A New High Contrast Imaging Program at Palomar

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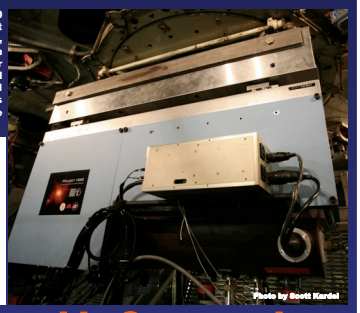
Abstract: Project 1640 and PALM-3000 represent a combined long-term high contrast imaging effort at the 5m telescope at Palomar observatory. During our 100 night survey over the next several years, we will obtain images and spectroscopy of brown dwarfs and exoplanets. Project 1640 utilizes a diffraction-limited apodized pupil Lyot coronagraph that has been integrated with a microlens-based Integral Field Spectrograph. The IFS operates in the J and H passbands (1.1 - 1.75 μm) with 19 mas microlenses. With this high sampling of the spatial field of view, we achieve a spectral resolution ($\lambda/\Delta\lambda$ ~30-60). The wavelength diversity provided by our spectral resolution allows for speckle suppression to increase our sensitivity by a factor of 10 to 20. For the initial phase of the project, we have undertaken an initial survey of nearby stars, focusing primarily on a survey of nearby A-stars with the existing AO system. In 2010, after the implementation of an internal wave front calibration system and an upgrade to PALM-3000, a 3000-actuator AO system detailed below, we will undertake a much longer 100-night survey on the 5m. Our next generation AO system and speckle suppression results are detailed below.

Project 1640: IFS, Coronagraph & Wave Front Calibration System

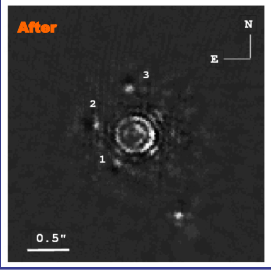
Project 1640 (Hinkley et al, 2008, 2010 submitted) is an Apodized Pupil Lyot Coronagraph, a microlens based IFS, combined with a wave front calibration interferometer located at Palomar Observatory. We achieve spectral resolution of 30-60 in the J and H bands, with 19 mas pixels. Specifics for the system are given in the table below .



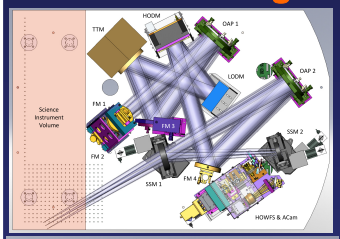
Coronagraph:	
Apodizer diameter (mm)	3.80
Astrometric Grid	2% undersized from pupil $\Delta m = 7.4$ 4 spots at $22\lambda/D$
Focal Plane Mask Size	370 mas $=5.37\ \lambda/\Delta$ at $\lambda = 1.65\mu$m $=1322\ \mu$m for f/149.1 beam
Undersized Lyot Stop Factor	2% from Apodizer 4% from primary pupil
Final f/ratio	f/164.6 at IFS microlenses
Final diffraction limit (mas)	22.08 at 1.05μm
IFS:	
Wavelength Coverage (μm)	1.05 - 1.75
IFS Field of View (mas)	38×0
IFS pixel scale (mas/microlens)	19.4
Microlens Pitch (μm)	75
Number of Spectra	$200 \times 200 = 4 \times 10^4$
Spectral Resolution ($\lambda/\Delta\lambda$)	33 to 58

Chromatic Speckle Suppression

Our LOCI-based speckle suppression algorithm (Crepp et al. 2010, submitted) utilizes the chromatic variation of the speckle noise halo to achieve an increase in sensitivity of a factor of 10 to 20. Below we show a broadband image of the star Alcor (Zimmerman et al. 2010) prior to (left) and subsequent to speckle suppresssion (right). Three fake companions with spectra identical to the Alcor companion, but one magnitude fainter, have been inserted in three places to highlight the sensitivity at small inner working angles.

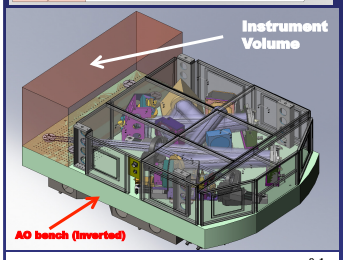


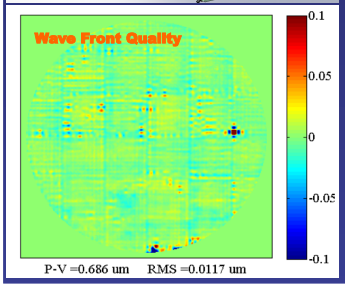
PALM-3000: A High Order AO System at Palomar

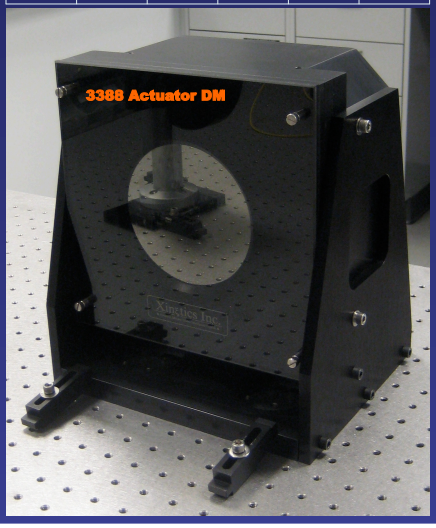


In Early 2011, a new AO system will be commissioned on the 5.1m Hale Telescope at Palomar delivering extreme AO correction in the near infrared. The system will use the existing 241-actuator DM acting in a "woofer" mode with a with a new 3388-actuator DM serving as the "tweeter" to correct wave front aberrations at scales as fine as 8.1 cm at the telescope pupil. The system utilizes a Shack-Hartmann wave front sensor with 8, 16, 32 63 subapertures for adjustable pupil sampling.

Seeing	r_0 (.5 μm)	Wave Front Error	J	H	K
Good	15 cm	87 nm	81%	90%	94%
Med	10 cm	97 nm	77%	87%	93%
Poor	5 cm	166 nm	47%	67%	80%

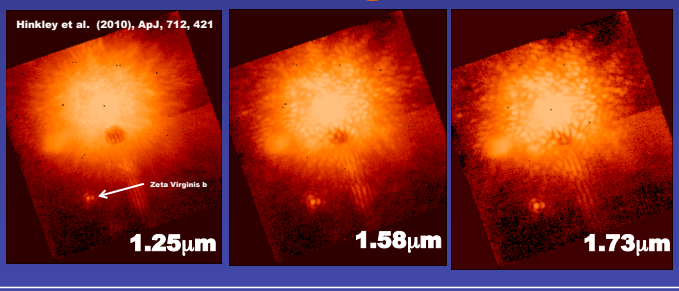


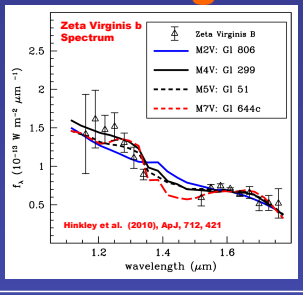




Early Science: An M Dwarf Orbiting An A3V Star: Zeta Virginis

Our initial observations have focused on a survey of nearby A-type stars, imaging at least two M-dwarf companions to these stars. These results (Hinkley et al 2010 & Zimmerman et al 2010) highlight the spectroscopic capabiliites of the instrument---see spectrum at far right showing this companion. The spectrum is consistent with a mid-M dwarf companion. The three panels at right illustrate typical (unocculted) data obtained with the IFS of the star Zeta Virginis. This target as well as the Alcor system show mass ratios of 5 to 10% and may give insight into the anomolously high X-ray flux detected from some A-type stars.





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