

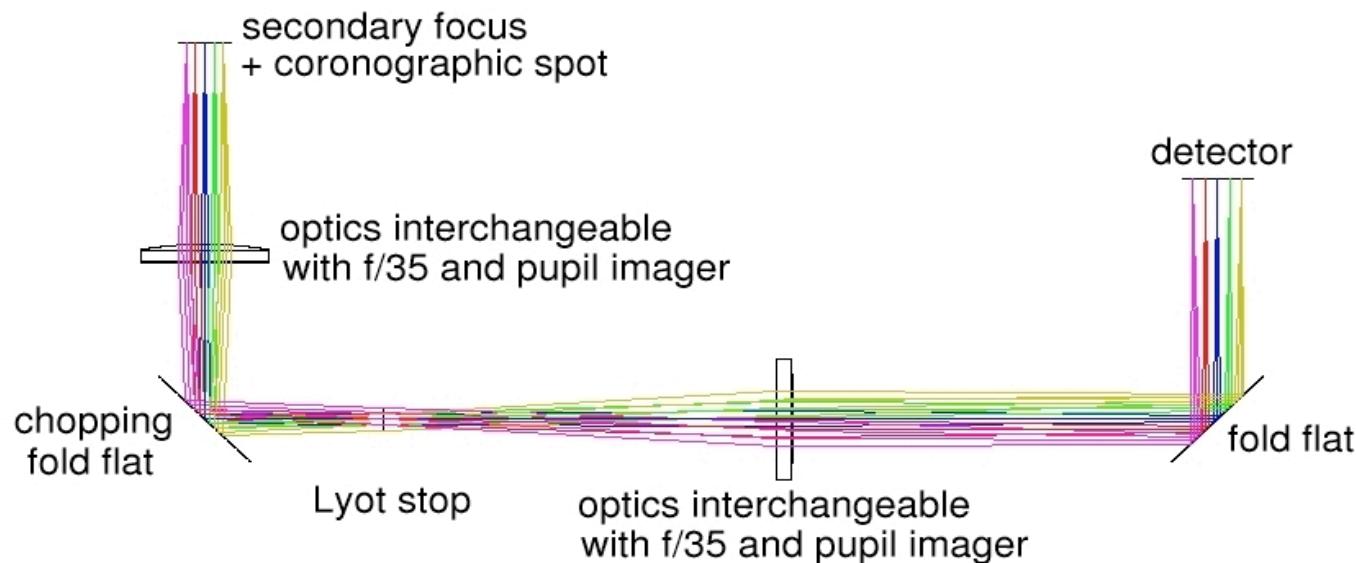
Introduction to the Clio Camera

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July 4, 2012

Pre-presentation version: June 17, 2012



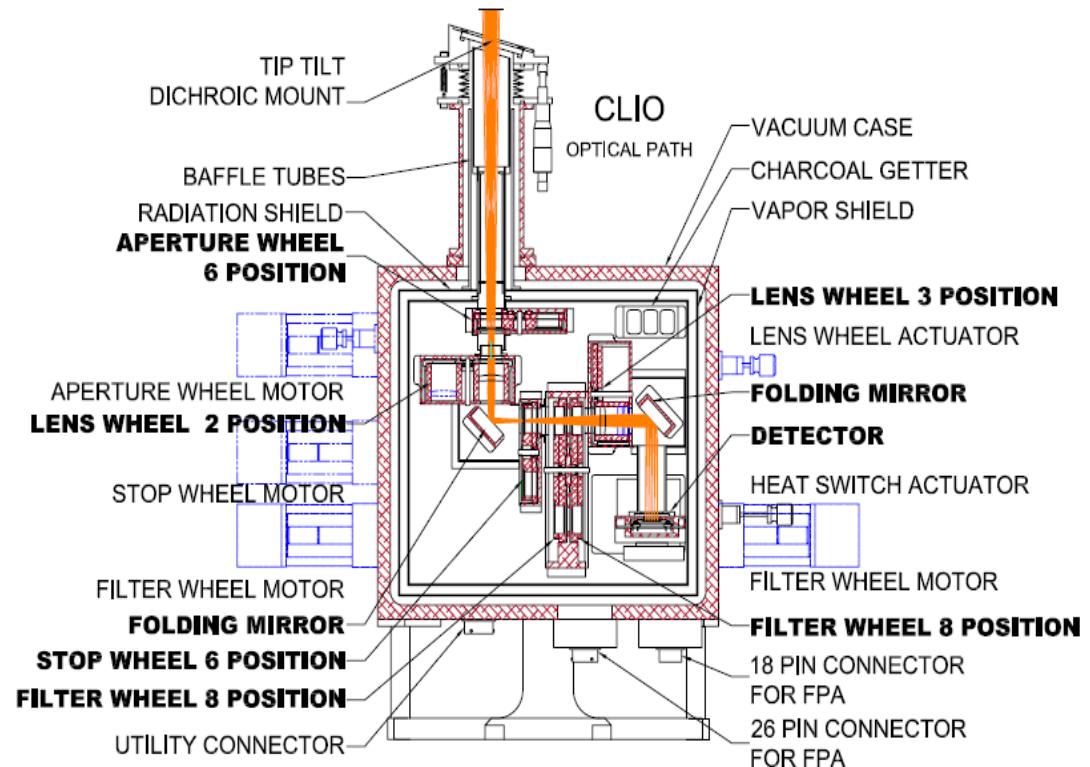
Optical Parameters



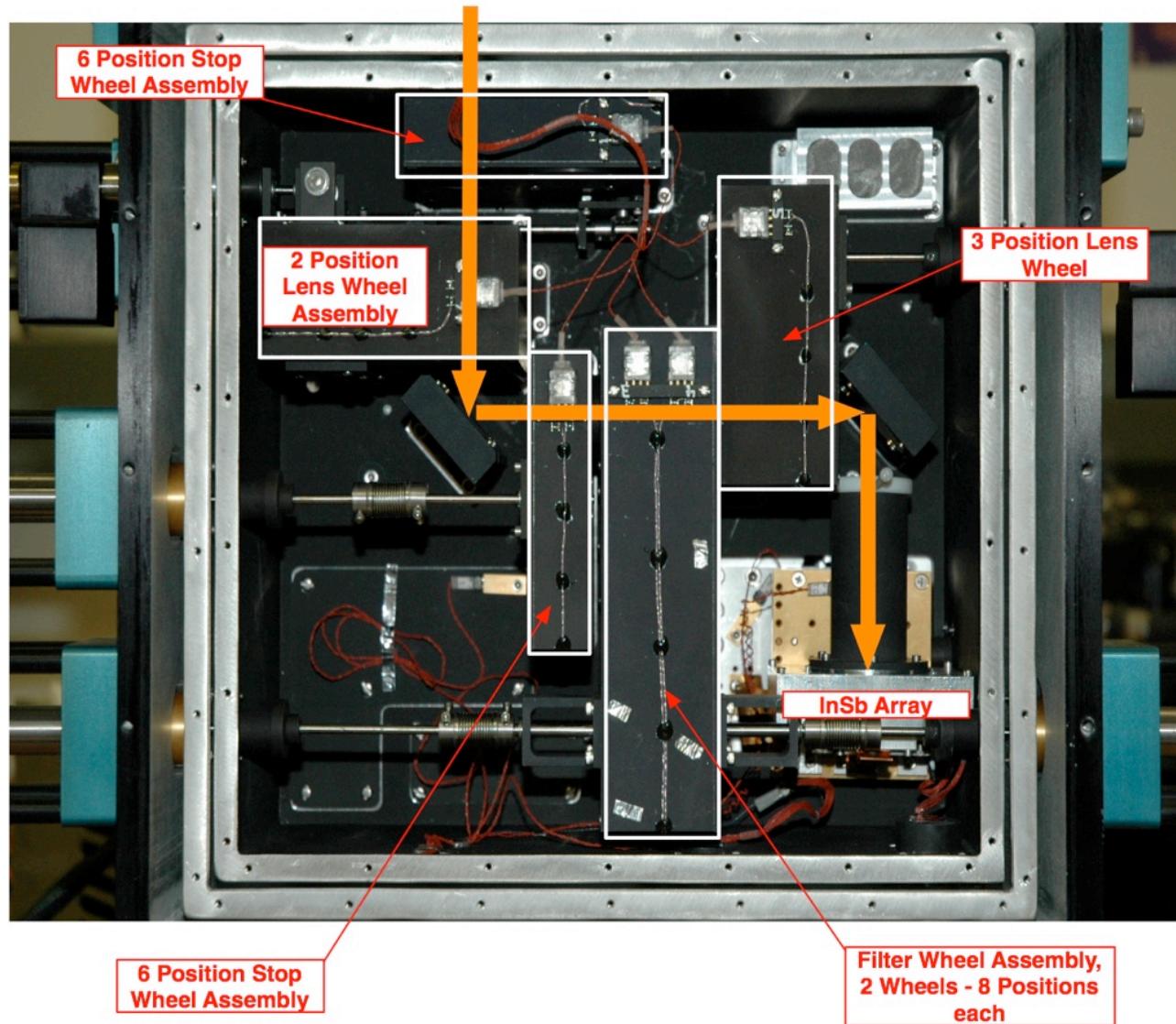
- Diffraction-limited imaging from **H through M-bands**
- 3 imaging modes: **f/37.7** (H and K-bands), **f/21.5** (L and M-bands), and **pupil imaging** (for alignment of cold-stops) modes
- HAWAII-1 HgCdTe array with a 5.3 μm cutoff (Teledyne)
- **Cooled optics** (77K), **baffling**, and **cold stops** to minimize instrument thermal background
- **Coronagraphic option** built in (have ability to add field and pupil stops and PSF shaping wave plates)

Mechanical Design

- Optics, filters and cold stops are selectable with stepper motors.
- Entrance window is dichroic to reflect the WFS light ($< 1 \mu\text{m}$).

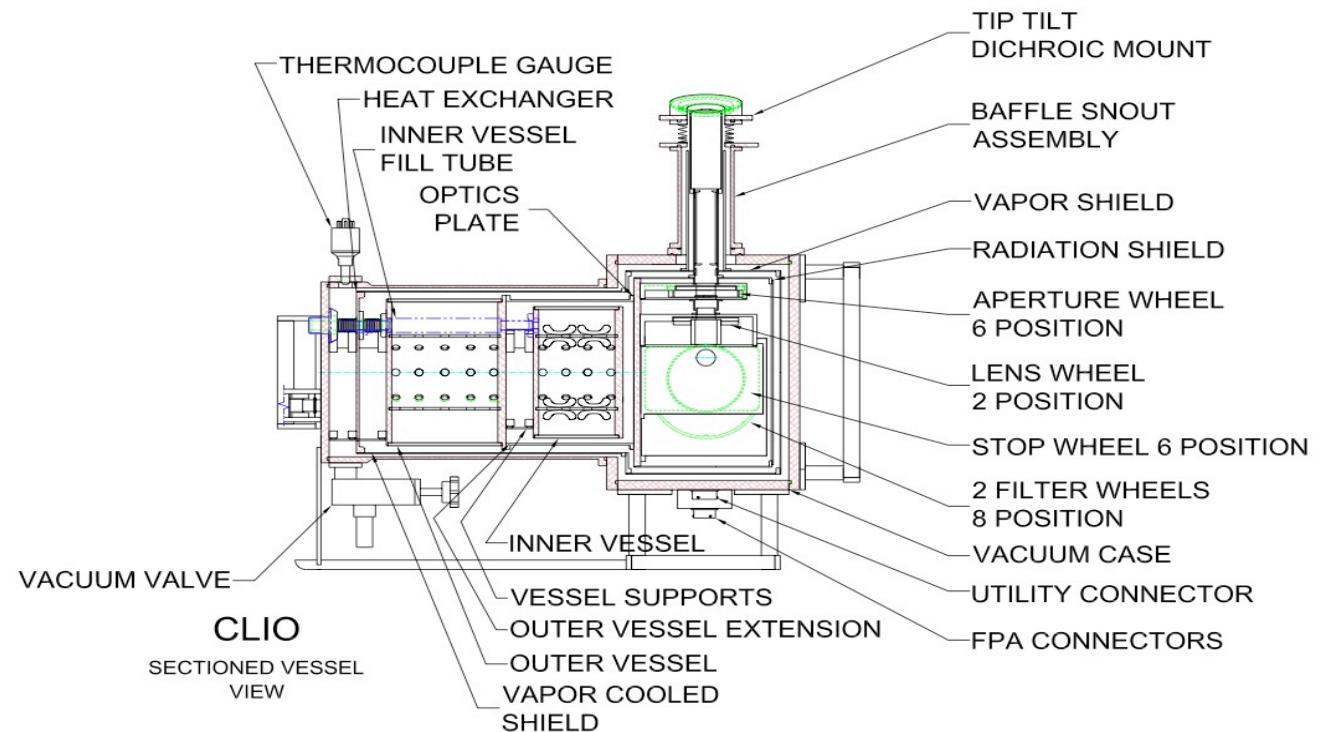


Mechanical Design



Thermal Design

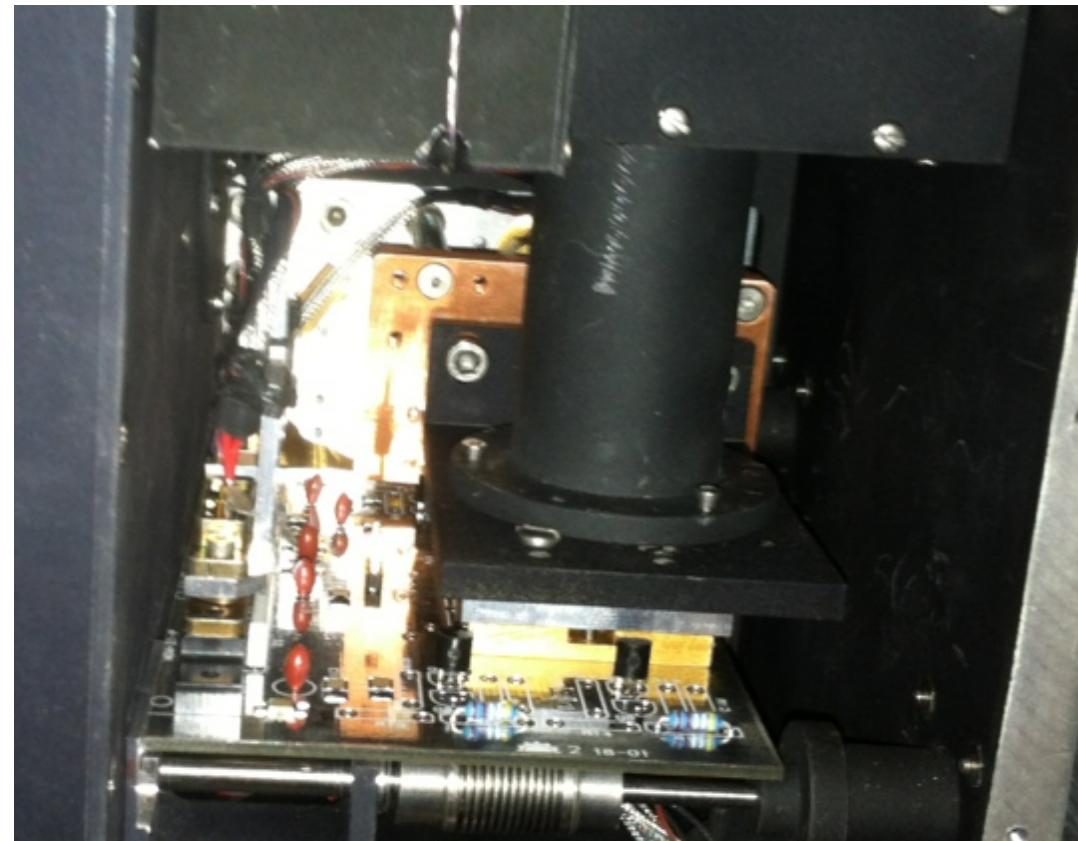
- Two stage cryostat:
 - First stage: Optics (LN₂: 77 K)
 - Second stage: Detector (Solid N₂: 60 K)



Clio Detector

- Uses two quadrants of an engineering grade HAWAII-I MBE long wavelength detector.
- SDSU Gen. II electronics

Temperature	60 K
Pixel Rate	1 MHz
Readouts	1 per quadrant
Duty Cycle	~ 90%
Frame Rate	≤ 3.8 Hz full frame
QE _{3-5 μm}	0.6
Well Depth	2.5×10^5 e ⁻
Dark Current	<3 e ⁻ /s
Read Noise	100 e ⁻ single read 20e ⁻ CDS
Gain	5 e ⁻ /DN

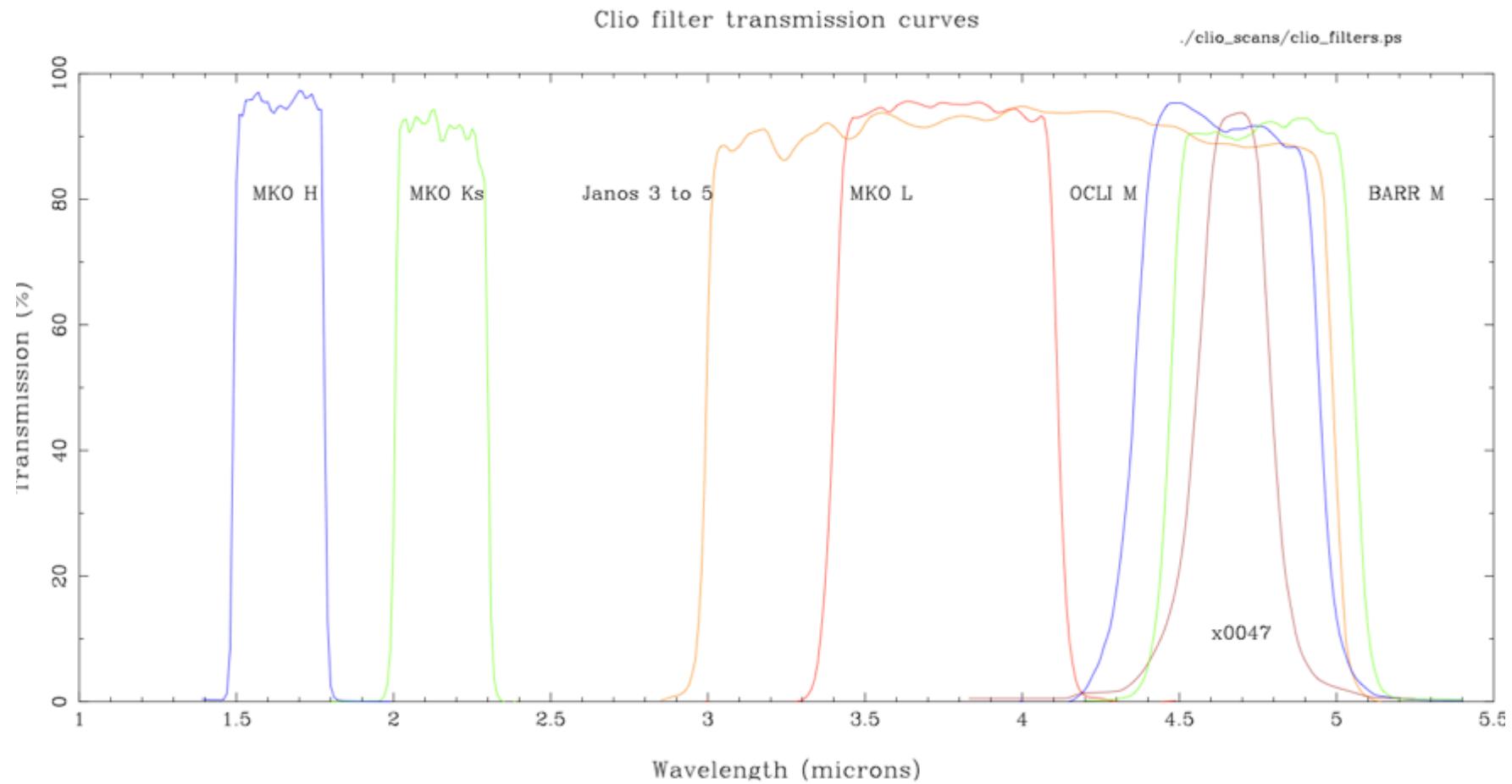


Clio Readout Modes

- Full Reset-Read mode used for fast imaging.
 - Overhead of 1 read time (262 ms) is incurred for any readout.
- “Strip” mode used for higher efficiency in L' band
 - 183 ms overhead
- “Stamp” mode used for M band imaging
 - 43 ms overhead.



Filter Complement

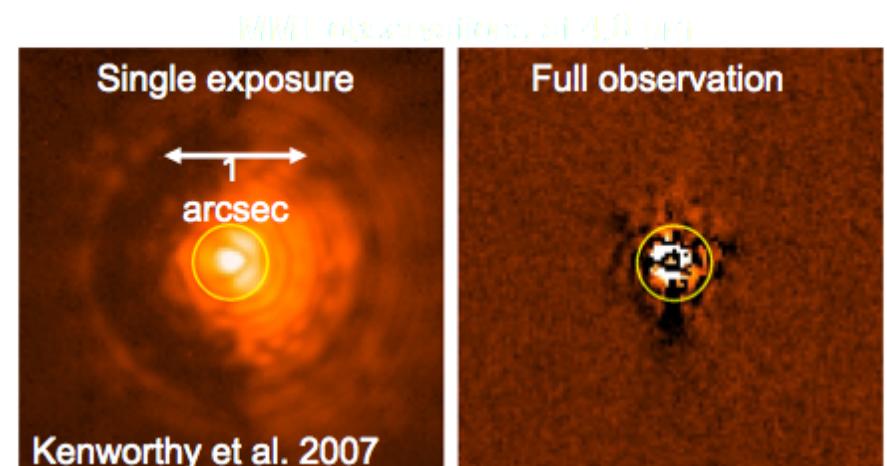


- 3.1, 3.3, 3.4, and 3.9 μm filters also available.



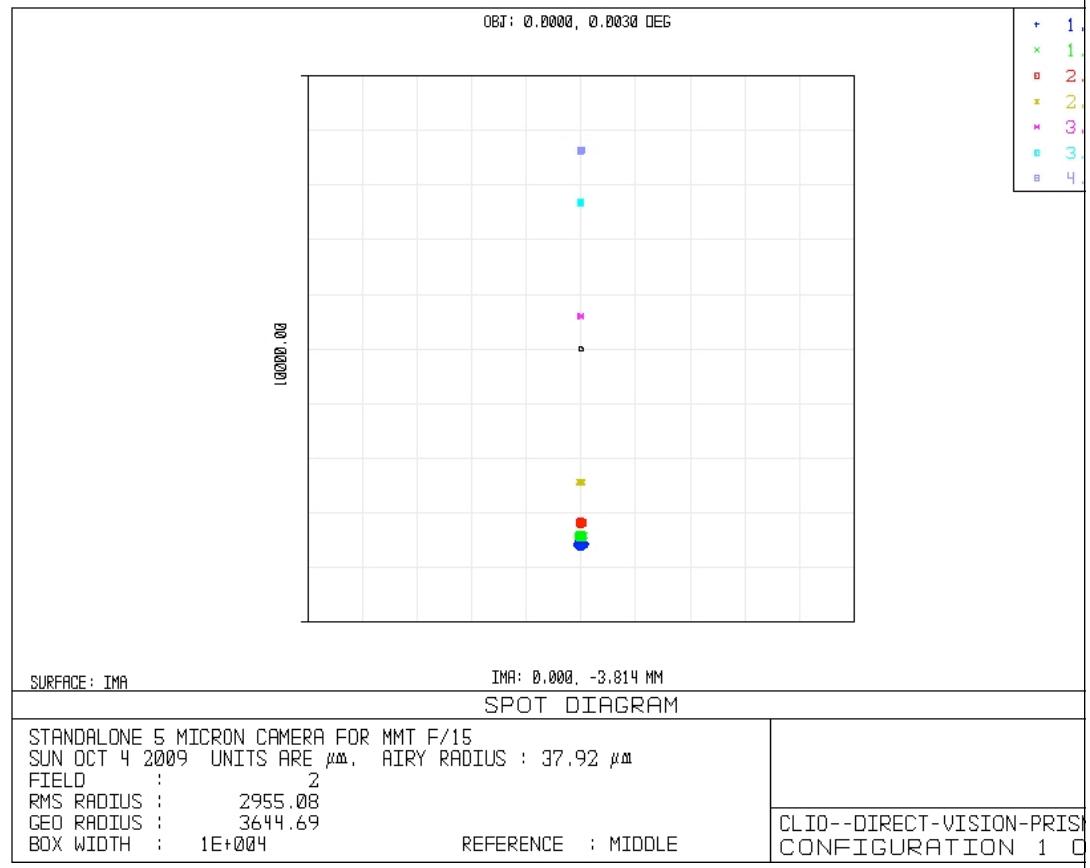
Other Modes

- Apodizing Phase Plates are available in the cold stop wheel to provide a “dark hole” at L' and M band for high contrast imaging.
- 3 hole and 6 hole nonredundant masks are available for NRM data acquisition.

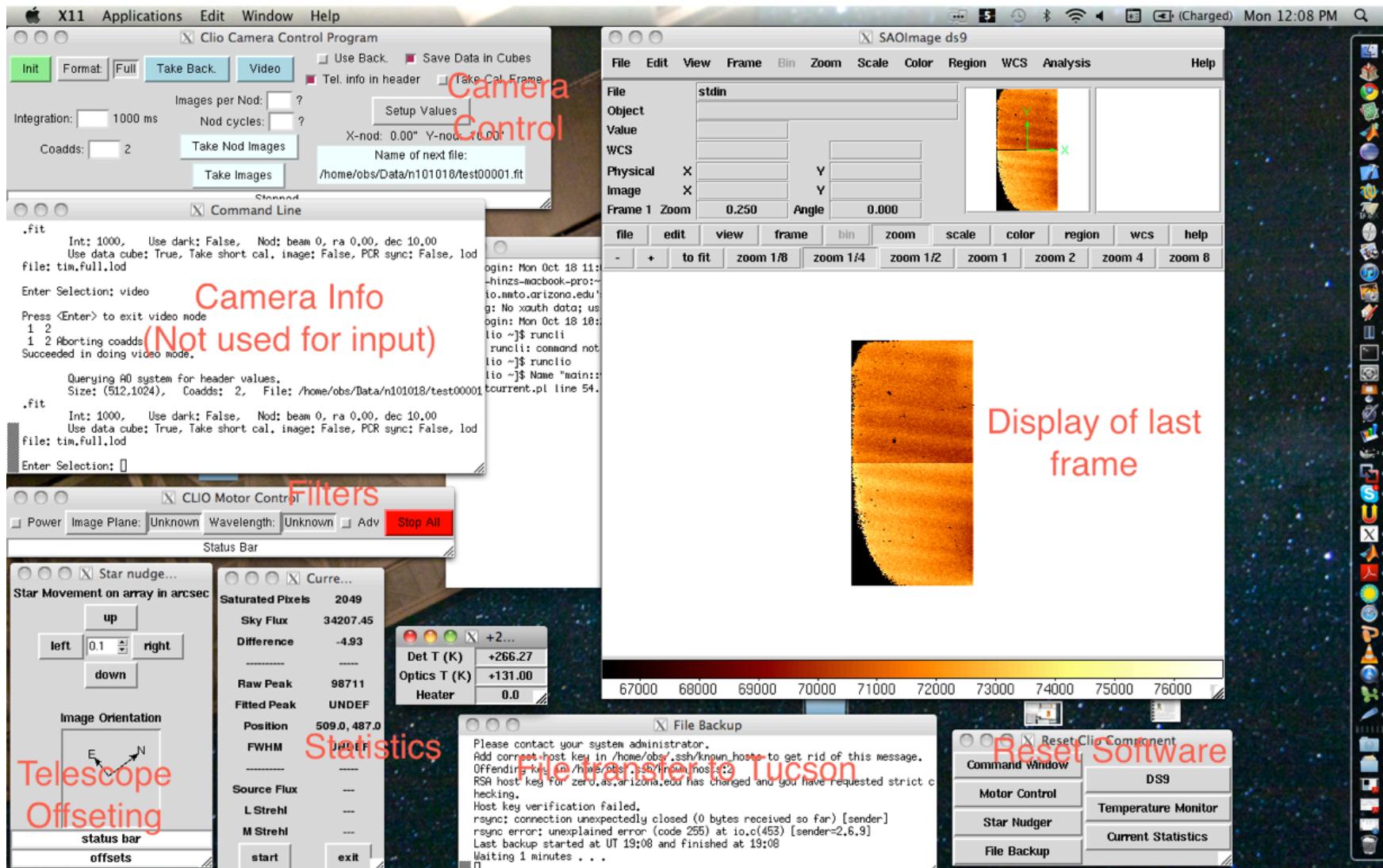


Prism spectroscopy

- A direct vision prism is available.
 - R @ 2 μm is ~30
 - R @ 3.5 μm is 130



Clio Software

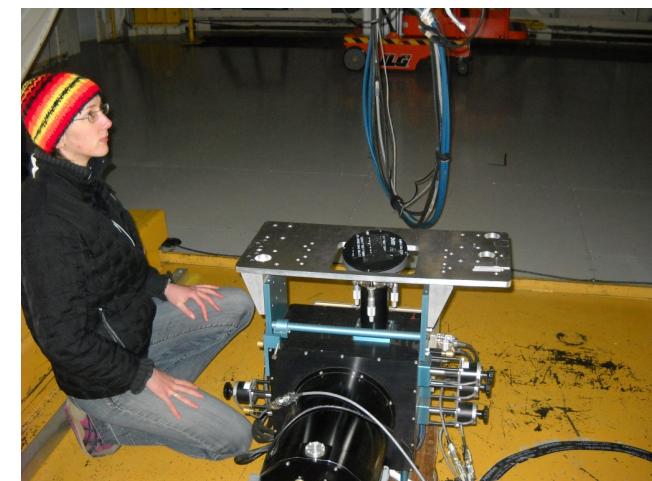
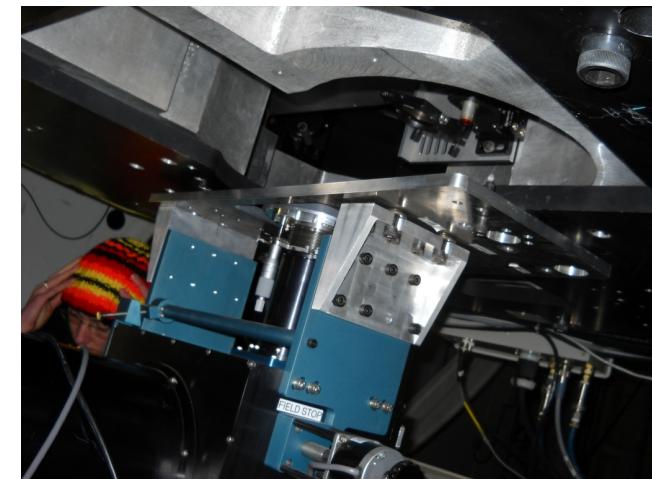


Clio in Operation

- Clio communicates with the AO system to carry out automated nods and dithers.
- FITS header information is retrieved from the AO system to provide all relevant instrument and telescope information.
- Remote operation is achieved via remote X display.

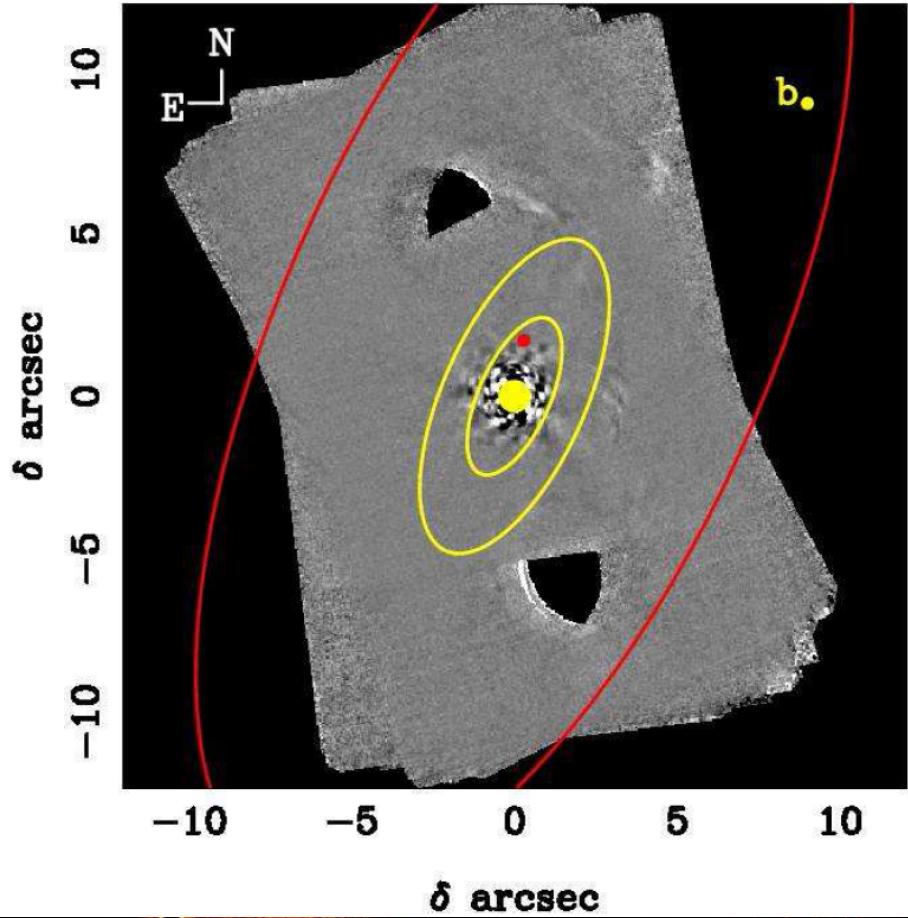
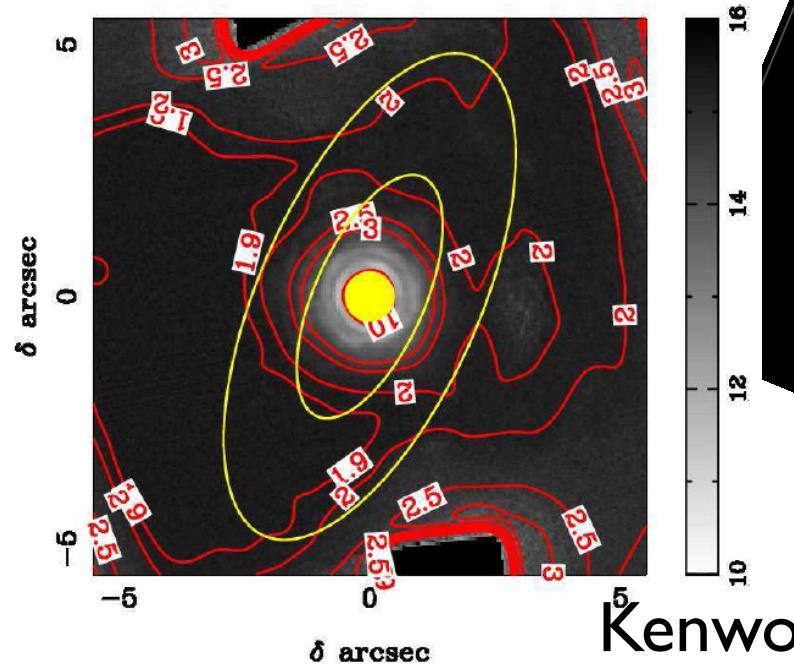
Clio at the MMT

- Clio has been used at the MMT since 2006.
- Clio2 started operation in 2010.
- Simple camera operation has allowed use by a range of observers.



Selected Results: Other planets around Fomalhaut?

- Clio used at M band
to eliminate existence
of inner companions
to Fomalhaut of > 3
MJ

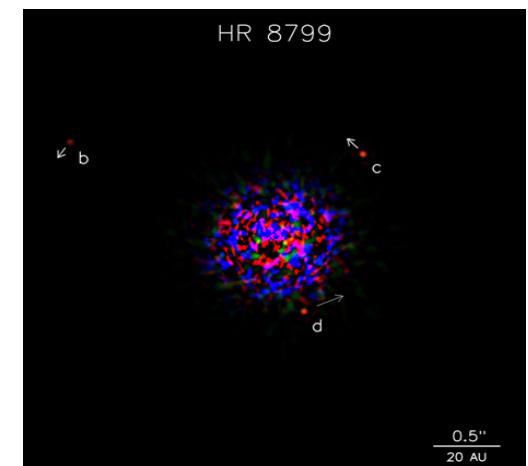


Kenworthy et al. 2009

Clio

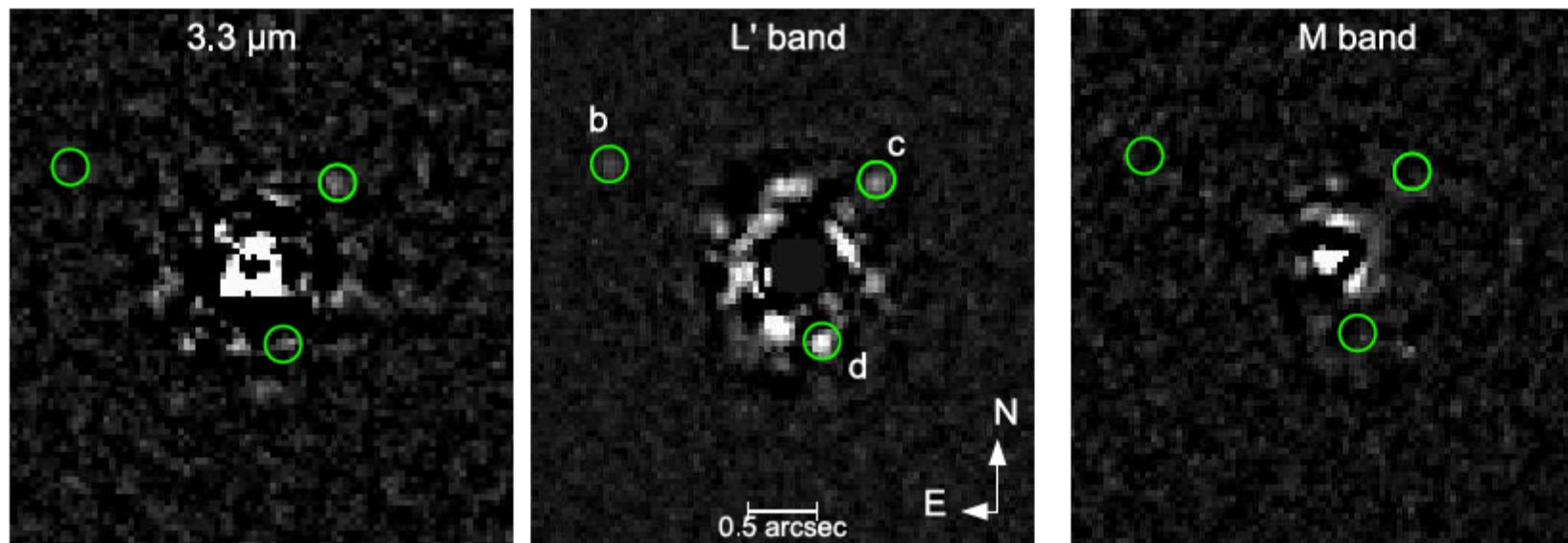
Selected Results: Imaging the Planets around HR 8799

- Clio used to probe lack of methane absorption in HR 8799b,c,d



Discovery by Marois
et al. 2008

Clio Imaging of HR 8799



Hinz et al. 2010

Changes for Clio at Magellan

Motorized Optics Mode
Change



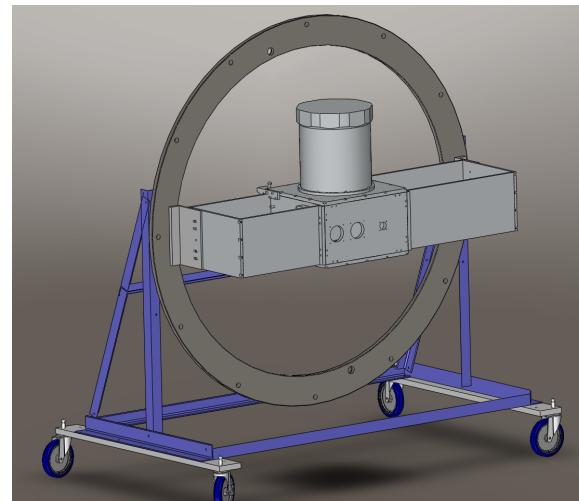
Modified Clio to
operate inverted

Added
super-insulation

Changed Dichroic for
MagAO WFS



New Mount and Cart



Thermalized E-rack



Clio ready to mount on Magellan

