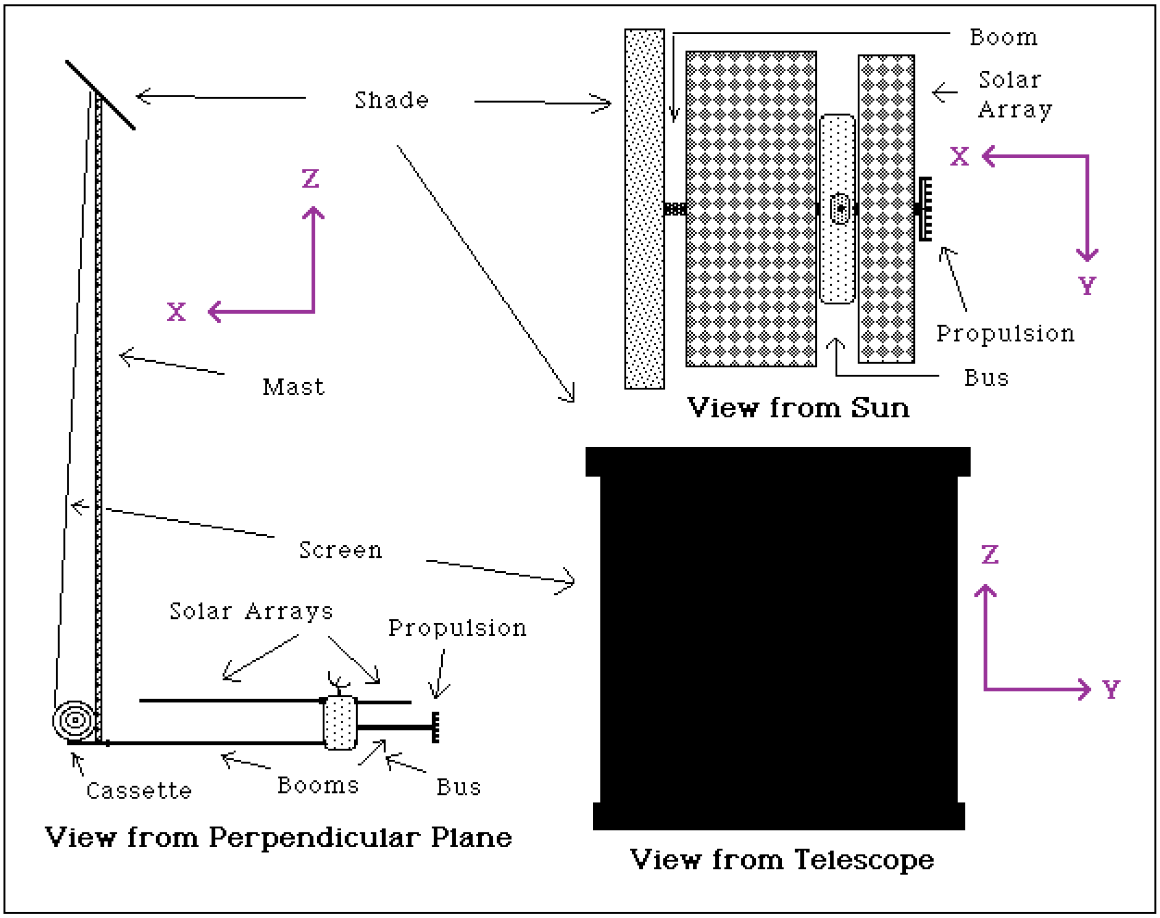

Figure 3: Three different plan views of the UMBRAS' SPIDER occulter and relative location of major components of the craft. At bottom right, conceptually the occulter appears completely dark from the telescope. At top right, the shade hides the occulting screen from the sun in its *umbra*. At left, the occulter is shown from the side.

UMBRAS/SPIDER Features:

· Occulting Screen unfurled from `window shade' cassette on Screen Pedestal.
· Controlled 1-time unfurling of Screen & Propulsion Boom deployment.
· Bistems or coiled *Astromasts* for shade/screen support.
· Sun Shade shields screen from direct solar exposure during observations.
· Screen Pedestal articulates for:
  -- transit to provide symmetry for thrust control.
  -- observations in order to hide bus/array/propulsion from telescope view.

· Propulsion Module on boom minimizes contamination & interference.
· Xenon propellant tanks stored in bus.
· Solar Electric Propulsion (SEP) offers significant observation rates.
· Attitude Control thrusters mounted on Bus and Propulsion Module.
· Three-axis stabilization for stationkeeping, maneuvering, & transits.

4. UMBRAS operation is compatible with NGST

An operations concept has been developed allowing the occulter to move from target to target and offer significant observation rates while using only a small fraction of NGST observing time. Like NGST, UMBRAS cannot operate at NGST's antisolar point. Operation near the 'quadrature ring' is preferred, because the occulting screen must be visible to the telescope and present as large an aspect as possible, yet remain shielded from the sun by the screen shade.

The screen will present various sizes and aspects during occultation work depending on screen size and proximity of SPIDER to the telescope, and anti-solar angle. Either a 'knife-edge' or 'centered-disk' mode can be used to block light from a bright target.

5. How will UMBRAS get to NGST?

Various delivery options exist. The occulting craft can fold to fit within a Titan IV fairing or STS payload bay. Once on-orbit, after staging high-thrust motors, the propulsion boom, solar arrays, screen shade, occulting screen, and screen-pedestal boom are deployed. Once unfurled, SPIDER proceeds toward rendezvous with NGST.

If under 6 tonnes, shuttle deployment with 4 staged PAM DII solid motors attached to SPIDER (2 at each end of the bus) allow escape velocity from low Earth orbit. If UMBRAS' mass is more, then additional, prolonged SEP thrusting & lunar swing-by can allow Earth-escape. Alternately, an IUS or Atlas Centaur-G upper stage atop a Titan IV, Proton, or Ariane can boost UMBRAS to station depending upon occulter mass.

6. What Operating Constraints does UMBRAS have?

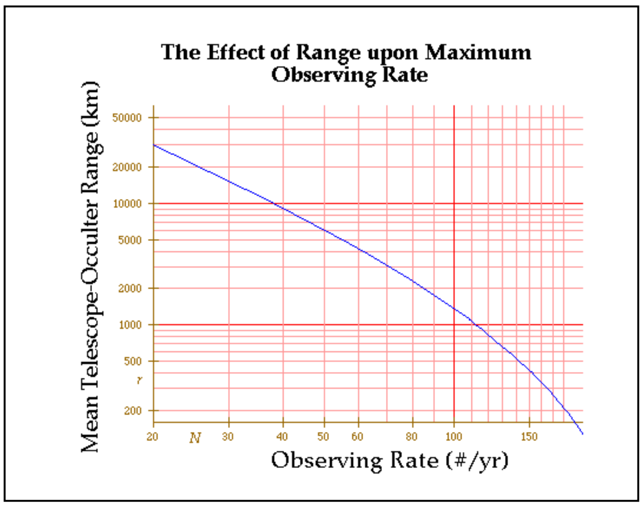

Figure 4: Mass and SEP-thrust constraints, and operations assumptions combine to produce limits on UMBRAS' achievable target observation rates.

The number of targets which NGST can observe using SPIDER depends strongly upon the sequencing strategy and the mode the occulter is used in (Telescope-Occulter range). The graph of maximum achievable targets/year assumes a 10-tonne, fully fueled SPIDER, using 6 NASA/Hughes 90-mN NSTAR thrusters, moving at an attitude to optimize solar array exposure between uniformly distributed targets.

SPIDER’s thrust is power-limited, therefore science goals not optimizing target-to-target movement yield target observation rates below Figure 4’s curve.

7. Can UMBRAS be built?

No advances in either delivery systems or manufacturing techniques are assumed in this design. SPIDER could be built today. Several designs for occulting screens have been discussed in the literature. UMBRAS uses a conventional MLI approach with a benefit that observations at wavelengths approaching 5 microns are possible.

Free-flying occulters are not a new idea [1,2,4,5,6]. UMBRAS offers a design option that can be built with existing technology. While not part of the currently funded NGST systems design, UMBRAS offers a way to enhance NGST science output.

References:

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