Synergies of Subaru and CGI

Tyler D. Groff

High Level “What can Subaru observations do for CGI”

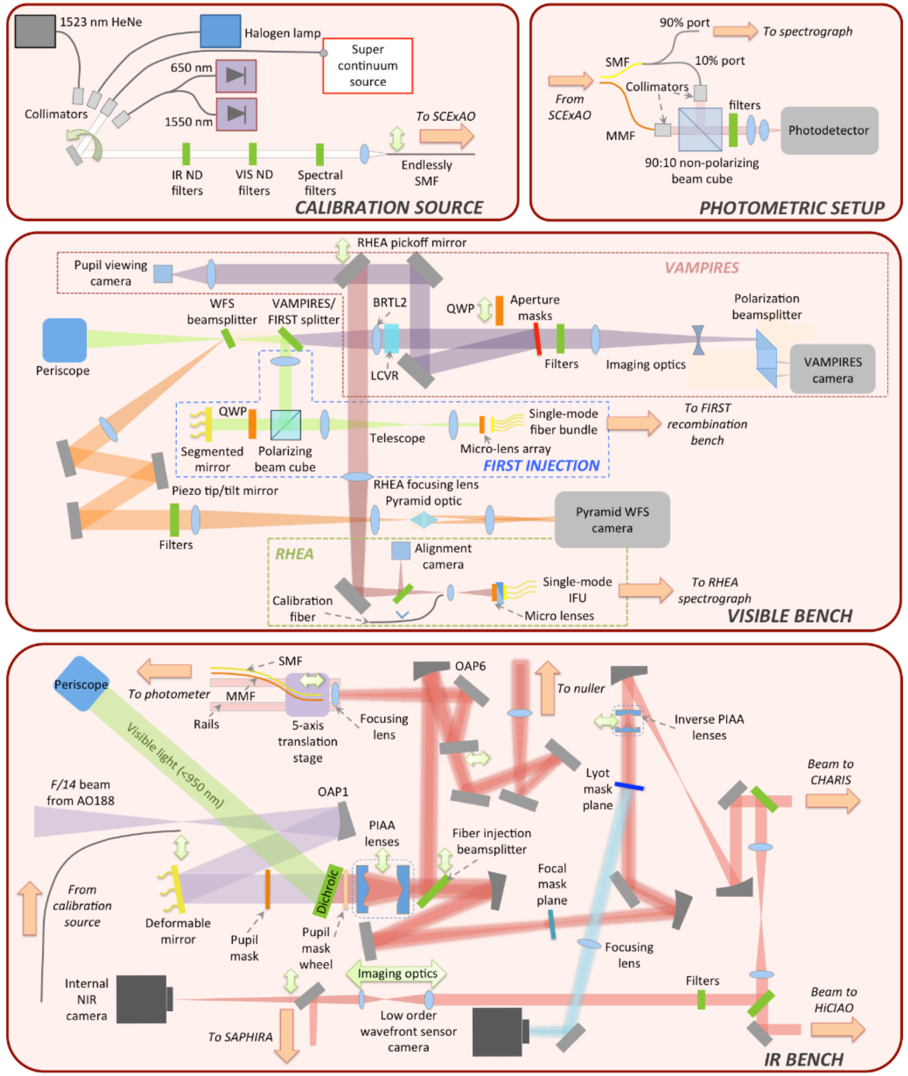
- Precursor Observations with extreme adaptive optics (ExAO)
  - Any CGI targets of opportunity are generally Vmag~5,
    - Well within the wheelhouse of target brightness for SCExAO’s modules
    - If observable from Mauna Kea they are highly complementary
  - Detection and characterization of binaries and bright (>5x10^{-6} contrast) companions in the near-infrared
    - Potentially some value added science
    - Basic vetting of targets for suitability of target at 10^{-5} contrast levels
  - Disk detection
- Small inner working angle detections using VAMPIRES module
  - Measured spin axis of host star, but generally there will be a performance mismatch.
  - Disk measurements at small separations, but nearest RV stars likely won’t have bright disks
- Conventional AO detection of background objects ahead of CGI observations
  - IRCS

Instrument Phasing with CGI observations

- SCExAO+CHARIS and modules are PI instruments with a 3-year phasing and re-evaluation
- SCExAO+CHARIS will likely not exist at Subaru by 2026
- Plan is to evolve SCExAO+CHARIS into a TMT instrument by the time CGI observations and potential GO/Starshade missions are in operation
- Consequence
  - Subaru/SCExAO observations of CGI strategic targets would have to be identified and observed in the next few years
  - We should be looking to the ELTs
  - Assuming a US-Japan collaboration on developing SCExAO+CHARIS for TMT, observations could be planned with CGI to both vet targets and do follow up science if the GO program happens and/or CGI finds something interesting during the technology demonstration
  - The TMT US-Japan collaboration would provide a healthy base for data processing and analysis if CGI has a GO program

Subaru's SCExAO Modules and Current Capabilities

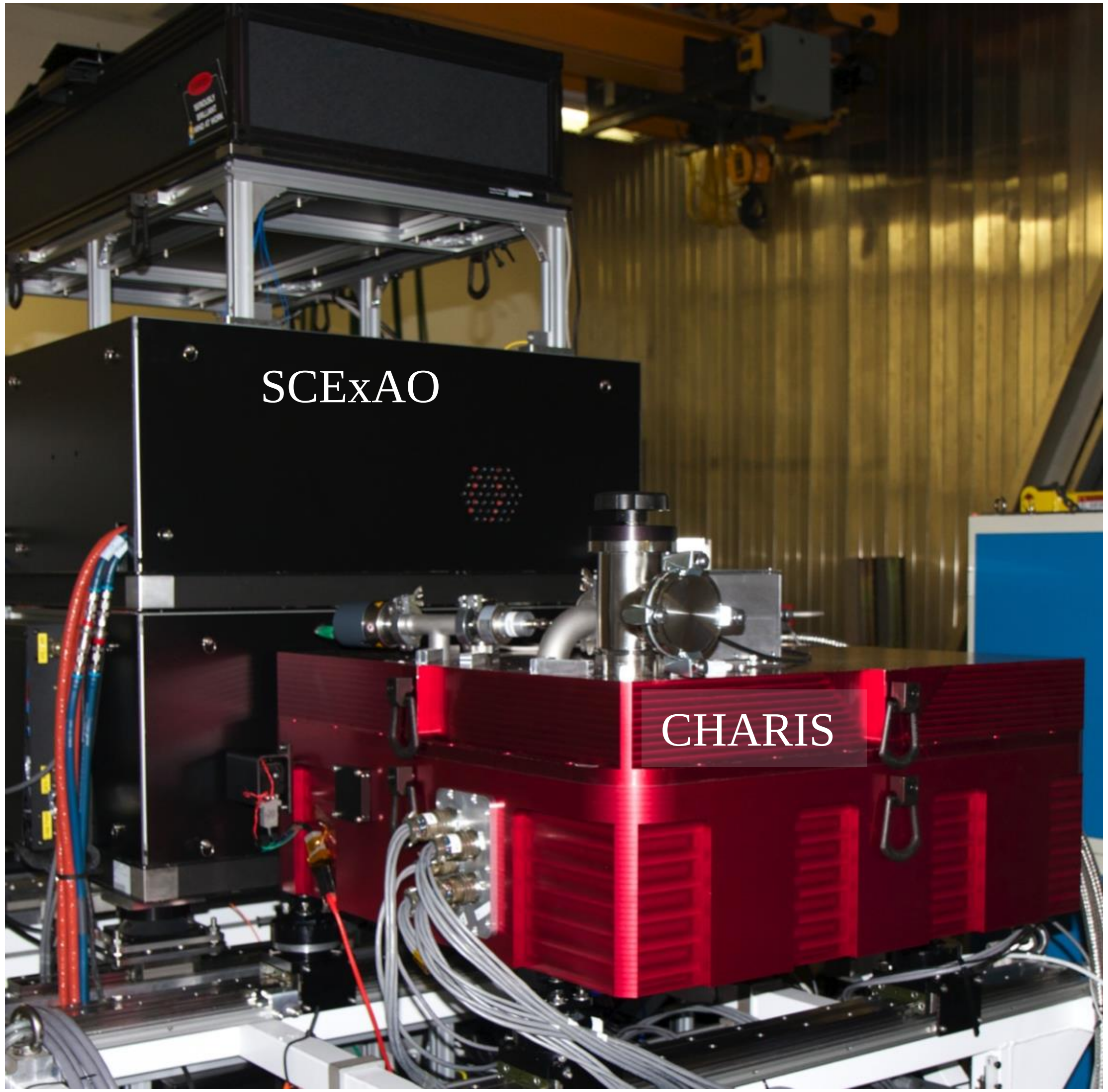
- The wavefront control feeds a high Strehl PSF to various modules, from 600 nm to K band.
- Visible (600 – 950 nm):
  - **VAMPIRES**, non-redundant masking, polarimetry, with spectral differential imaging capability (h-alpha, SII)
  - FIRST, non-redundant remapping interferometer, with spectroscopic analysis
  - RHEA, single mode fiber injection, high-res spectroscopy, high-spatial resolution on resolved stars
- Infrared (950-2400 nm):
  - Various small IWA (1-3 l/D) **coronagraphs** for high contrast imaging – PIAA, vector vortex, 8OPM
  - **CHARIS** - IFS (J to K-band)
  - MEC - MKIDs detector, high-speed, energy discriminating photon counting imager (y to J-band)
  - NIR single mode injection, high throughput high resolution spectroscopy. Soon will be connected to the new IRD
  - SAPHIRA - high-speed photon counting imager, (H-band for now)
  - GLINT - NIR nulling interferometer based on photonics



Jovanovic et al, PASP, 127, 890 (2015)

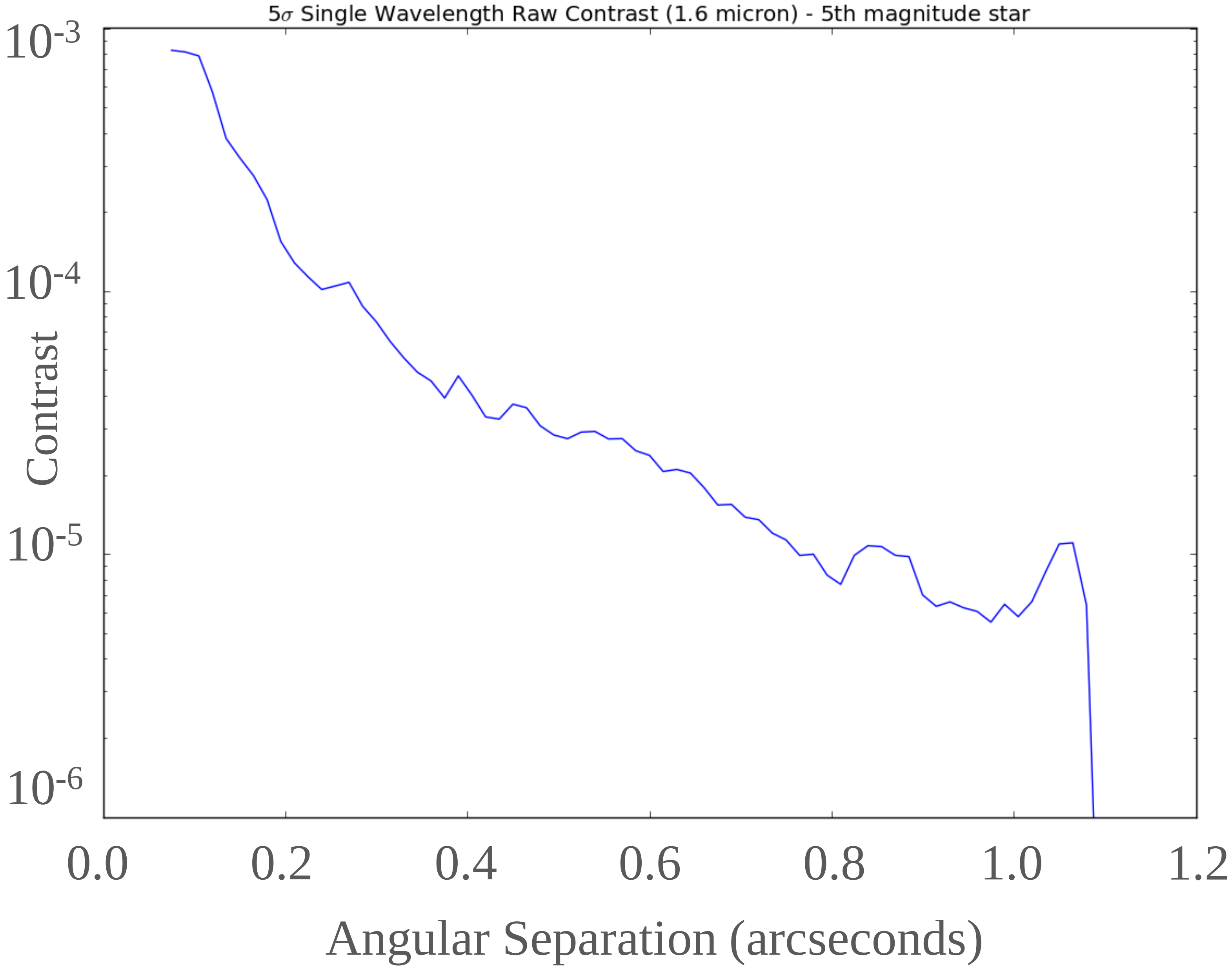
SCExAO and CHARIS

- Major Science Objective:
  - Spectral characterization
    - Exoplanets
    - Disks
    - Brown dwarfs
  - Supports Coronagraph IWA = 3 λ/D = 90 mas
    Current coronagraphs are pushing inside
  - 2.07”x2.07” FOV
  - R~19, J+H+K Band
    - ~53% Throughput
  - R~65-85: J,H, and K Bands
    - ~40% Throughput

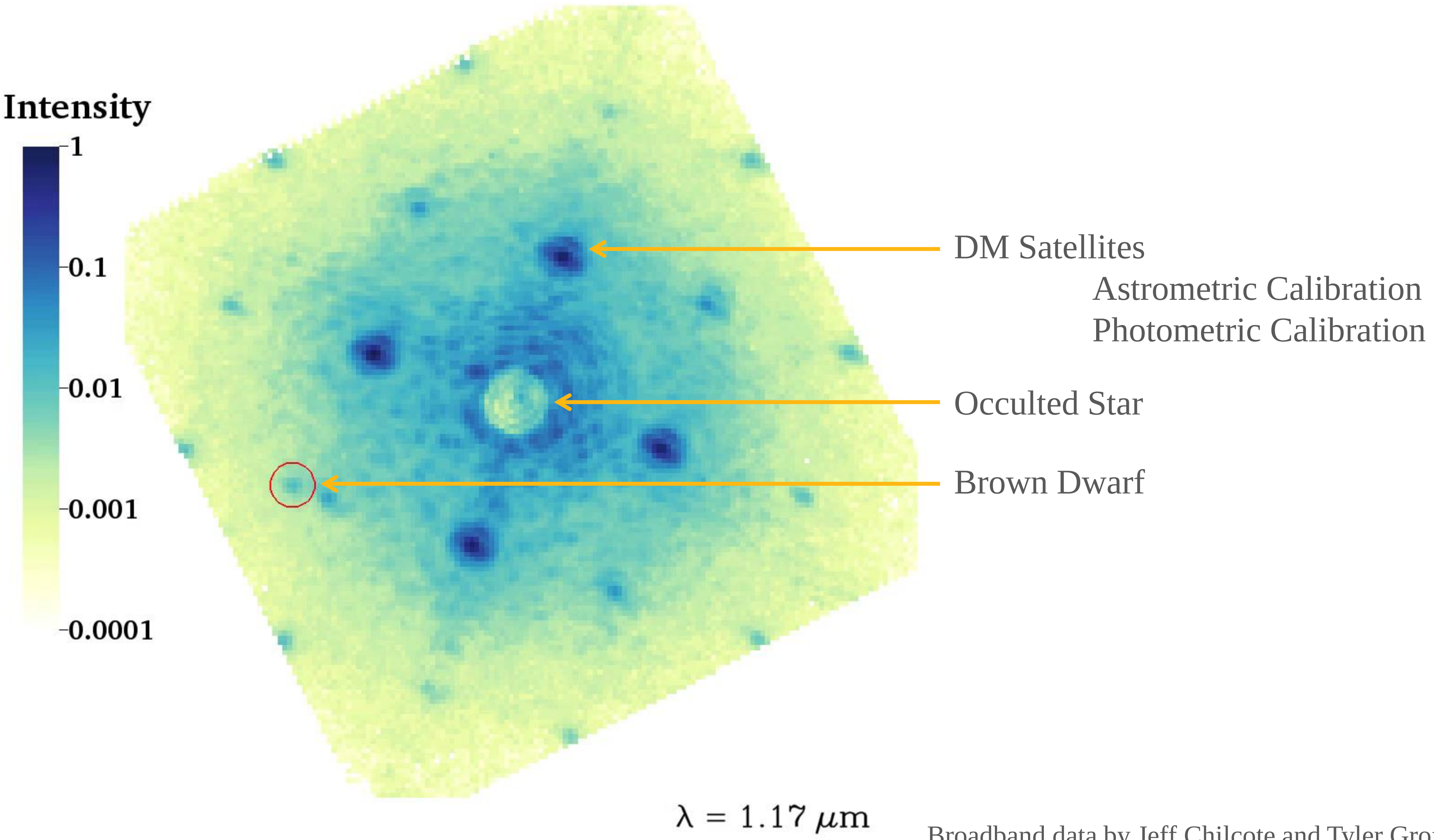


CHARIS work was performed under a Grant-in-Aid for Scientific Research on
Innovative Areas from MEXT of the Japanese government (Number 23103002) (Hayashi, Kasdin)

~First Light 5-sigma Contrast Curve for CHARIS

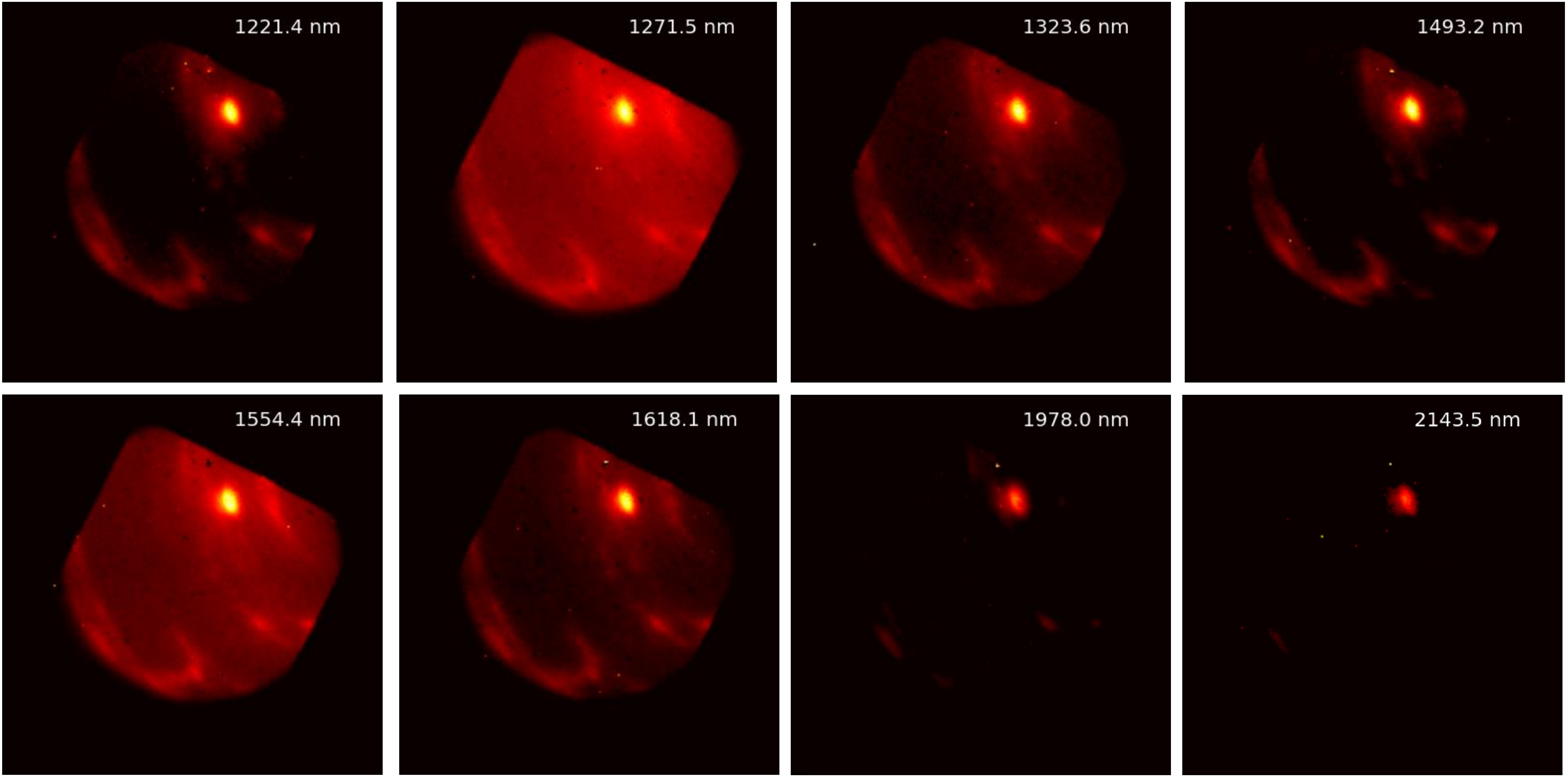


Brown Dwarf HD 1160



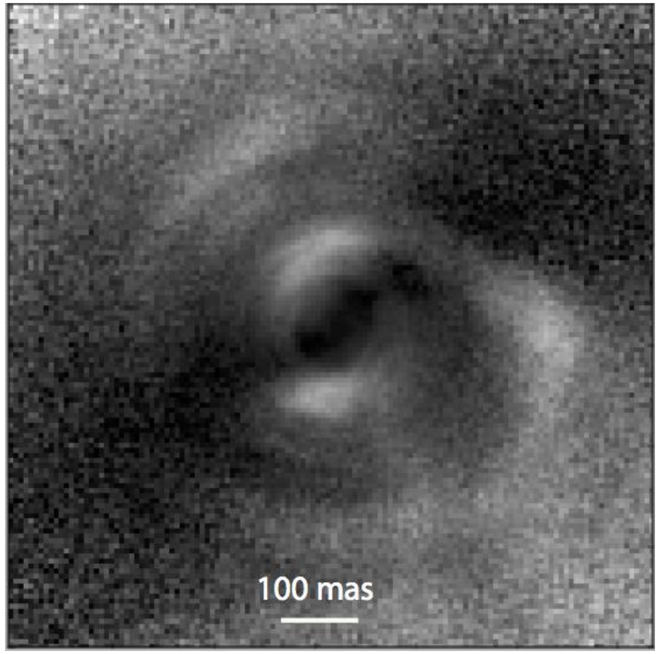
Broadband data by Jeff Chilcote and Tyler Groff
Pretty GIF made by Tim BRandt

Example CHARIS image with Neptune

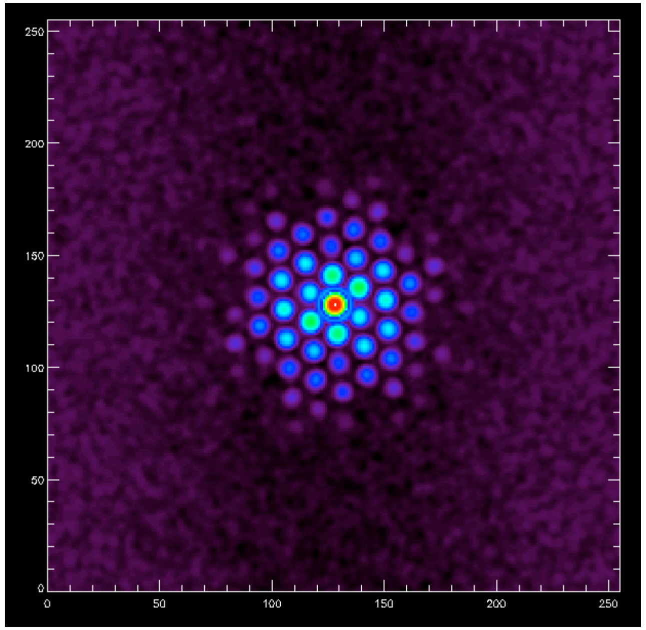


Polarimetric Imaging

AB Aur
(preliminary data reduction)



Non-Polarized Mode, Aperture Masking



Chi Cyg Power spectrum (log scale)
Note fall-off in power at longer BLs, since object is resolved.

Observed S-type star chi Cyg

V ~ 8 at time of observation

VAMPIRES UD Diameter

32.2 ± 0.1 mas (750 nm)

c.f. CHARM Catalogue,
Richichi et al. 2005:

UD = 32.8 ± 4.1 mas (V band)

Observed close binary eta Peg

Detection confidence (MC) > 99.9%

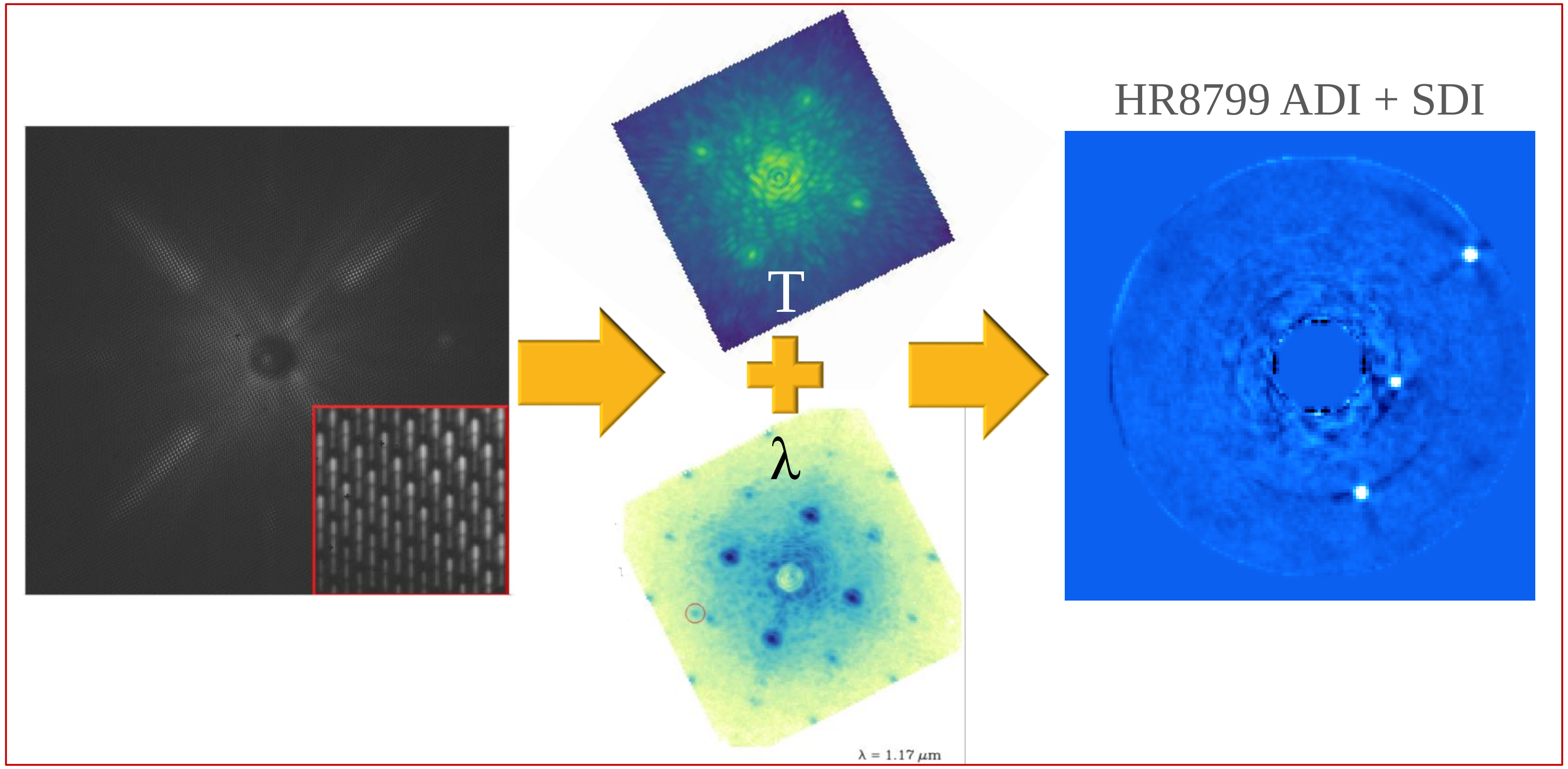
Separation 48.9 ± 0.6 mas
c.f. orb. params. Hummel+ 1998 →49.9 mas

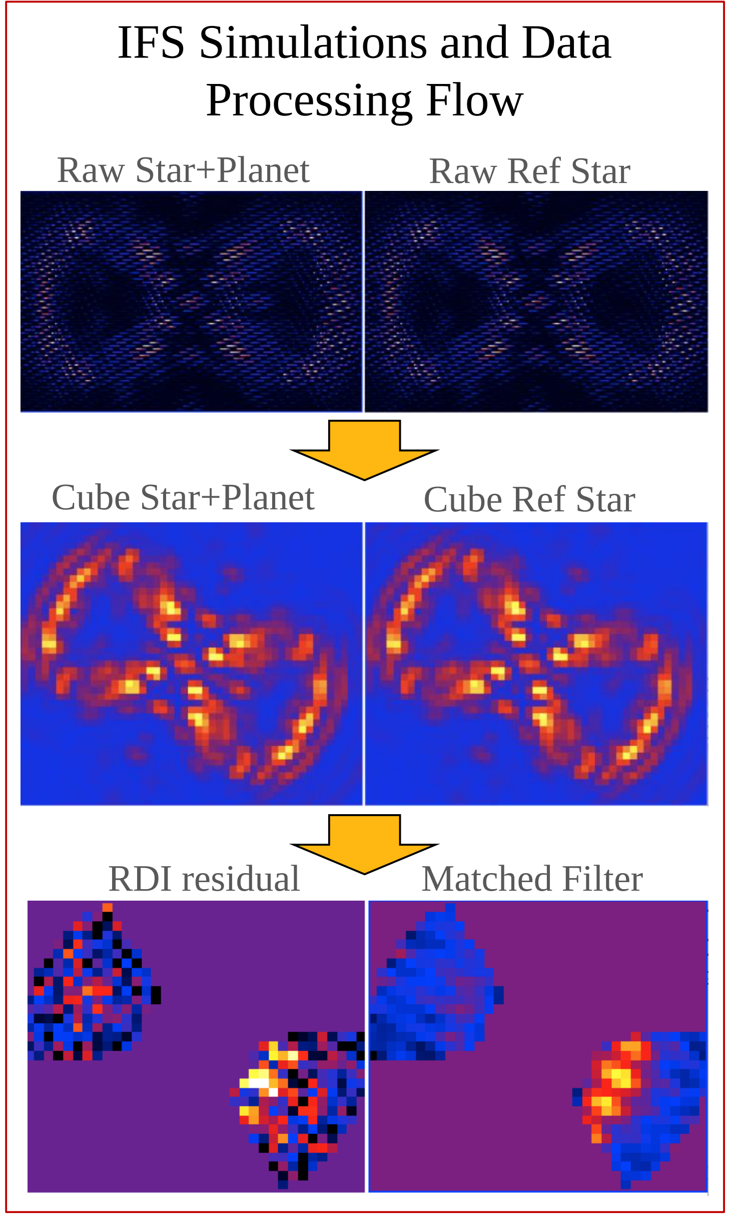
Contrast 3.55 ± 0.06 mag
c.f. Hummel+ 1998: 3.61 ± 0.05 mag

Thanks to Olivier Guyon and Vampires Team

Post-Processing on ground data

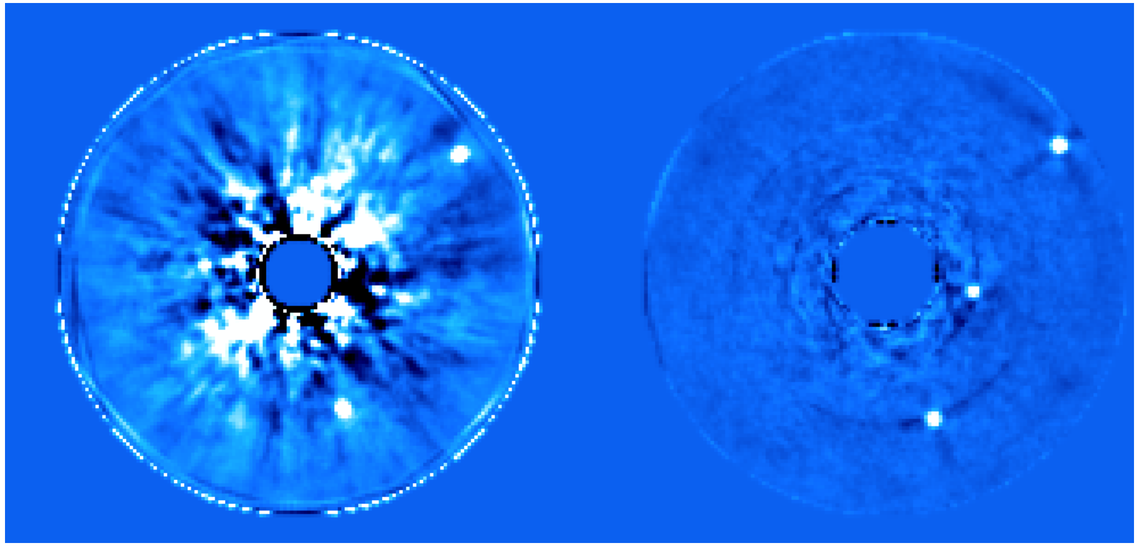
- Post-processing techniques are being assumed for CGI performance
- Great successes with this on the ground
- Progress and extension to WFIRST models
  - Apply extensive experience from ground observers to help define CGI post-processing and calibration needs



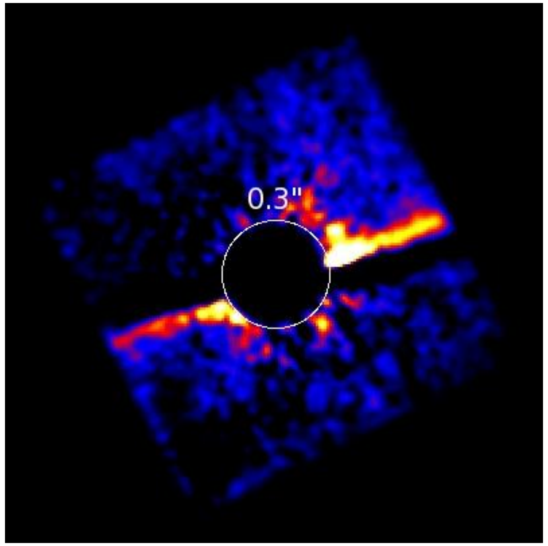


Example Subaru Data Products: CHARIS First detections

HR8799 ADI only HR8799 ADI + SDI



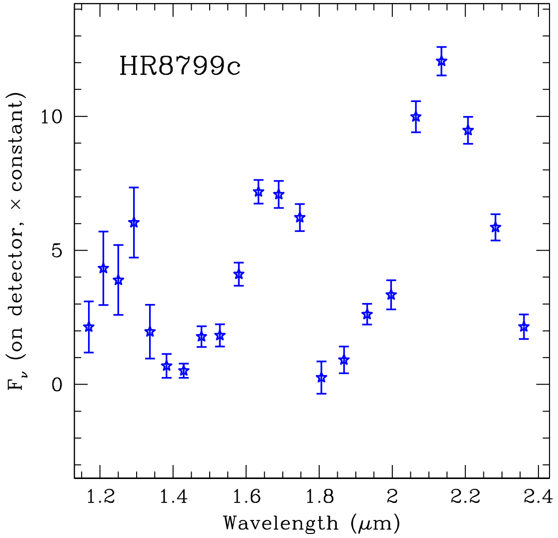
HD32297 Roll Subtracted

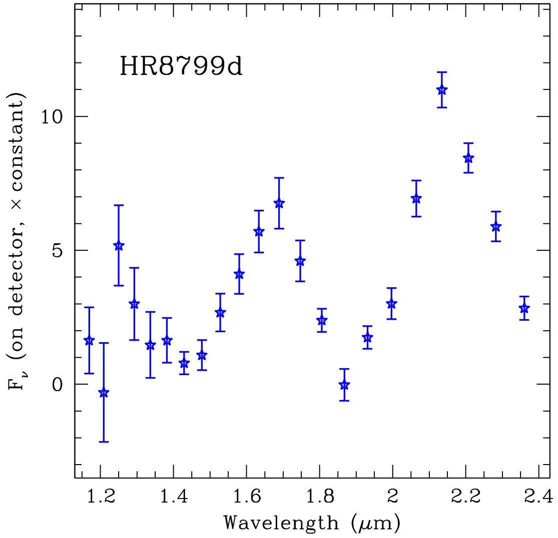


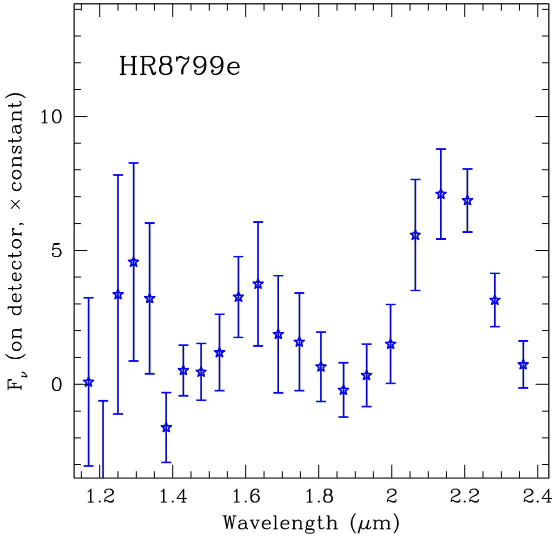
ADI+SDI detection of HR8799 c,d,e at SNR of 50, 35, and 15 respectively (~2-3 x 10^{-5})

Predicted Visible contrast:

- Beta Pic Contrast ~ 8 x 10^{-7}
- HR8799c,d,e ~ 10^{-7}



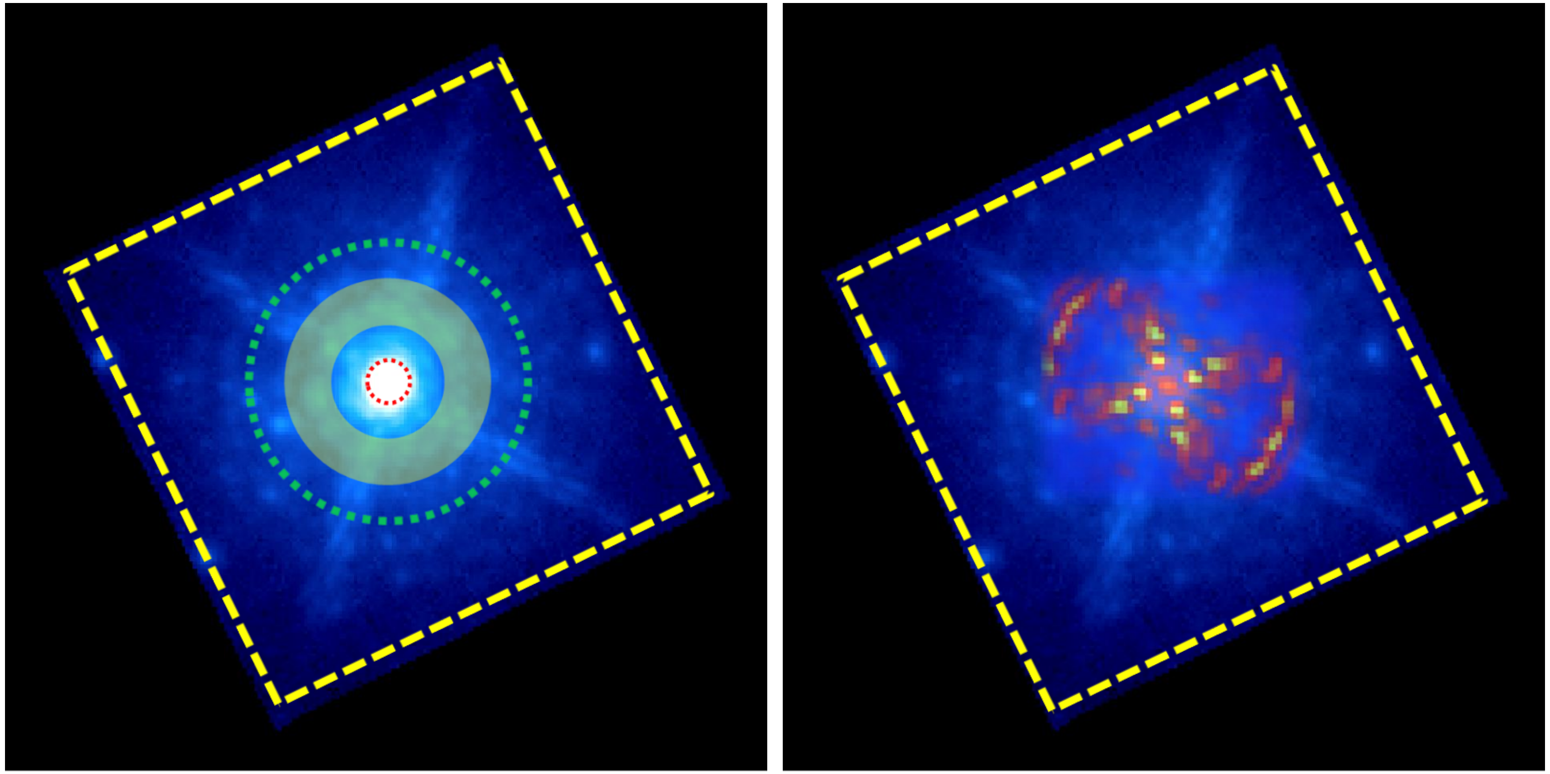




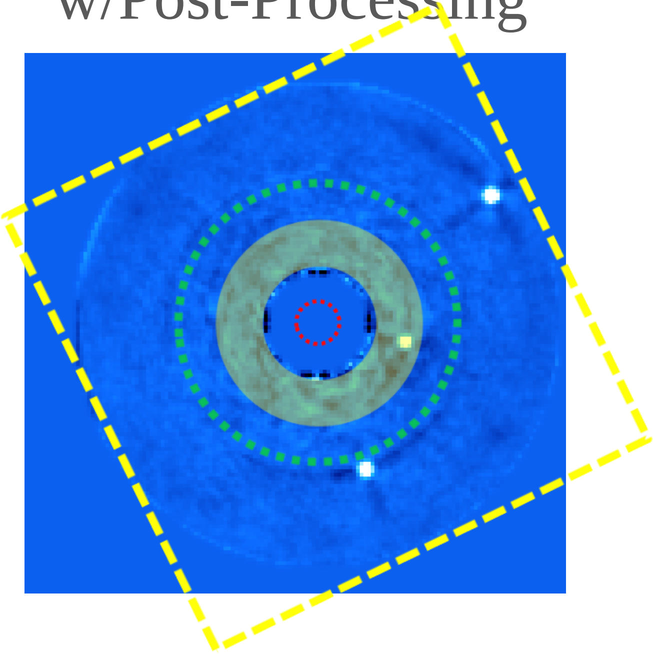
HR8799 preliminary data processing by Tim Brandt, HD32297 Processing by Thayne Currie

Example Observational Overlap

M5 Globular Cluster



HR8799
w/Post-Processing



Published CGI FOV overlaid onto a CHARIS image from the Subaru telescope

- Detector field of view
- 10 λ/D (~0.5”) Coronagraph outer working angle
- 3 λ/D radial inner working angle
- Angular separation where requirements are set