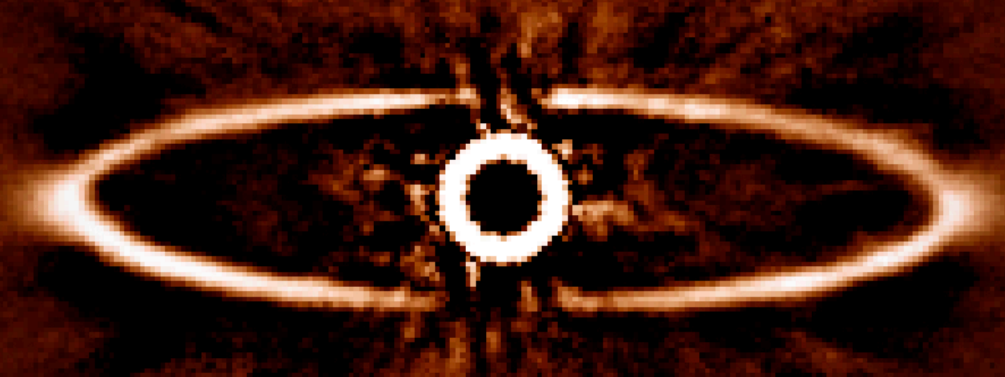


Improving S/N in the direct imaging of exoplanets with MLOCI

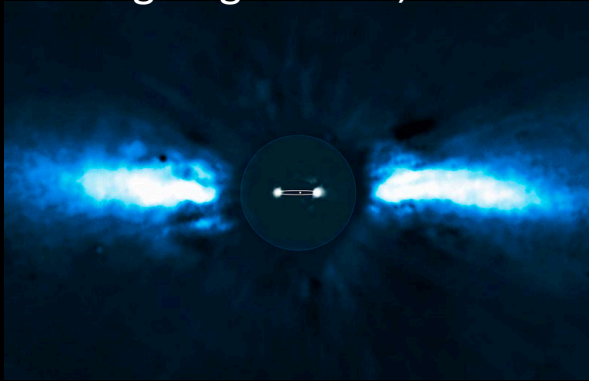


HR 4796 A with SPHERE

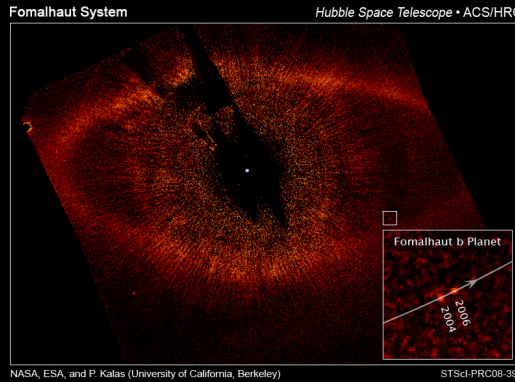
Zahed Wahhaj
ESO, Chile.

Directly Imaged Planets

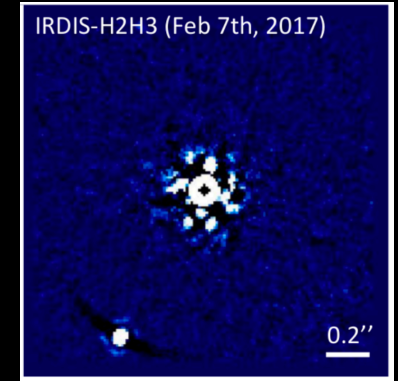
Beta Pic b: 8.5 AU, 10 M_J ,
Lagrange+ 2008, 2010



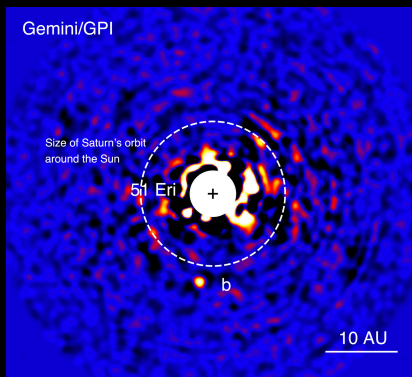
Fomalhaut b: 115 AU, 2 M_J ,
Kalas+ 2008



HIP 65426: 92 AU, 9 M_J ,
Chauvin+ 2017



51 Eri b: 13 AU, 2 M_J ,
Macintosh+ 2015

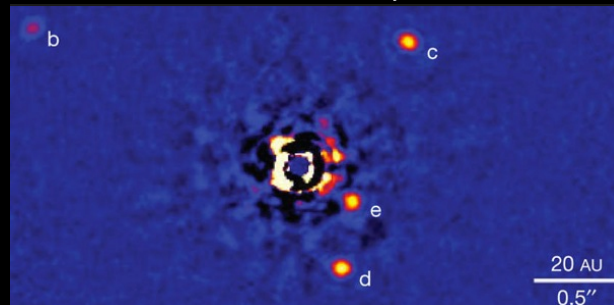


HR 8799 bcde:

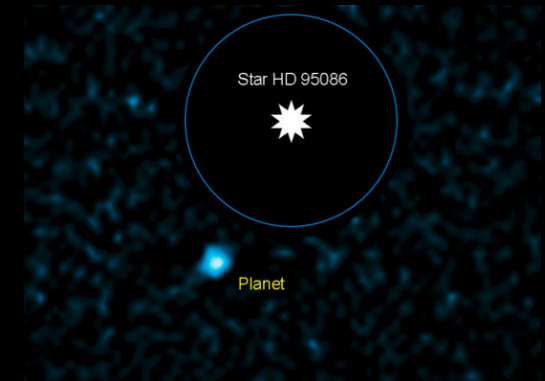
14, 27, 43, 68 AU

7, 10, 10, 9 M_J

Marois+ 2008, 2010

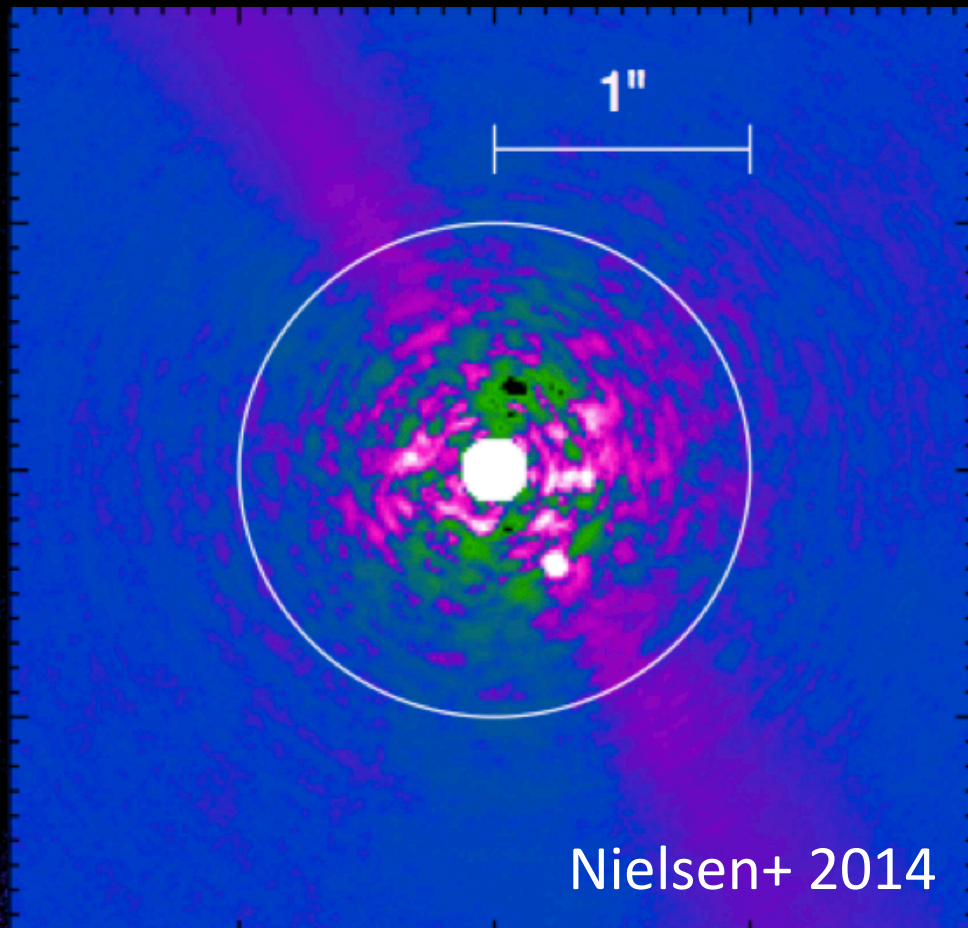
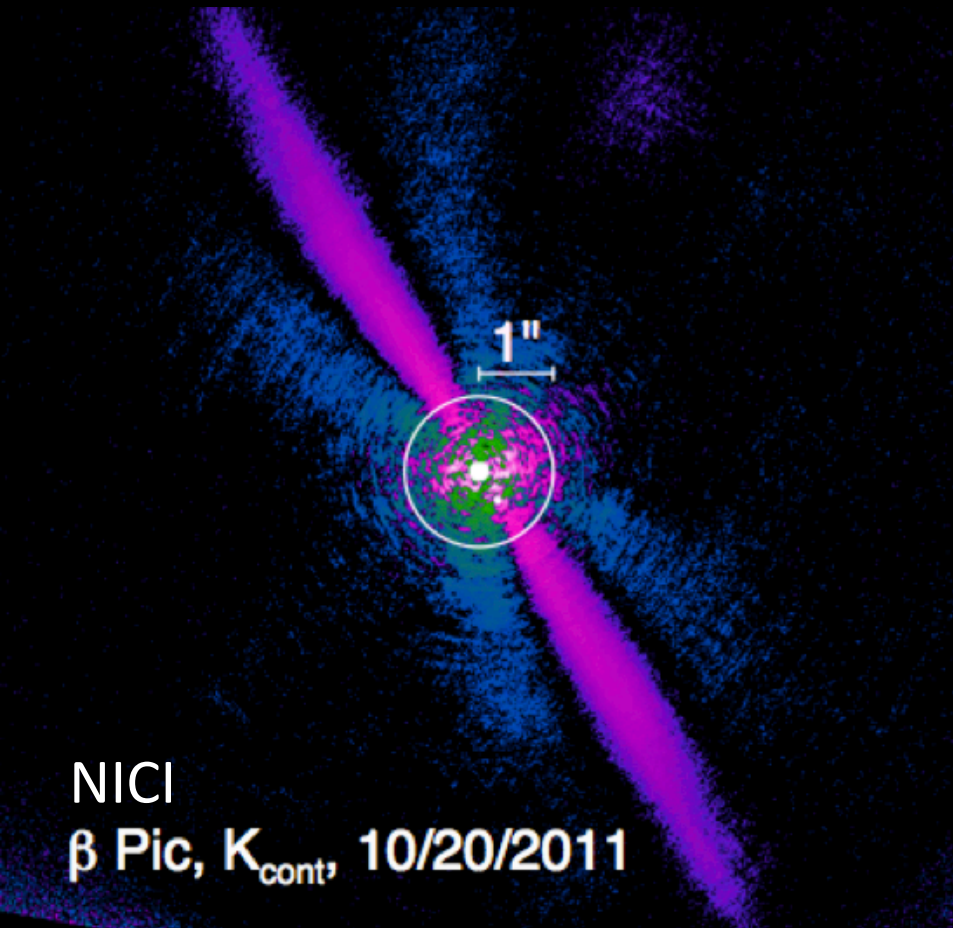


HD 95086 b: 56 AU, 4.5 M_J ,
Rameau+ 2013



Accurate measurements from Debris Disks.

β Pic b orbital inclination
between inner and outer disk



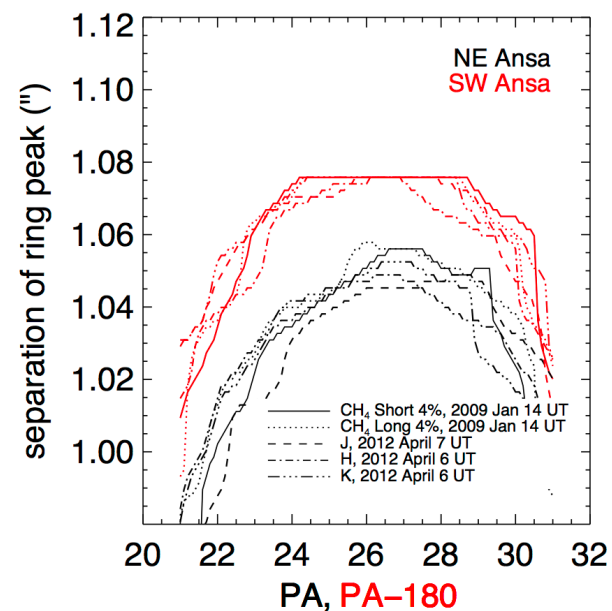
HR 4796 A

Ring offset from
star
by 1.3 ± 0.1 AU

Wahhaj+ 2014

NICI

3" x 3"

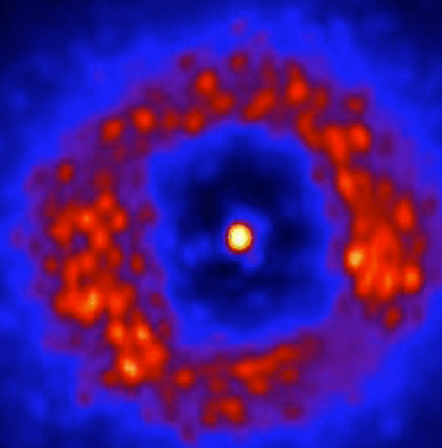


Direct Imaging techniques ADI + SDI + AO + Coro (NICI)

fake T6



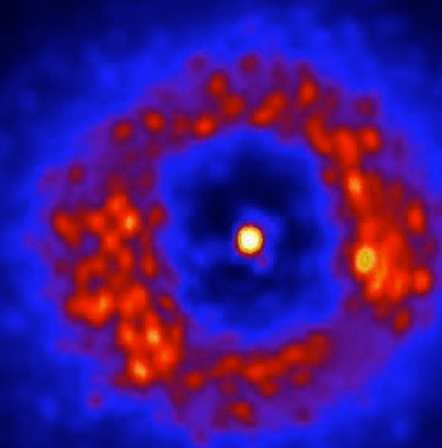
BLUE 1.58um



fake T6



RED 1.65um

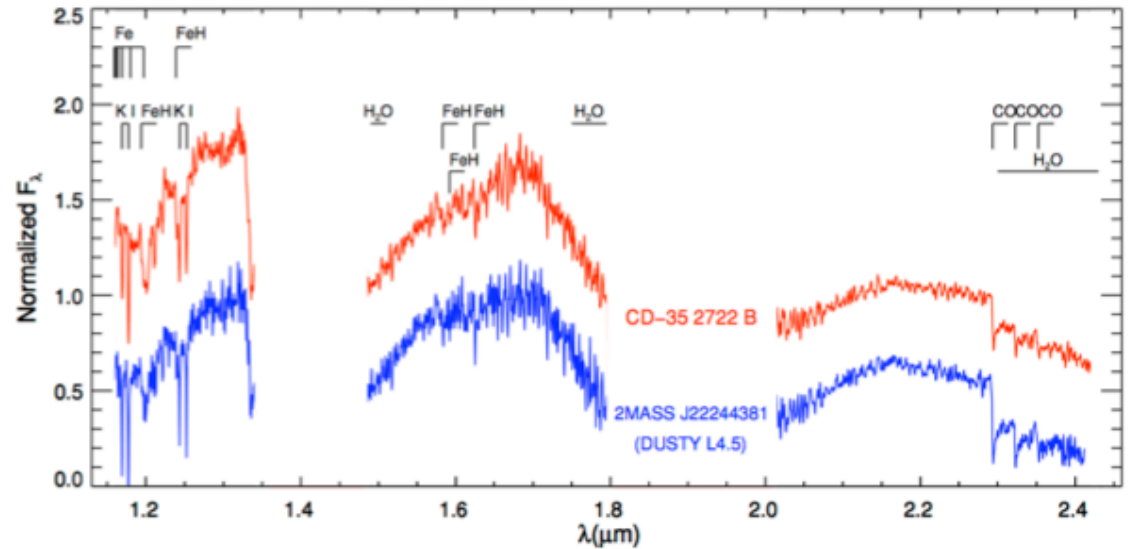
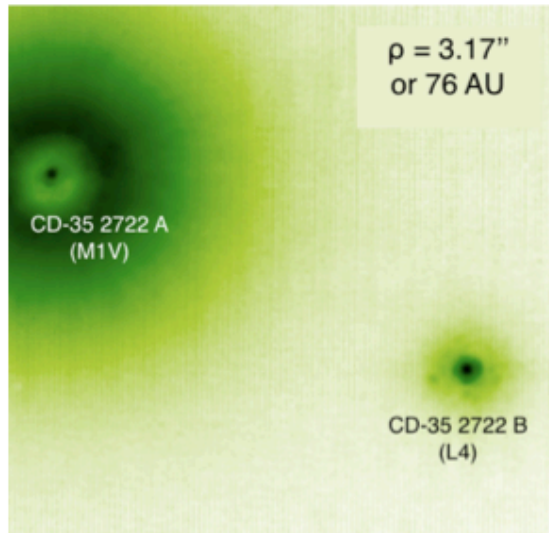


Sky rotates in pupil tracking mode

Wahhaj et al. 2011



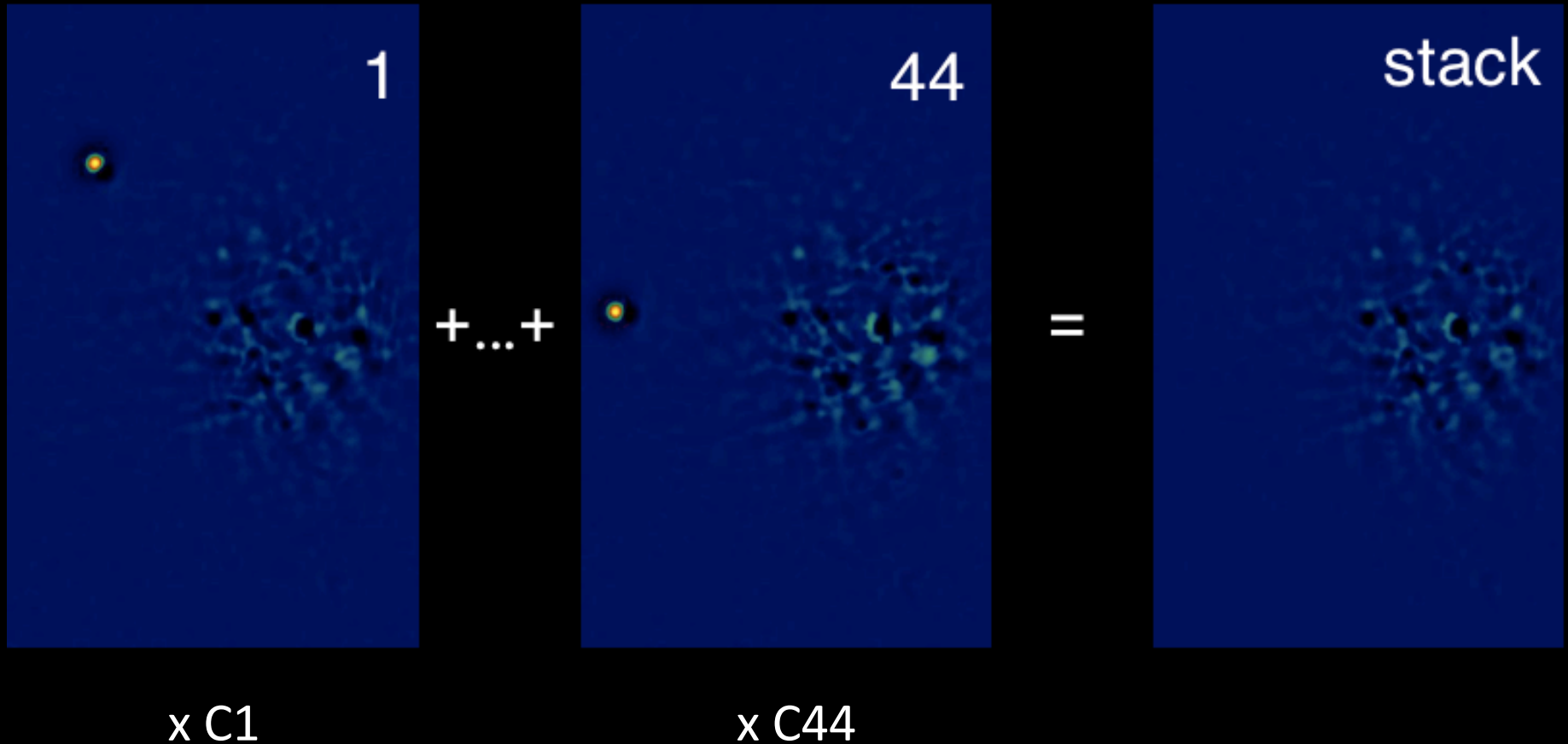
Brown Dwarf and Exo-planet Atmospheres



Wahhaj et al 2011: Left: My discovery image of the 30 Jupiter-mass brown dwarf CD-35 2722 B. Right: The discovery spectra of the brown dwarf shows that a more peaked methane feature at 1.7 micron compared to a known object of the same spectral, indicating that CD-35 2722 B has lower surface gravity and is therefore much younger.

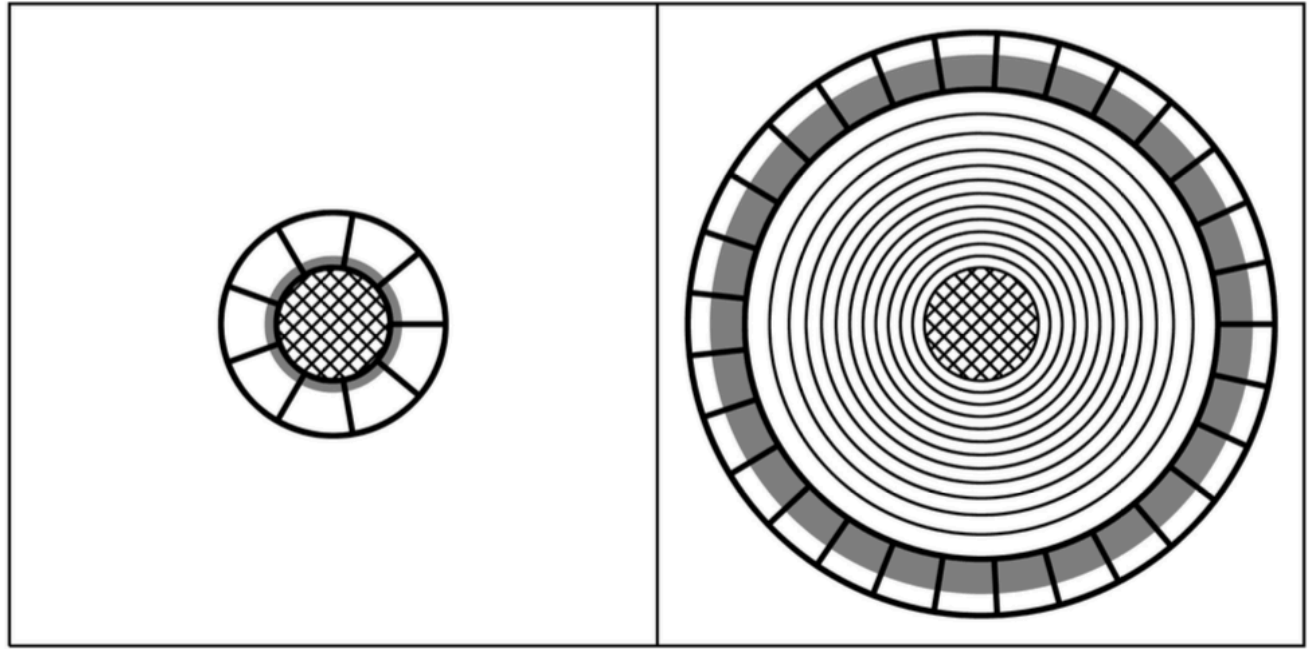
Wahhaj et al. 2011

Where the methods differ



Creating the PSF for subtraction

LOCI

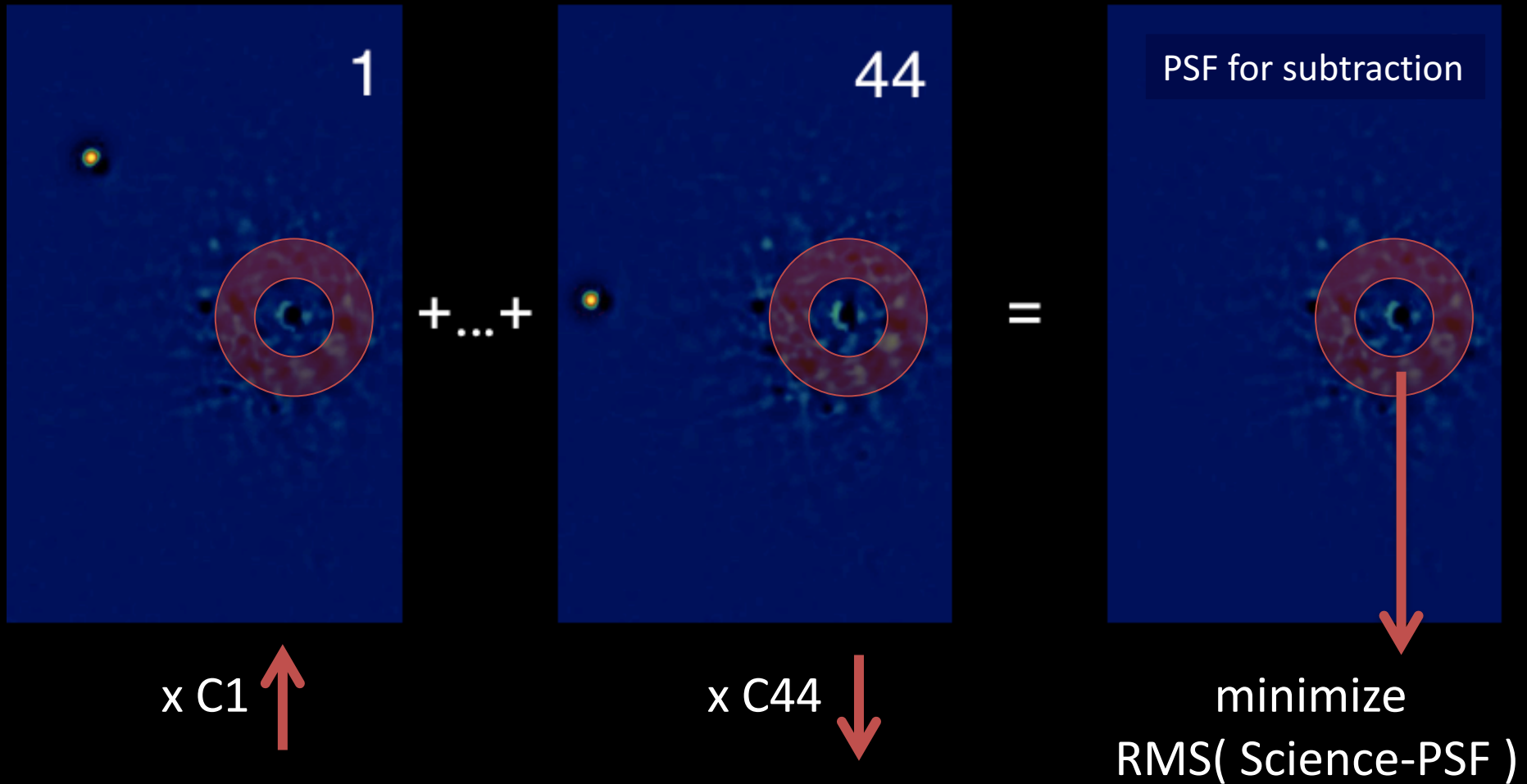


Gemini North
data
with simulated
planets

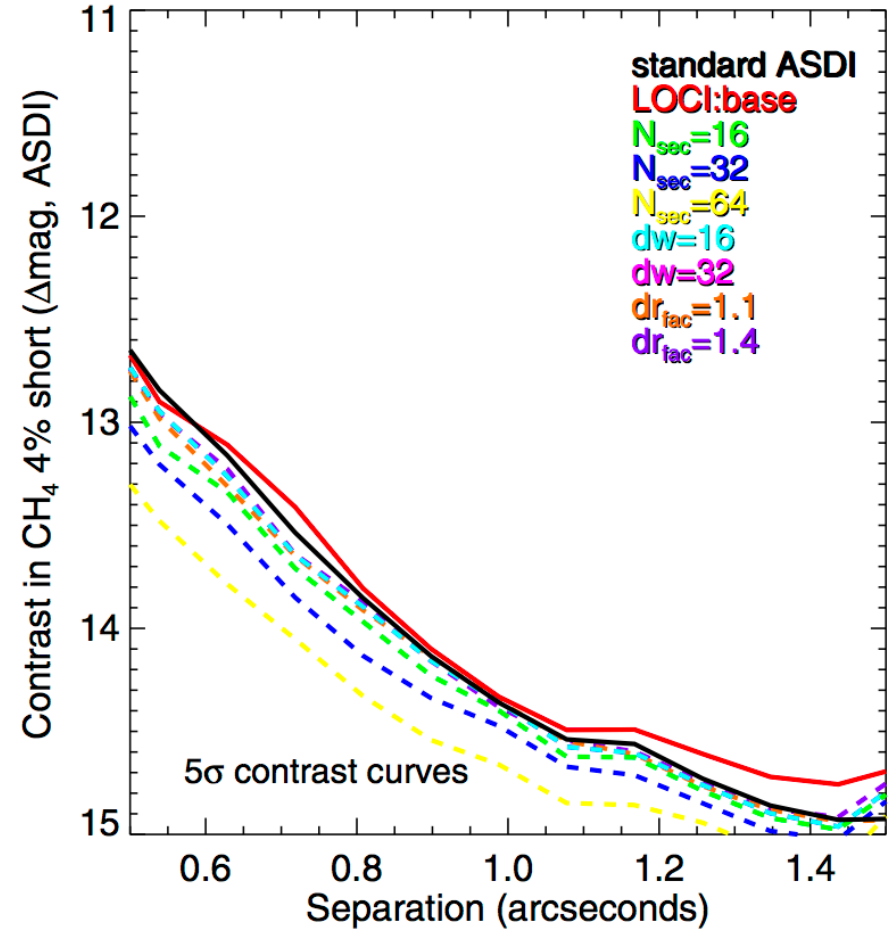
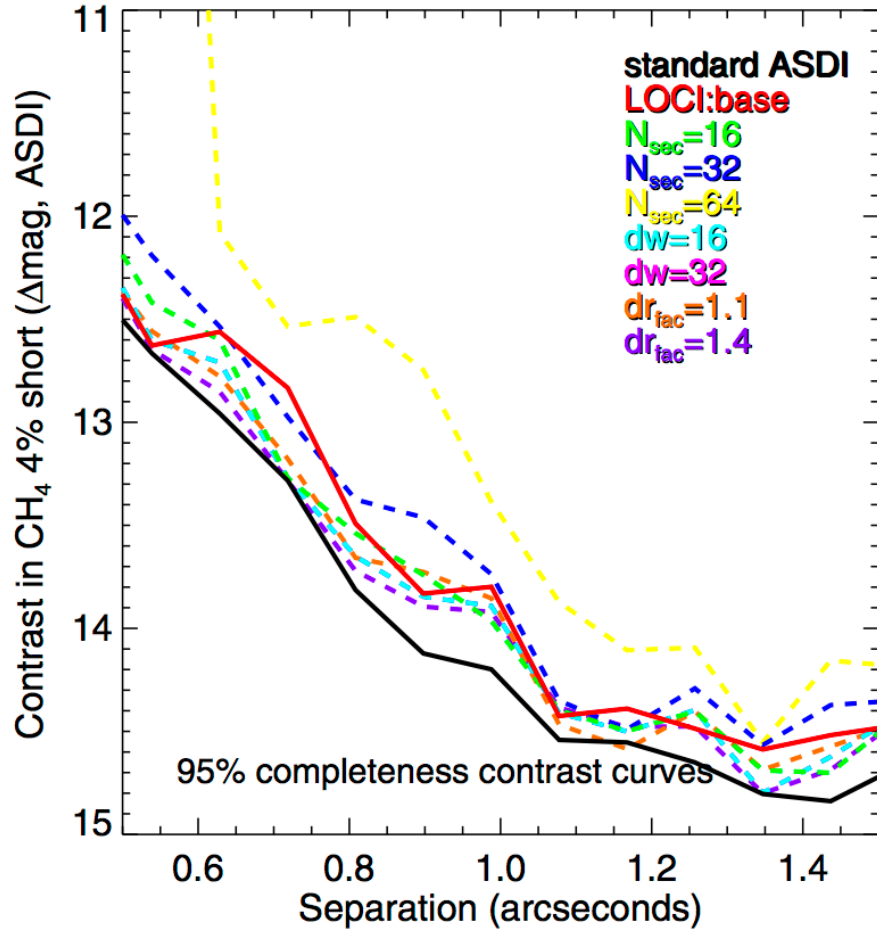
Lafreniere+
2007

LOCI

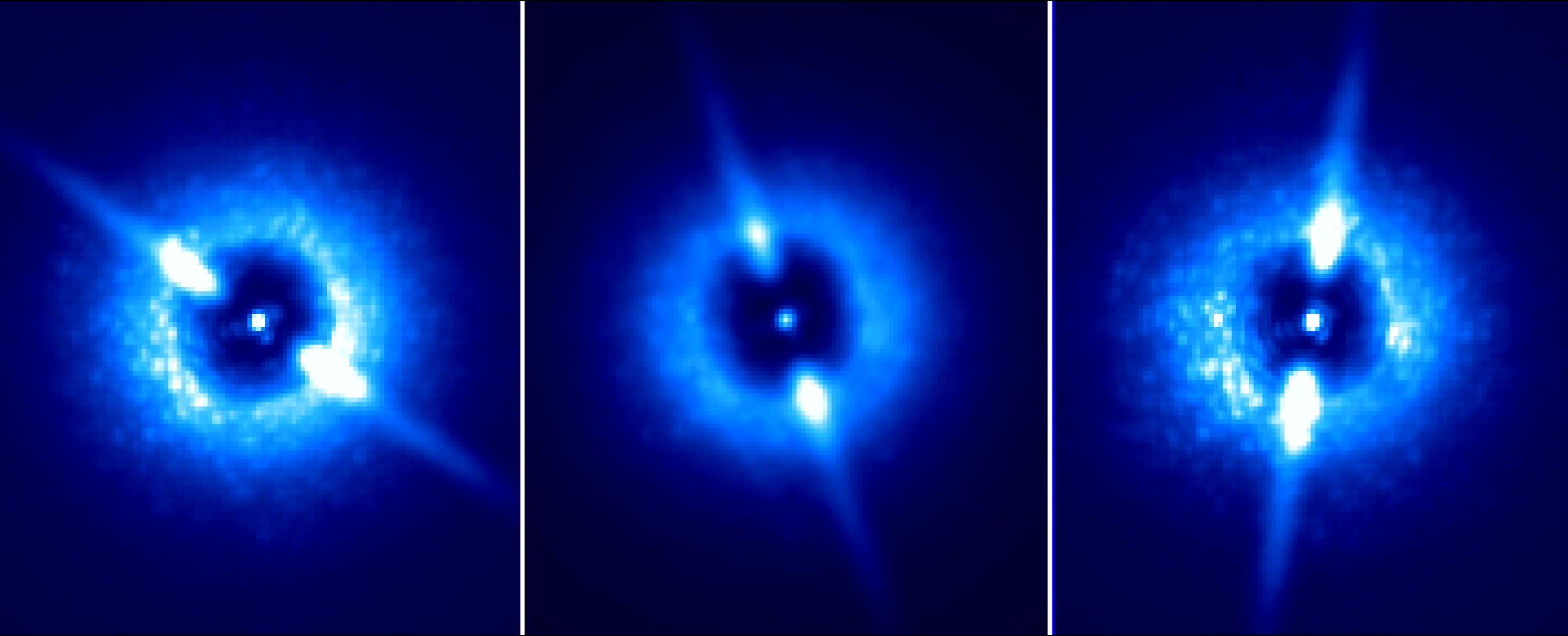
LOCI: Image Weighting



LOCI: Losing too much signal



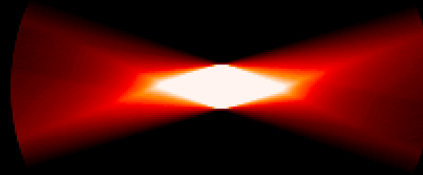
Problems with typical methods.



Both Signal and PSF (time-correlated pattern) changing slowly.

Self-subtraction of Disk

Average Intensity of Disk in PSF images



True Disk



Remaining Disk
in Median



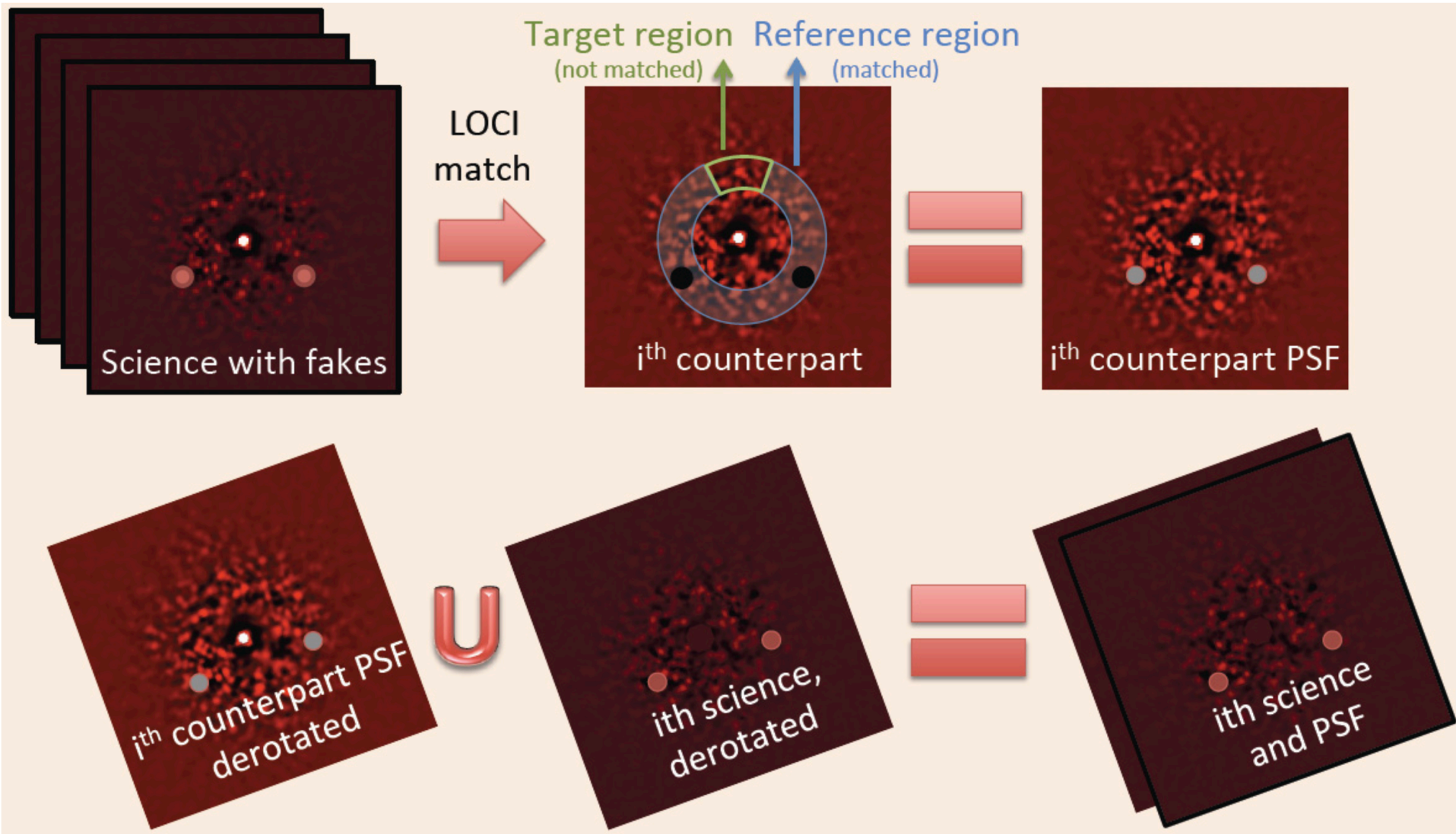
Reduced Image of Disk



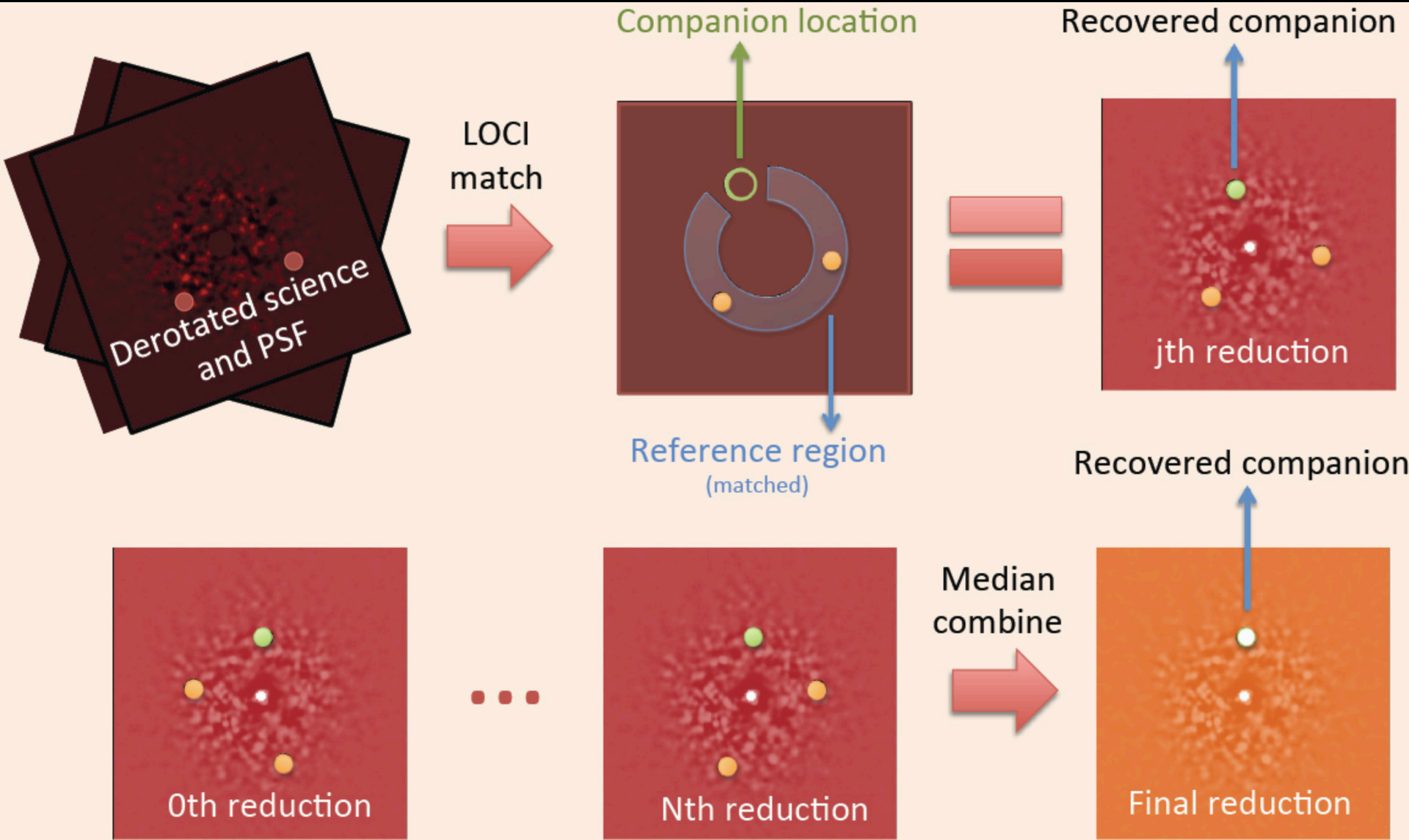
Problems

- Best PSF reference matches also cause most signal-loss.
- How to optimize in case of varying strehl?
- Relative how to optimize addition and subtraction?

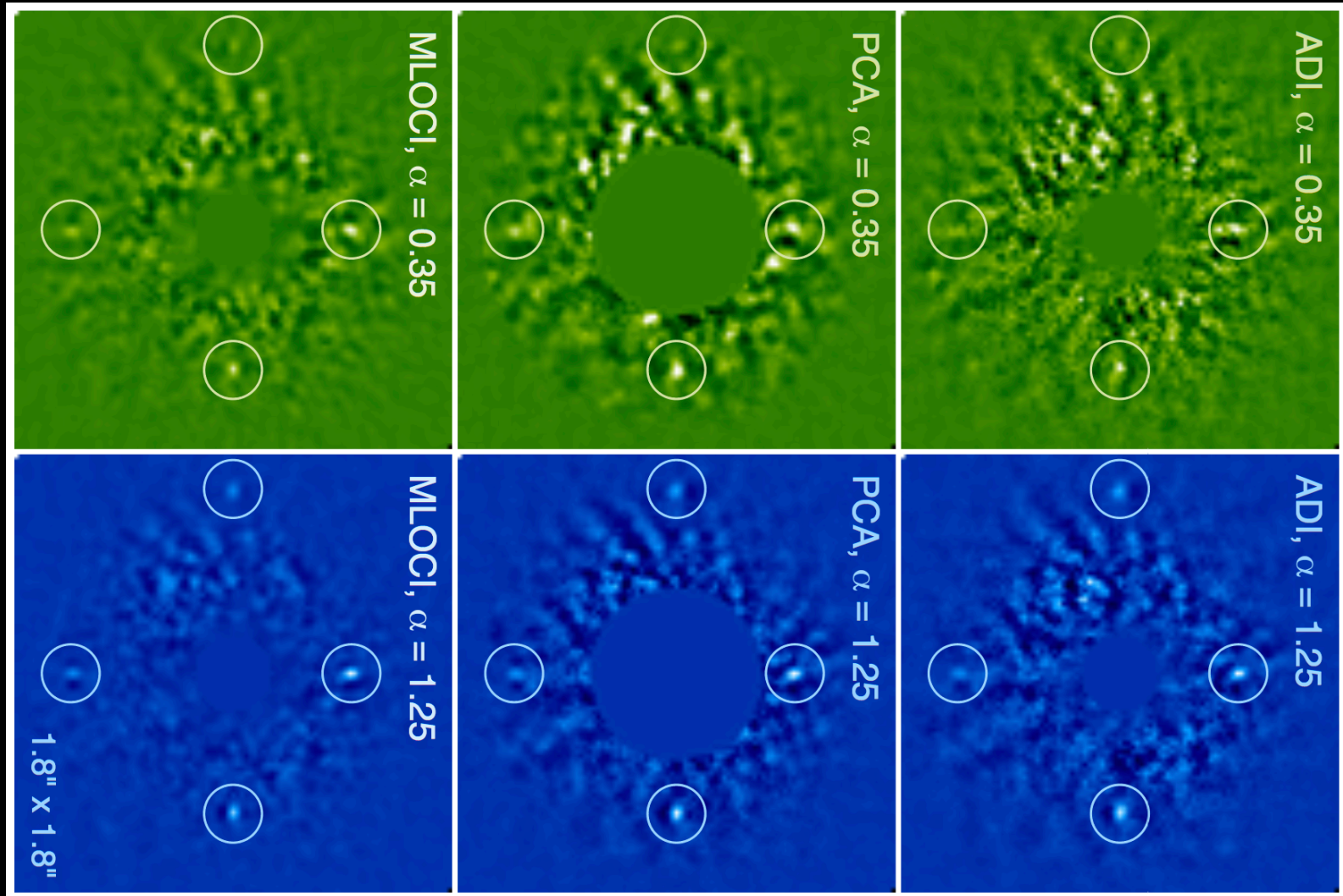
Matched LOCI



Matched LOCI

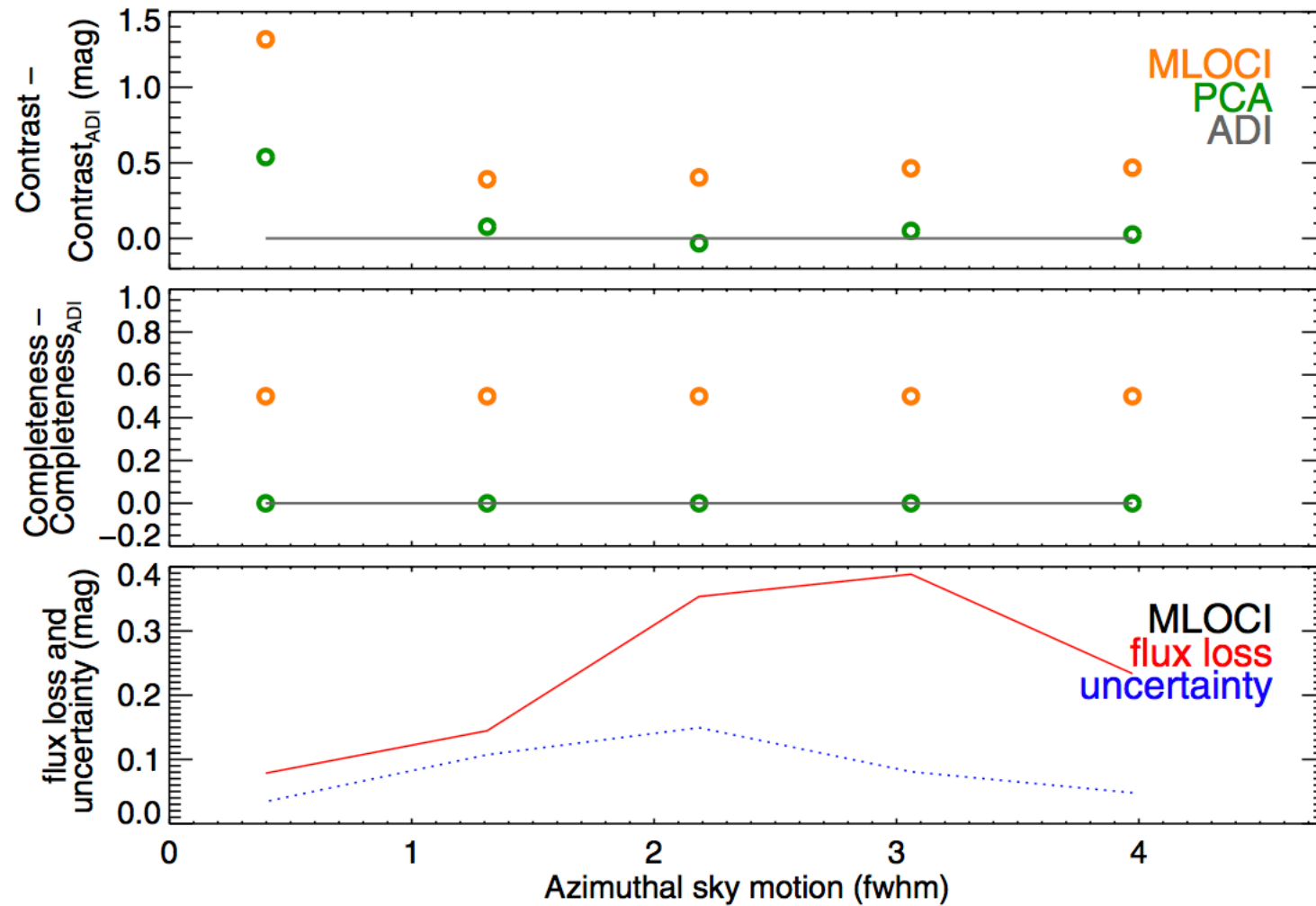


Matched LOCI vs PCA vs ADI



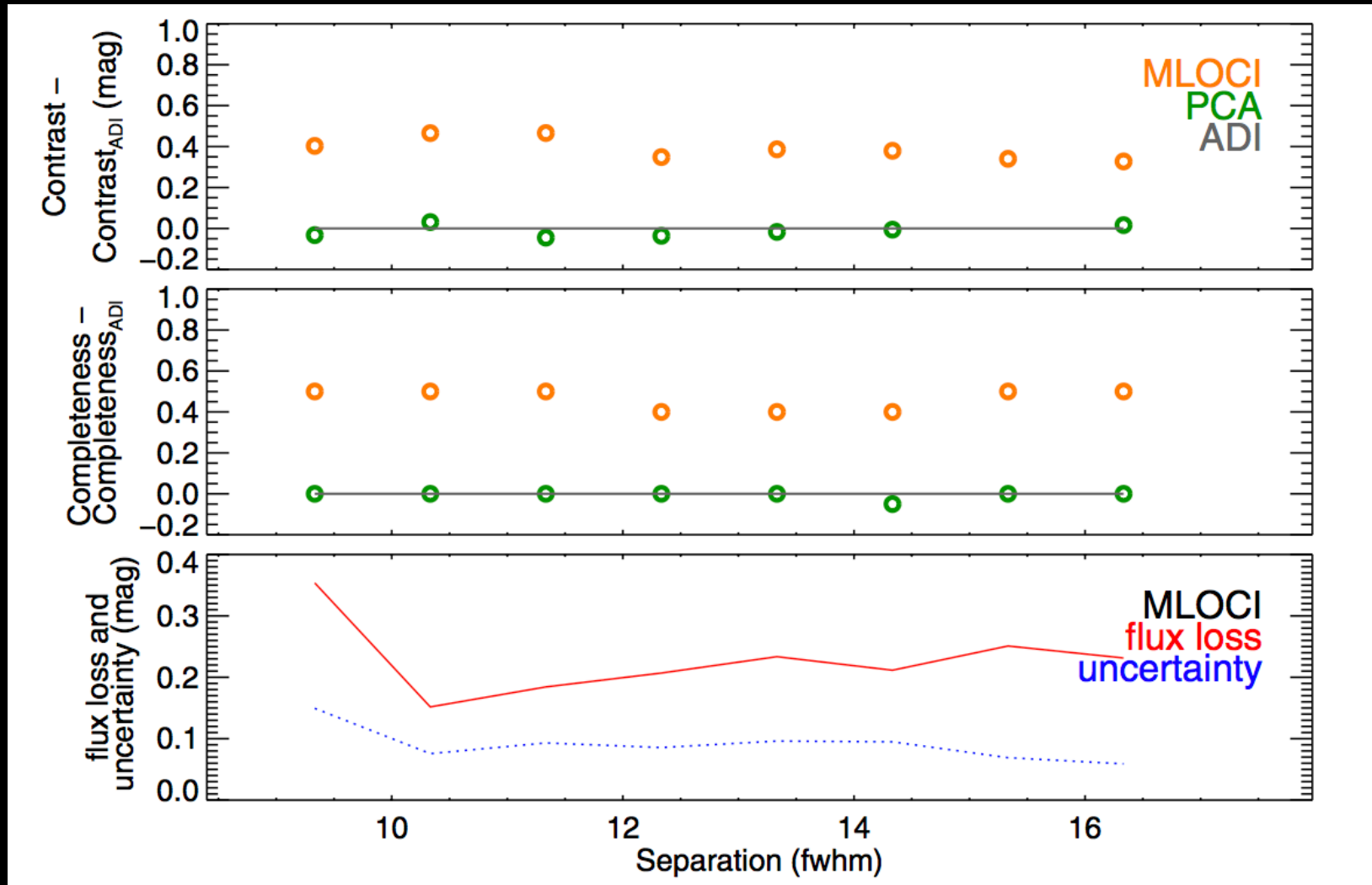
Wahhaj+ 2015

Contrast Gain vs Sky Rotation



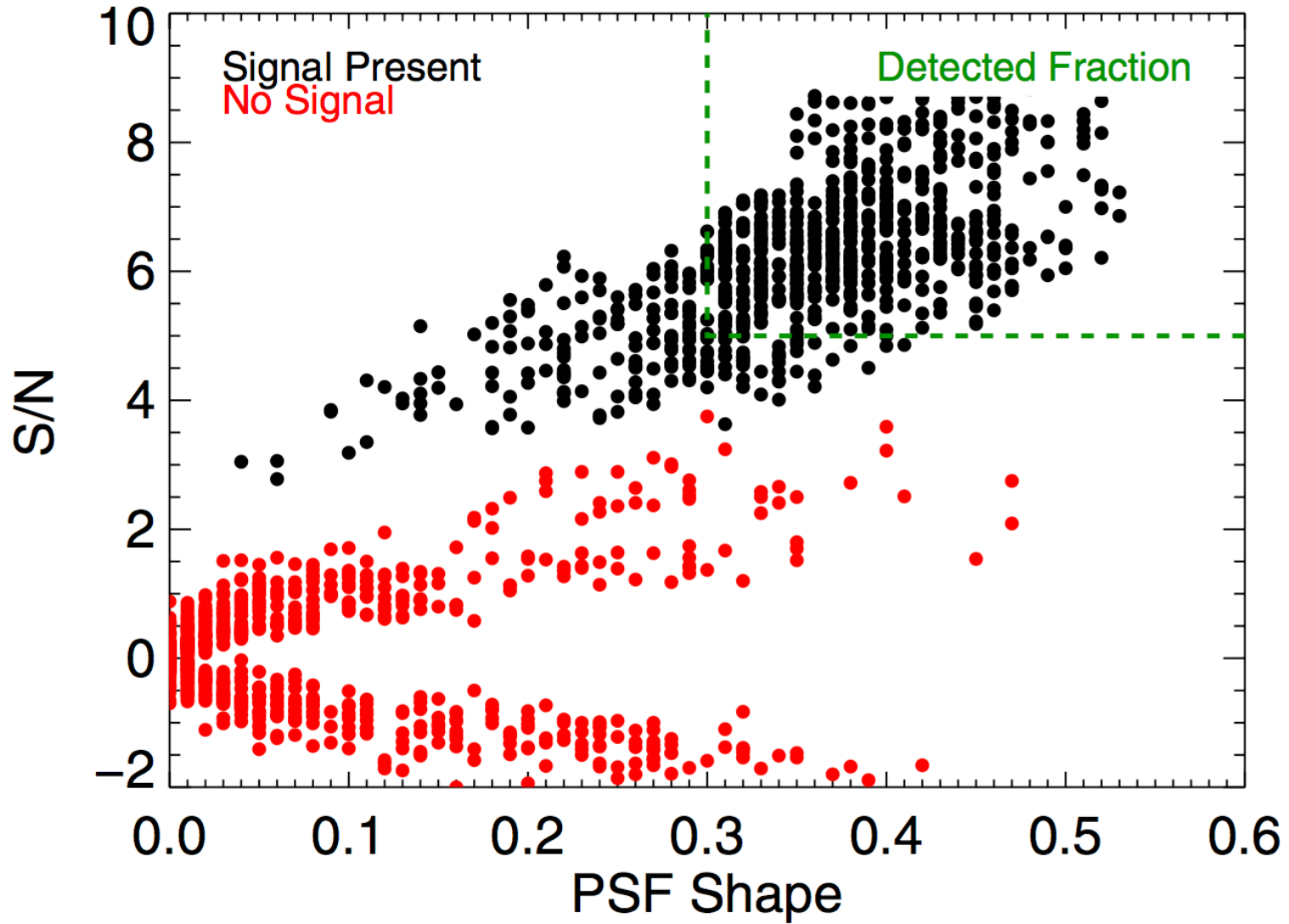
Wahhaj+ 2015

Contrast Gain vs Sky Rotation



Wahhaj+ 2015

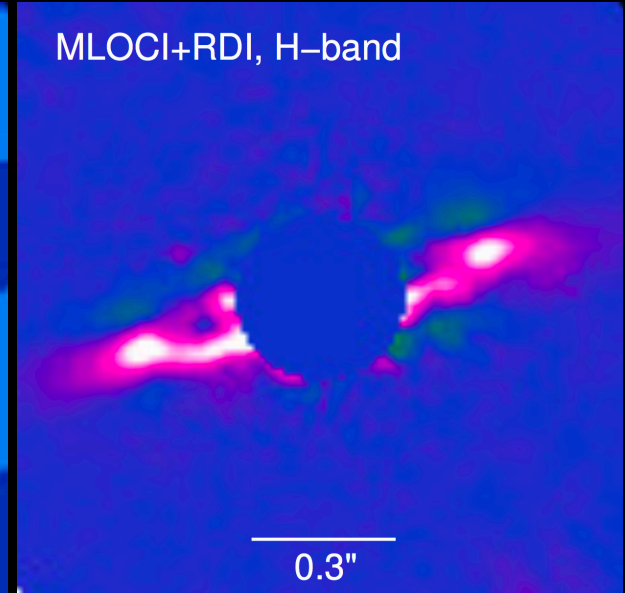
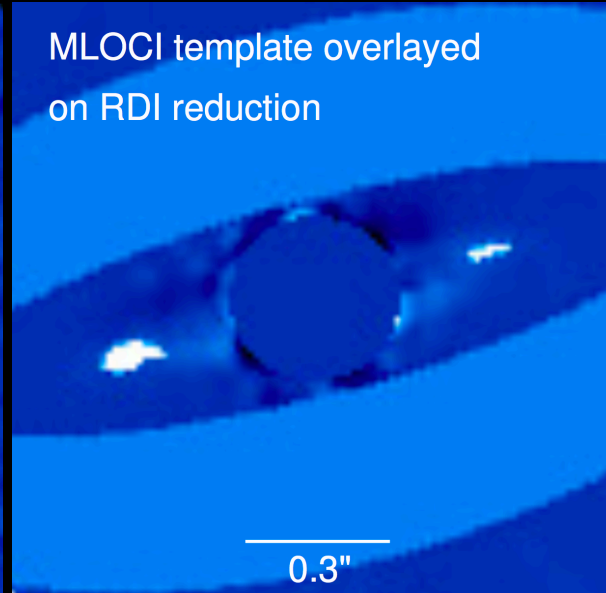
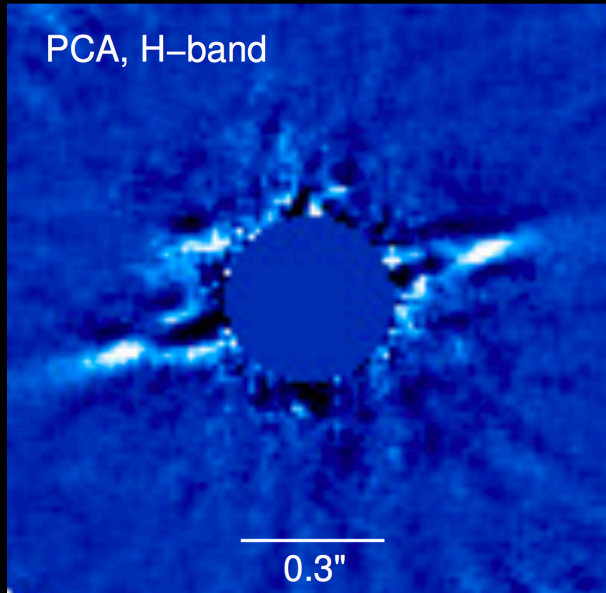
800 test planets: No False Positives.



Wahhaj+ 2015

MLOCI for Circumstellar Disks

HD 114082, 17 Myr debris ring



Wahhaj+ 2016

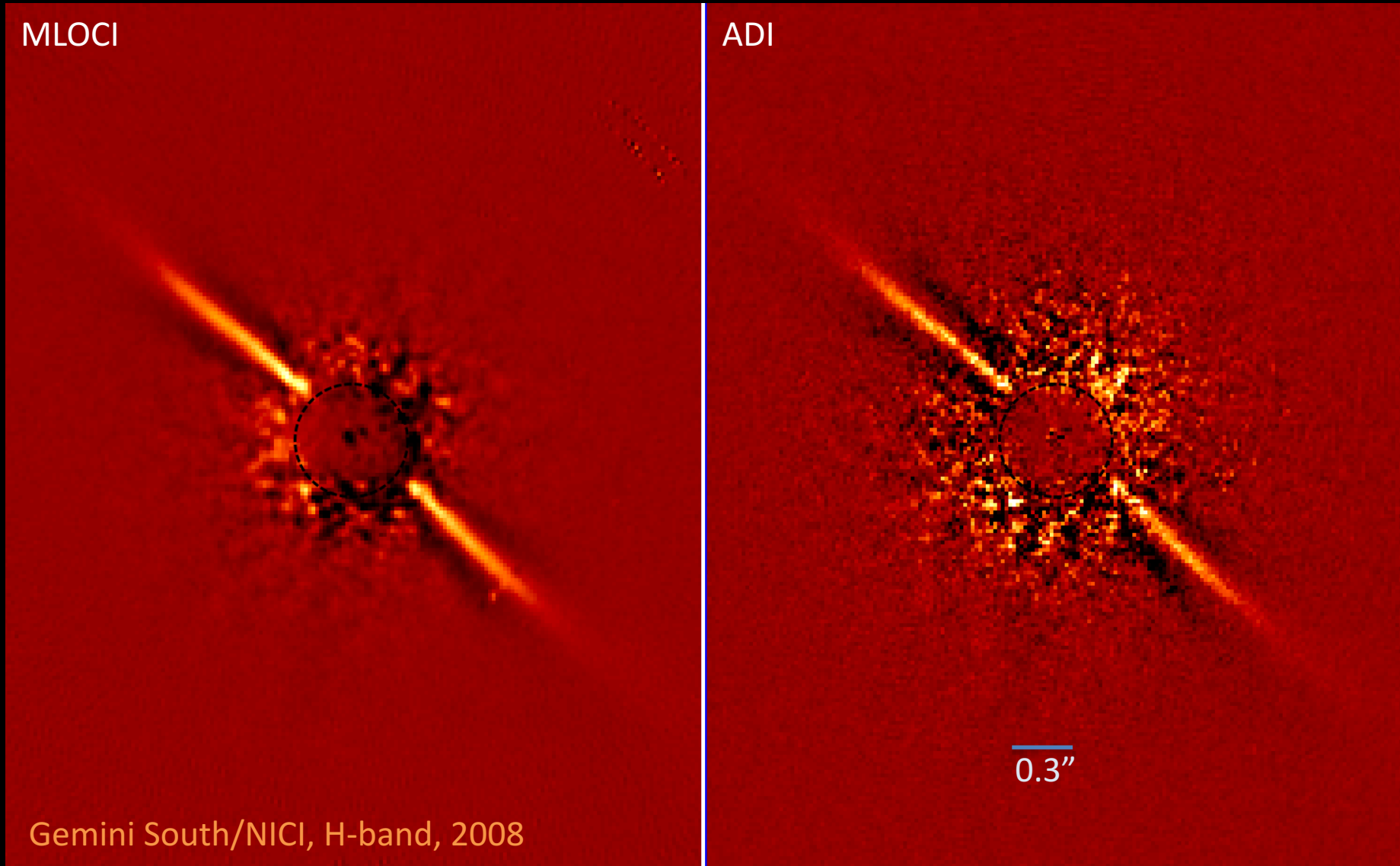
HD 32297: Comparison of ADI and MLOCI, $R > 0.27''$

MLOCI

ADI

Gemini South/NICI, H-band, 2008

0.3''



HD 32297

3X S/N improvement from MLOCI

