PICTURE, a sounding rocket to characterize the debris disk of Epsilon Eridani

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ABSTRACT

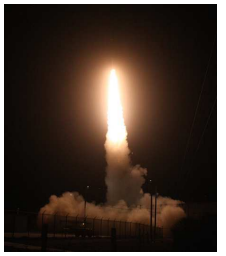
The PICTURE (Planetary Imaging Concept Testbed Using a Rocket Experiment) sounding rocket will demonstrate a nulling interferometer (a "nuller") to characterize the exozodiacal dust disk of Epsilon Eridani (K2V, 3.22 pc) in reflected visible light to an inner radius of 1.5 AU (0.5") from the surface of the star. The first launch of PICTURE suffered a telemetry failure and the primary mirror was shattered upon landing. A new launch is scheduled and the PICTURE payload is currently undergoing refurbishment, including receiving a new SiC primary mirror. PICTURE visible light observations will constrain scattering properties of the Epsilon Eridani exozodiacal dust and debris environment. Measuring the dust brightness of the system constraints the background which must be overcome for future exoplanet observations. Additionally, PICTURE will demonstrate operation of a MEMS deformable mirror and a visible nulling coronagraph in space. Improved modeling and post-flight measurement of instrument performance allow us to present refined exozodiacal dust sensitivities.

Mission Properties

Telescope	0.5 m, f/12.3 Gregorian
Nuller	Visible Nulling Coronagraph, 600-750 nm, shear of 0.15m
Science and Wavefront Sensing CCDs	1024x1024 pixel, back-illuminated CCDs from Astro-E2 X-ray mission
Inner & Outer Working Angles	1.5λ/d (0.5") & 5"
Pointing System	Tip-Tilt steering mirror, 5 mas pointing (Mendillo et al. 2012a)

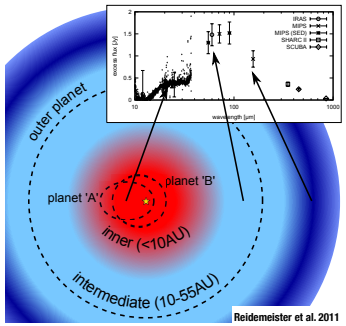
Observing Plan

TARGET	Observing Time	Purpose
Rigel	60 Sec	Demonstrate nulling, record reference PSF
εEri, Roll 1	>105 Sec	Characterize Exozodi
εEri, Roll 2	>105 Sec	Characterize Exozodi and track speckles

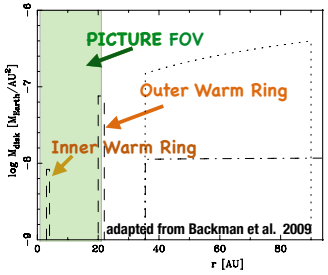


The first PICTURE launch in October 2011. (Courtesy WSMR.)

Epsilon Eridani Debris Disk:



Epsilon Eridani's Spectral energy distribution (SED) shows a significant flux excess at 24um and beyond, indicating a warm ring within 10AU, proposed by Reidemeister et al. (2011) to be sustained by solar wind-driven Poynting-Robertson drag.



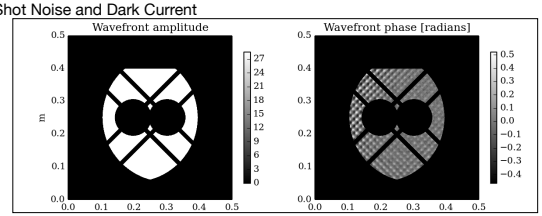
From the SED, Backman et al. (2009) infer a system of rings, shown above, with a thin ring near 3AU, scattering starlight with an expected integrated brightness of $2*10^{-4}$ F_*.
(F_* ~3e8 phot/sec for PICTURE).

Interfering the PICTURE wavefronts:

Nuller performance is simulated by interfering the complex wavefronts of the sheared nuller arms and generating the resultant point-spread-function (PSF) for a list of discrete points, composed of the central star and the warm inner ring, with POPPY (Physical Optics Propagation with PYthon) [Perrin et al 2012, *github.com/mperrin/poppy*]. We computed the polychromatic PSFs in parallel using *PiCloud.com*, which after stacking and addition of noise, produce realistic images.

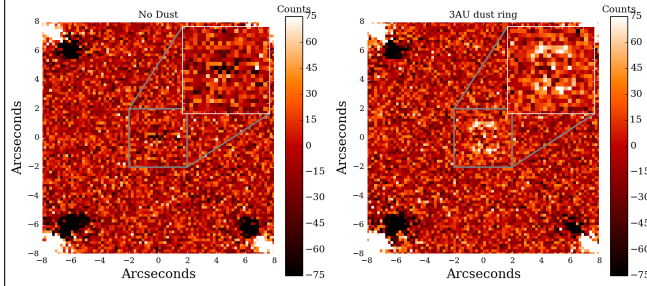
Simulation Inputs:

- Baseline leakage: 1% amplitude (E_0) mismatch (limiting central null to $2.5*10^{-5}$)
- Measured Flight Deformable Mirror (DM) Surface Figure
- Secondary/Spider Obscuration & Lyot Mask shape
- Template source spectra (e.g. Pickles et al. 1998, via *pysynphot*) & surface brightness distribution
- Shot Noise and Dark Current



Example wavefronts from the DM mirror arm of the nuller.

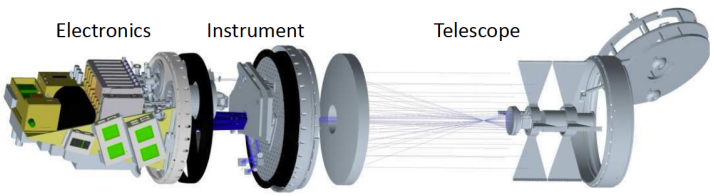
Simulated εEri observations after subtraction of dustless Rigel PSF

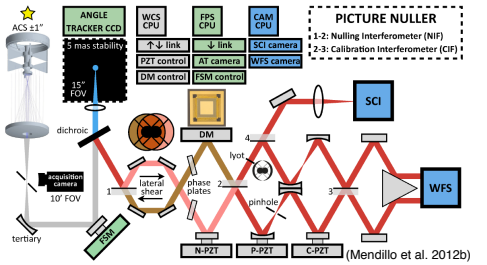


A dustless simulation showing four regions of scattered light (corners) from the DM at large radii and a residual central leakage from color mismatch between Epilson Eridani (210 second observation) and Rigel (20 second).

The predicted 3AU ring can seen above, the circle is cut-off by the (horizontally oriented) nuller transmission minima at 0" and 0.9".

The Payload

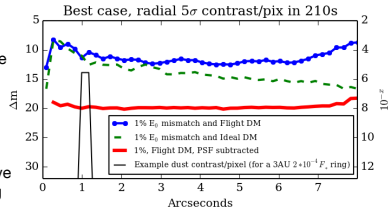




(Mendillo et al. 2012b)

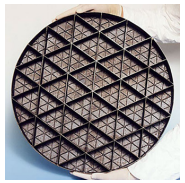
Contrast

The 5σ contrast curves at right are derived from the annular, one pixel wide, standard deviation of the expected background (from dustless simulation shown above) versus the star brightness (as in Bailey et al 2013). The star brightness is taken to be the peak pixel intensity of a smoothed, simulated bright output.
Subtraction of a noisy reference PSF removes speckles and increases the effective contrast (solid red line) and enables imaging the expected inner debris disk.

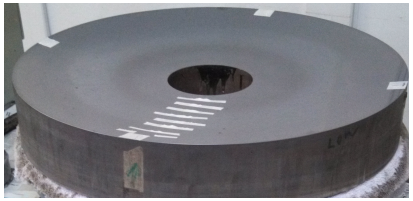


New Primary Mirror

A new lightweight Silicon Carbide primary mirror is currently being manufactured by Northrop Grumman AOA Xinetics.



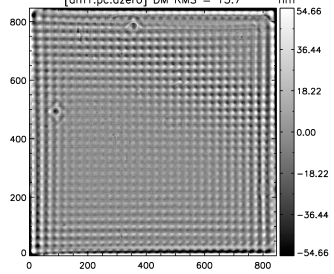
Example 20" SiC mirror, http://www.northropgrumman.com.



New primary mirror undergoing initial figuring.

New Deformable Mirror

A new MEMS deformable mirror from Boston Micromachines is being prepared for integration.
The figure at right shows the expected flattened surface figure.



Acknowledgements:

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References:
Backman, D., M., et al. 2009..ApJ 690,2.
Bailey, V., et al. 2013. ApJ 767, 31.
Mendillo, C. B et al. 2012a. Applied Optics 51, 29.
Mendillo, C. B., et al. 2012b. In Proc. SPIE, 84420E–84420E.
Perrin, et al. 2012. In Proc. SPIE, 8442:84423D–84423D–11.
Pickles, A. J. 1998. PASP, 110, 749.
Reidemeister, et al. 2011. Astronomy & Astrophysics 527, A57.

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