Imaging Planets in the Thermal Infrared

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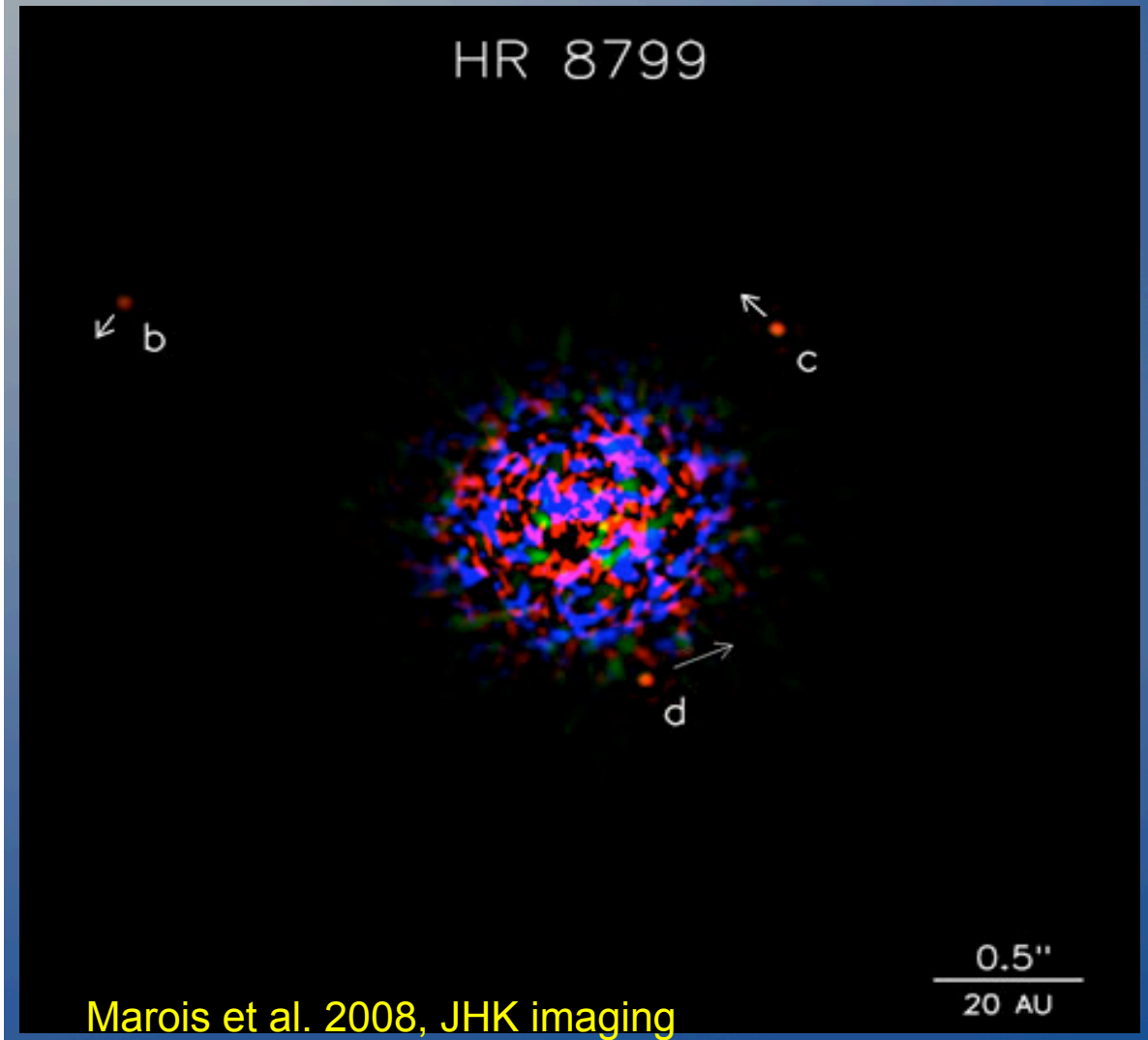
Outline:

- Observations of HR 8799 and Fomalhaut
- Survey of FGK stars in the thermal infrared
- LBTI status and plans

Exoplanets: Where are we?

- We are at the point of “mapping out” exoplanetary systems
- Direct Imaging contributes by probing the wide-period planets

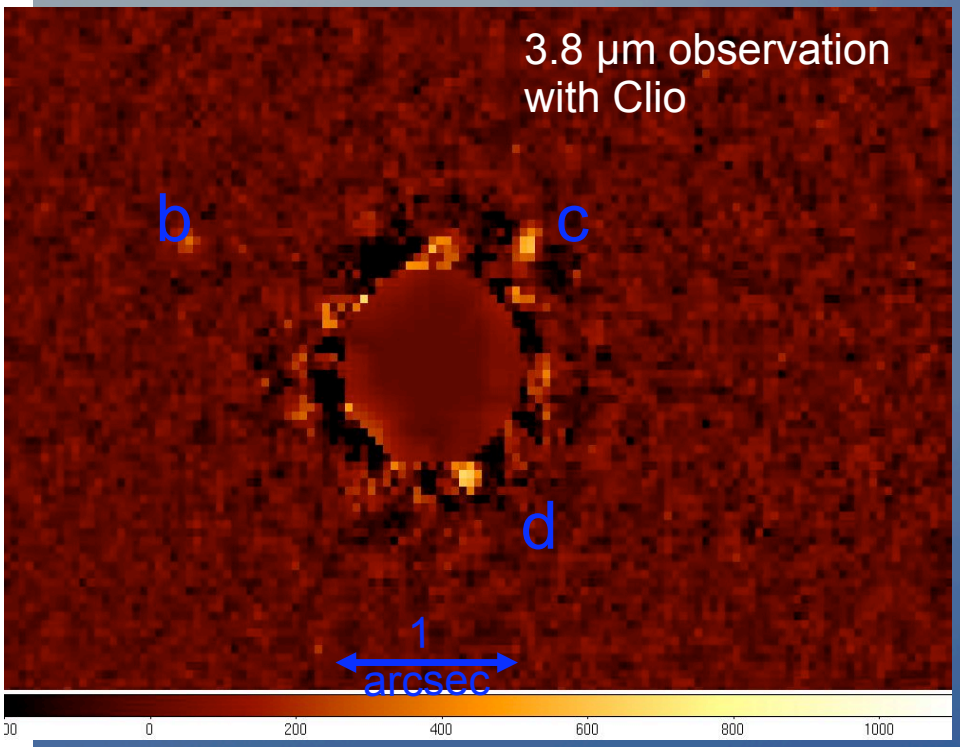
Direct Imaging of a 3 planet system



Marois et al. 2008, JHK imaging

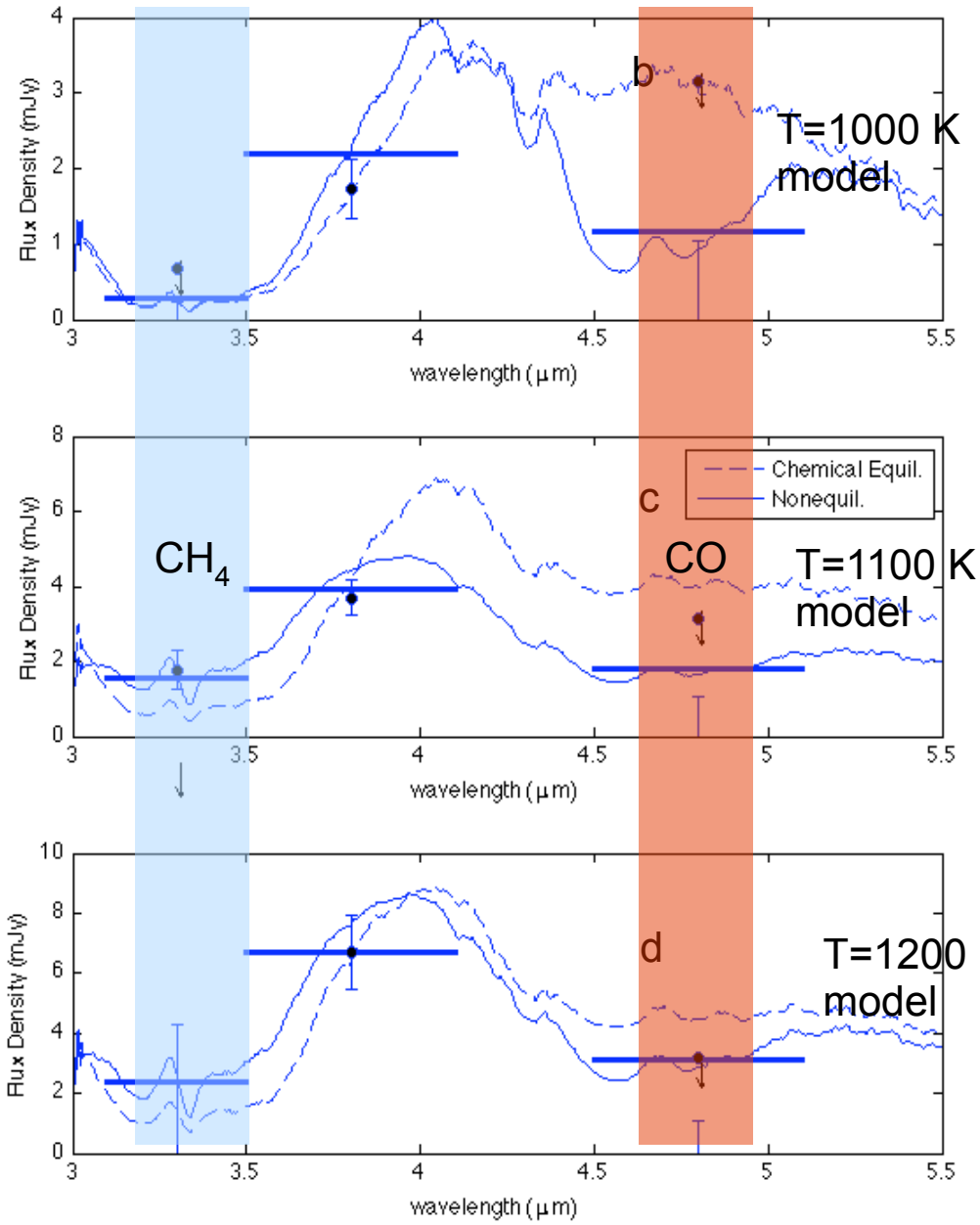
- Relatively massive planets (7, 10, and 10 MJ)
- Planets in wide orbits.

MMT observations of the planets around HR 8799



Hinz et al. 2009, submitted

- All three planets detected at L'
- Upper limits of M=14.7 set for all three objects.
- c is detected at 3.3 μm.
- Data broadly consistent with Marois results.



Saumon models (2006)

Model Spectrum

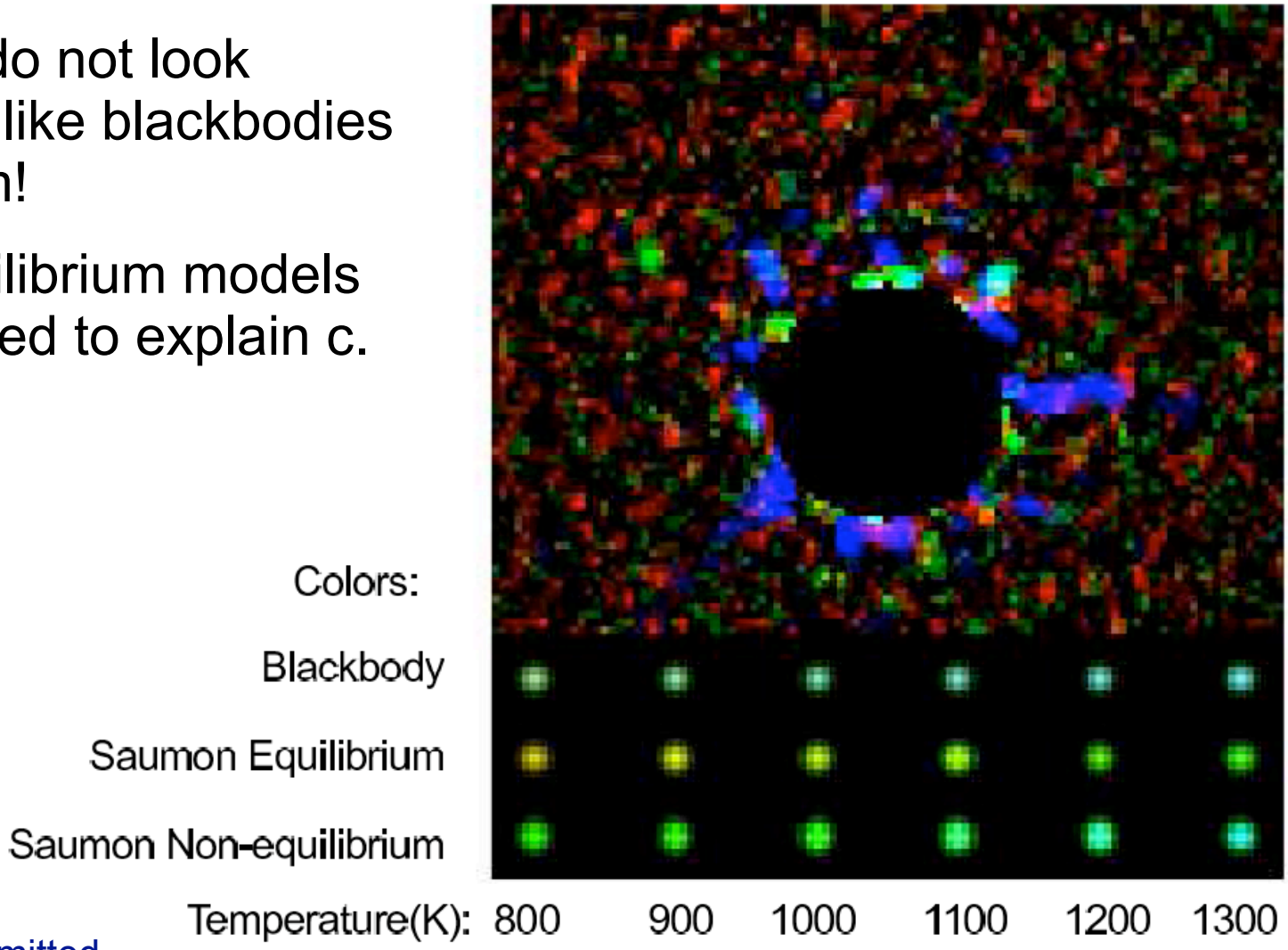
Objects appear bluer than expected from equilibrium models

Vertical mixing can explain the colors.

Hinz et al. 2009, submitted

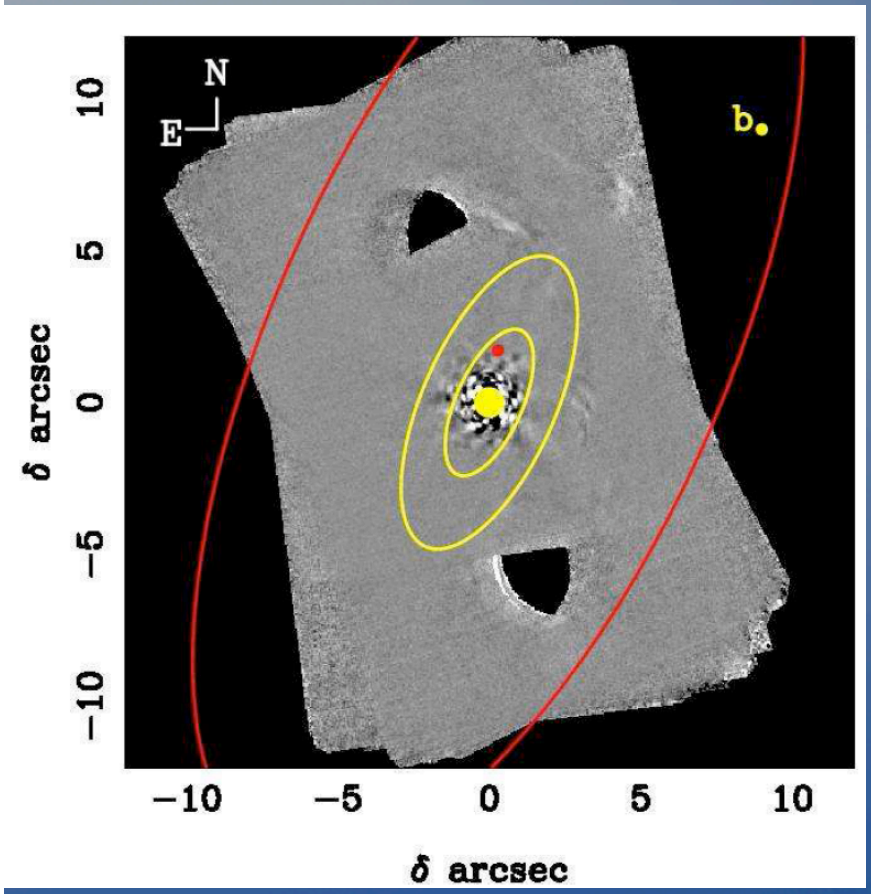
False Color Image in the Thermal-IR

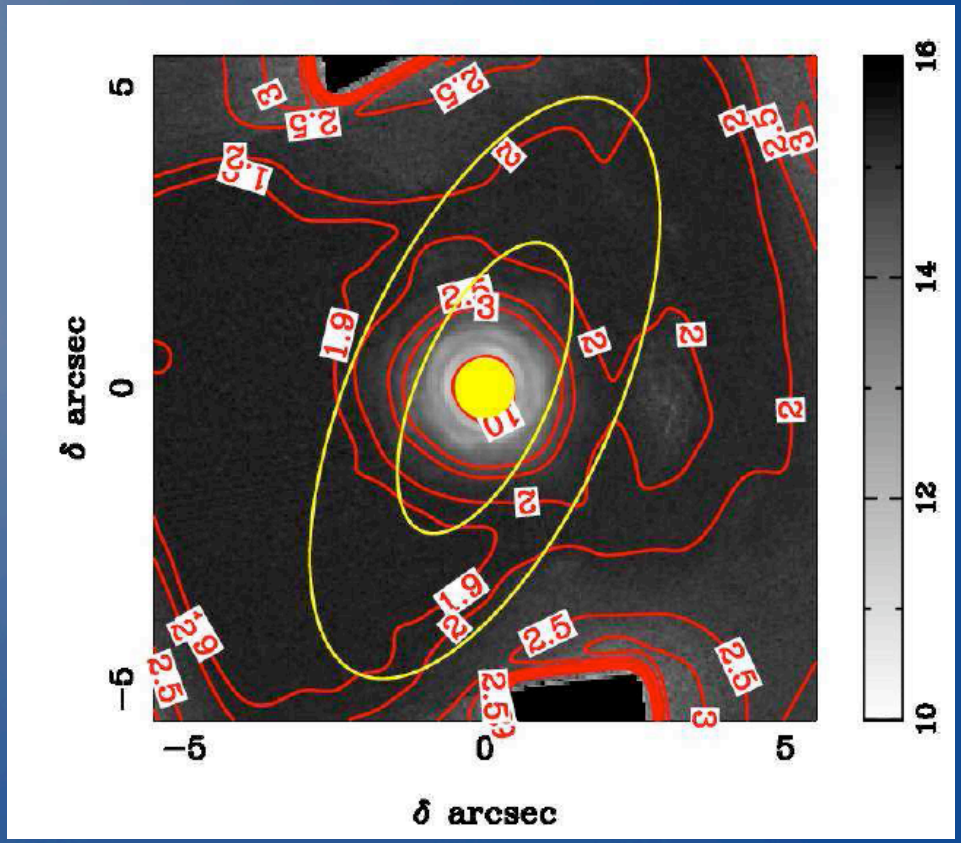
- Planets do not look anything like blackbodies at 3-5 μm!
- Non-equilibrium models are needed to explain c.



Hinz et al. 2009, submitted

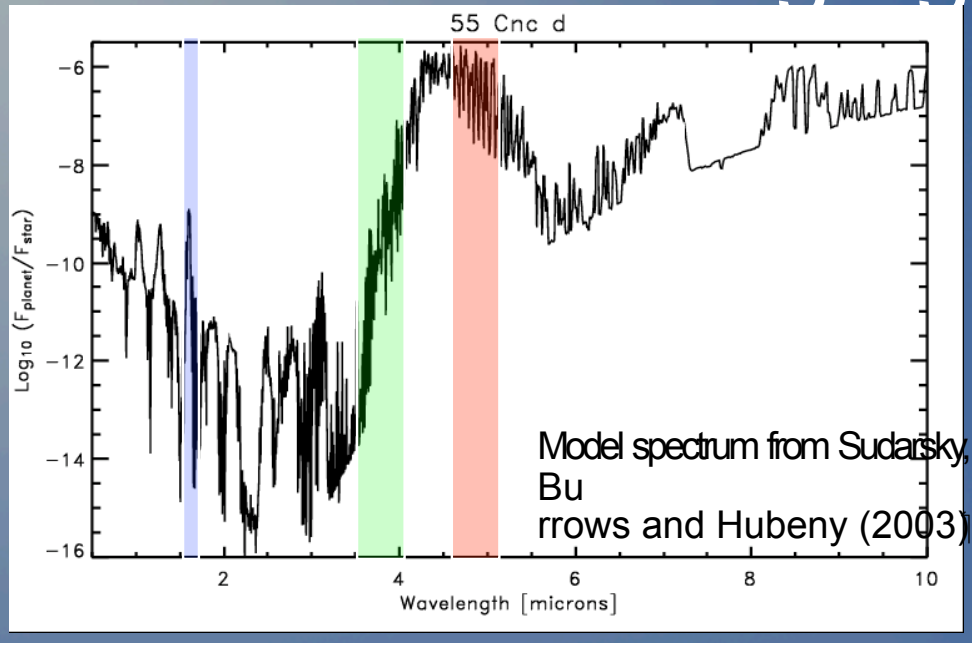
Fomalhaut Constraints





Kenworthy et al. 2009

Motivation for Imaging in Thermal IR

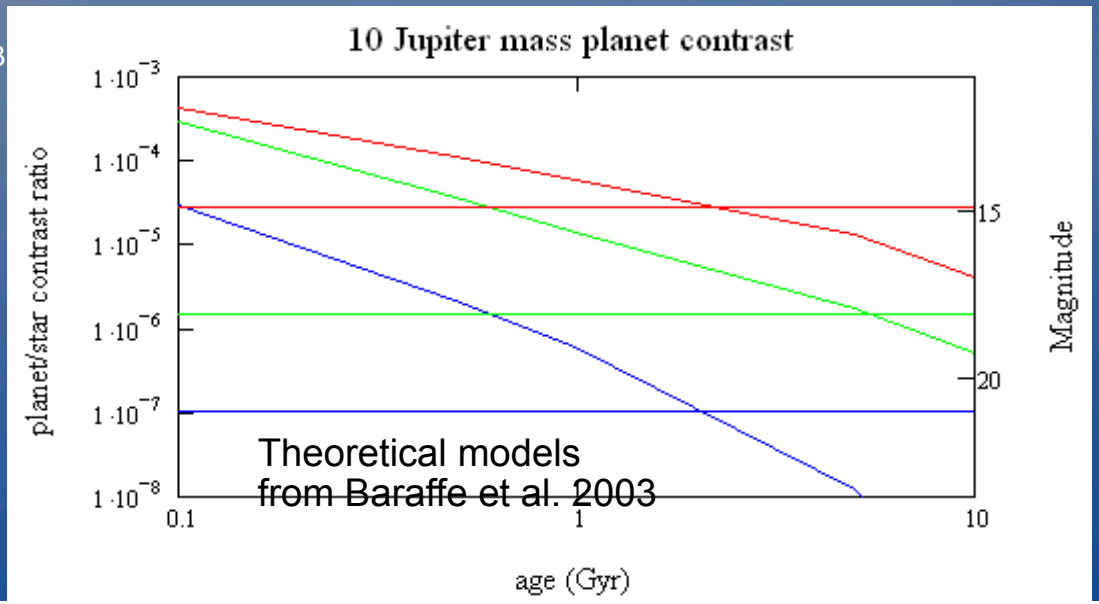


10^{-6}

10^{-10}

Conventional AO systems have focused on H band detection

The anomalous brightness of gas giant planets at 4-5 microns allows for improved contrast.



10^{-3}

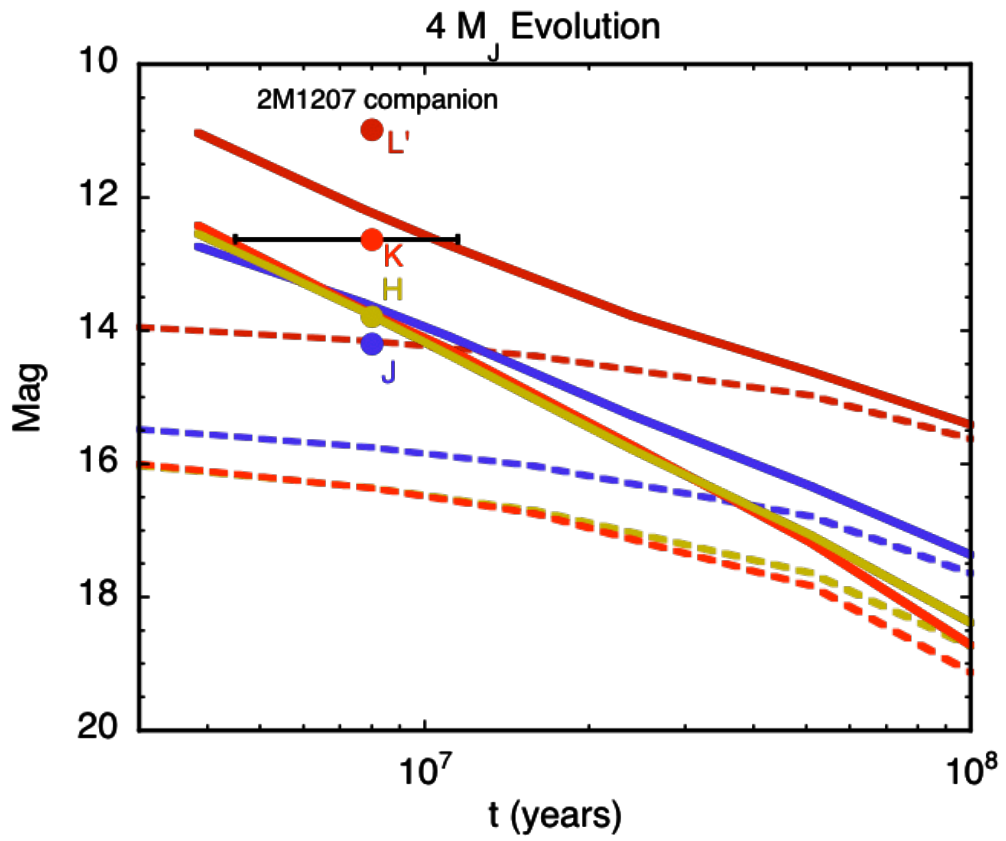
10^{-8}

M photometric limit

L' photometric limit

H photometric limit

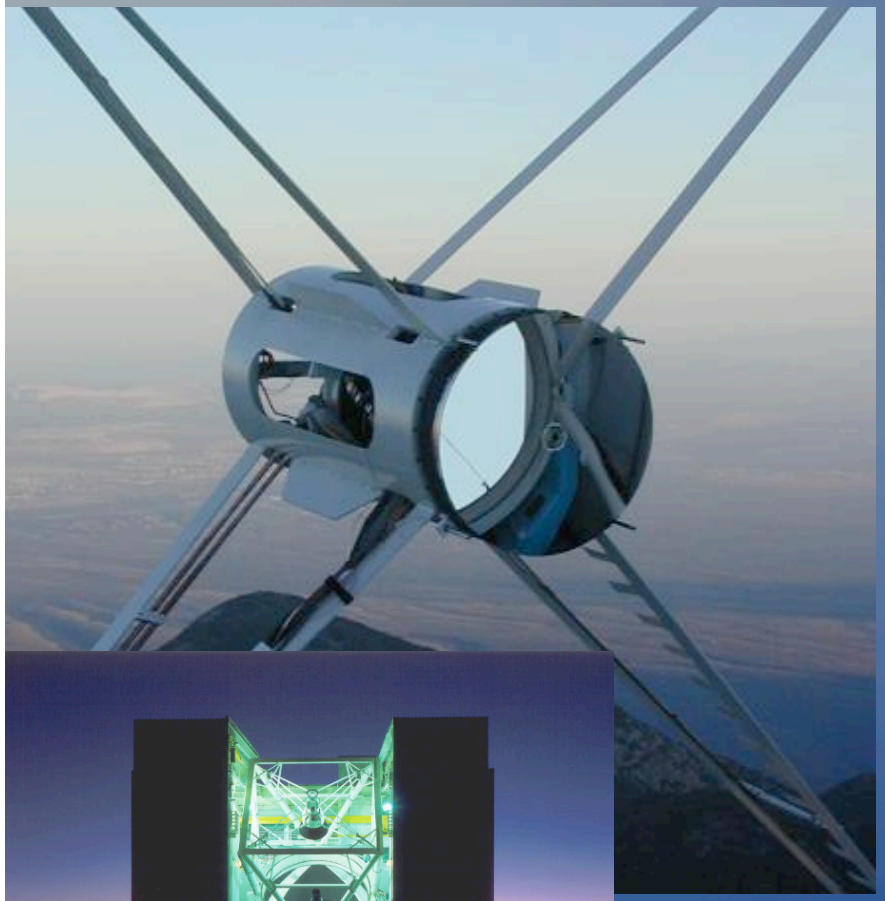
Cold Start Models suggest young planets may be fainter

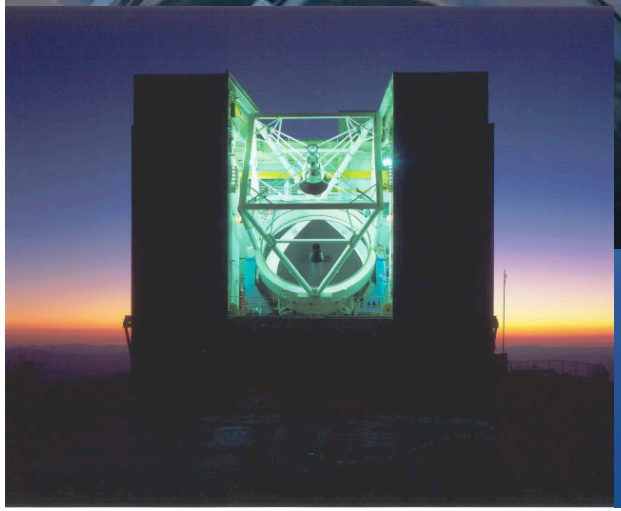


- Less of a discrepancy at older ages
- Smaller effect at L' and M

From Fortney et al. 2008

AO in the thermal IR

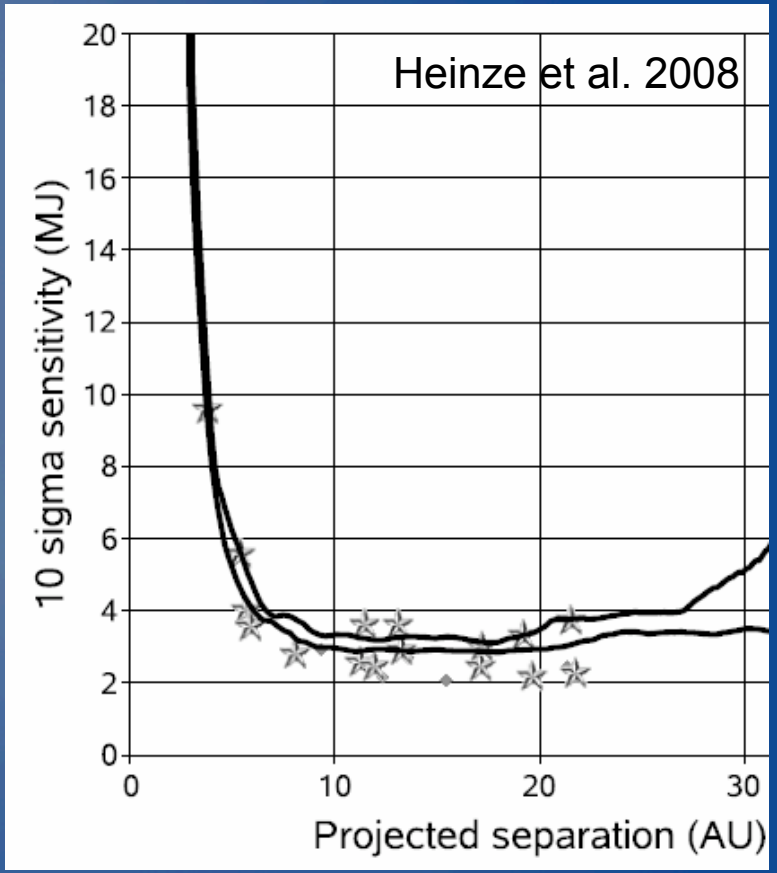




- AO is integrated into the telescope.
- 2 mm glass shell deformed by 336 actuators
- Unlike conventional AO, no reimaging optics are needed.
  - Good for thermal background
- First light in 2002
  - Routine operation begun in 2005

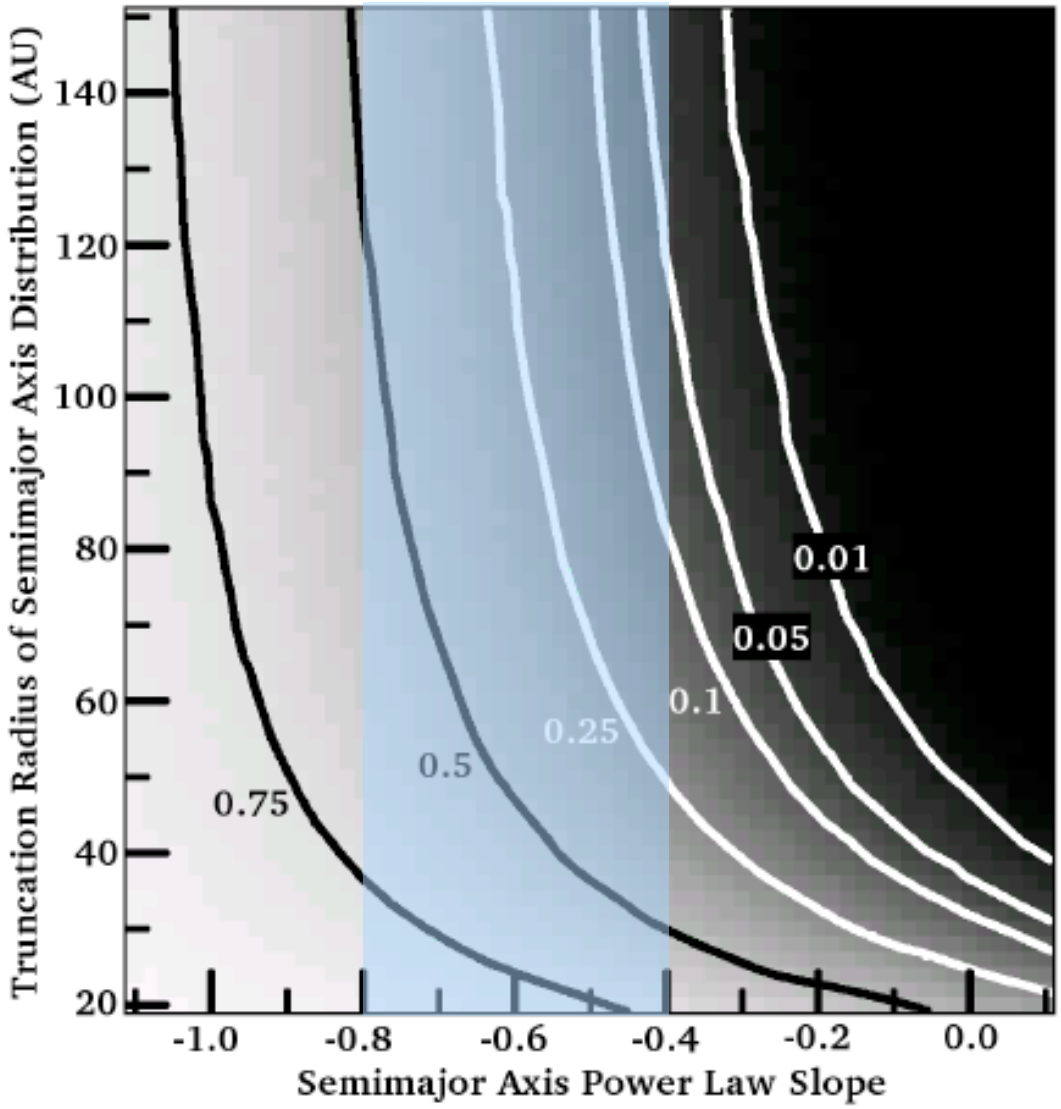
Thermal IR surveys with the MMT

- Survey of 54 FGK stars lead by Ari Heinze
- Survey of 32 M star lead by Daniel Apai
- Survey of 25 A stars lead by Eric Mamajek



See Heinze et al. 2008 and Kenworthy et al. 2009 for example results

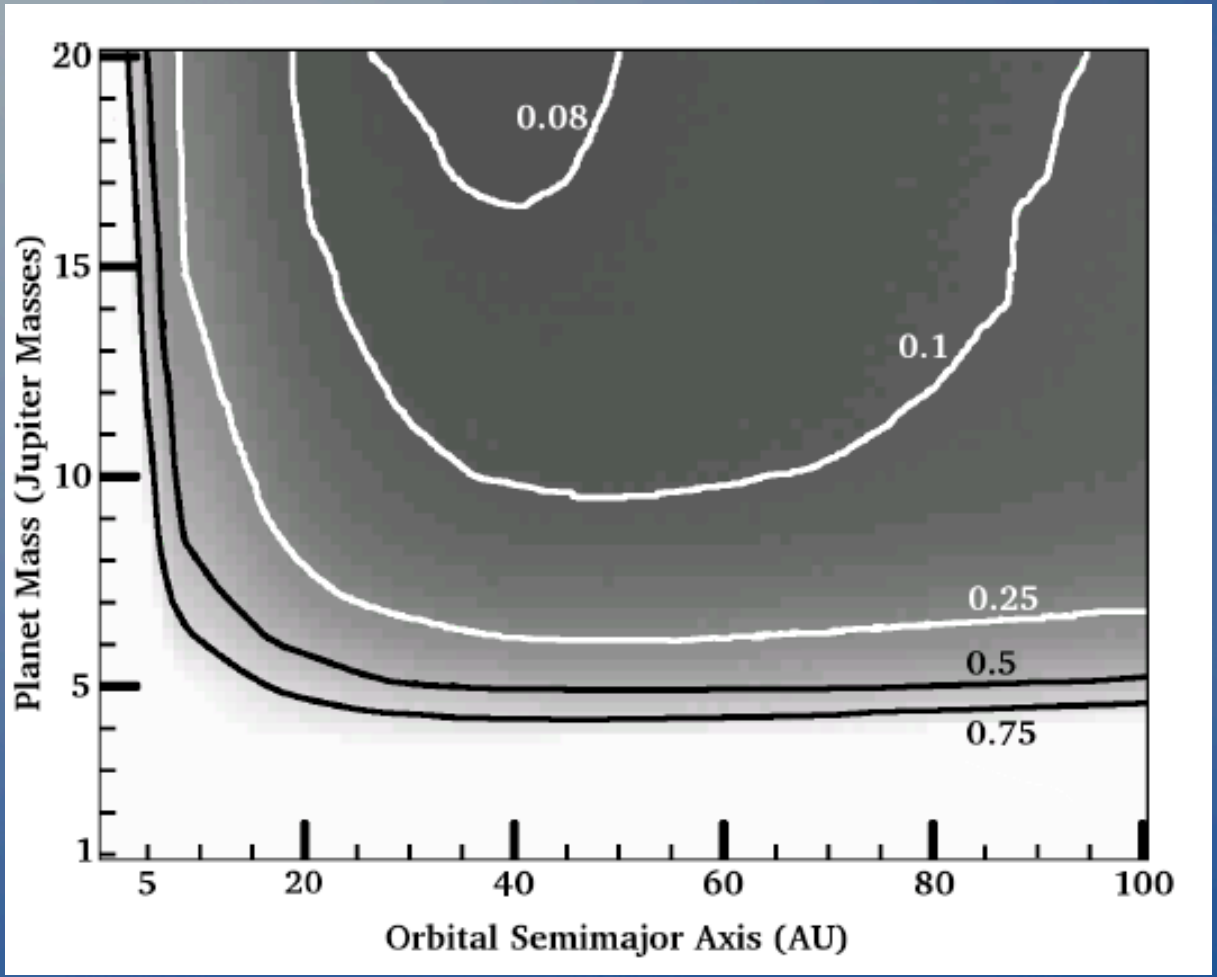
Planet Limits from Survey



- We can extrapolate RV results to test whether the populations are the same.
- Suggests planet systems have outer cutoffs of < 100 AU

Heinze et al. 2009, submitted

Model-Independent Limits



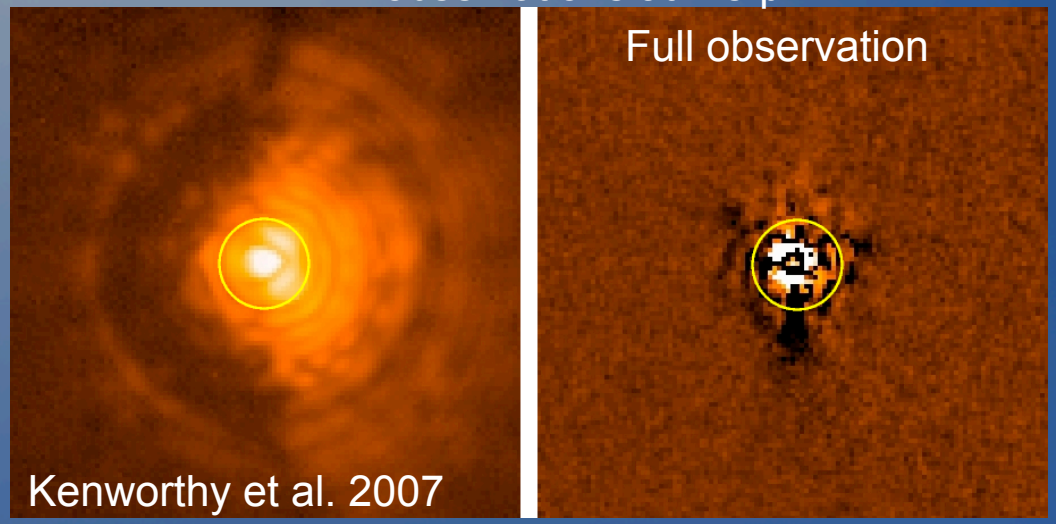
- Less than 8% of FGK stars have planets similar to HR 8799

Heinze et al. 2009, submitted

High Contrast Improvement

- Phase Apodization Coronagraphy has been demonstrated to achieve 10^{-5} at 3 λ/D

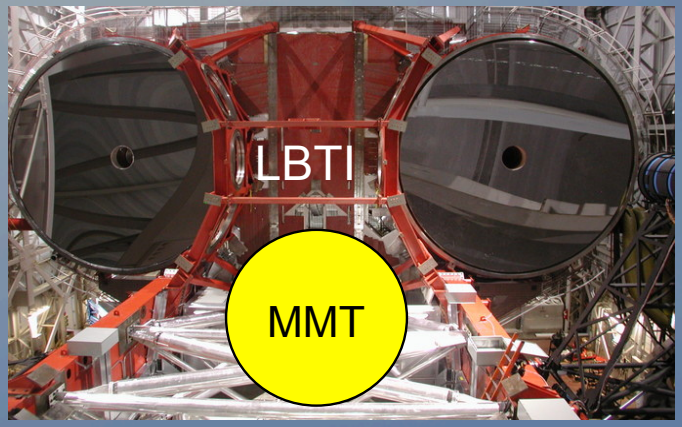
MMT observations at 4.8 μm

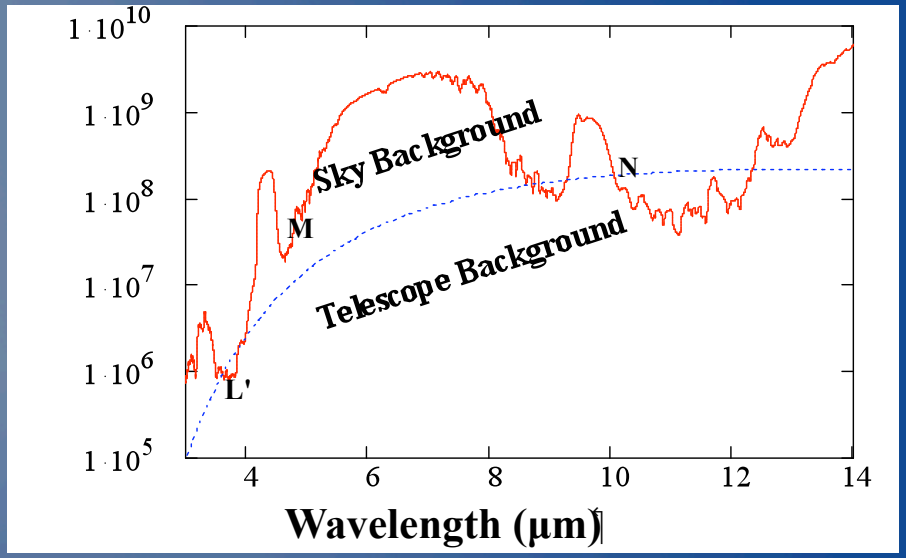


Inner Working Angle
Is half that of direct
Imaging results

- Matt Kenworthy is leading a survey to explore the ice line region around nearby stars with this technique.

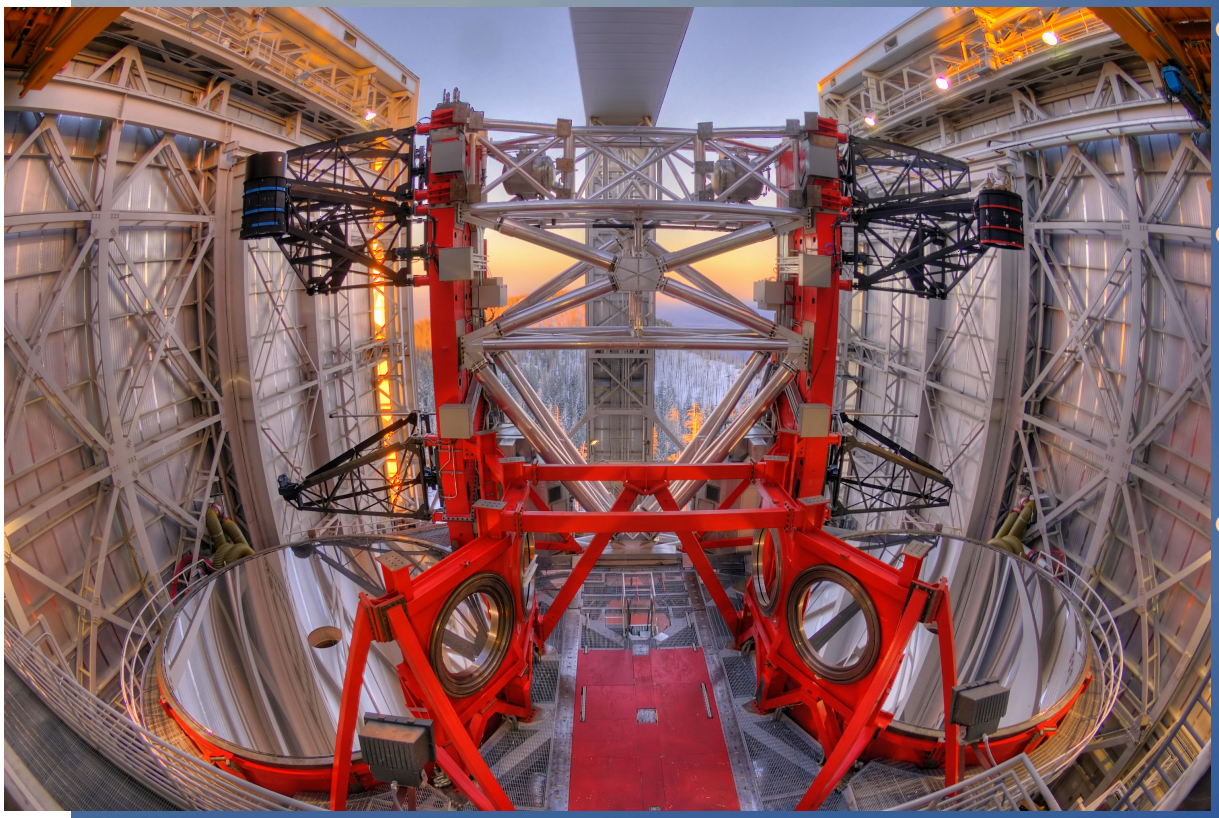
The Large Binocular Telescope





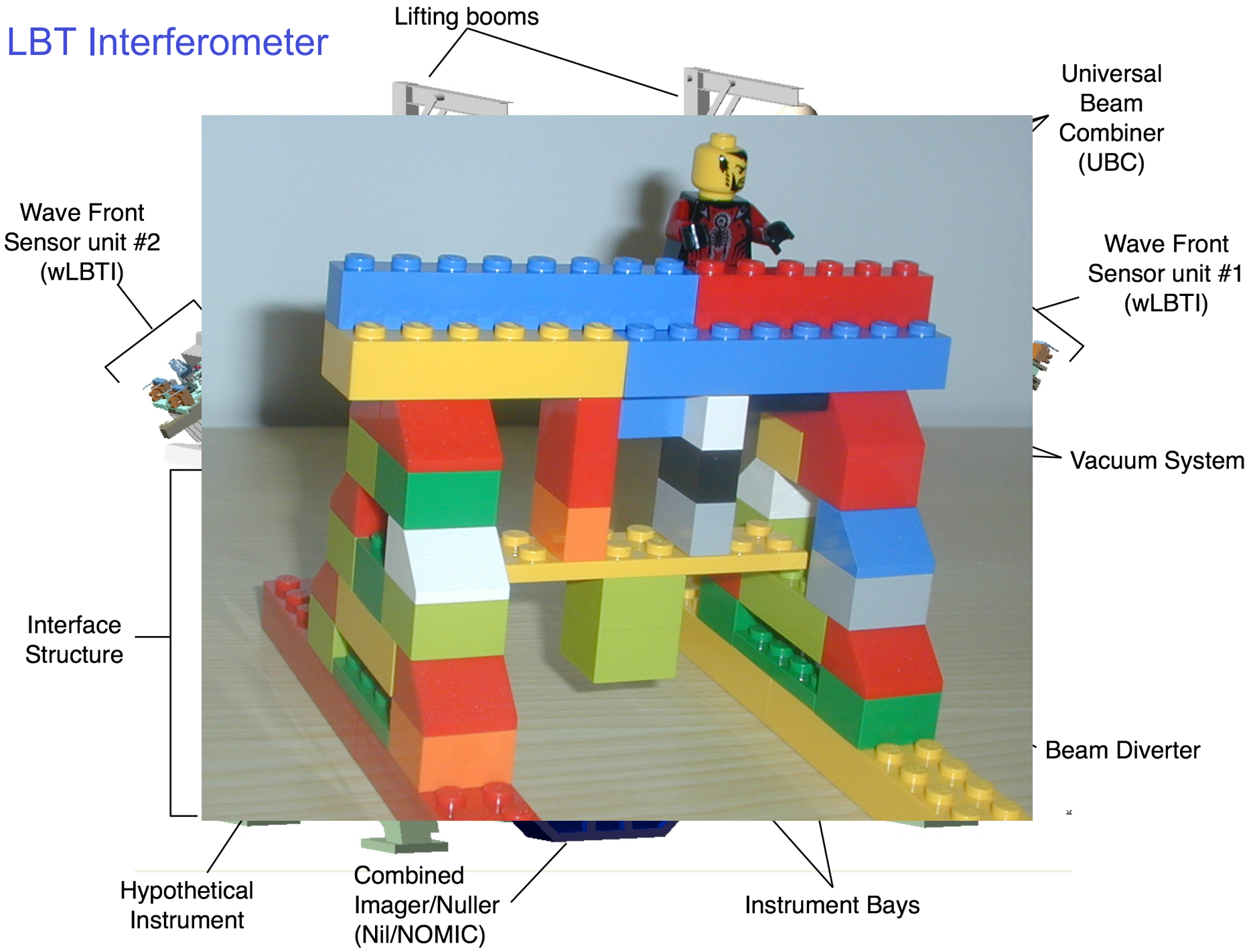
- 2x8.4 m apertures on a 14.4 m baseline
- Adaptive Secondary Mirrors
- Interferometers are mounted on telescope
  - Simple optical arrangement
  - Low background

Telescope Status

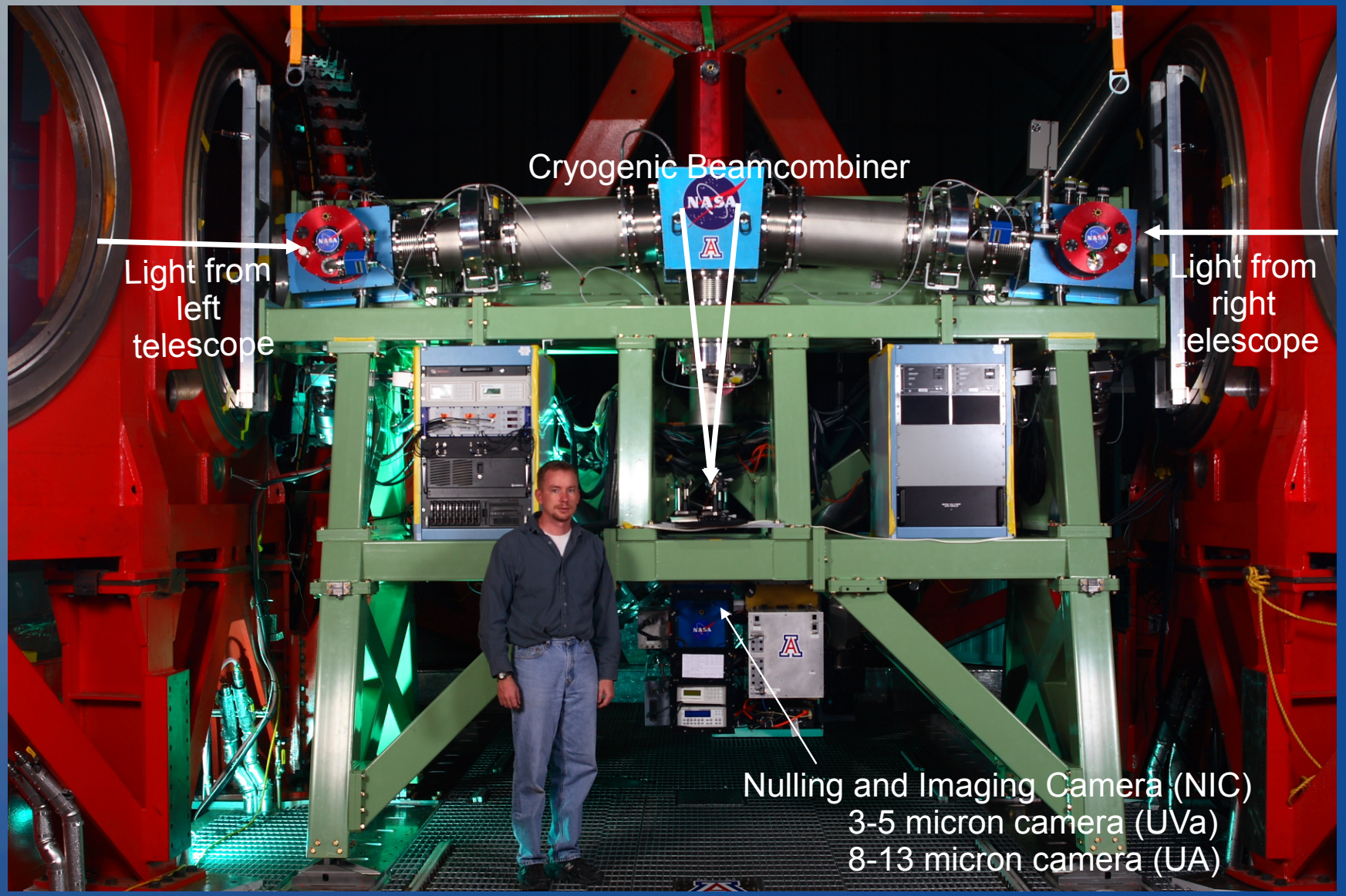


- Fixed secondary installed on left side
- AO secondary will be commissioned in Spring 2010.
- Two AO secondaries planned for late 2011.

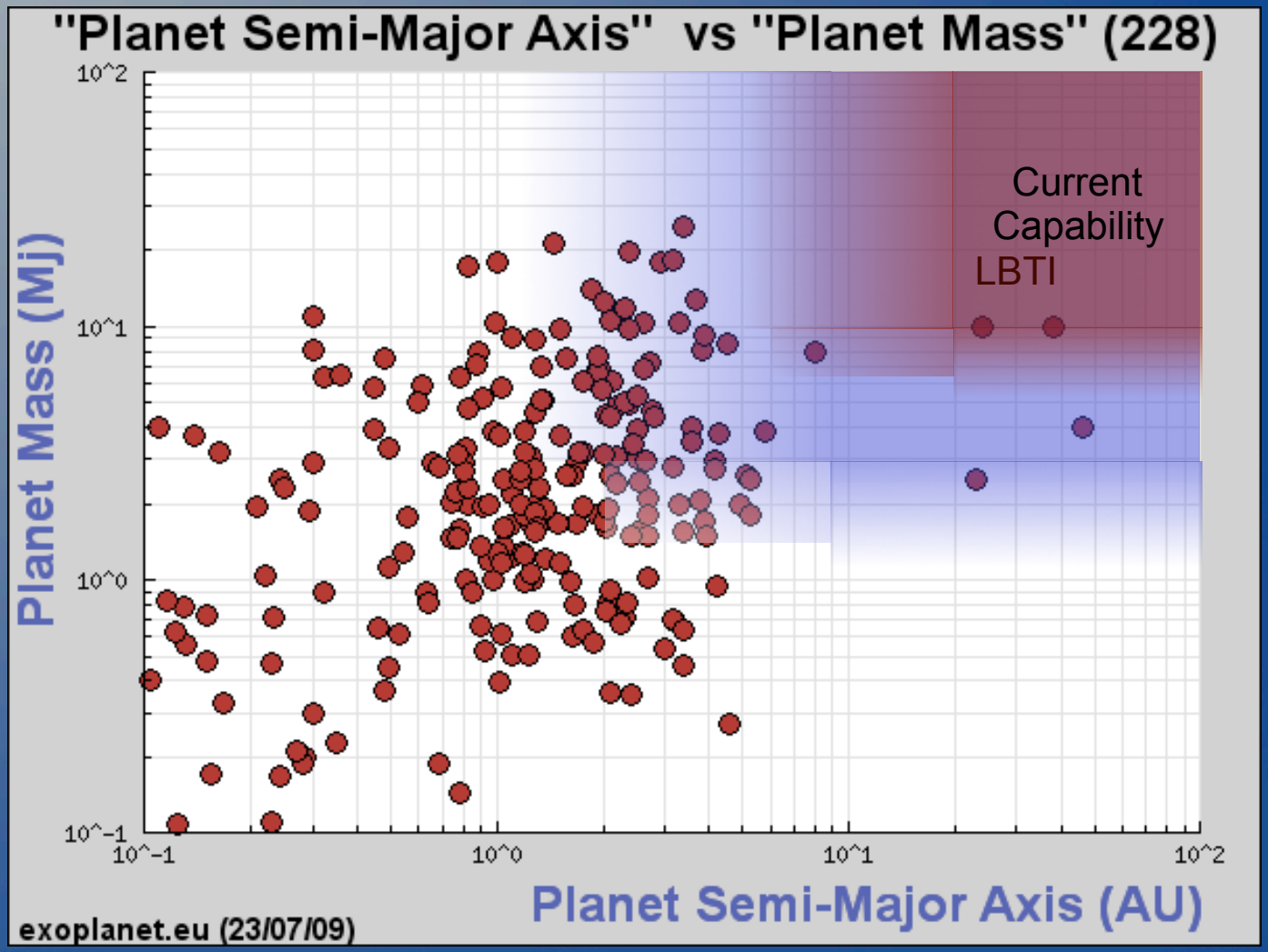
LBT Interferometer



LBT Interferometer



LBTI Phase Space



Summary

- The 3-5 μm range is a useful region for constraining the physical conditions of cool objects.
  - HR 8799 planets appear to have significant chemical non-equilibrium, similar to brown dwarfs.
- FGK star survey has constrained outer planets around more mature, nearby stars, relative to NIR surveys.
  - Wide period, massive planets are not common
  - Consistent with NIR surveys (and a good cross-check)
- LBTI will probe similar systems to ~1-3 MJ planets at 1-3 AU.