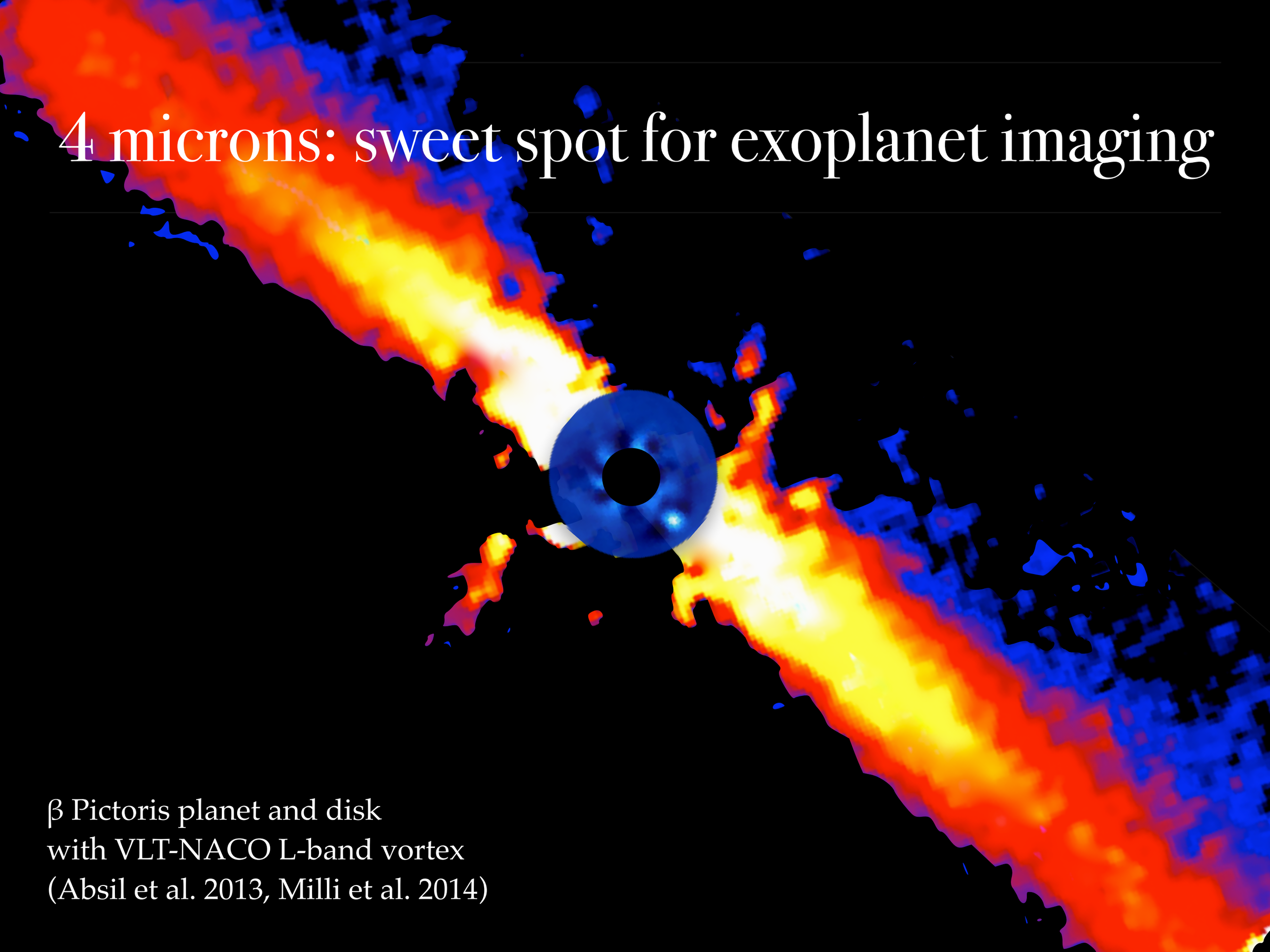
2015ExSoCal

High contrast imaging with the L-band vortex coronagraph at Keck/NIRC2

D. Mawet, Caltech

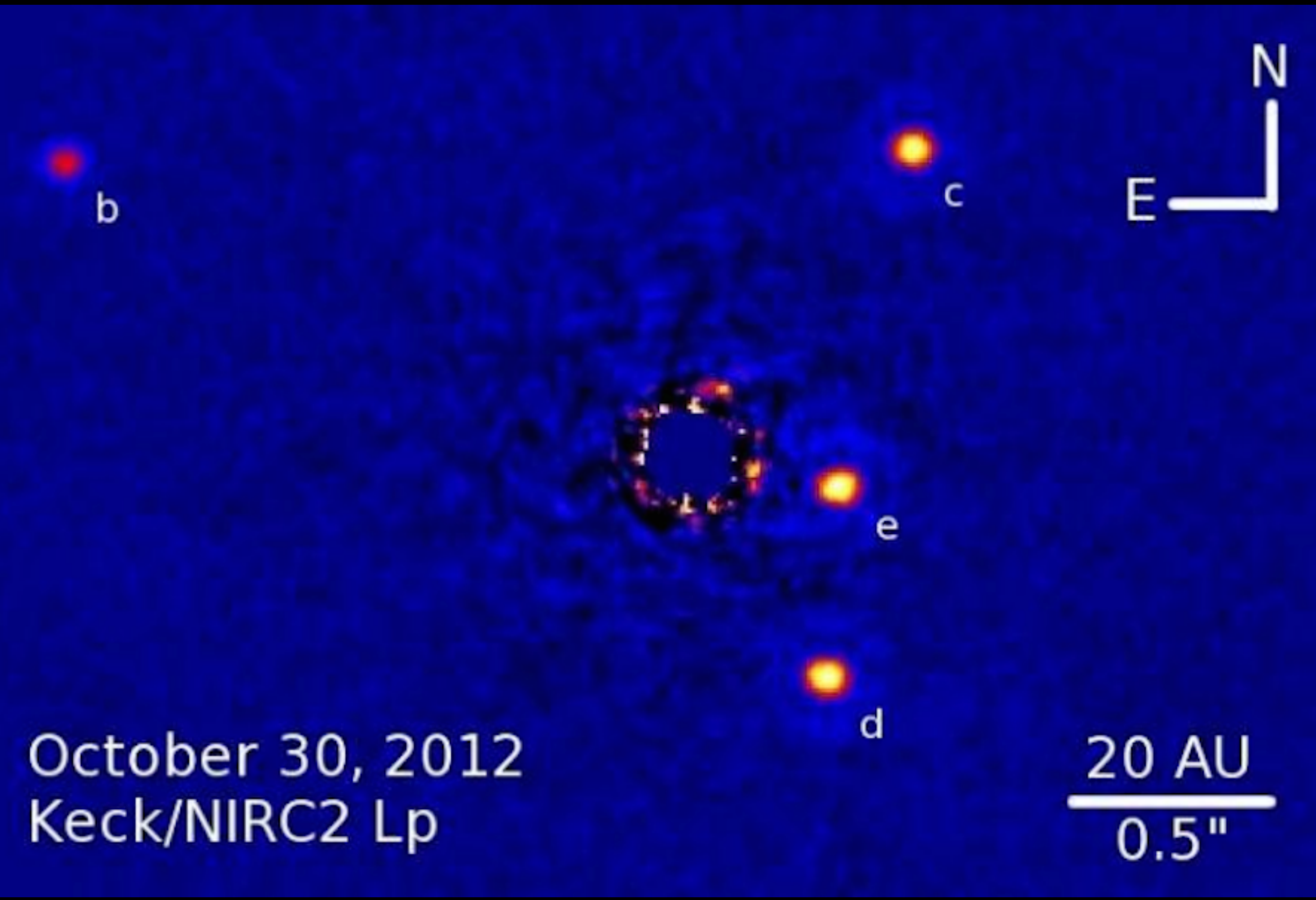
Mainland team: E. Serabyn (JPL), K. Matthews (CIT), H. Ngo (CIT), and D. Mawet (CIT).
Oversea team: O. Absil (PI EU vortex project), E. Huby, B. Carlomagno, C. Delacroix, C. Gomez, A. Jolivet, O. Wertz.
Keck AO team: B. Femenia, R. Campbell, S. Lilley, D. Chan, H. Tran, S. Ragland, and P. Wizinowich.

4 microns: sweet spot for exoplanet imaging

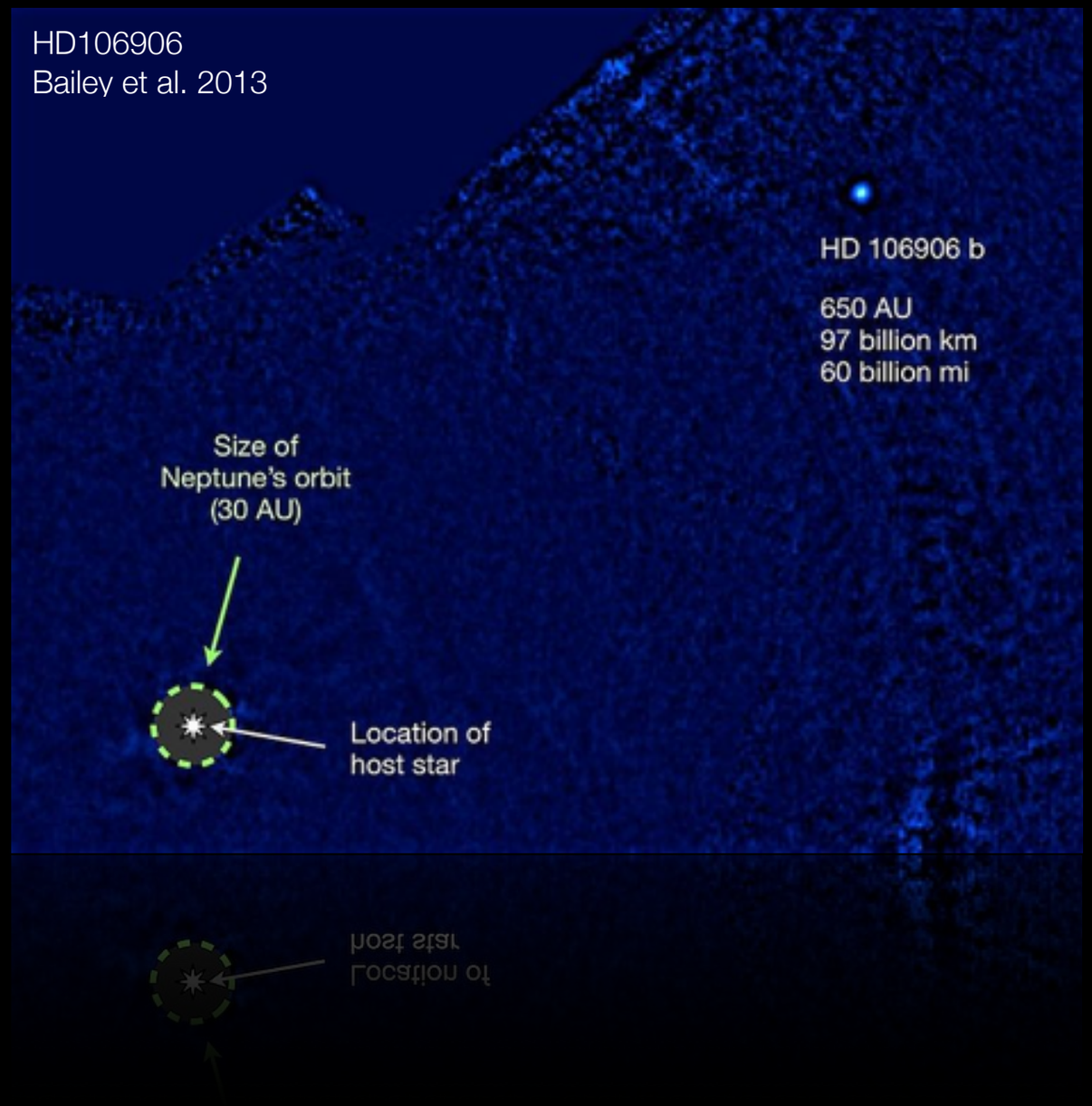


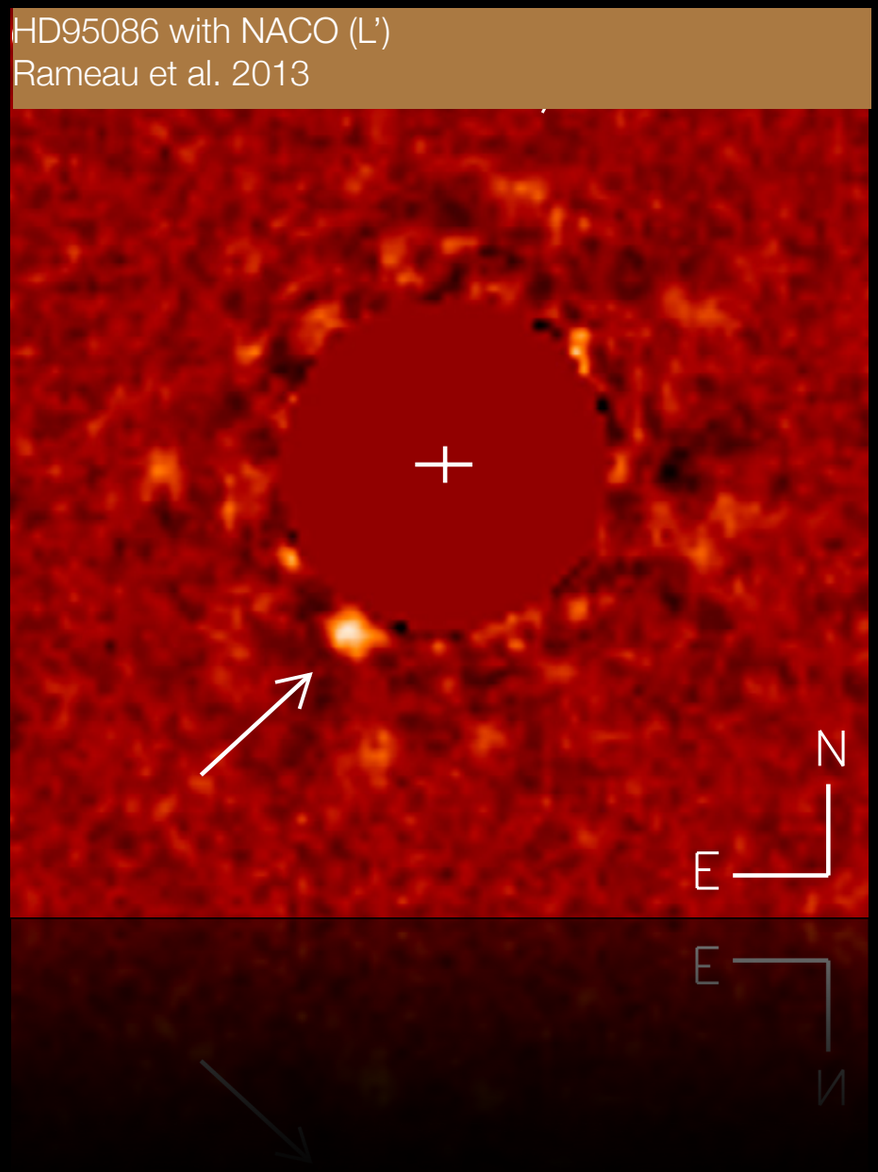
β Pictoris planet and disk
with VLT-NACO L-band vortex
(Absil et al. 2013, Milli et al. 2014)

Marois et al. 2009

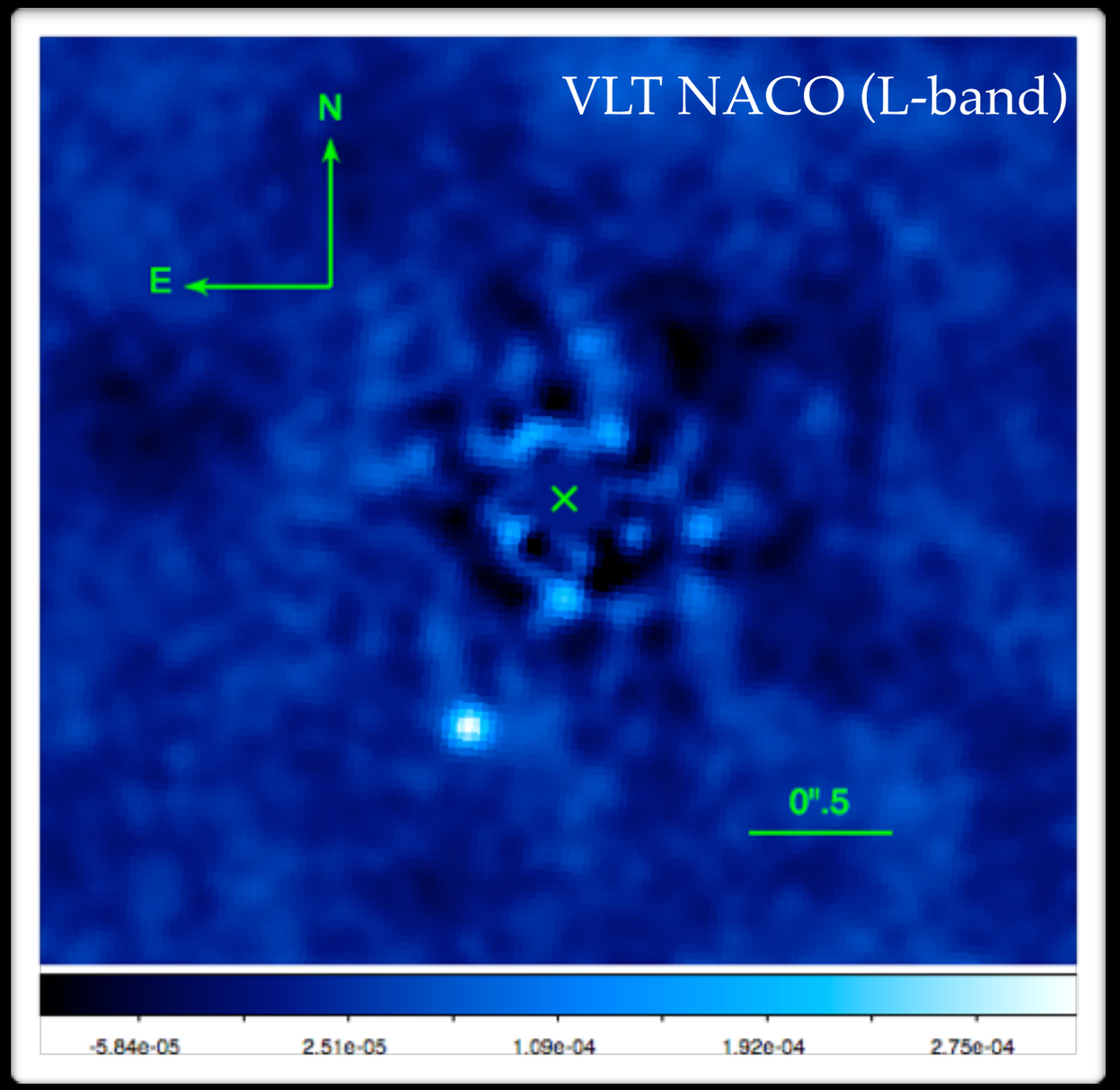


Other famous examples





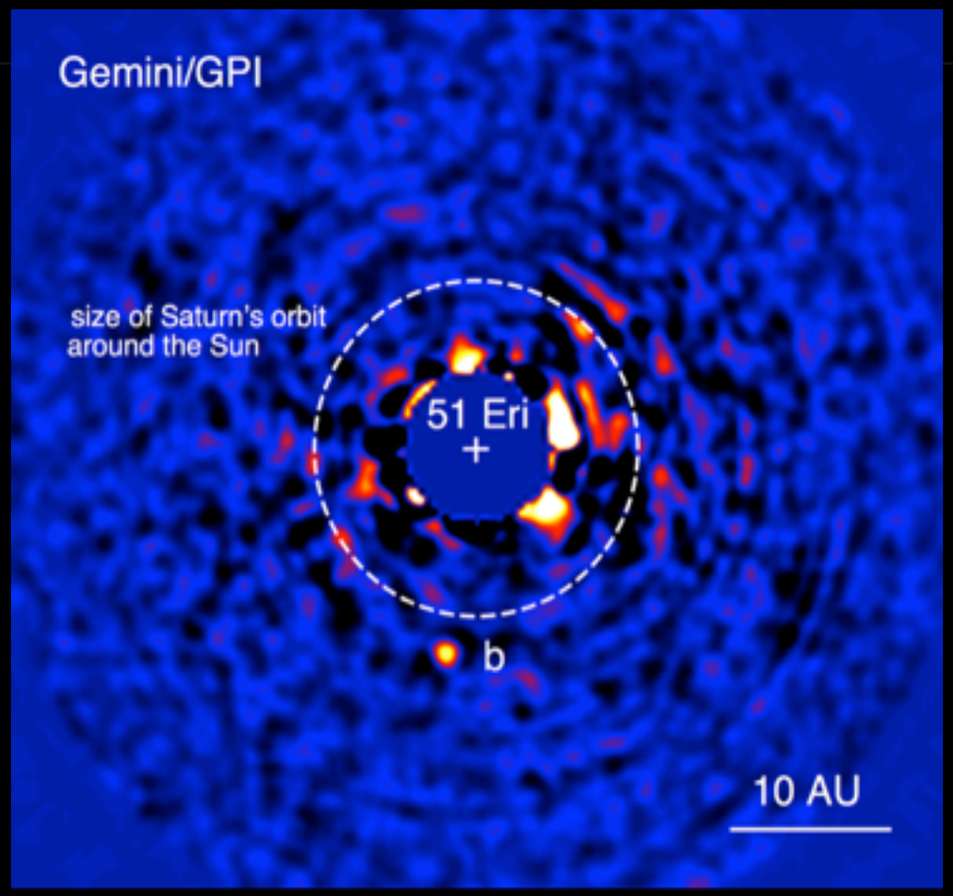
Another low-mass companion around disk-bearing star

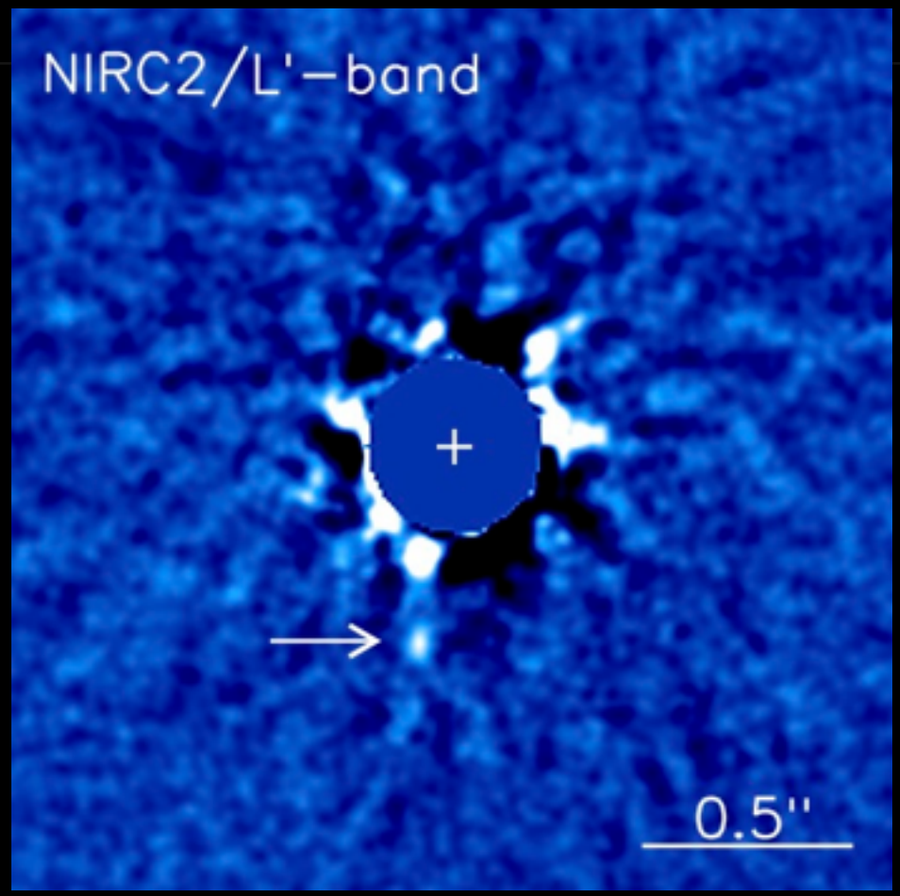


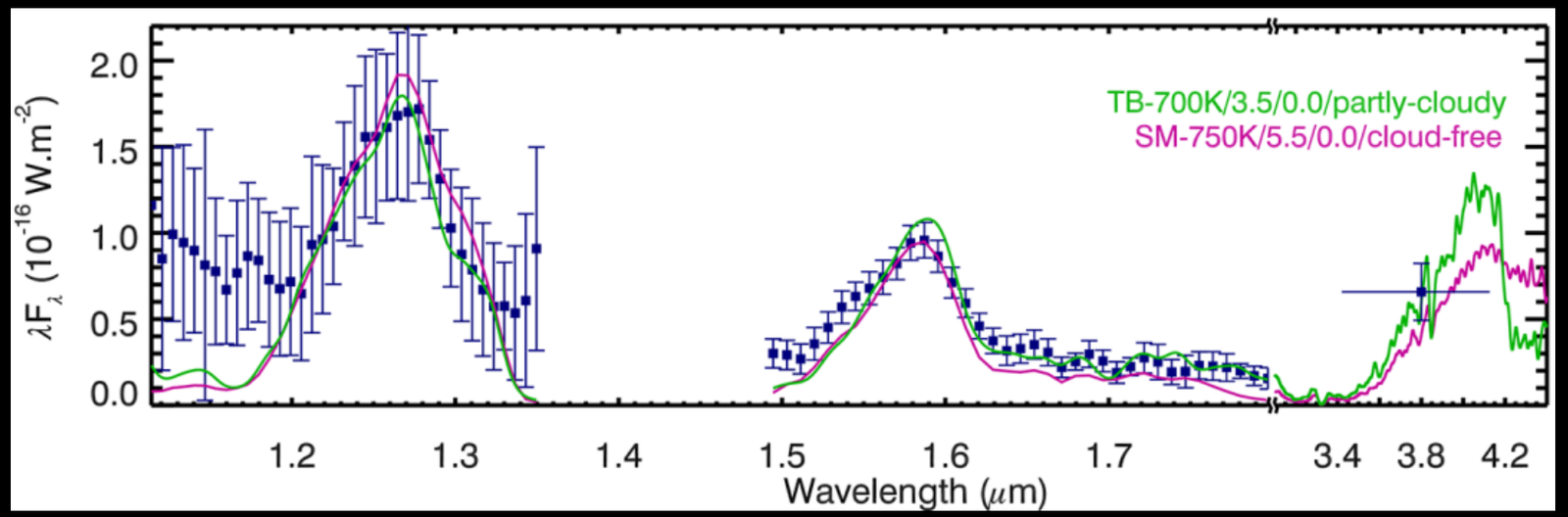
Mawet et al. 2015, ApJ, in press

The best demonstration

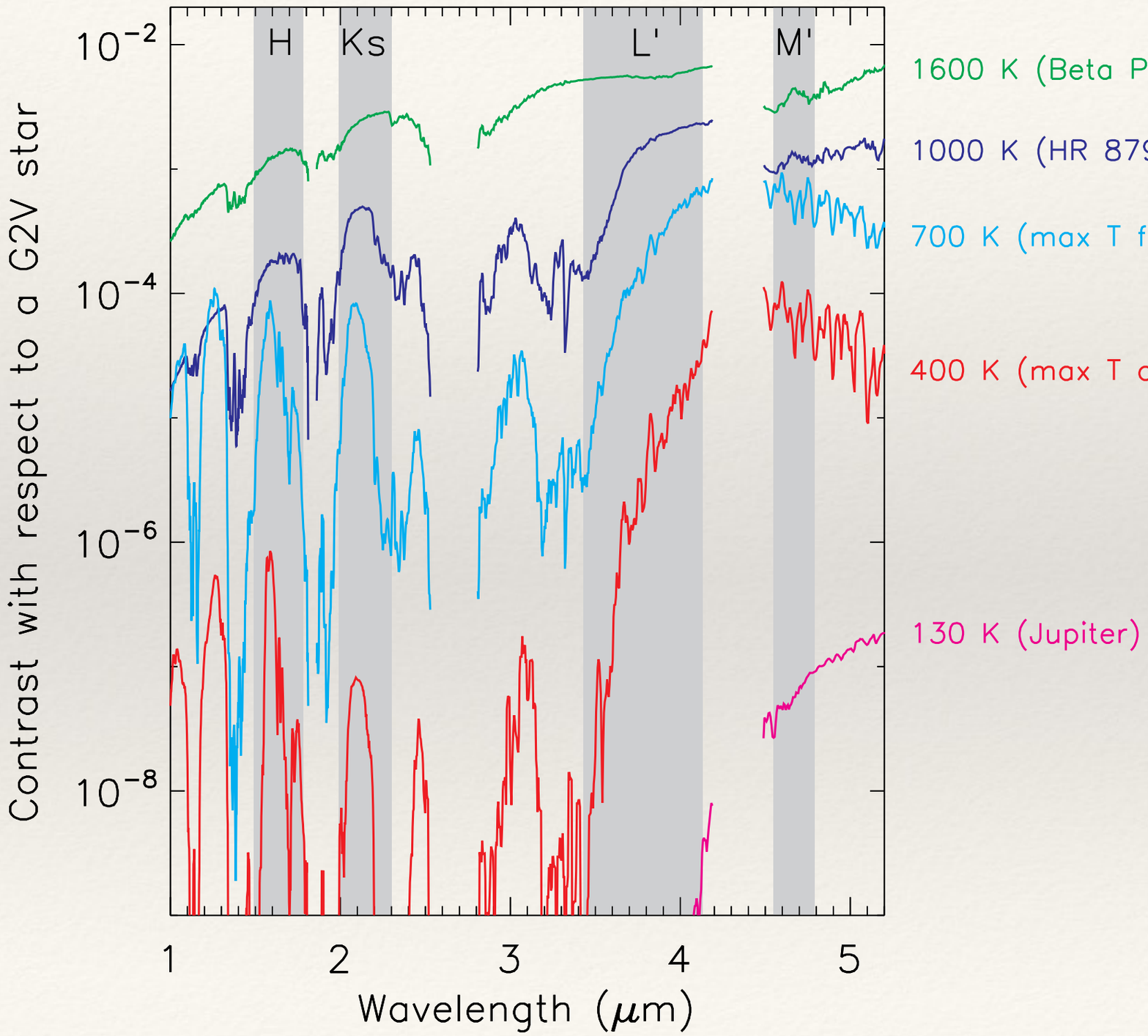
Macintosh et al. 2015



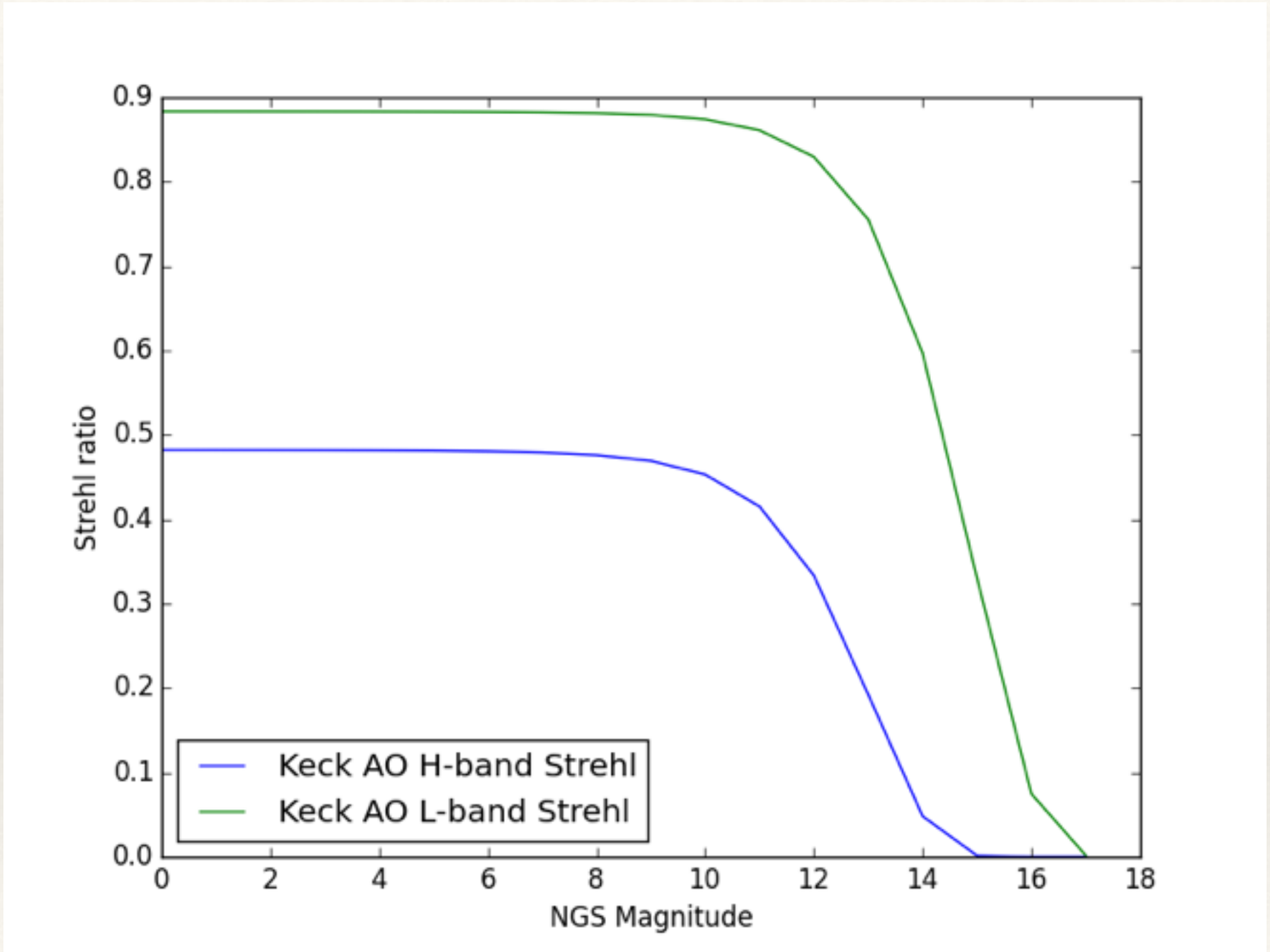




Reason #1: lower contrast



Reason #2: better image quality… for free



Caveats

- Increased sky background:

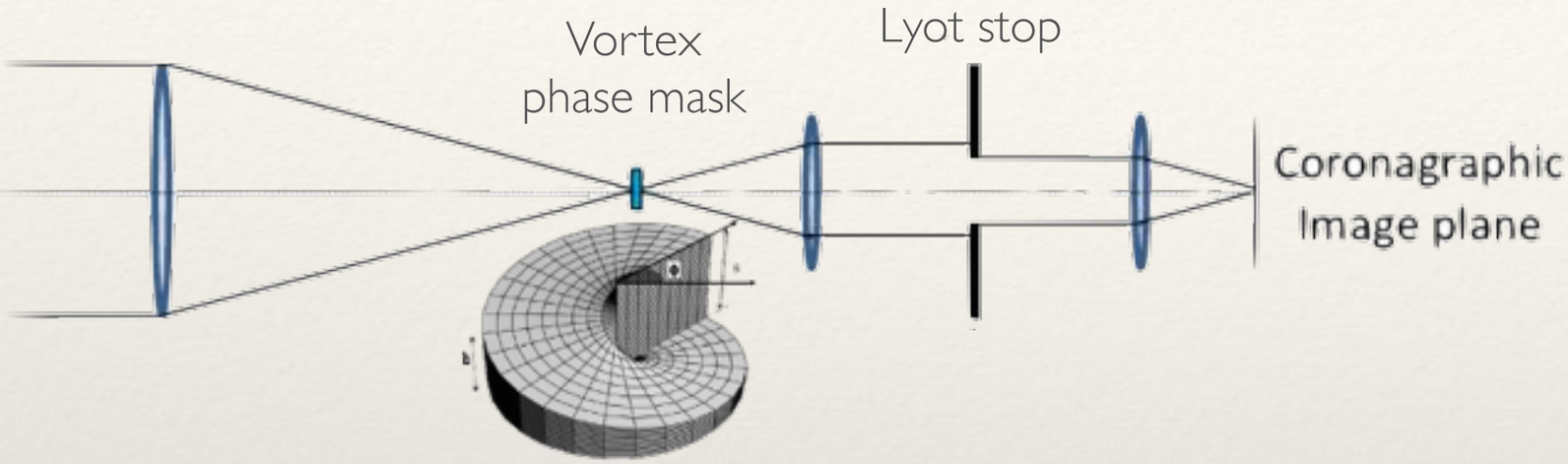
  L=16-18 5σ point source sensitivity in 1 hour at Keck
  (cooling the AO bench would help)

- Loss in angular resolution:

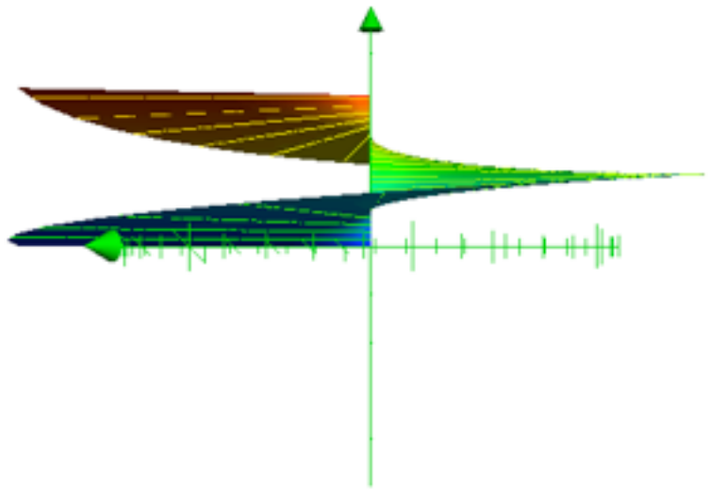
  => use of small inner working angle coronagraph

Vortex coronagraph in a nutshell

Mawet et al. 2005

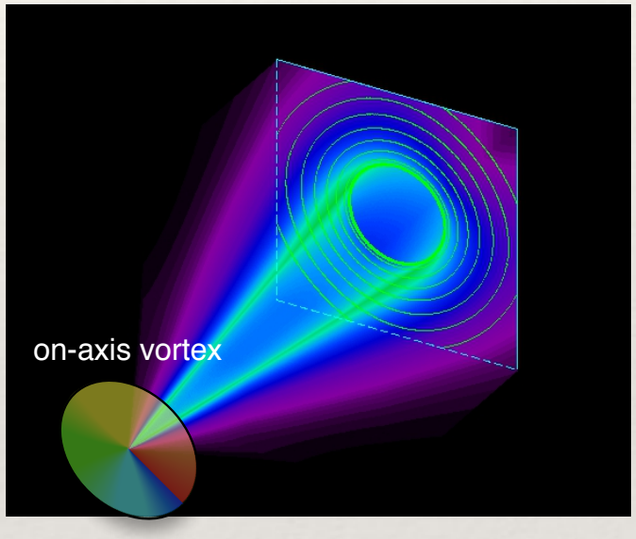


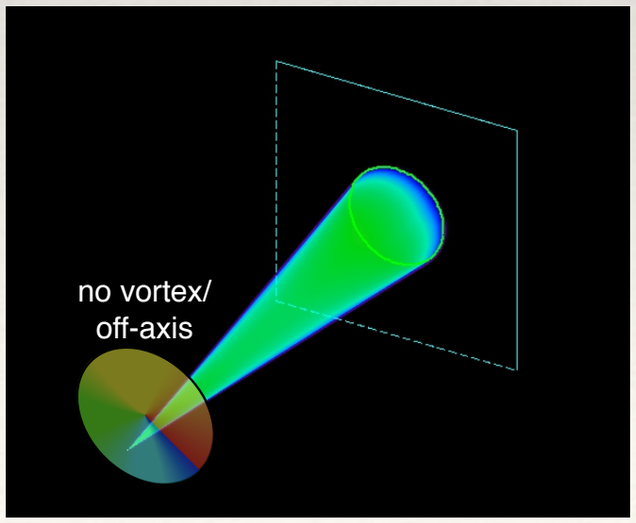
$e^{il\theta}$



l = topological charge (winding number)
= height of the screw dislocation

Perfect on-axis cancellation





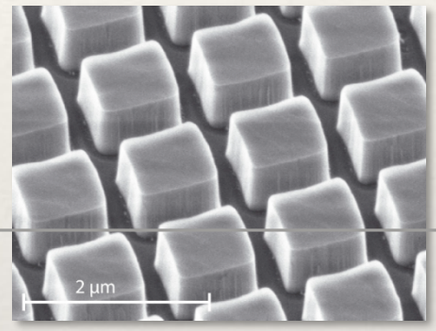
Annular Groove Phase Mask

- Rotationally symmetric half-wave plate made of sub-wavelength (aka zero-order) gratings
- Small IWA, 360° discovery, can be made achromatic, drop-in device

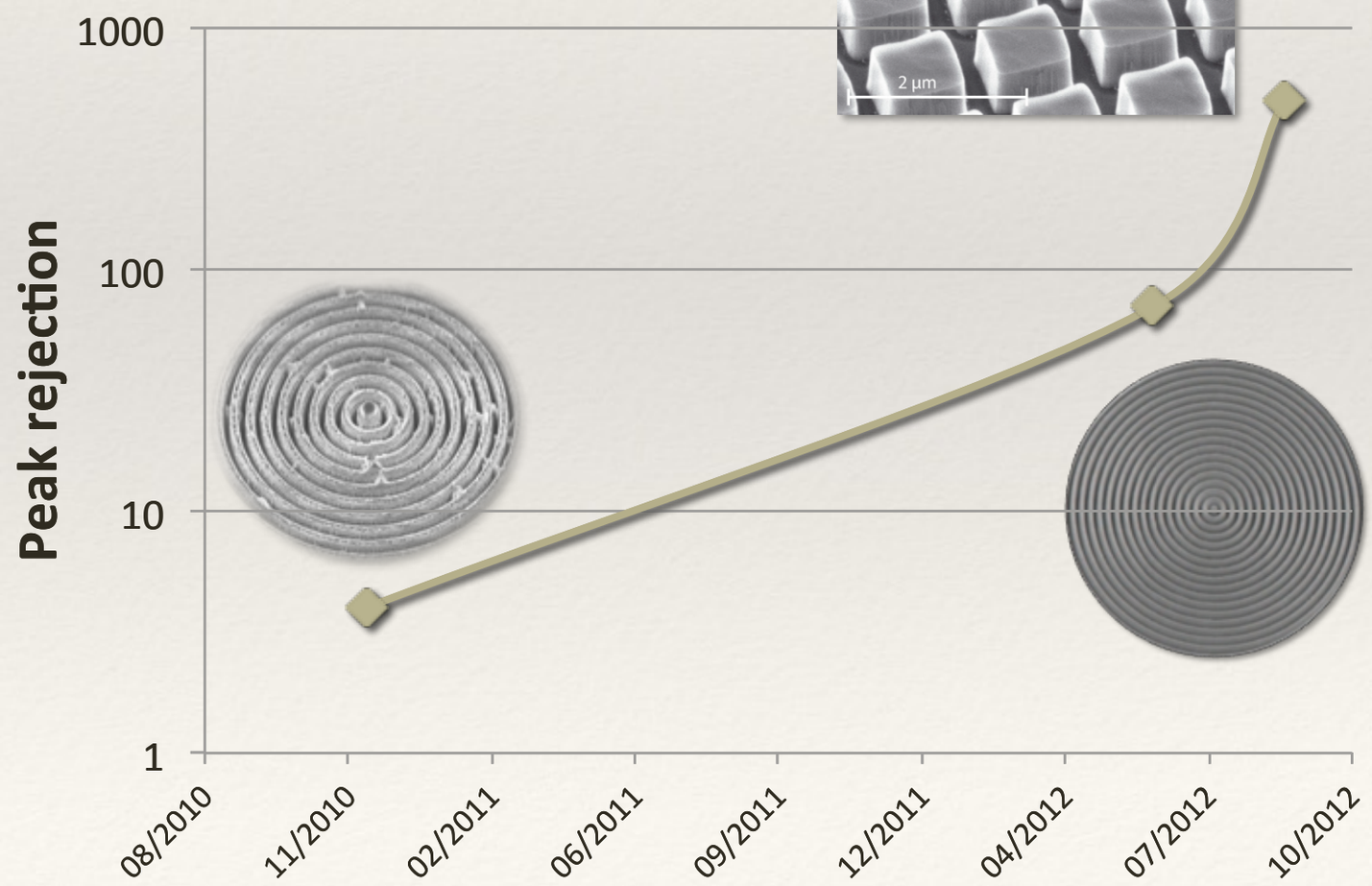
Mawet et al. 2005

State-of-the-art micro-technology

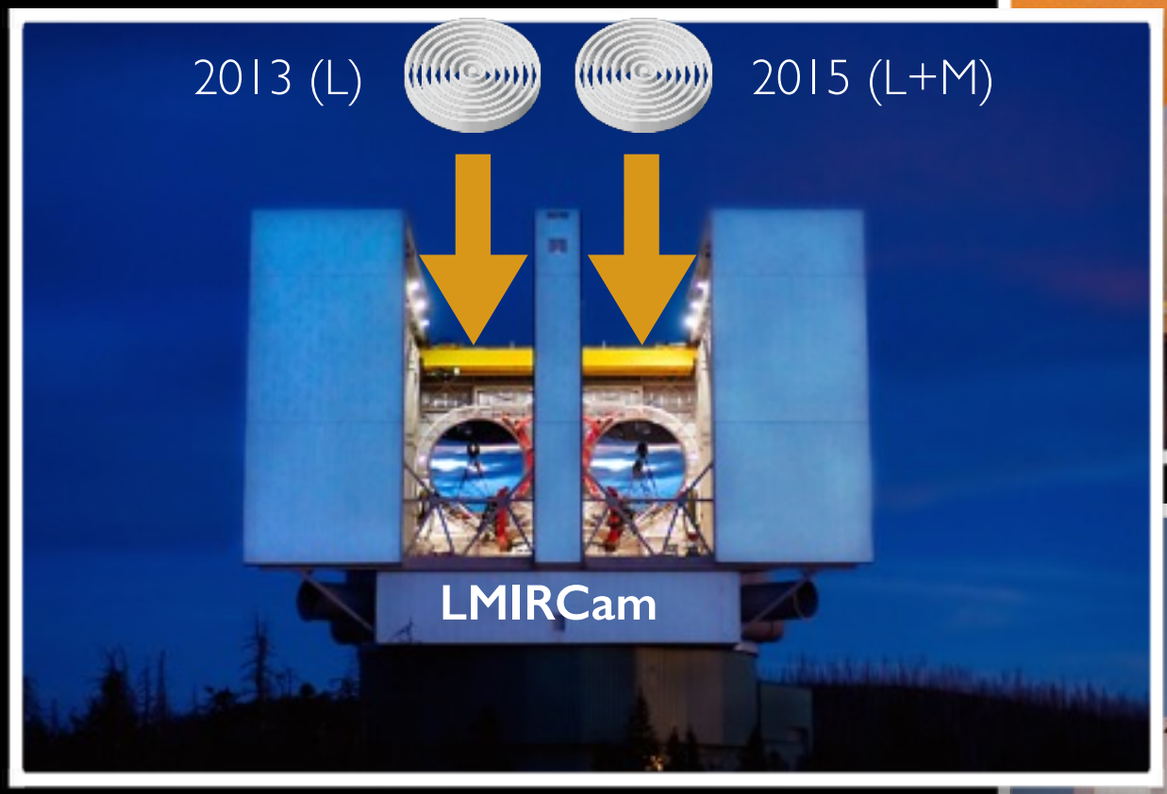
antireflective grating

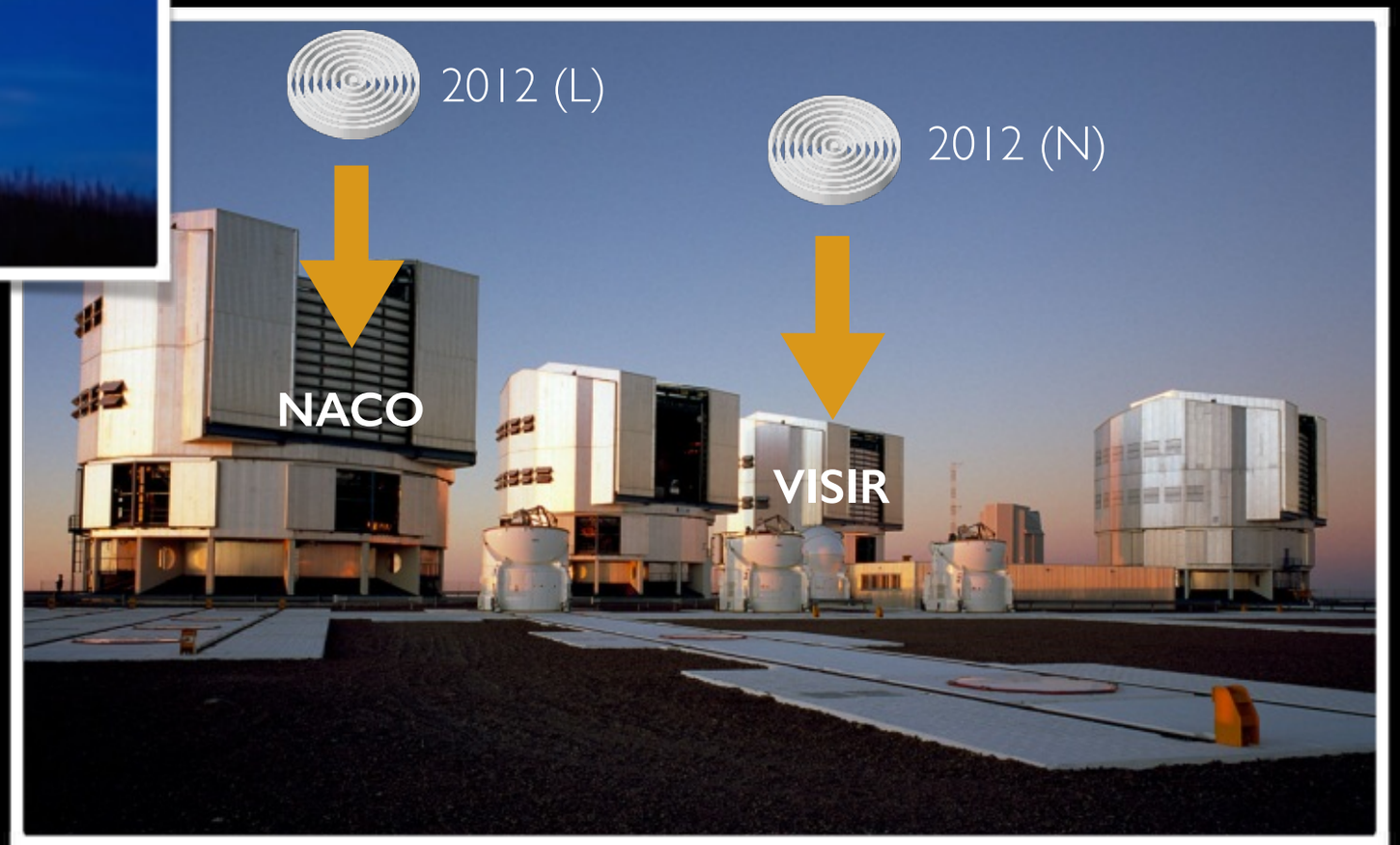


- First N- and L-band AGPMs
- Peak rejection measured at L band



Deployment at major observatories

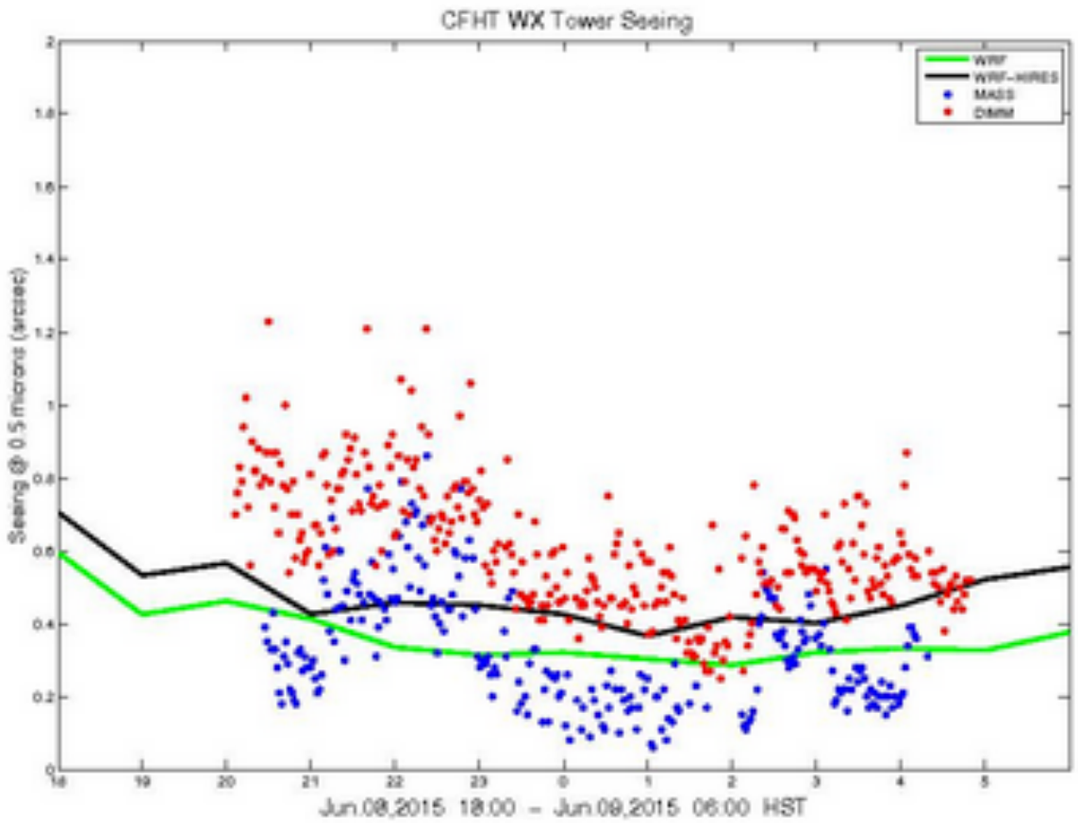


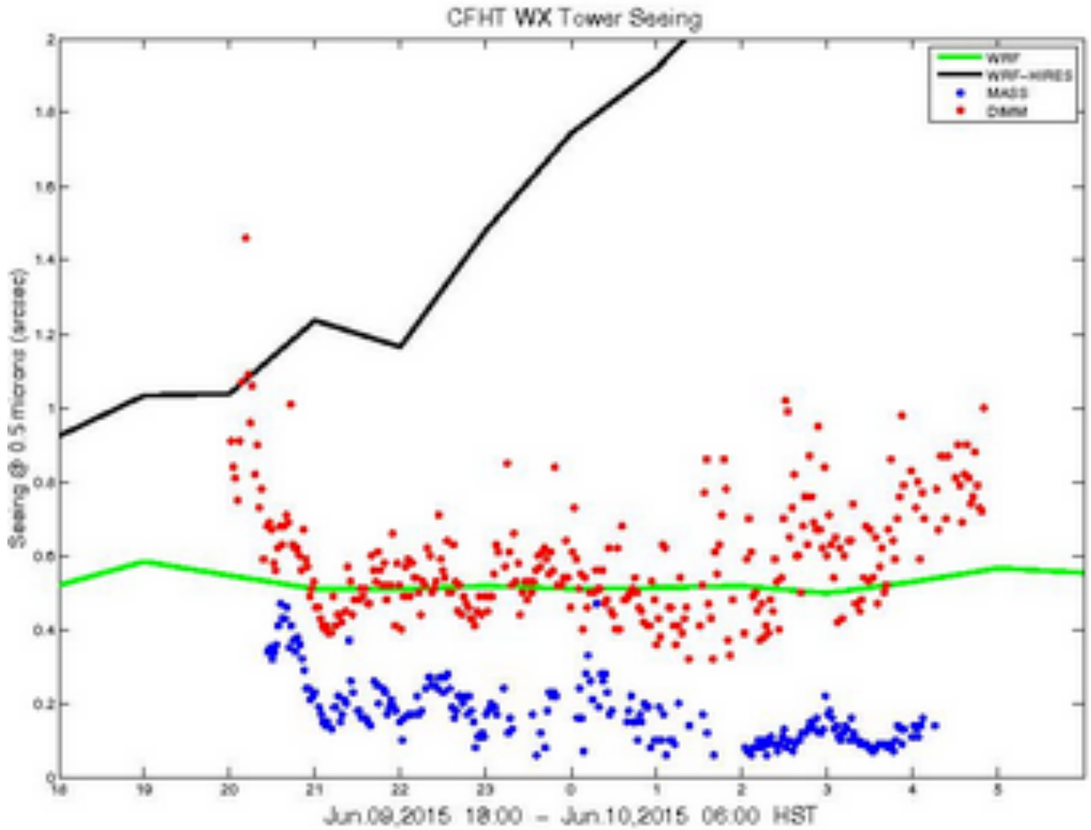


Commissioning of L-band vortex coronagraph on Keck NIRC2

People and logistics

- **Mainland team** (Caltech remote observing): E. Serabyn, O. Absil, E. Huby, K. Matthews, H. Ngo, and D. Mawet.
- **Keck AO team**: B. Femenia, R. Campbell, S. Lilley, D. Chan, H. Tran, S. Ragland, and P. Wizinowich.
- Support at **University of Liege**: lab mask testing (A. Jolivet, C. Delacroix), modeling (B. Carlomagno).
- Commissioning dates: 2015-06-08 to 2015-06-10 (3 full nights).
- **Conditions**: excellent with average seeing ~0”.5, only 1 hour lost to fog.


CFHT WX Tower Seeing
WRF
WRF-HIRES
MASS
DIMM
Seeing @ 0.5 microns (arcsec)
Jun.08,2015 18:00 – Jun.09,2015 06:00 HST


CFHT WX Tower Seeing
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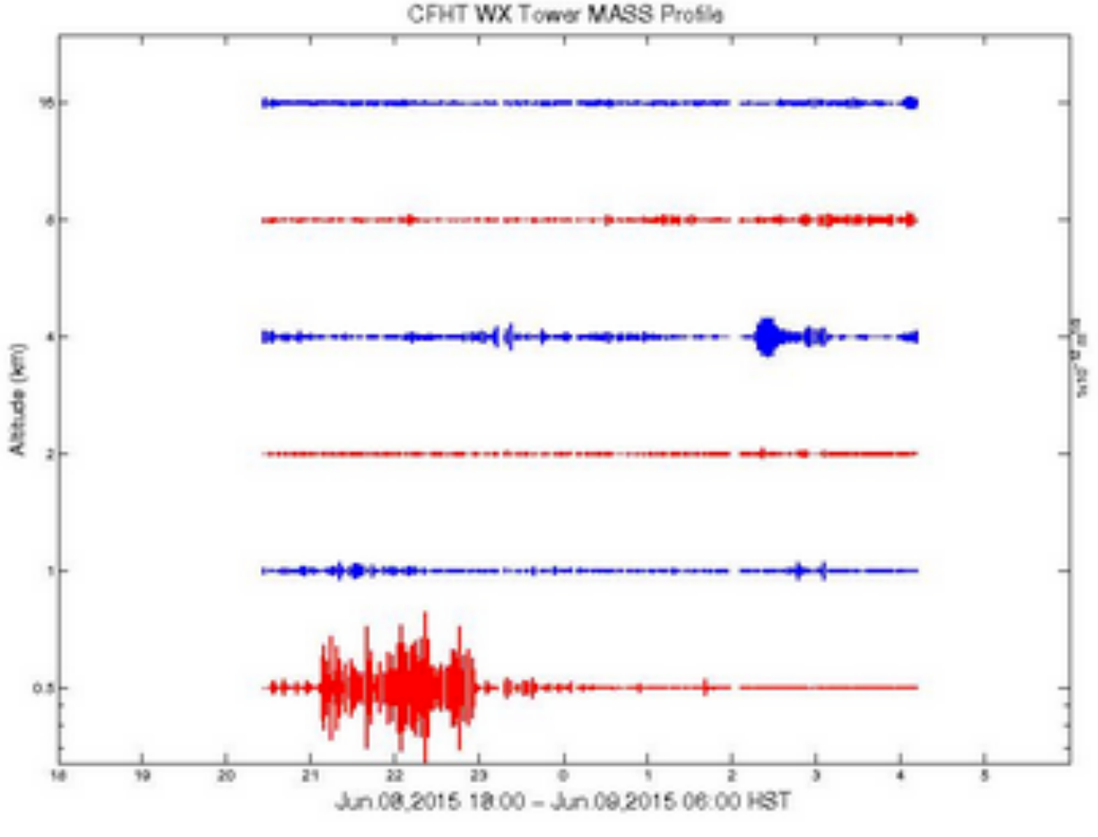
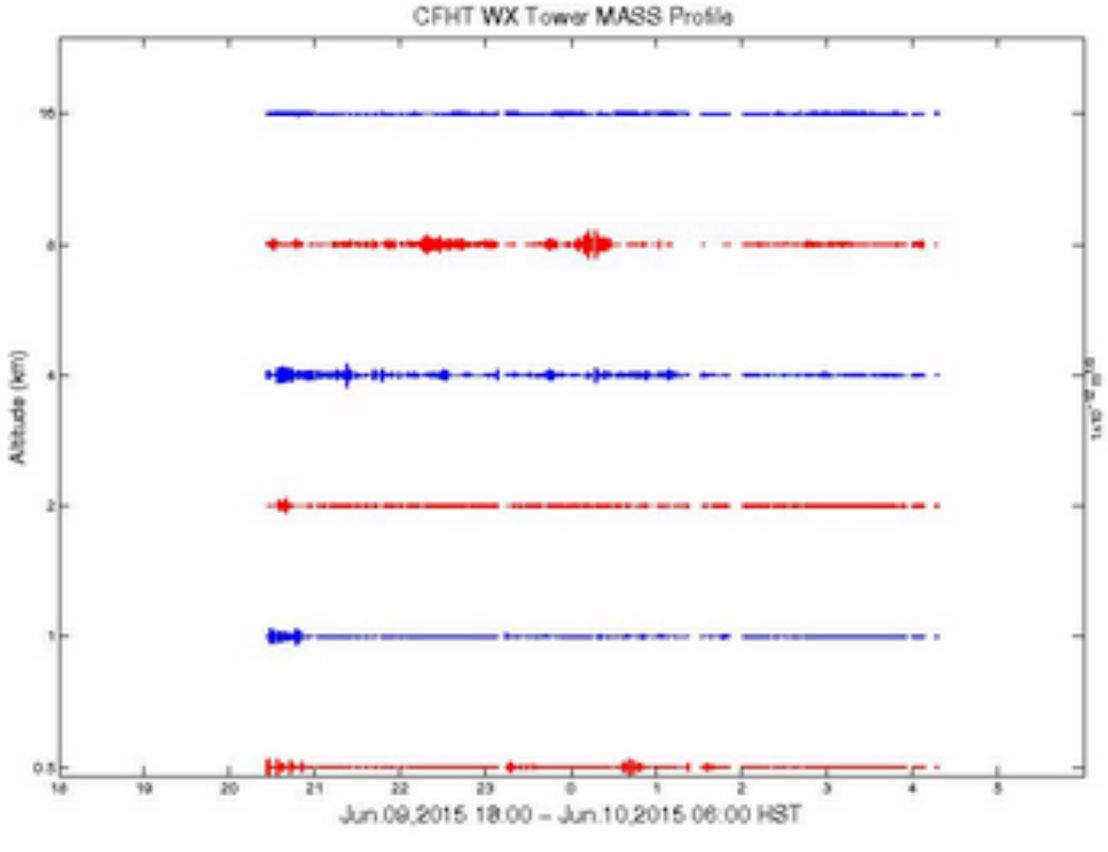

CFHT WX Tower MASS Profile
Altitude (km)
Jun.08,2015 18:00 – Jun.09,2015 06:00 HST

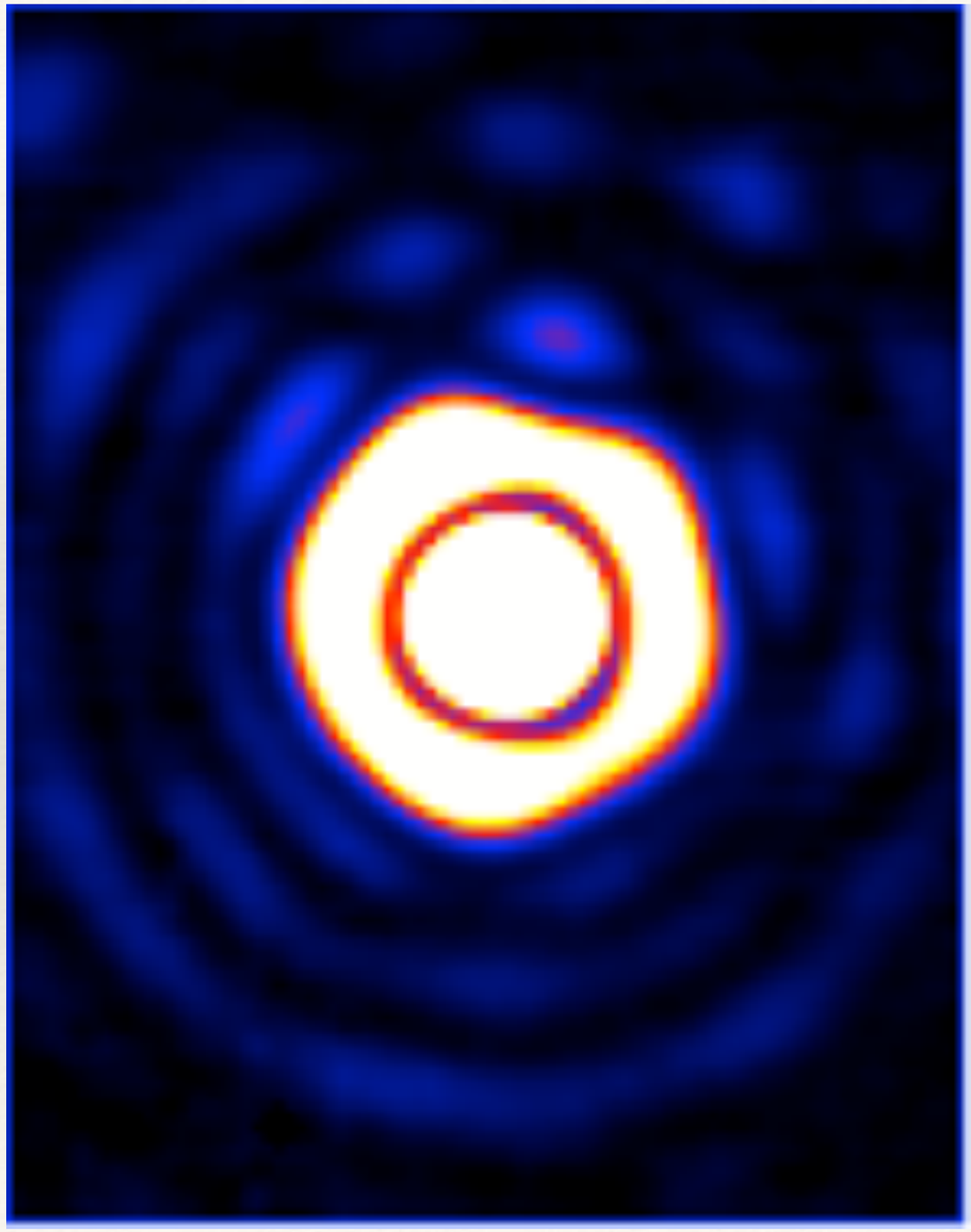

CFHT WX Tower MASS Profile
Altitude (km)
Jun.09,2015 18:00 – Jun.10,2015 06:00 HST

AO performance on typical targets

- Excellent AO performance and stability (not a single AO glitch recorded in 3 nights!),

  => L-band Strehl ratio consistently in excess of 85% (!), peaking at 88% (95% recorded at subsequent run).

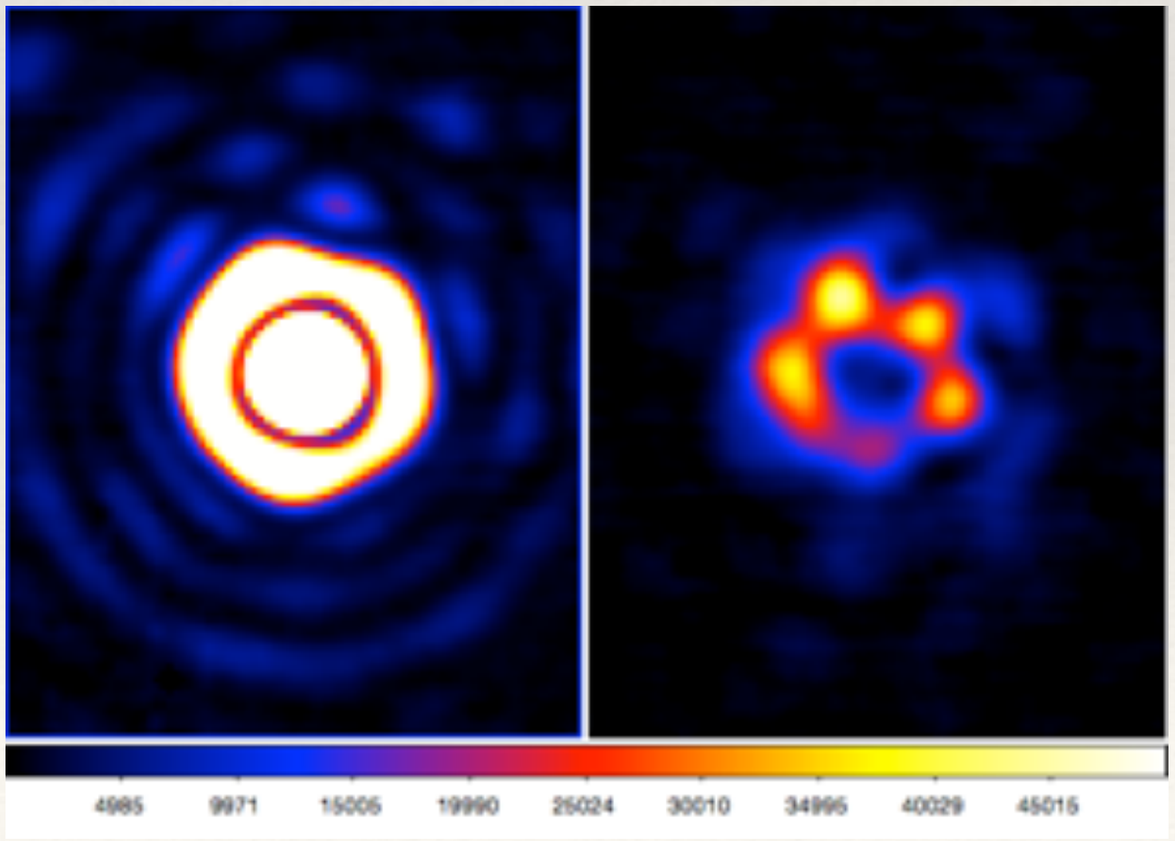
  => L-band image quality and stability verified to R~12.5 (M-dwarf), not pushed to the limits yet.



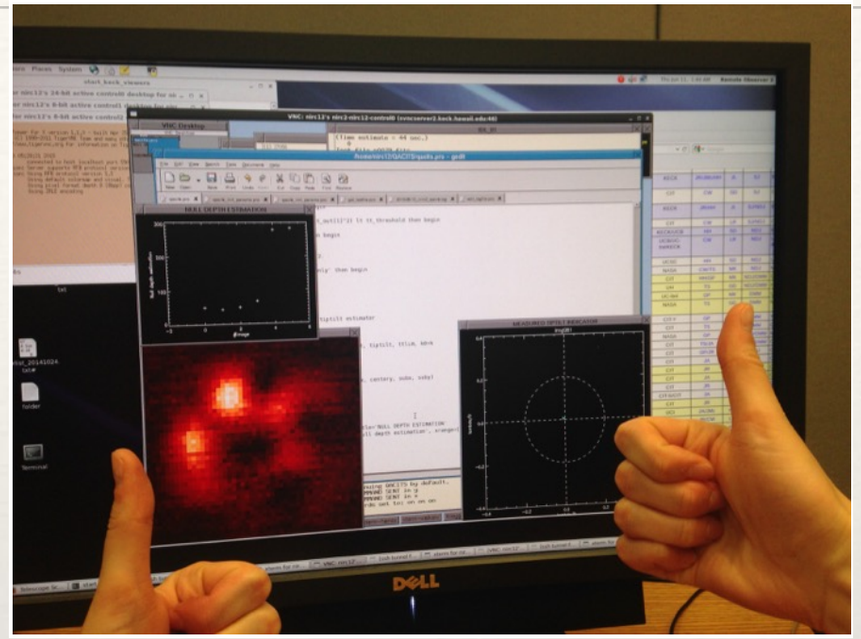
Trade-off between efficiency and performance

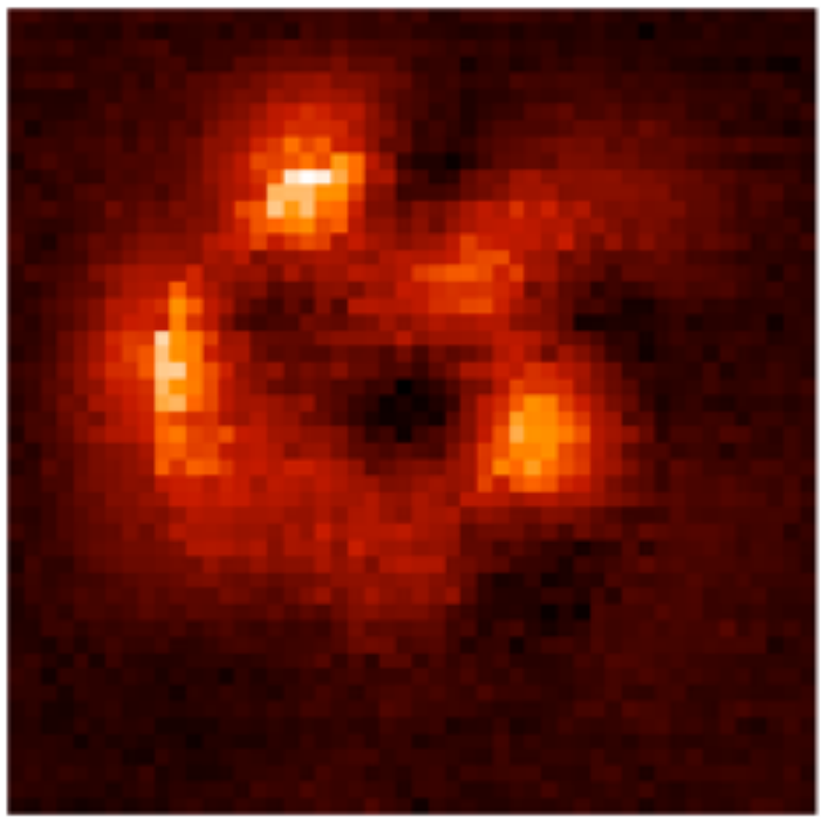
- **Acquisition time on the vortex and automatic pointing loop ~2-3 minutes.**
- Demonstration of nominal on-sky vortex performance.

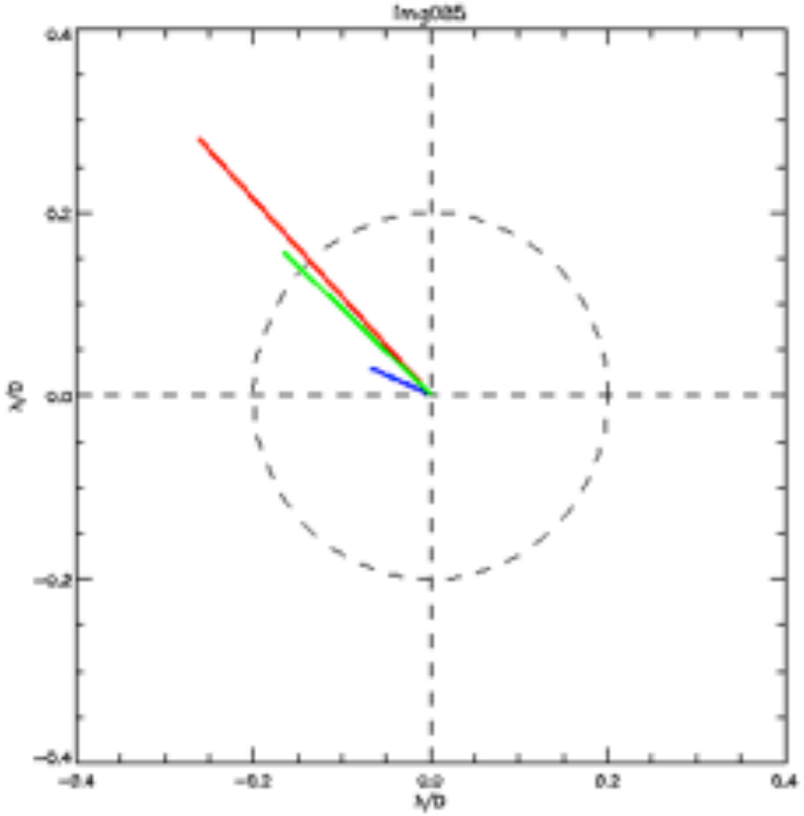
  => ~50:1 peak starlight rejection, limited by AO residuals

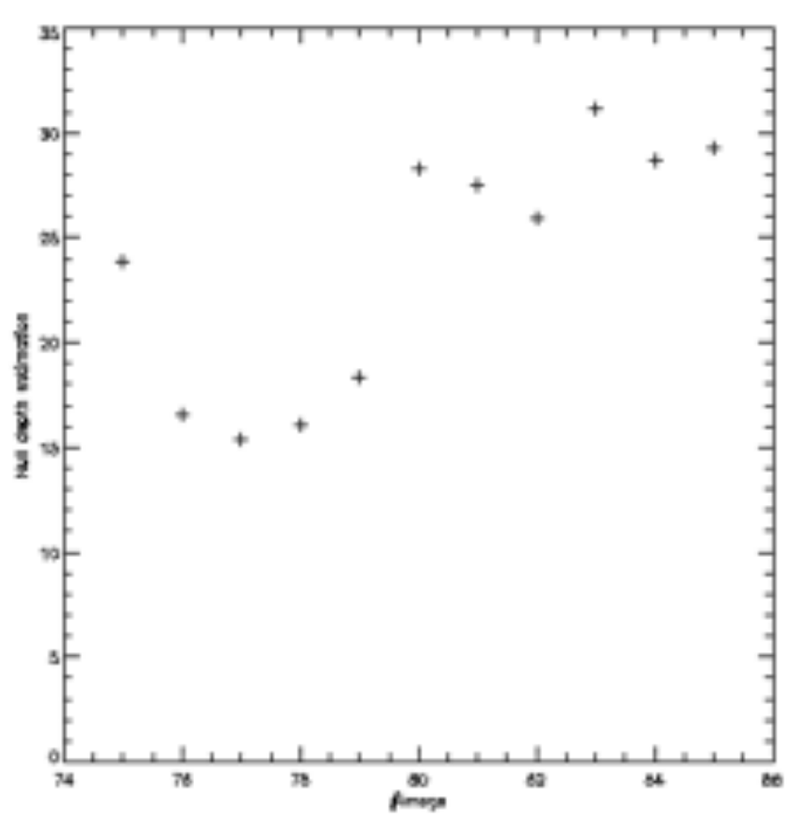


QACITS: automatic centering & scripting of observing sequence







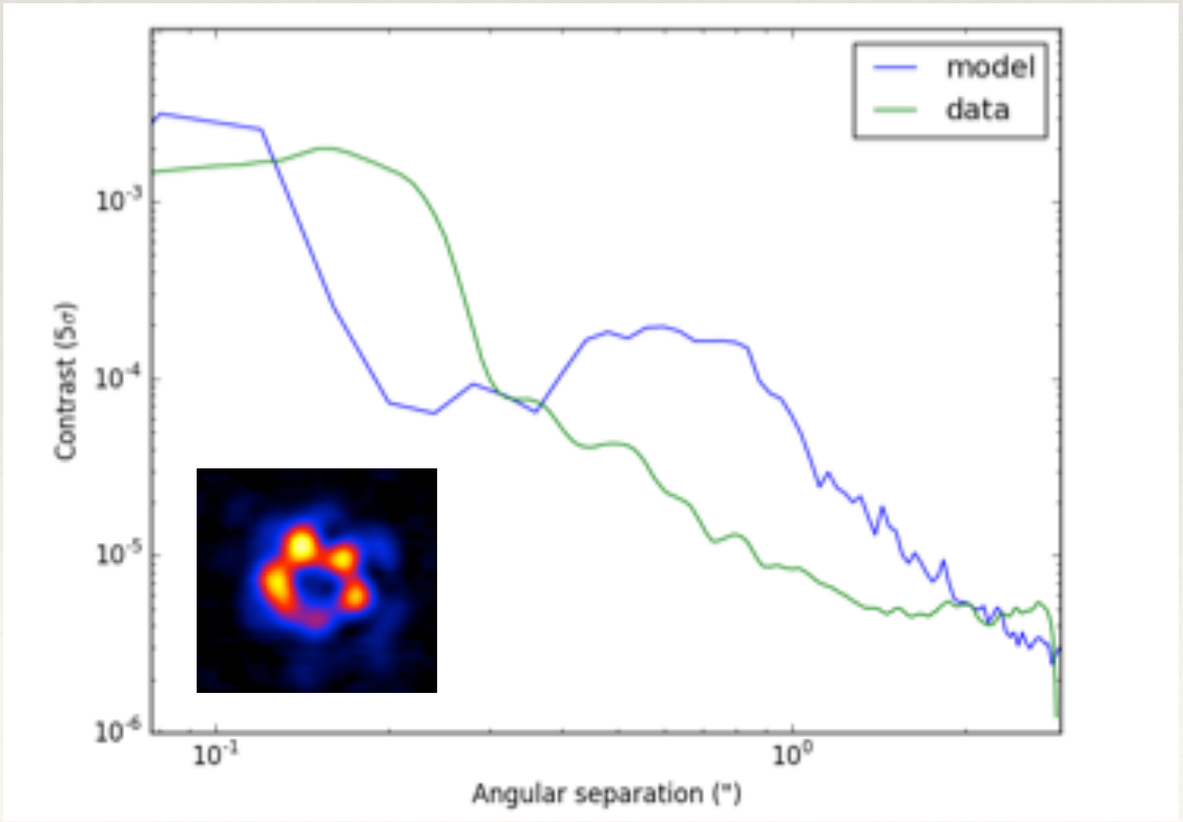


Performance

- Demonstration of **pupil-stabilized reference star differential imaging (RDI)**, aided by **minimal overheads** during re-acquisition on vortex

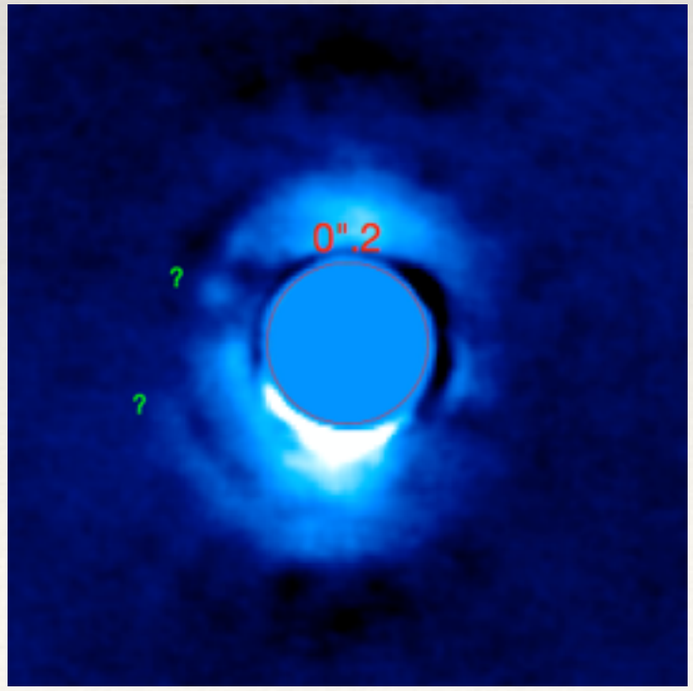
  => Enables small IWA science, using the vortex coronagraph at its maximum potential

- Contrast performance maintained and verified from R~2.5 up to R~12.5 (M4 at 15 pc).



Mawet et al. 2015, in preparation

Debris disk discovery



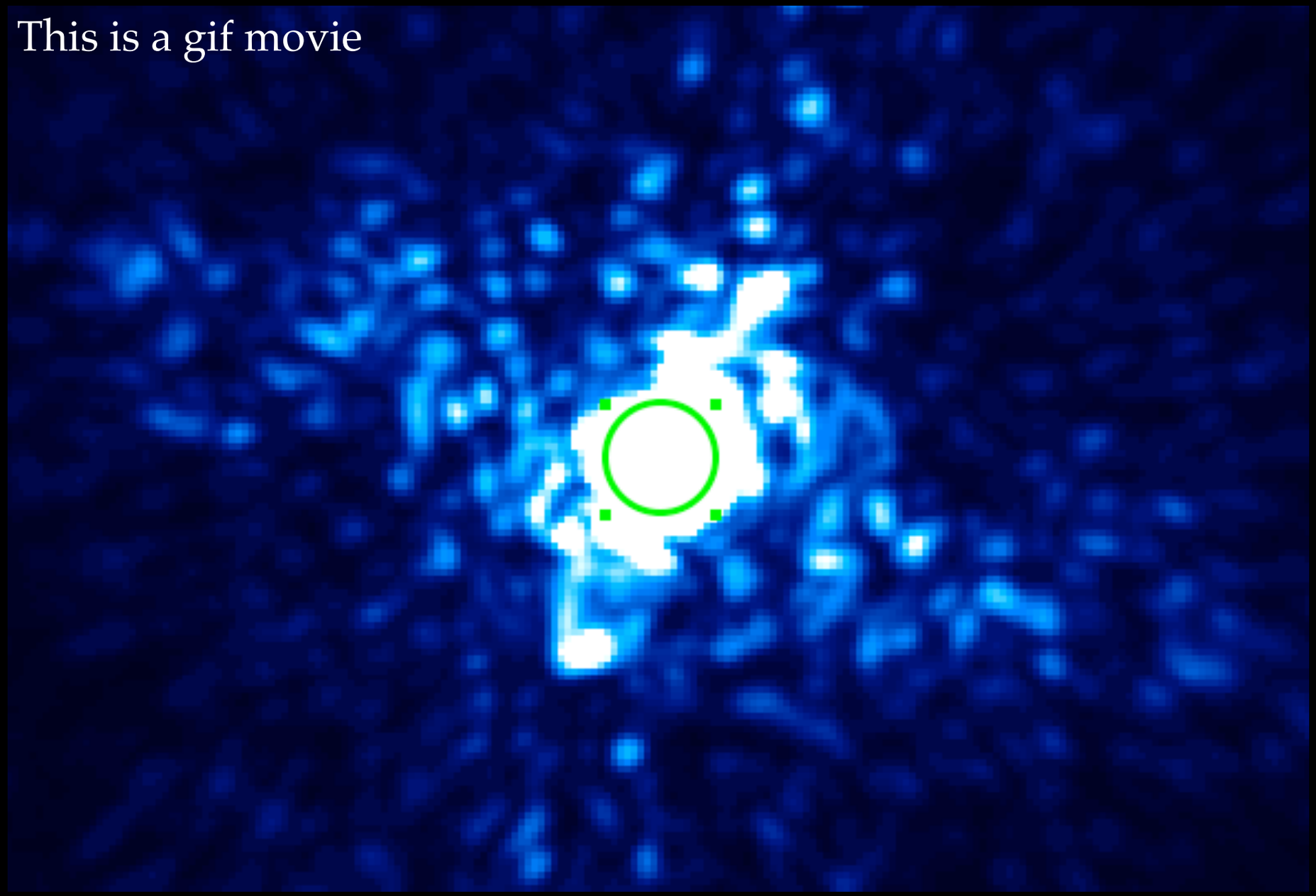
Future work

- Optimize pupil registration/Lyot stop alignment
- Improve image quality through **advanced focal-plane wavefront control with speckle nulling** (M. Bottom).
- Mode ready for prime time.
- From PI-based technical demo to facility:

  => Streamline all processes, open-source pipeline, documentation.

Speckle nulling: from Palomar to Keck

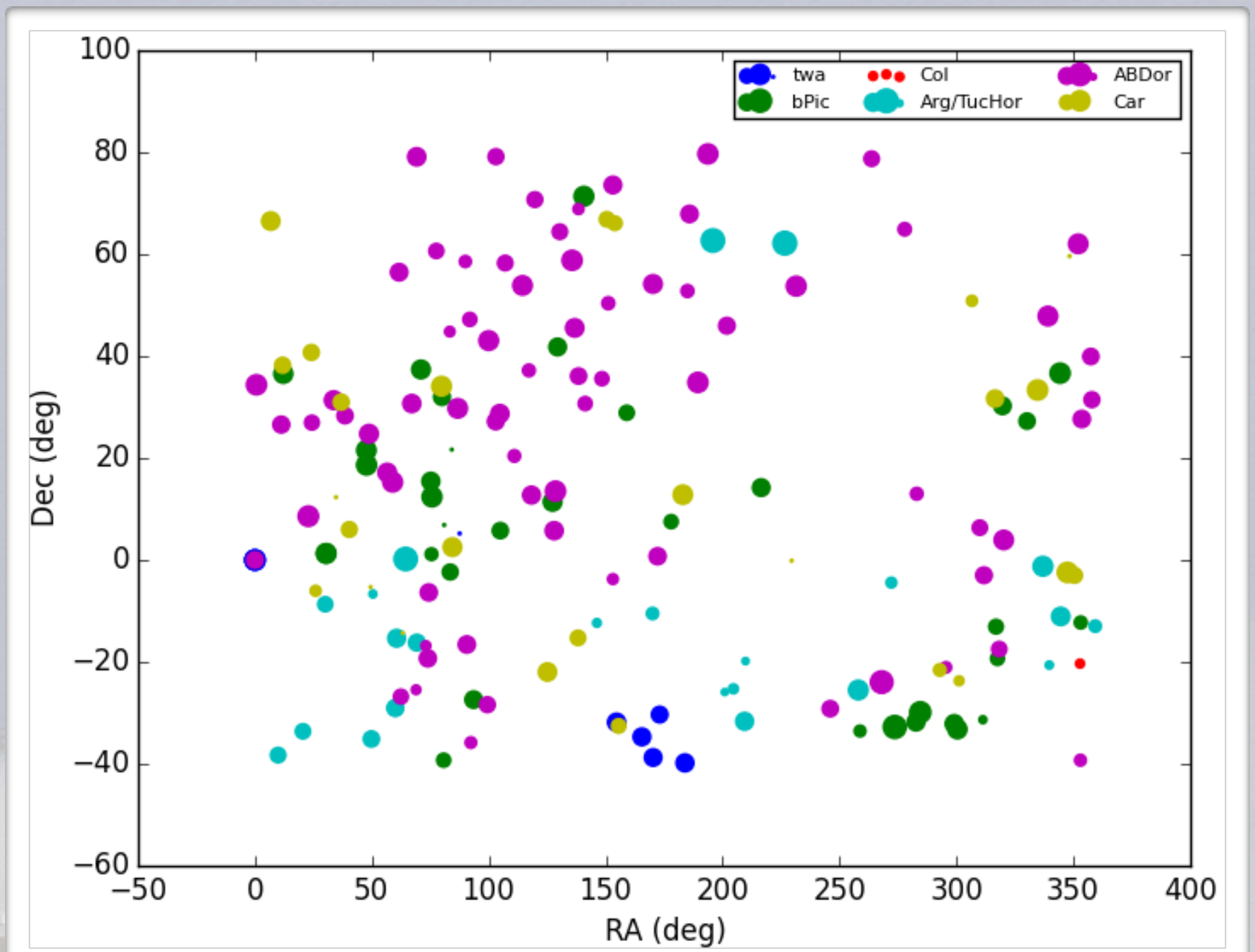
Implementation on-going, commissioning in October 2015



M. Bottom (Caltech), E. Huby (ULg), D. Mawet

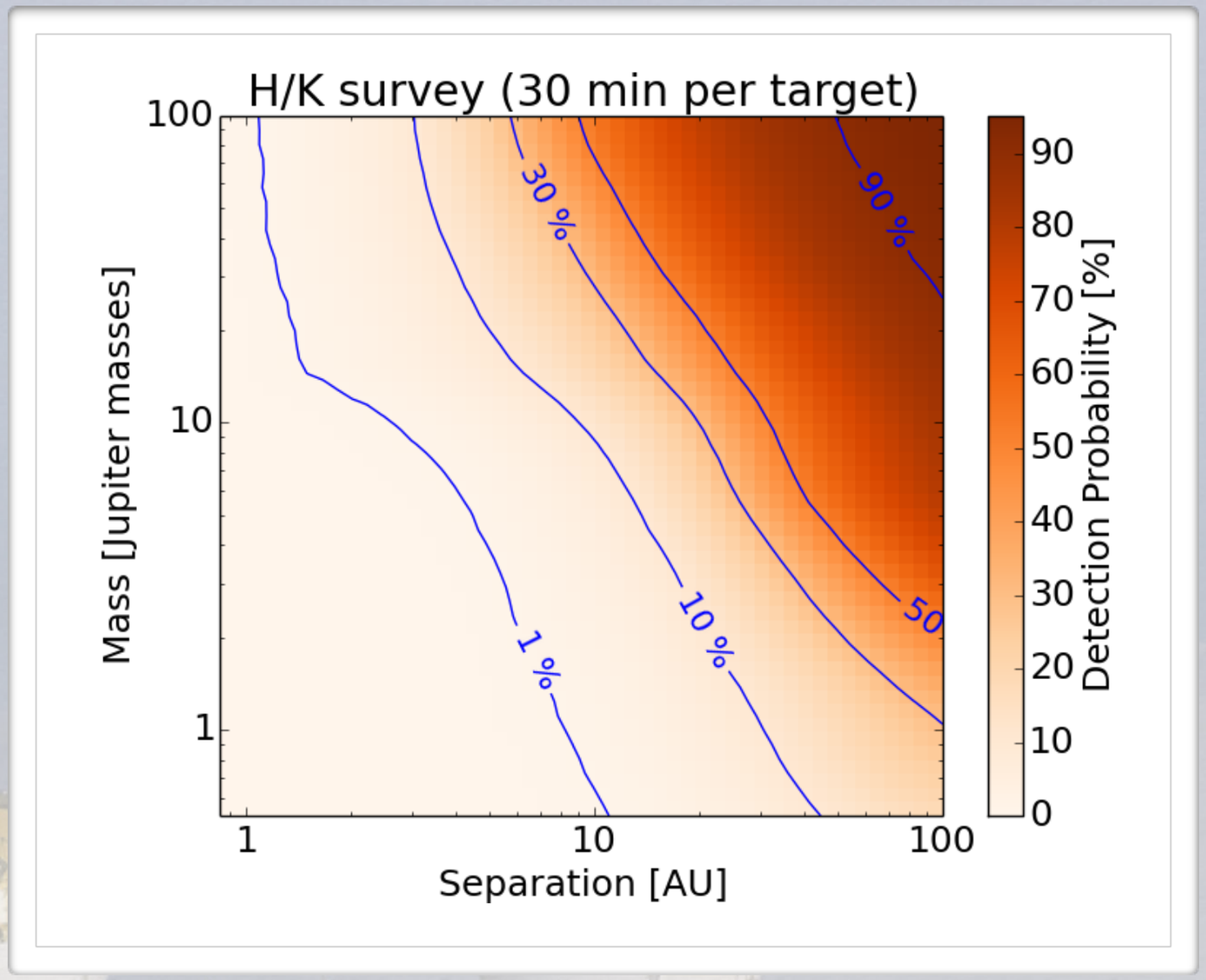
Core Science: planet formation around low-mass stars

with Henry Ngo, Brendan Bowler, and many others



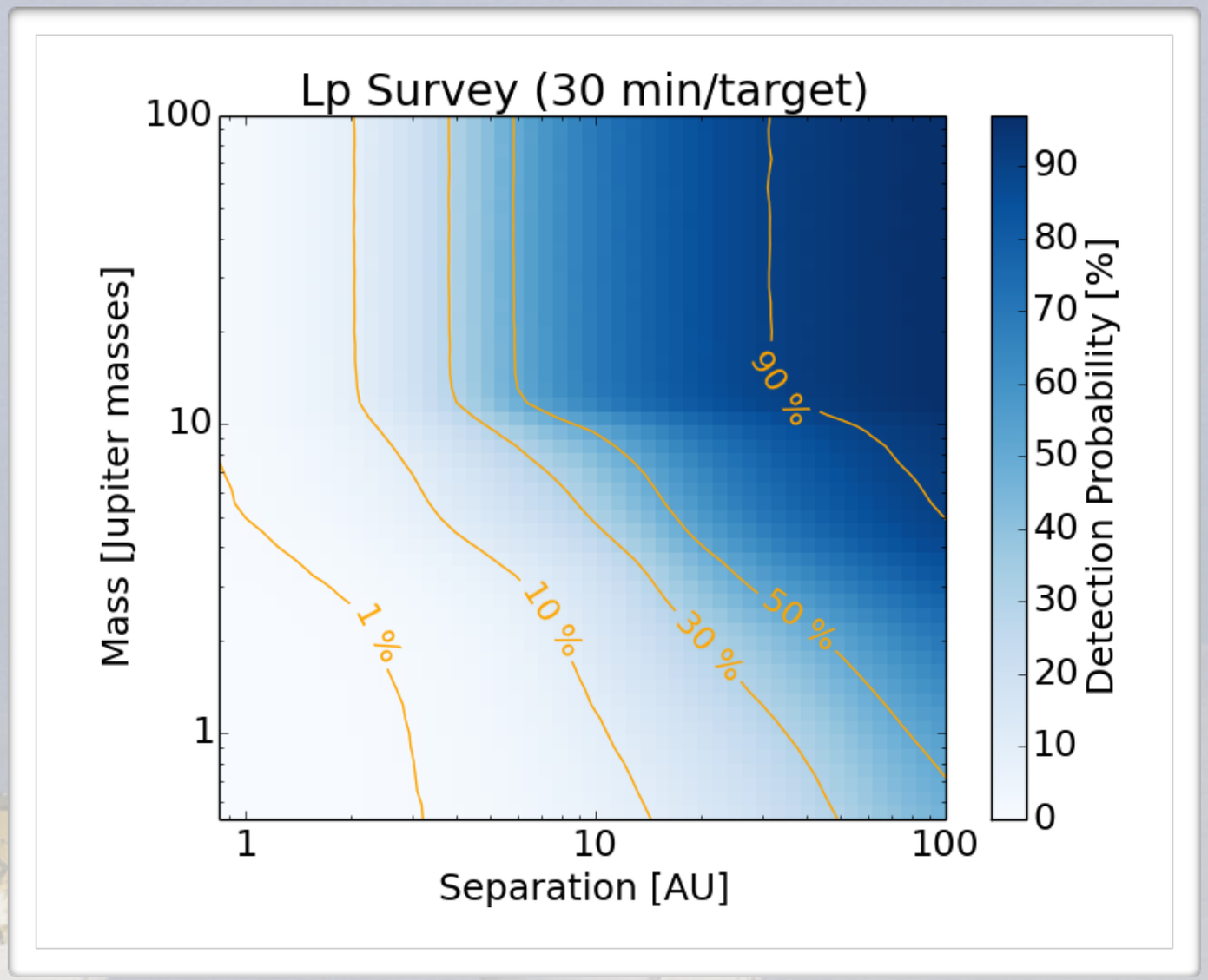
New unique sample of young M-dwarf (B. Bowler)

1st-generation survey: low-hanging fruits at large separations



Courtesy: Henry Ngo (GPS)

2nd-generation survey: pushing in!



Ground-breaking sensitivity thanks to L-band and coronagraph

Survey status