HIGH CONTRAST IMAGING WITH BAND LIMITED MASK TECHNOLOGIES

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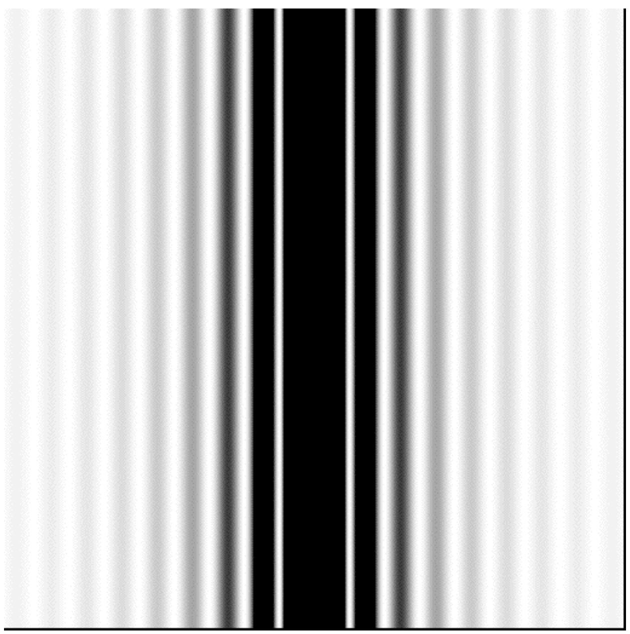
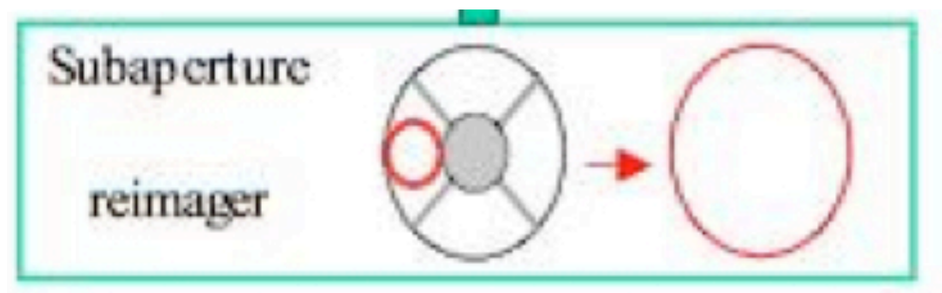
CONVENTIONAL CORONAGRAPHIC IMAGING MASKS

HIP 73470
Separation ~0.9”
Differential Mag ~3.5

Our Strategy: A band-limited focal plane mask implemented on a Palomar Off-Axis Subaperture



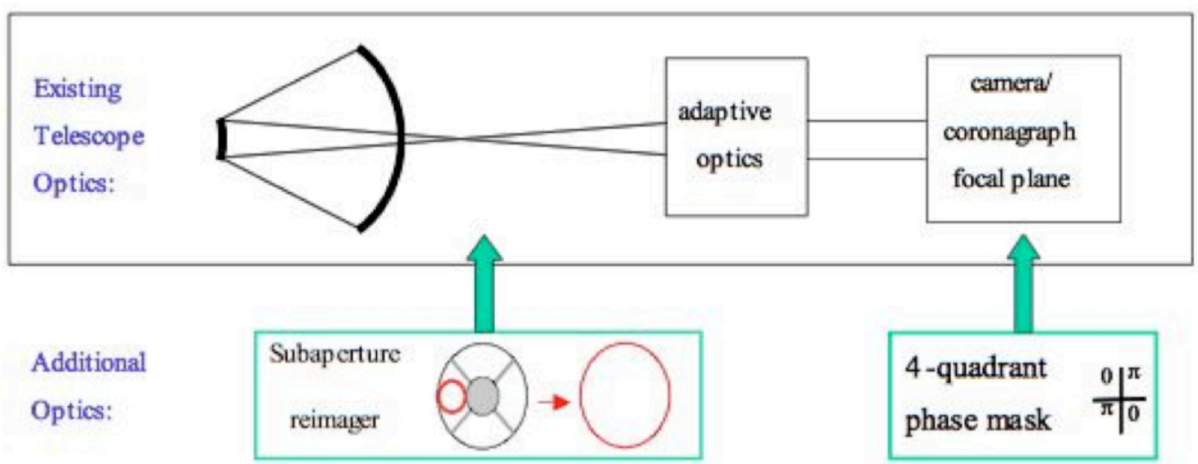
Band Limited Mask



Off-Axis Subaperture Reimager

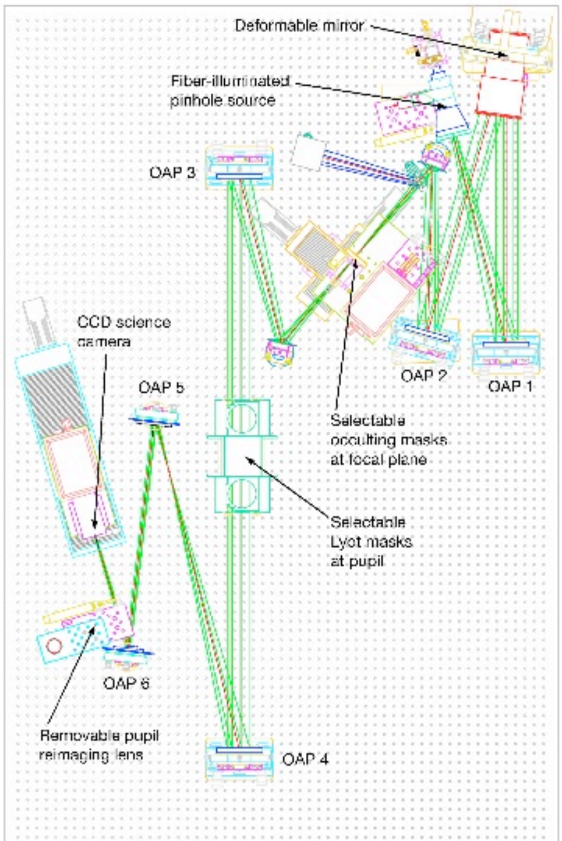
Our Observing Platform

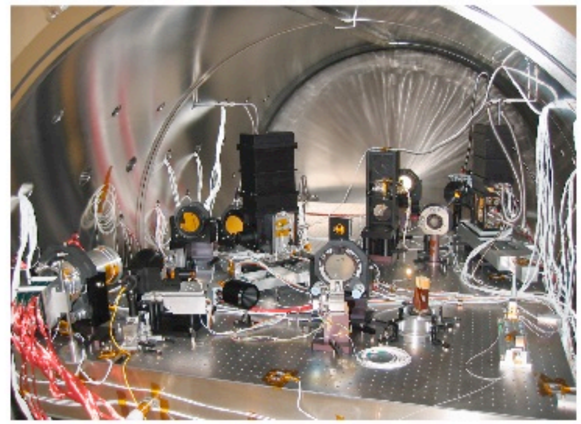
A 1.5 meter Off-Axis Subaperture Imaging Capability on the Palomar Hale Telescope



Haguenauer et al. 2005

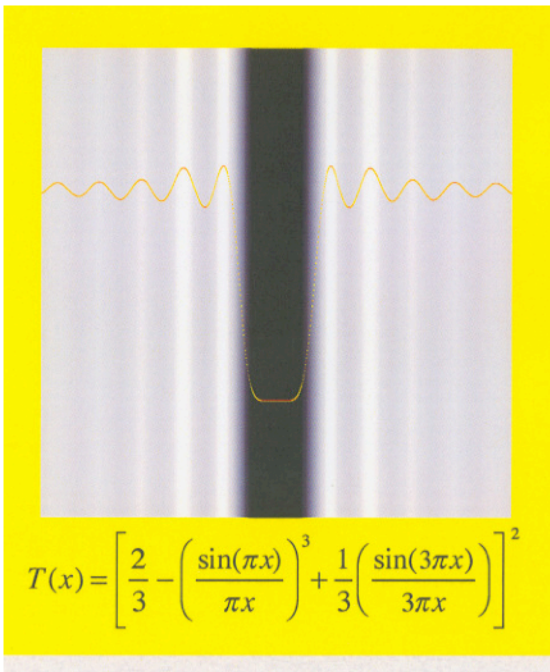
The JPL High Contrast Imaging Testbed (HCIT)



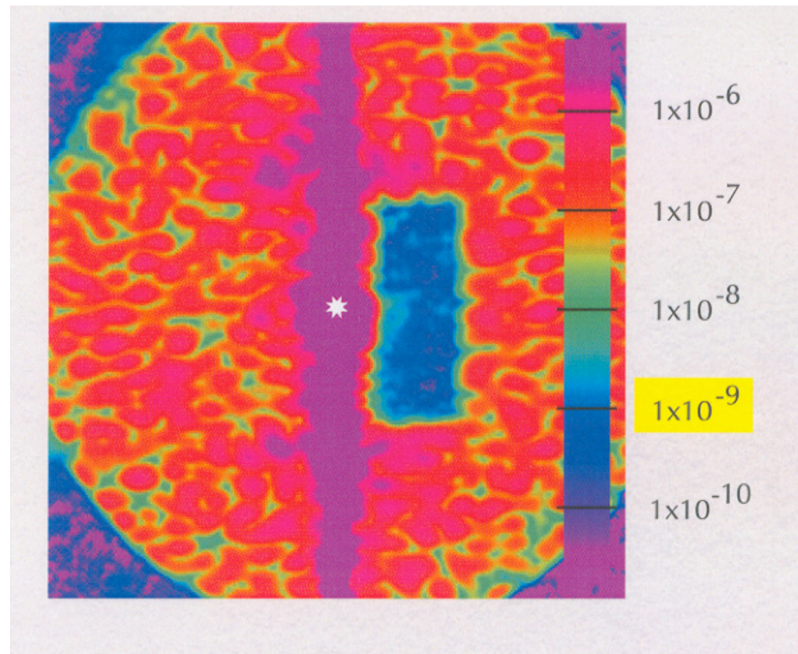


Trauger et al. 2004

HCIT Coronagraphy

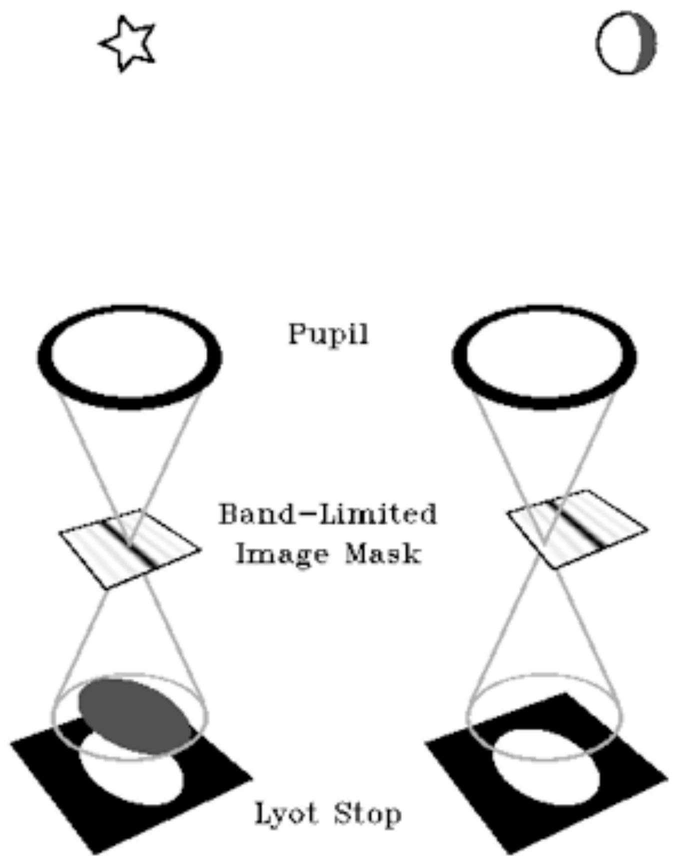


Band Limited Mask



10^{-9} Contrast at 4Lambda/D
(laser light)

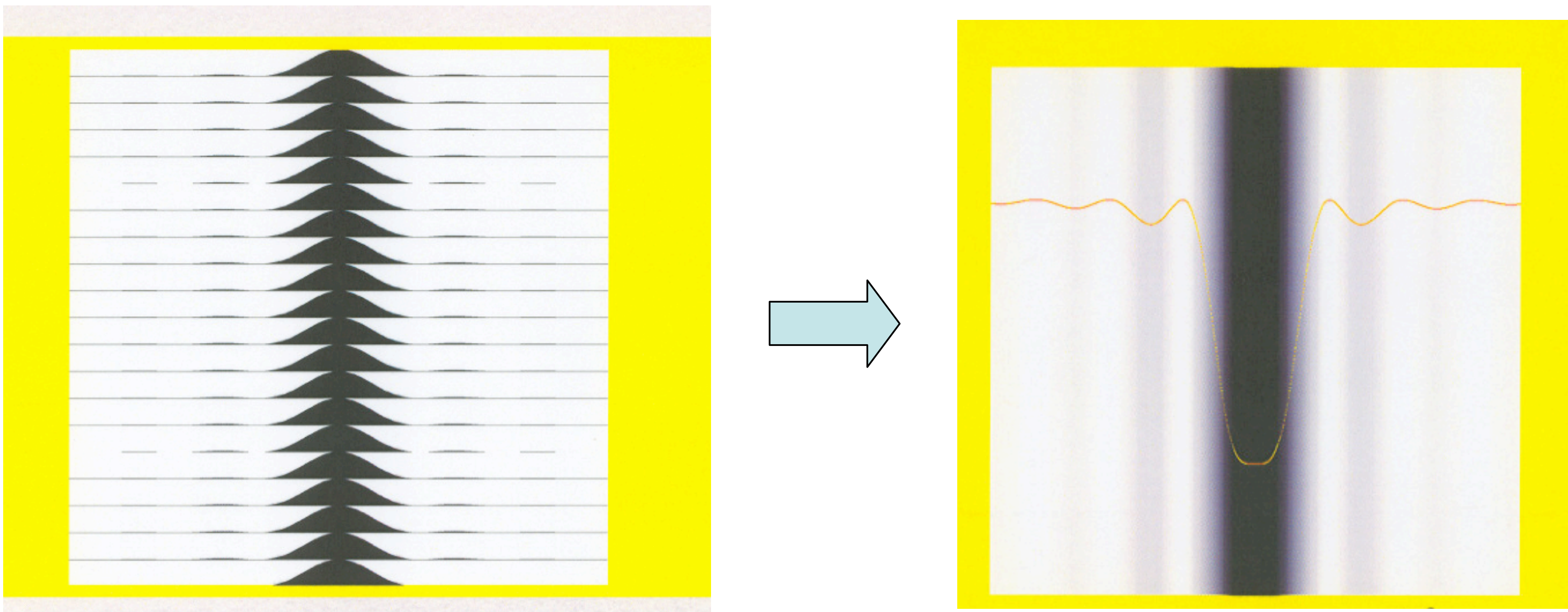
Band-Limited Mask



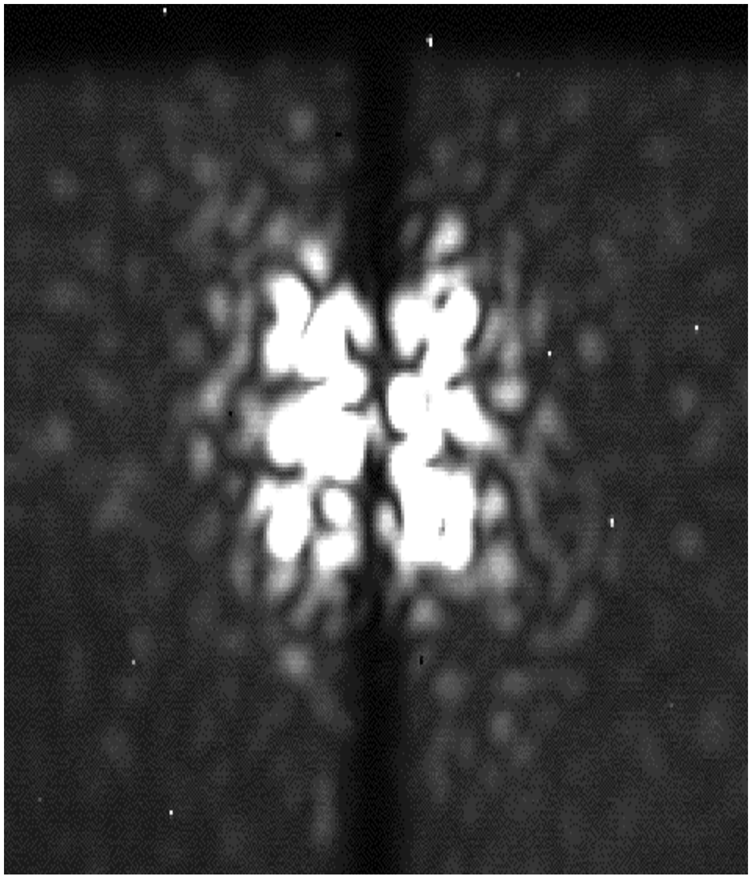
This figure illustrates schematically how a coronagraph works: light passes through the pupil and converges on an image mask, then the pupil is imaged onto a Lyot stop. Starlight focused on the center of the image mask diffracts to the pupil edges, where the Lyot stop can block it, as shown on the left of the figure. Light from an off-axis planet diffracts all around the second pupil plane, as shown on the right of the figure, and largely passes through the Lyot stop.

From Marc Kuchner's Webpage

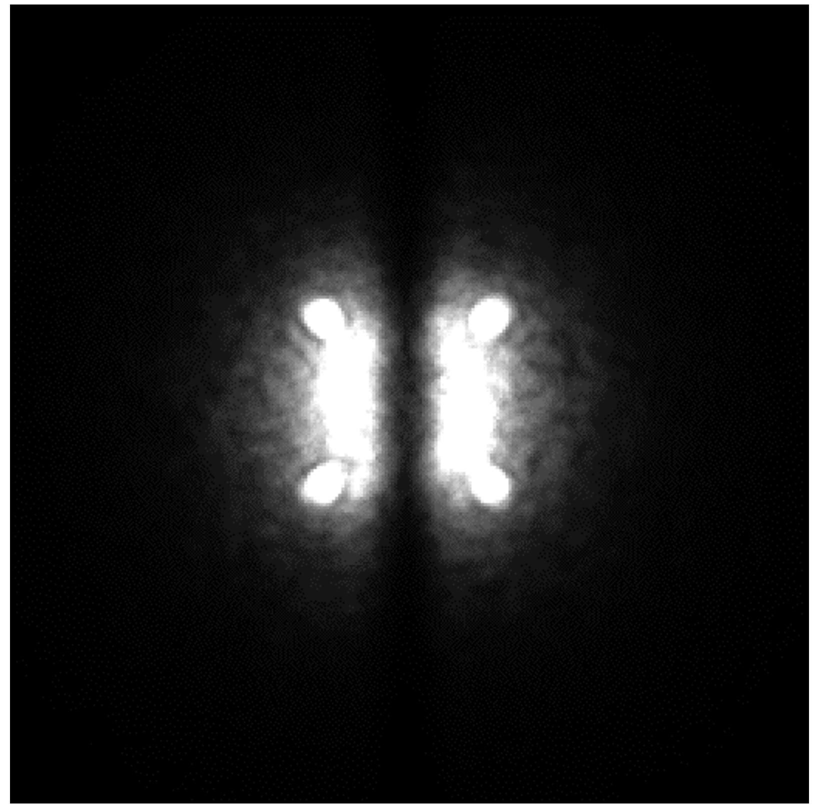
A Binary "Half-Tone" Band-Limited Mask



CORONAGRAPHED AO WHITE LIGHT

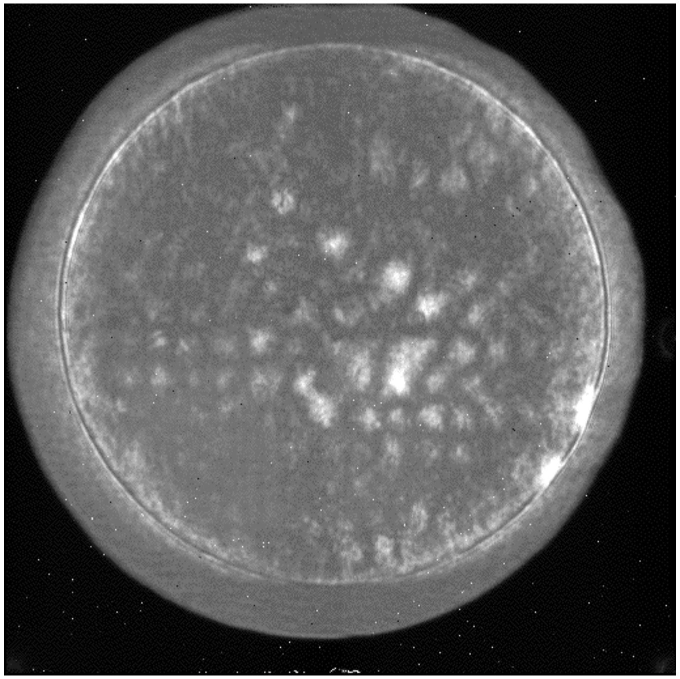


EXPERIMENTAL

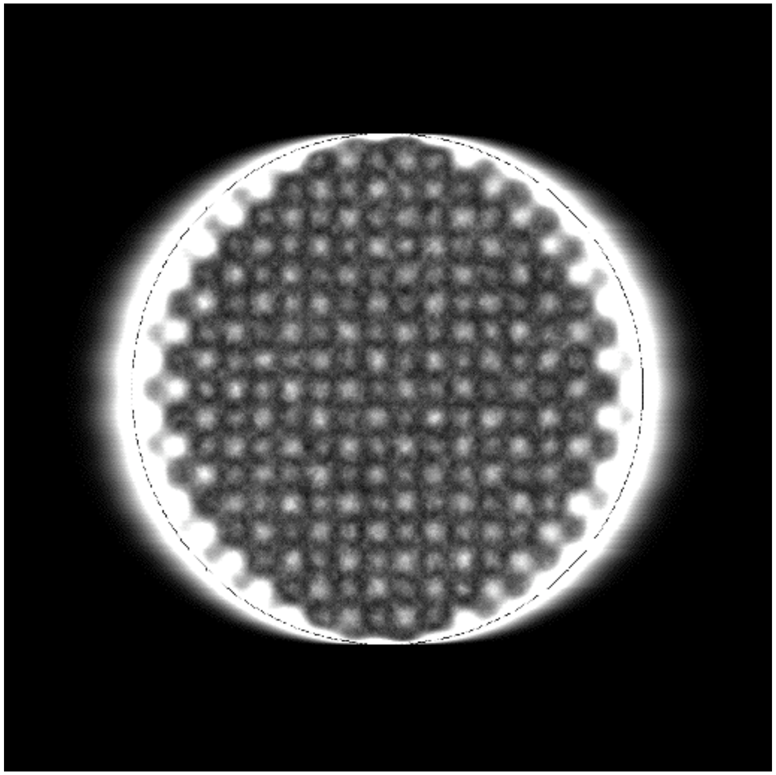


SIMULATED

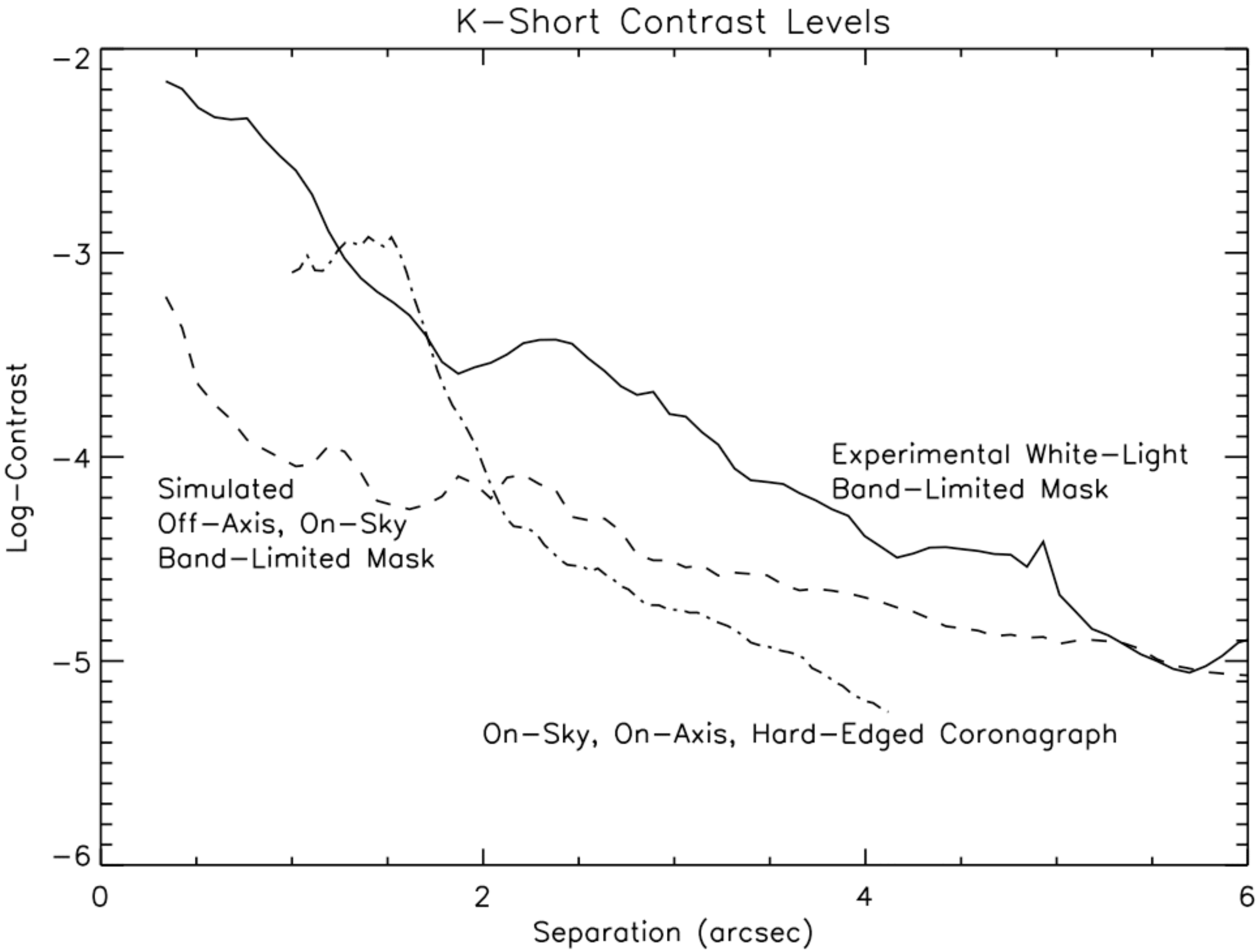
Pupil Image



Experimental



Simulation


K−Short Contrast Levels
Log−Contrast
Separation (arcsec)
−2
−3
−4
−5
−6
0
2
4
6
Simulated
Off−Axis, On−Sky
Band−Limited Mask
Experimental White−Light
Band−Limited Mask
On−Sky, On−Axis, Hard−Edged Coronagraph

Summary

- We implemented a binary version of a band limited mask for use with the Palomar Hale Telescope Adaptive Optics System.
- Preliminary instrument tests suggest we currently achieve only marginal improvement over hard-edged spot coronagraphy.
- We believe that we are limited by the AO wavefront performance.

Acknowledgments

- We thank the Palomar Observatory staff for their invaluable support with instrument testing.
- We thank the 4QPM group for their accommodation of our hardware and testing.
- We thank the JPL AO group for their guidance and advice for mask design and testing.
- We thank the JPL Innovative Spontaneous Concepts program for its support of this project.

A Palomar Adaptive Optics Coronagraphic Survey of TPF-C Candidate Targets

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Jet Propulsion Laboratory
Alex Rudolph, California State Polytechnic University, Pomona

We present here a status report on an ongoing Palomar Hale Telescope adaptive optics coronagraphic survey that searches for sub-stellar companions around 28 TPF-C candidate targets. Sub-stellar objects found around such targets could have important implications for space-based observing programs like TPF-C, that wish to image narrow-separation planetary objects; an existent brown dwarf companion, for instance, might degrade the sensitivity of narrow-separation space-based observations by way of its interfering light; or, the existence of an orbiting brown dwarf could affect the likelihood of a narrow-separation planetary orbit. Our survey therefore helps constrain and direct TPF-C candidate target selection, while providing scientifically important subsellar companion information on the nearby stellar neighborhood.

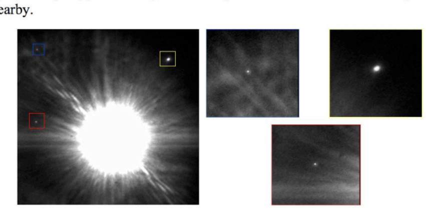
Targets

Object	RA	Dec	Remarks
HIP6379	01:21:59.12	76:42:37.02	V=7.17
HIP13402	02:52:32.13	-12:46:10.97	V=6.05
HIP18859	04:02:36.75	-00:16:08.12	V=5.38
HIP27435	05:48:34.94	-04:05:40.73	V=5.97
HIP28954	06:06:40.48	15:32:31.58	V=6.76
HIP29525	06:13:12.50	10:37:37.72	V=6.43
HIP32439	06:46:14.15	79:33:53.32	V=5.44
HIP34017	07:03:30.46	29:20:13.49	V=5.93
HIP35136	07:15:50.14	47:14:23.87	V=5.54
HIP38784	07:56:17.23	80:15:55.95	V=6.55
HIP39157	08:00:32.13	29:12:44.48	V=6.97
HIP40693	08:18:23.95	-12:37:55.82	V=5.95
HIP40843	08:20:03.86	27:13:03.74	V=5.13
HIP42438	08:39:11.70	65:01:15.26	V=5.63
HIP44897	09:08:51.07	33:52:55.98	V=5.95
HIP49081	10:01:00.66	31:55:25.22	V=5.37
HIP53721	10:59:27.97	40:25:48.92	V=5.03
HIP62207	12:44:59.41	39:16:44.10	V=5.95
HIP70319	14:23:15.29	01:14:29.65	V=6.25
HIP72567	14:50:15.81	23:54:42.64	V=5.86
HIP78775	16:04:56.79	39:09:23.43	V=6.66
HIP79248	16:10:24.31	43:49:03.52	V=6.61
HIP82588	16:52:58.80	-00:01:35.12	V=6.65
HIP83389	17:02:36.40	47:04:54.77	V=6.76
HIP95319	19:23:34.01	33:13:19.08	V=6.37
HIP98792	20:03:52.13	23:20:26.47	V=7.28
HIP100017	20:17:31.33	66:51:13.27	V=5.91
HIP116085	23:31:22.21	59:09:55.86	V=6.76

For our target list, we select the nearby (d < 20pc) FGK dwarfs that have been proposed as targets for NASA's Terrestrial Planet Finder Coronagraph (TPF-C) mission. We reviewed the top 100 targets for TPF-C and removed targets that had previously been observed by other programs such as ongoing SIM reconnaissance observations being conducted at Palomar. Our final target list, shown on the right, includes a median target distance of 16.9 parsecs, and a median spectral type of G3V.

Observing Procedures

We utilize the Palomar Hale Telescope Adaptive Optics (AO) System to achieve diffraction-limited resolutions at K-band (2.2-micron) for a 5-meter primary mirror aperture. We combine the AO system capabilities, with strehl ratios typically 30-70%, with PHARO's 0.91-arcsecond coronagraphic spot, to help suppress the light from the parent star and resolve faint objects nearby.

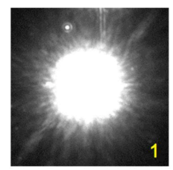


Above: Three objects can easily be seen in the field near the target star. These objects are at angular separations of 13.8, 11.3, 9.2 arcseconds clockwise from top left, which correspond to physical separations of 214, 175 and 142 AU, if they are indeed companions. Follow up observations are needed to check for companion status, as well as brown dwarf status.

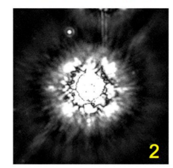
Data Reduction

Our data reduction begins with standard reduction procedures including sky-subtraction, flat-fielding, bad-pixel correction, and median-combination of individual frames. Next we apply a Fourier-filter, which filters out low-frequency spatial features such as internal instrument reflection ghosts. We next use our software to rotate the frame and subtract it from itself. Finally, we inspect Fourier-filtered, non-Fourier-filtered, rotationally-subtracted, and non-rotationally-subtracted frames to identify potential companions.

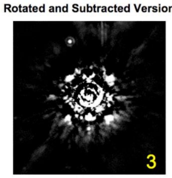
Median-Combined,Sky-Subtracted, Flatfielded, Coronagraphic Image



Fourier-Filtered Version



Rotated and Subtracted Version



Future Work

We are currently on schedule to complete the observing phase of the survey by December 2006. During our concluding observations, we expect to observe candidate companions for common proper motion, and complete reconnaisance of remaining new targets.

In parallel with this observing effort, we have developed Monte Carlo population simulations to derive the true companion fraction from the observed result. This phase is crucial to deriving accurate companion statistics since observational results may be biased by factors such as orbital projection effects. We expect to use our Monte Carlo simulations to combine these observational results with other surveys to conclude accurate population statistics.

Acknowledgements

We thank the Palomar Observatory staff for their support of these observations. K. Hiner was supported in part by the Kaye Reeder Scholarship at Cal Poly Pomona. The research conducted by J. Carson and K. Stapelfeldt, and part of the research conducted by K. Hiner, was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Association.

The Cornell High-order Adaptive Optics Survey for Brown Dwarfs in Stellar Systems–II: Results from Monte Carlo Population Analyses

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ABSTRACT

In this second of a two-paper sequence, we present Monte Carlo population simulation results of brown dwarf companion data collected during the Cornell High-order Adaptive Optics Survey for brown dwarf companions (CHAOS). Making reasonable assumptions of orbital parameters (random inclination, random eccentricity and random longitude of pericentre) and age distributions, and using published mass functions, we find that the brown dwarf companion fraction around main sequence stars is 0.0%-9.3% for the 25-100 AU semi-major axis region. We find a corresponding L-dwarf companion fraction of 0.0%-3.3%. We compare our population analysis methods and results with techniques and results presented by several other groups. In this comparison we discover that systematic errors (most notably resulting from orbital projection effects) occur in the majority of previously published brown dwarf companion population estimates, leading authors to claim results not supported by the observational data.

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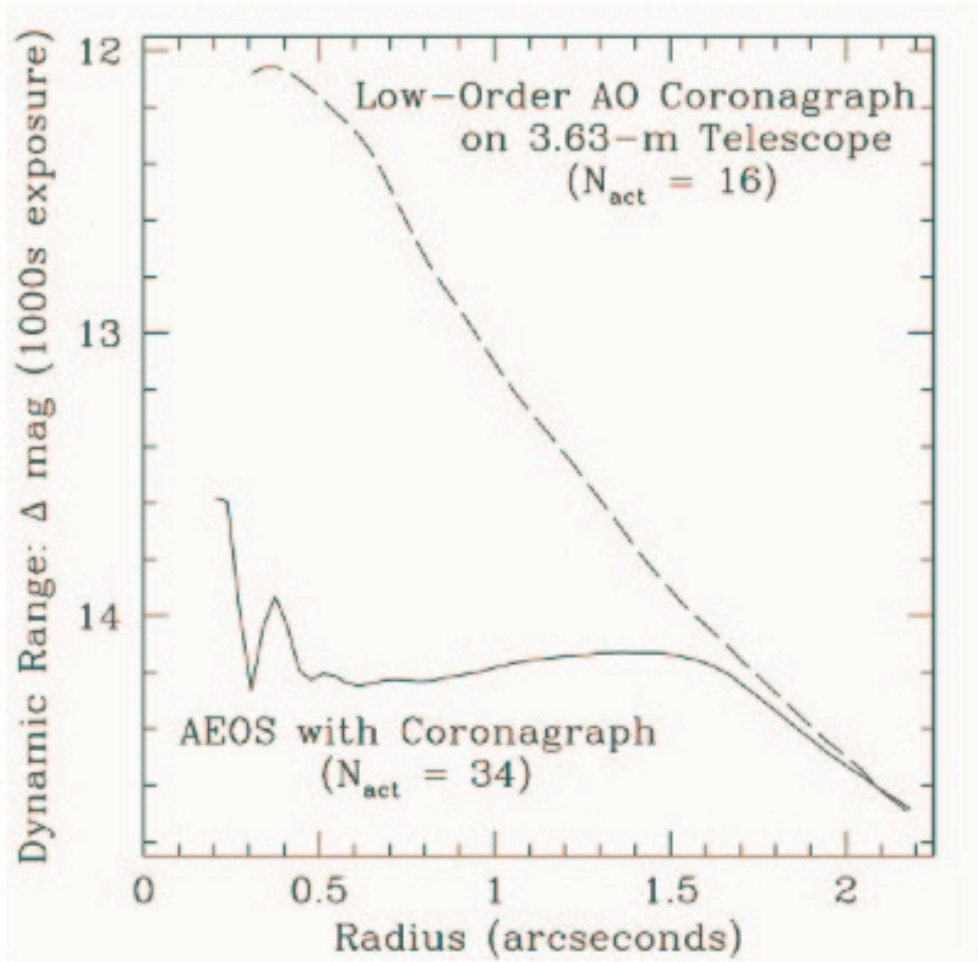
Other Operational High Contrast Systems

- Lyot Project

US Airforce AEOS Telescope on Haleakala

Other Operational High Contrast Systems

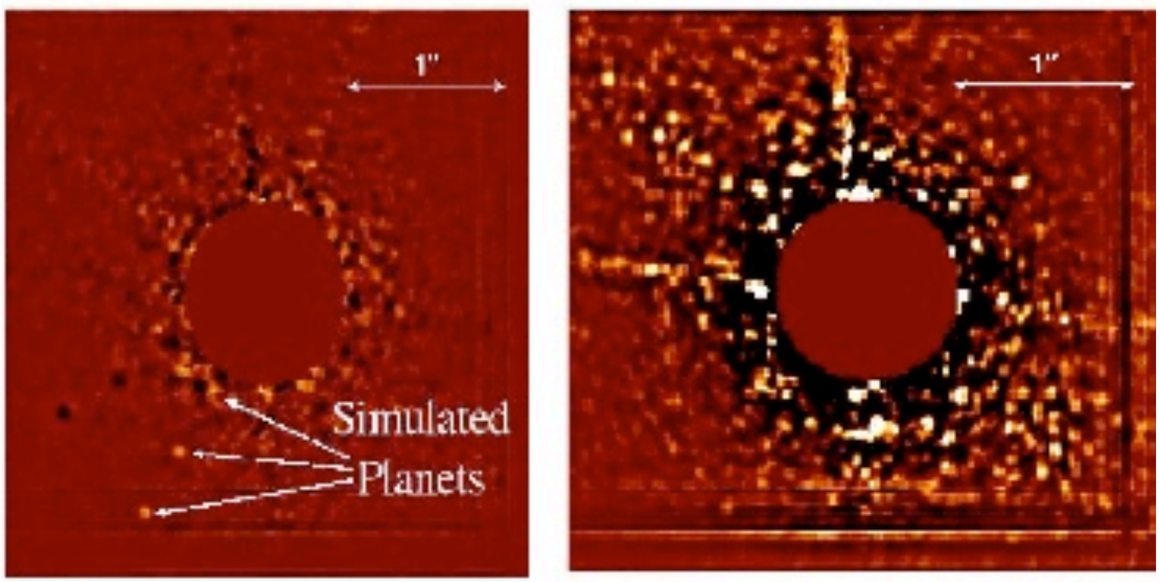


Dynamic range for a 1000 s exposure with the AEOS coronagraph

Oppenheimer et al. 2003

Other Operational High Contrast Systems

- Simultaneous Differential Imager on VLT NACO



Biller et al. 2005

Other Operational High Contrast Systems

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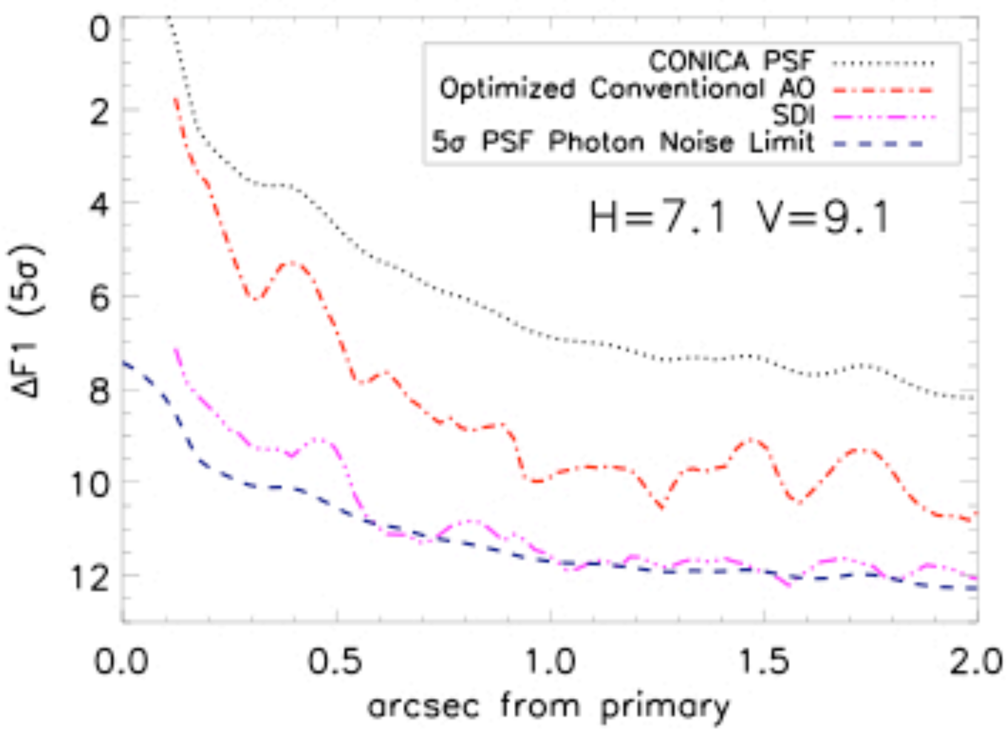
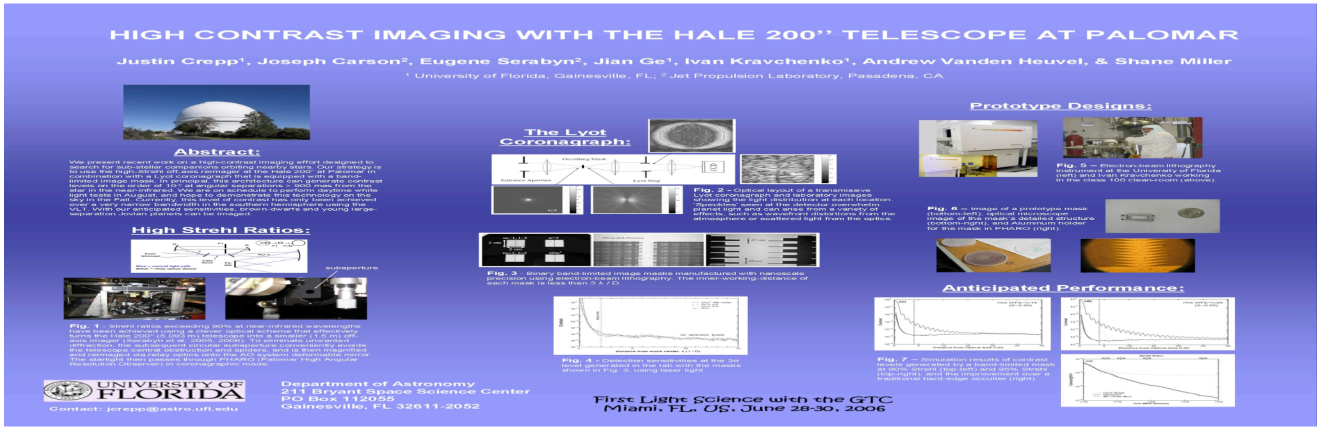


Biller et al. 2005

Advantages of our 1.5-meter Subaperture Setup

- Adaptive Optics system achieves better wavefront control, compared to a full aperture setup. (Subaperture Strehl ratios = 90%-95%.)
- No Secondary Mirror or Spider Support Obscurations.

Palomar Band-Limited Mask Tested In-Lab



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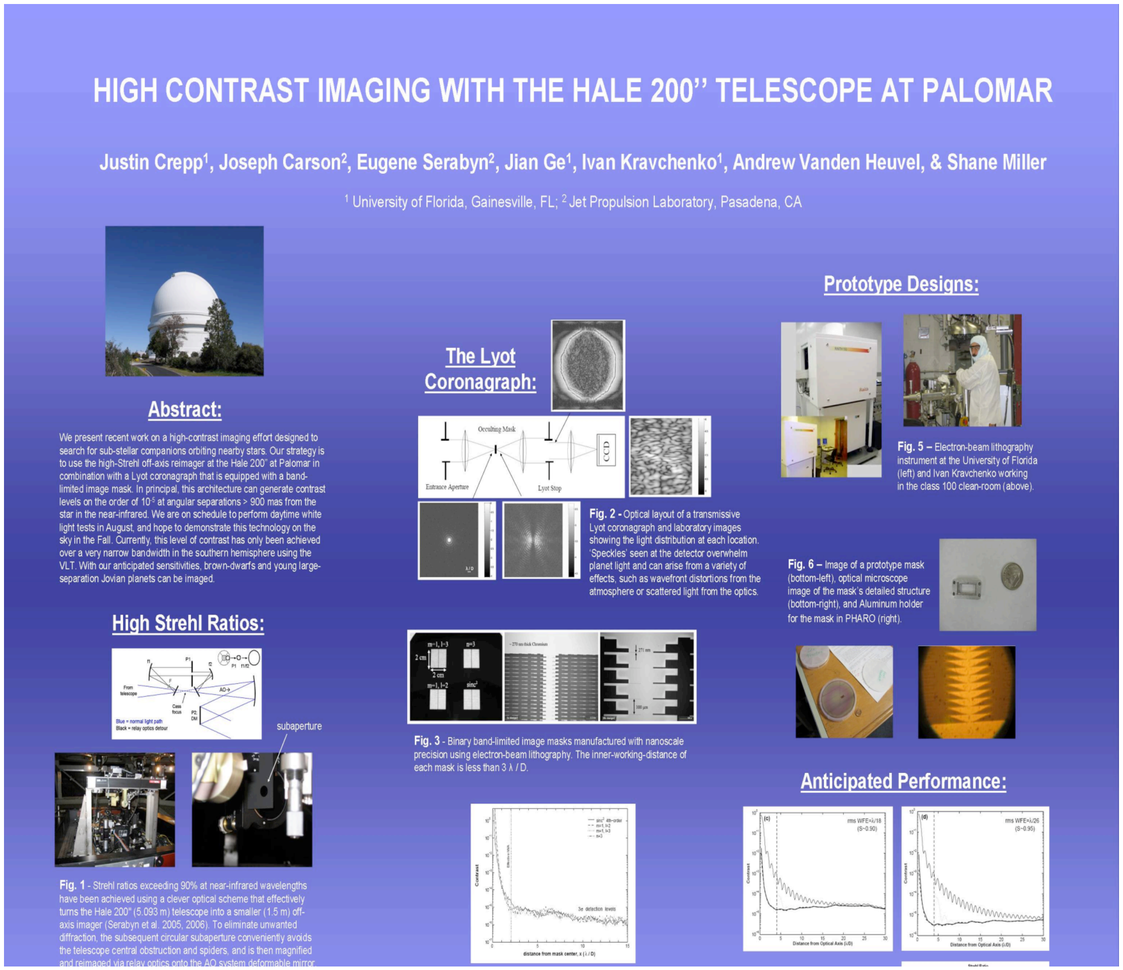
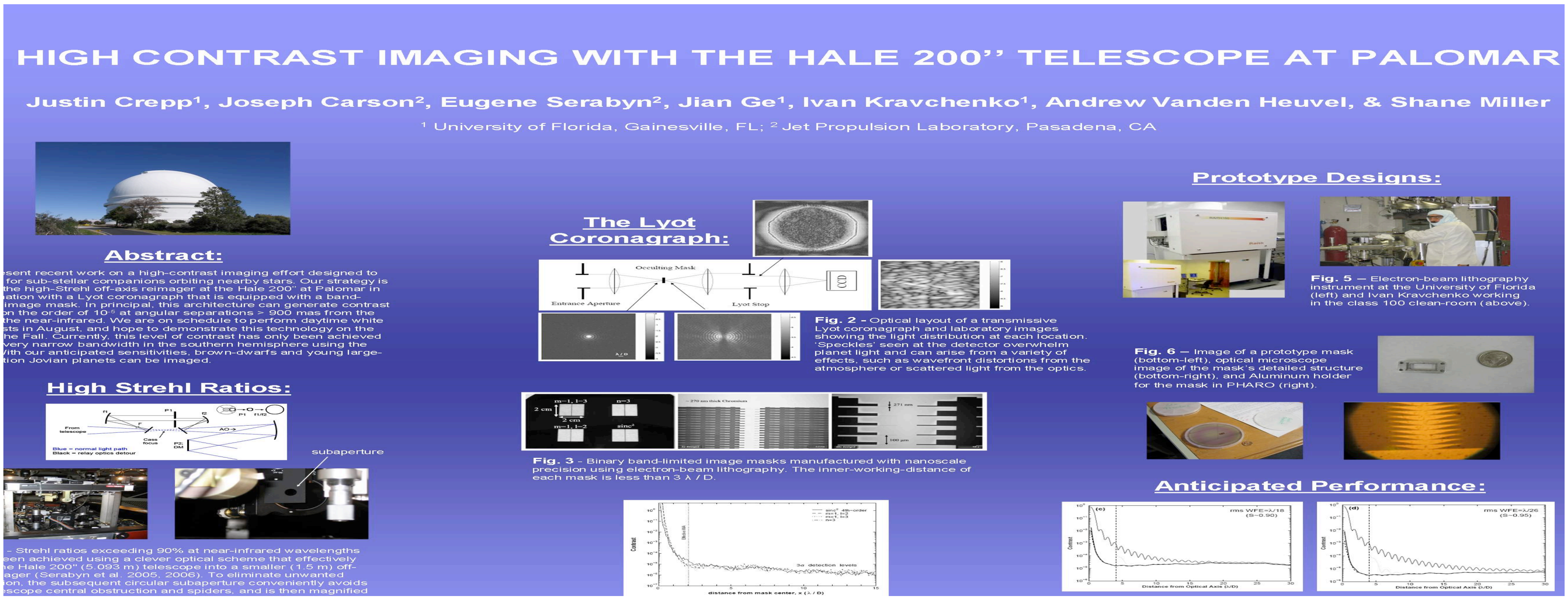


Band-Limited Mask Simulated On-Telescope Performance



Upcoming Schedule

- Mask calibration tests continue this Fall.
- Parallel development of a radial mask version using “sputter” fabrication techniques.
- On-sky calibration/science tests expected this winter..