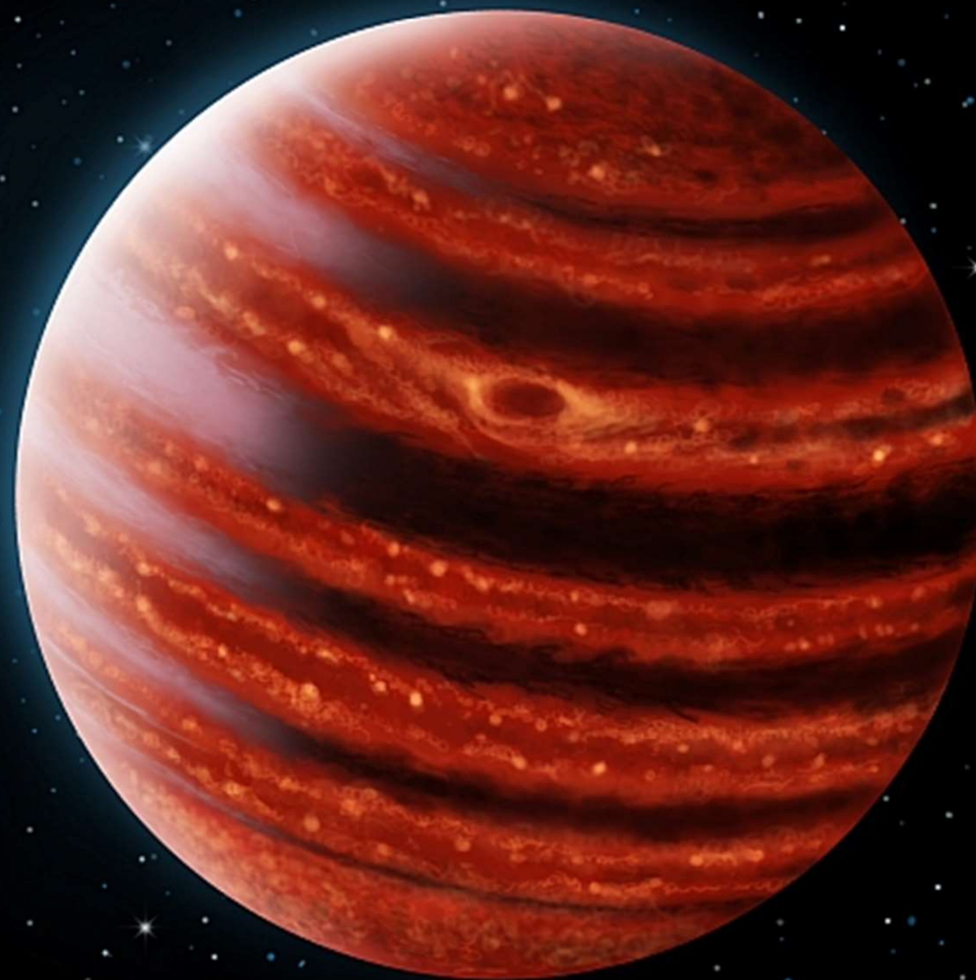
High Contrast Imaging and Adaptive Optics for Nearby Stars and Planetary Systems



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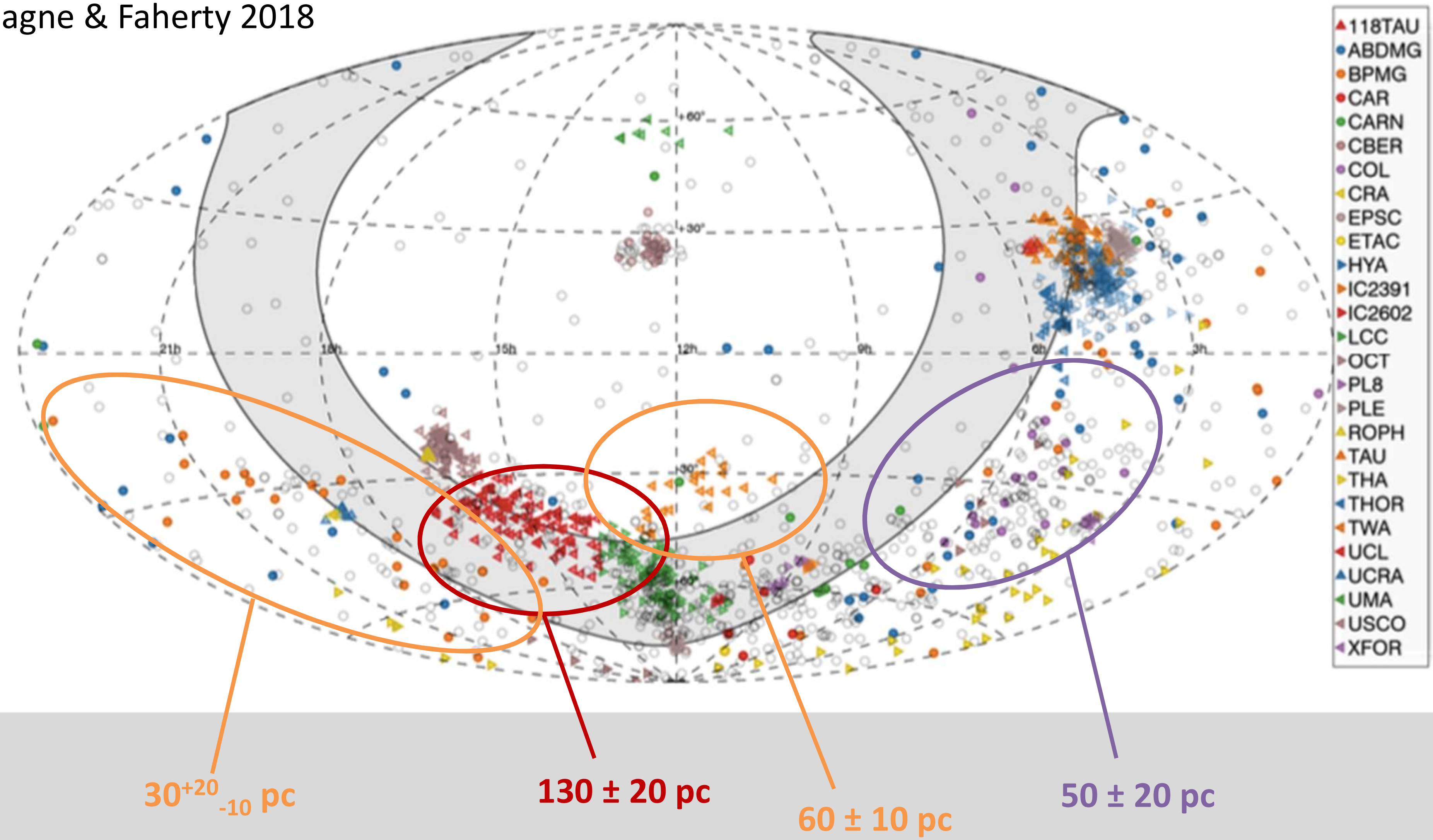
For direct imaging, two criteria are currently important for successful targets – nearby AND young

Gagne & Faherty 2018



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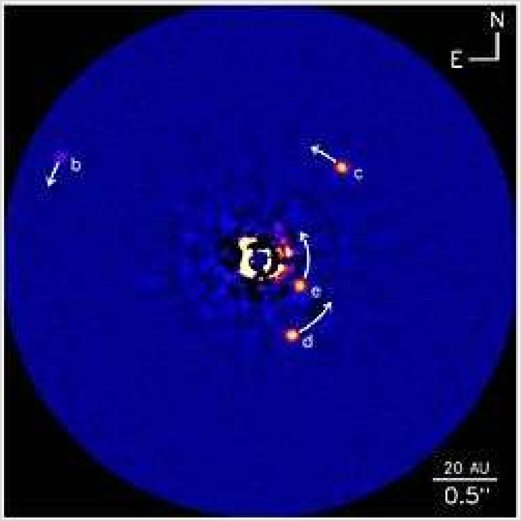
Using early generation AO systems and cameras, discoveries were exciting but surveys hinted that wide Jovians were rare.

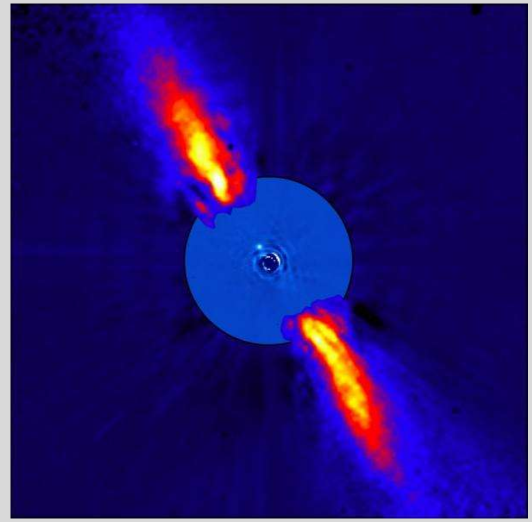
HR 8799bcde



Marois et al. 2008,2010

41 pc
15, 27, 43, 68 AU
~30-40 Myr
4-7 M_{Jup}

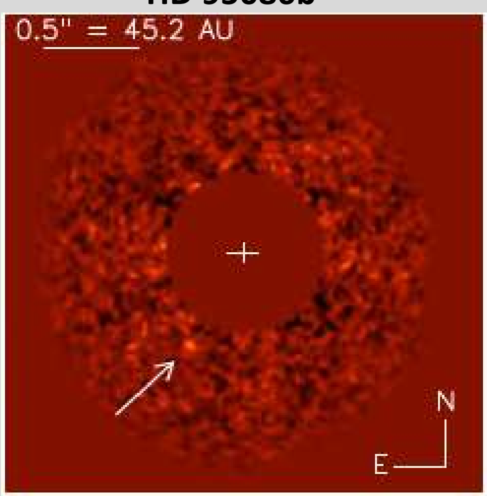
Beta Pic b



Lagrange et al. 2009

19 pc
12 AU
~25 Myr
13 M_{Jup}

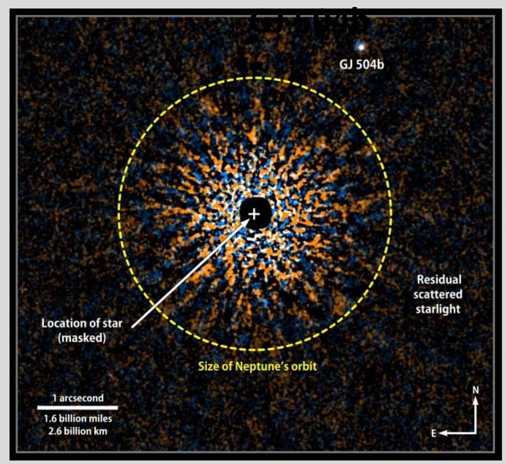
HD 95086b



Rameau et al. 2013

86 pc
62 AU
~17 Myr
4 M_{Jup}

GJ 504b



Kuzuhara et al. 2013

18 pc
44 AU
<1.5 Gyr
3-35 M_{Jup}

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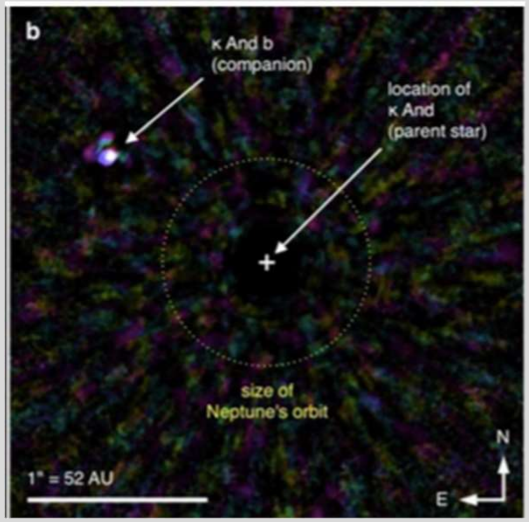
Surveys have also revealed a number of brown dwarf companions, highlighting the challenge of distinguishing substellar companion type in direct imaging.

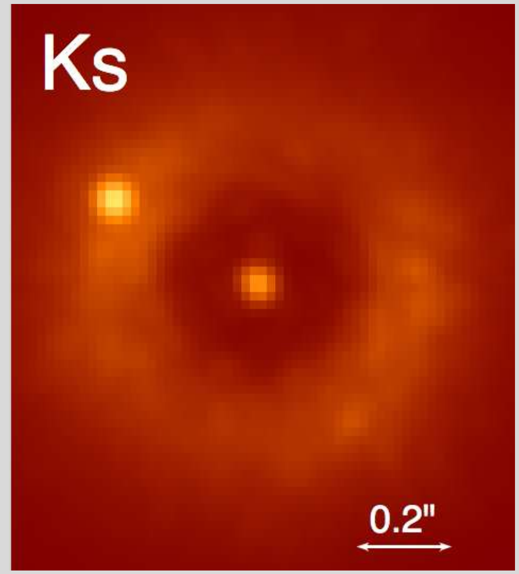
Kappa And B



Carson et al. 2013

52 pc
100 AU
~30-300 Myr
12-40 M_{Jup}

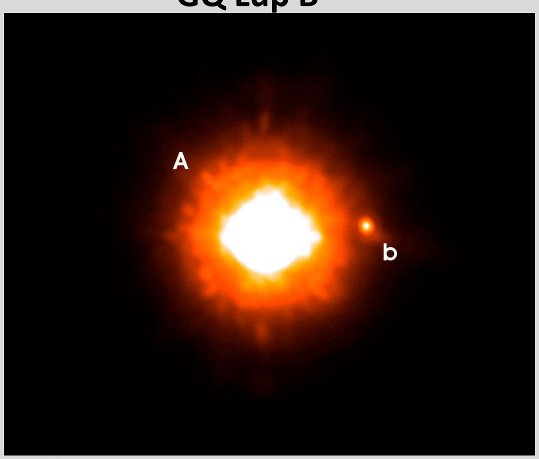
PZ Tel B



Biller et al. 2010

52 pc
20 AU
~25 Myr
~21 M_{Jup}

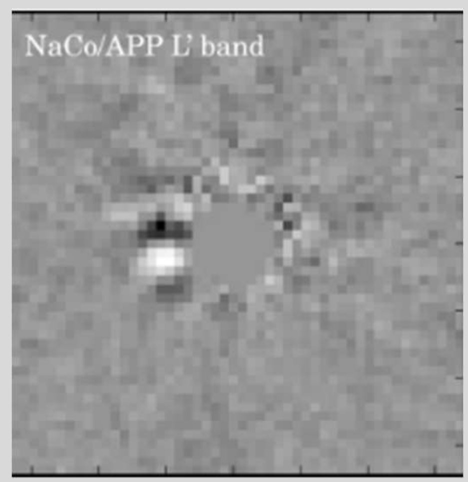
GQ Lup B



Neuhauser et al. 2005

156 pc
110 AU
~5 Myr
20-30 M_{Jup}

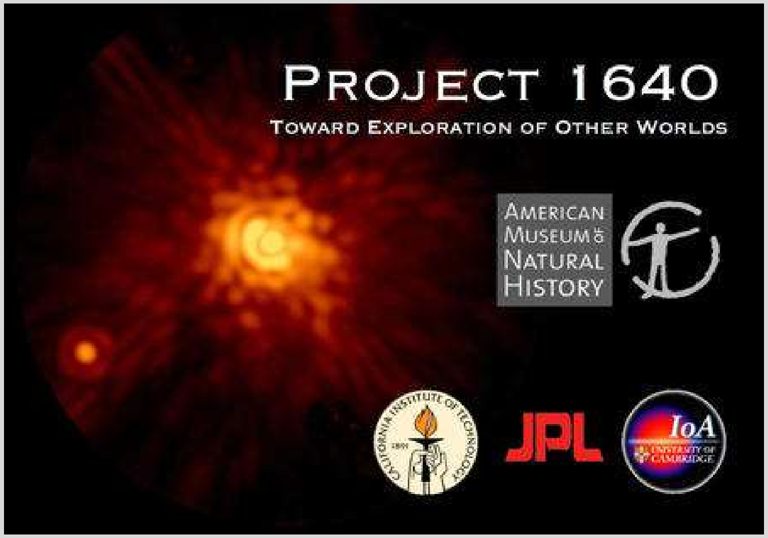
HD 984 B



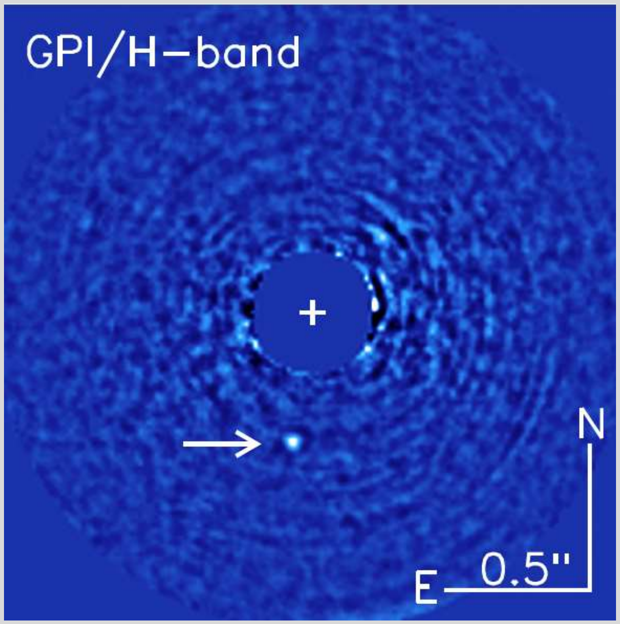
Meshkat et al. 2015

46 pc
18 AU
~115 Myr
33-96 M_{Jup}

The newest generation of high contrast imagers are optimized to look for fainter and/or closer companions.

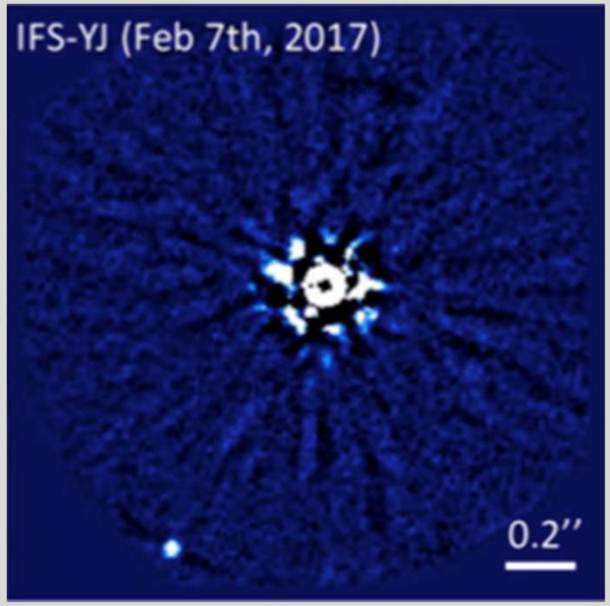


These new instruments have only revealed a few more planets than were detected with previous generation instruments.



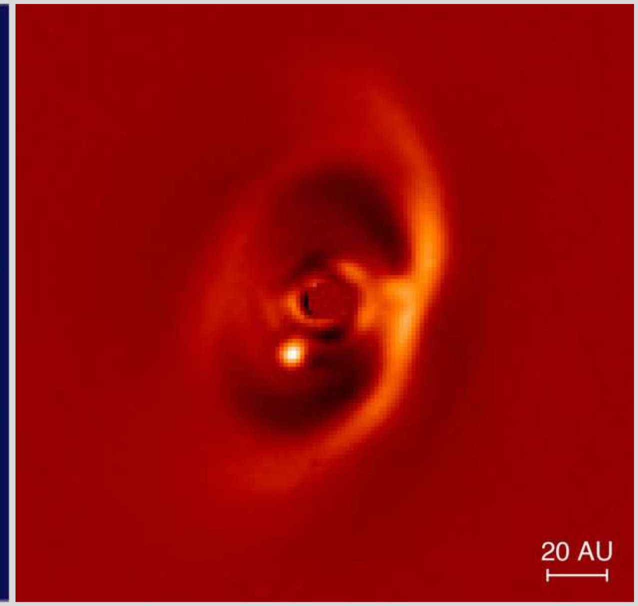
51 Eri b, Macintosh et al. 2015 (GPI)

30 pc
13 AU
~25 Myr
2-10 M_{Jup}



HIP 65426b, Chauvin et al. 2017 (SPHERE)

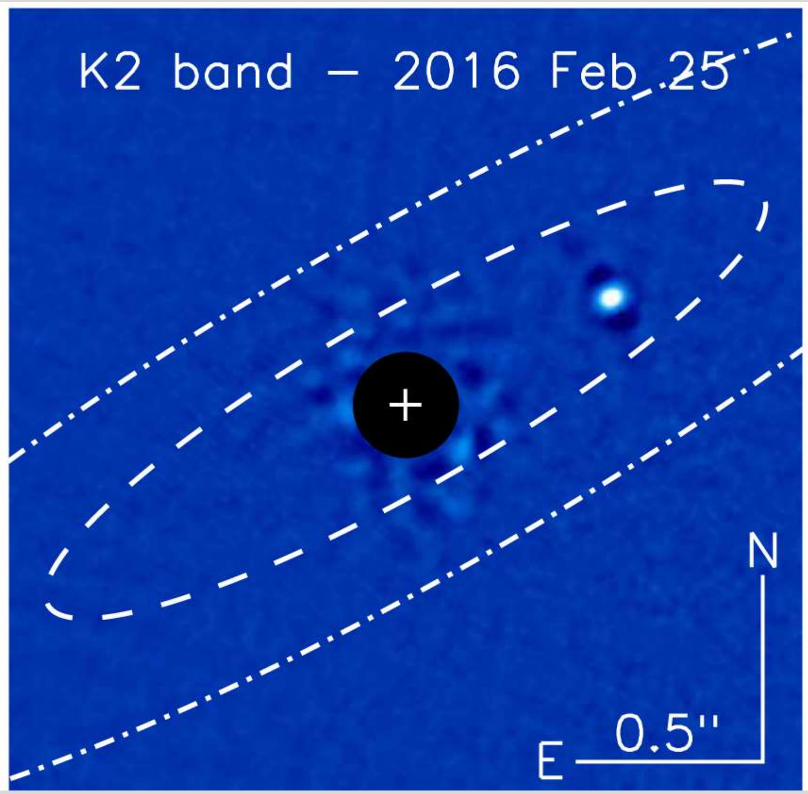
110 pc
92 AU
~17 Myr
6-12 M_{Jup}



PDS 70b, Keppler et al. 2018,
Müller et al. 2018 (SPHERE)

113 pc
22 AU
~5 Myr
5-14 M_{Jup}

New brown dwarfs have been detected, several in an interesting class of sources that orbit interior to debris disks.



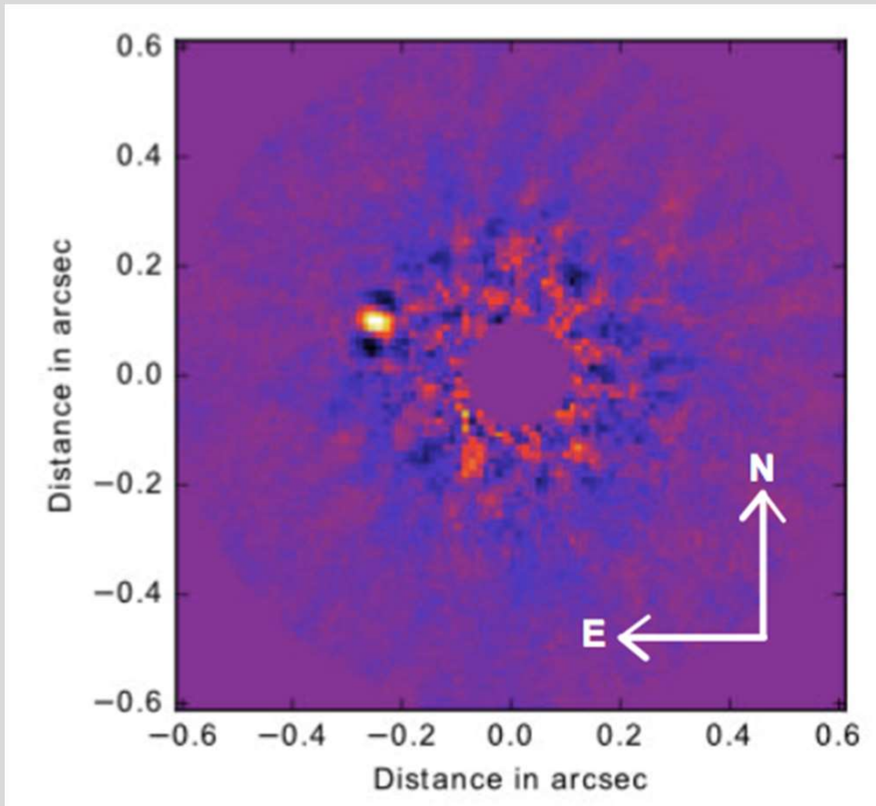
HR 2562B, Konopacky et al. 2016 (GPI)

34 pc

20 AU

<1 Gyr

15-45 M_{Jup}



HD 206893B, Milli et al. 2017 (SPHERE)

41 pc

10 AU

~500 Myr

24-73 M_{Jup}

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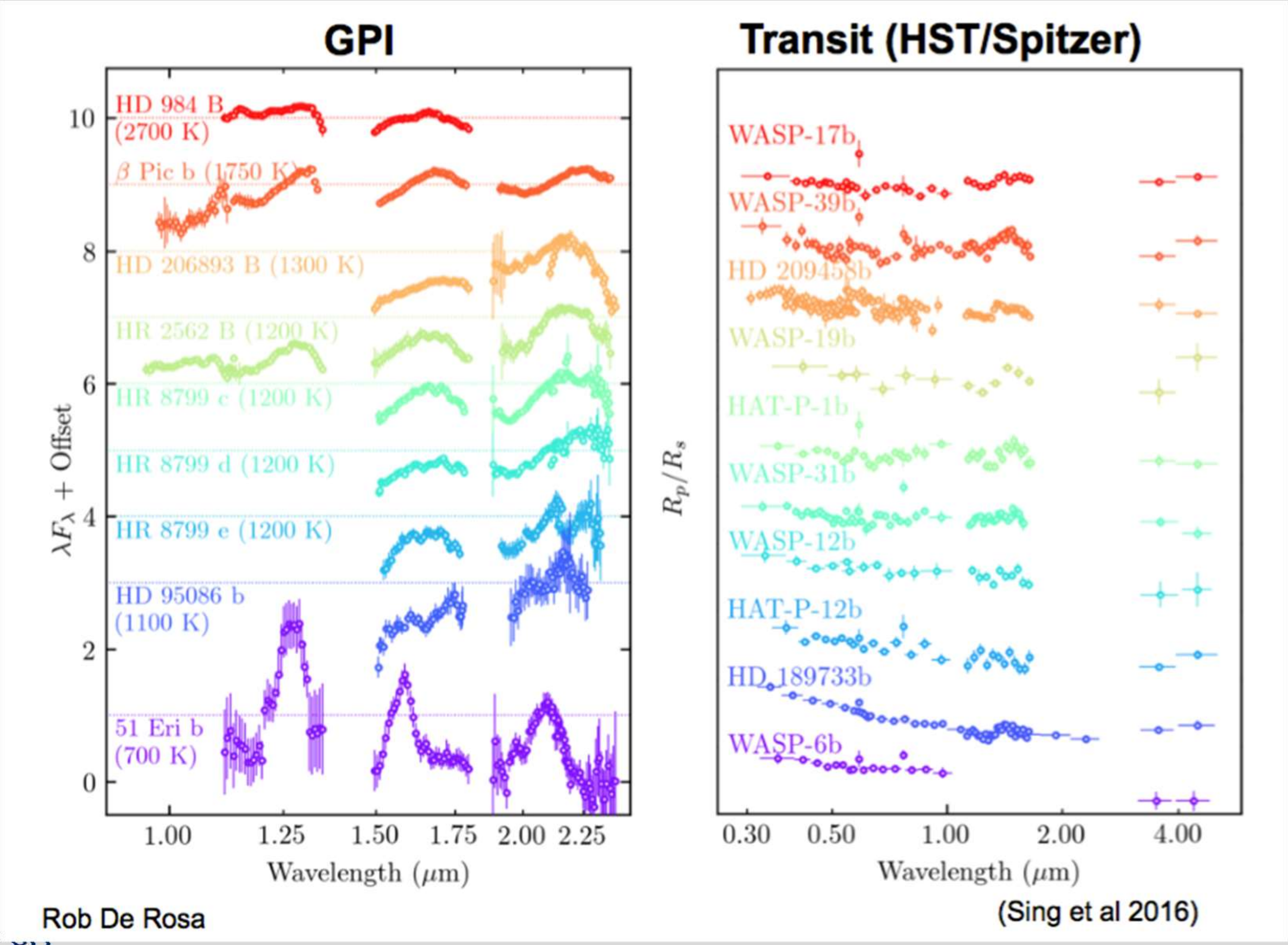
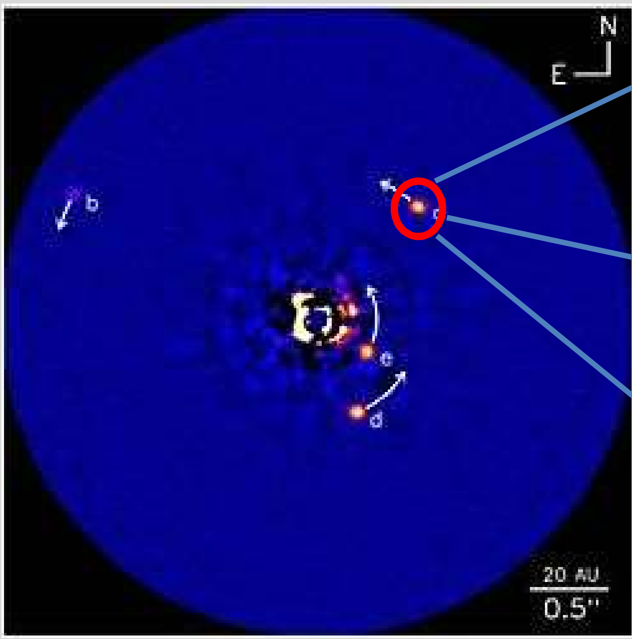
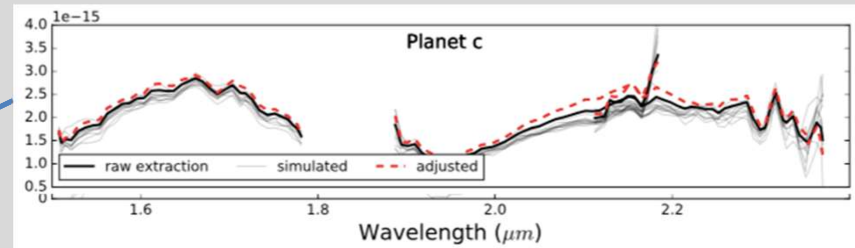
The spectral libraries are yielding powerful insights into atmospheric properties, highlighting the advantages of direct imaging.



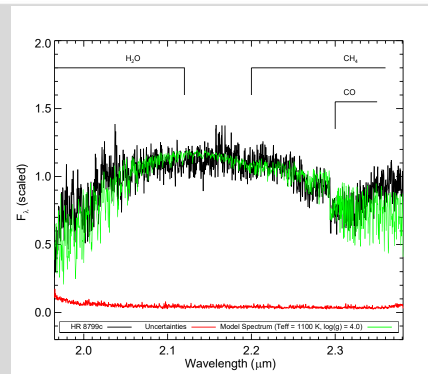
The march to higher spectral resolution observations continues, with new success.



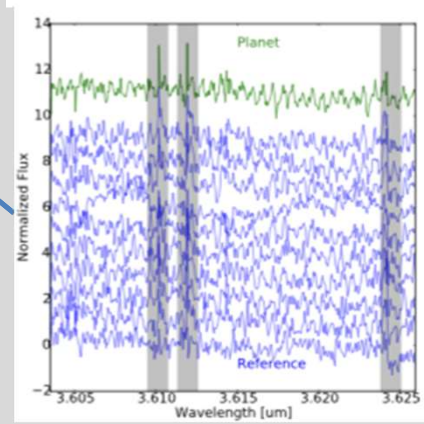
HR 8799c



Greenbaum et al. 2018

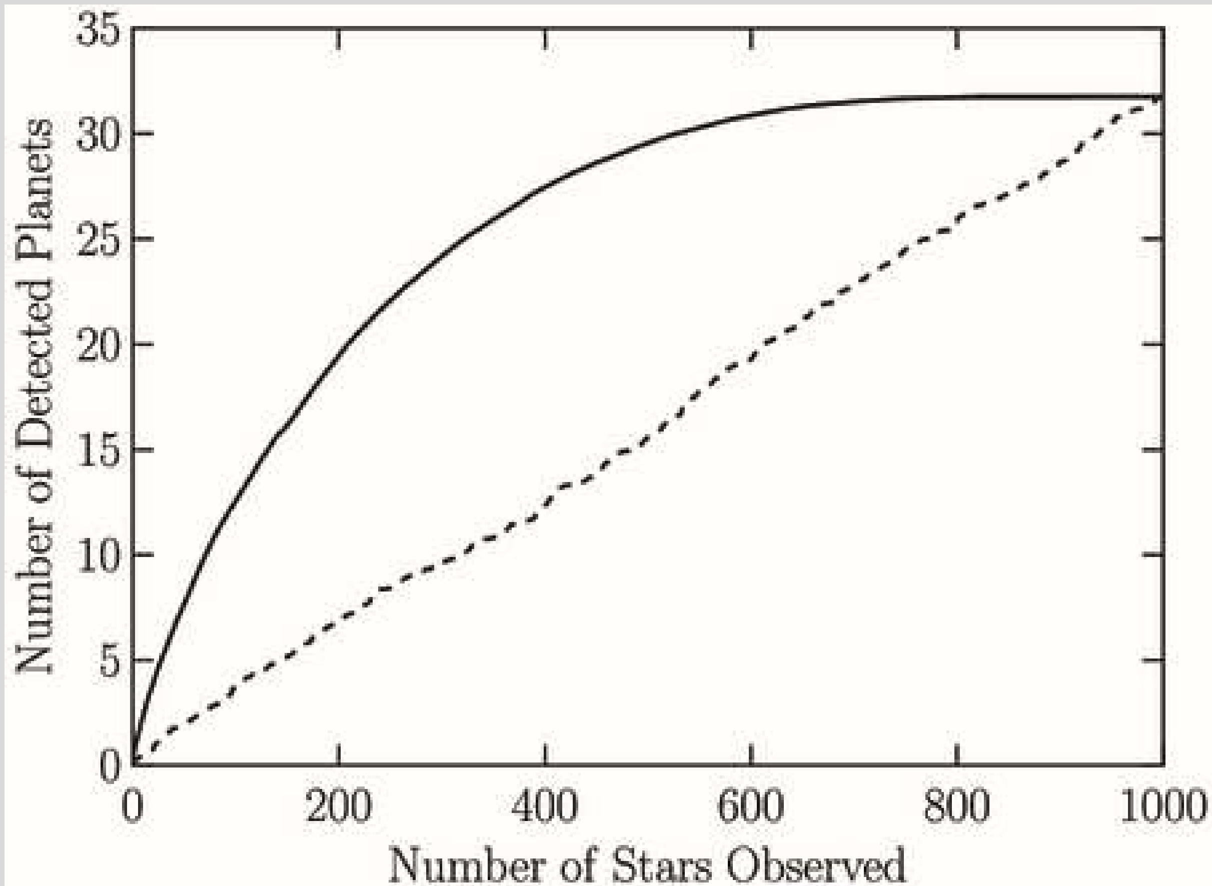


Konopacky et al. 2013



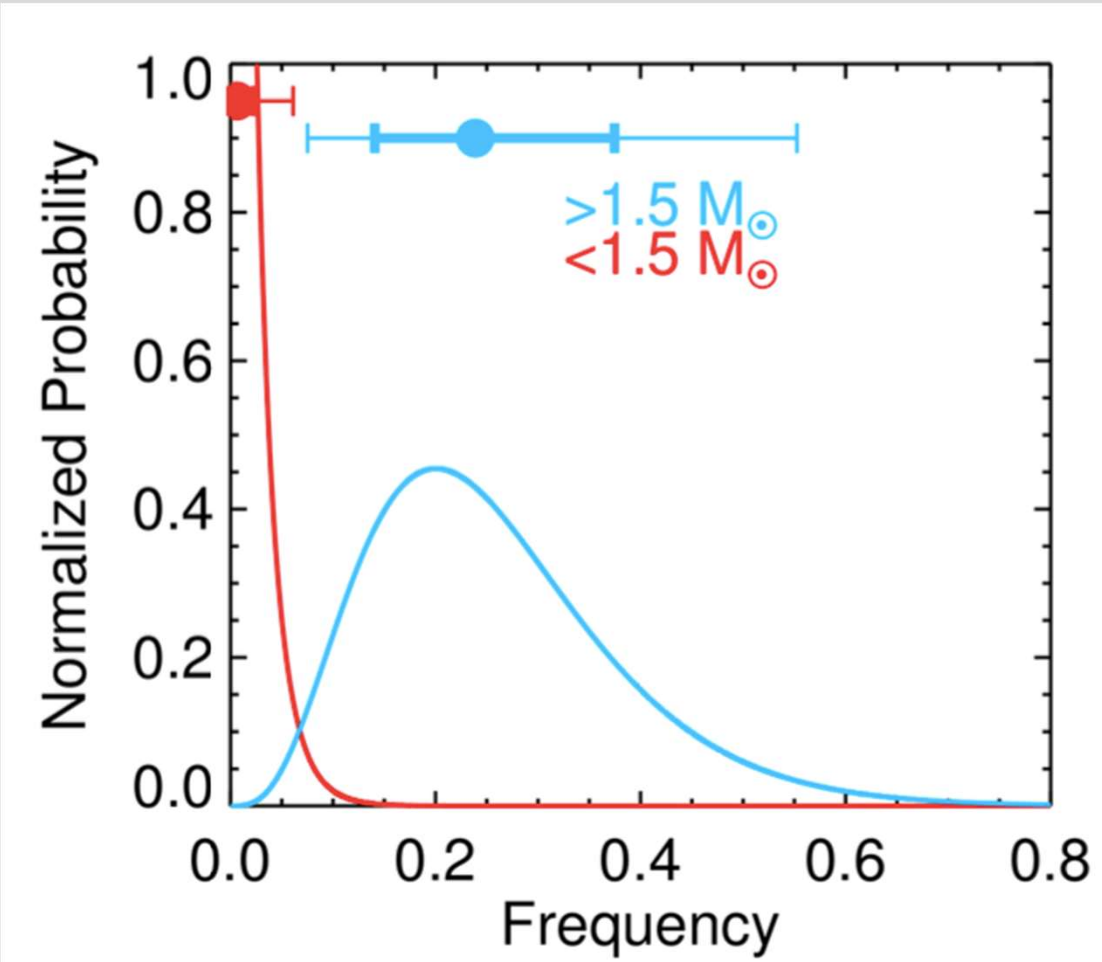
Wang et al. 2018

Overall planetary mass yields are low compared to early predictions based on extrapolation from RV samples.



McBride et al. 2011 predictions for GPIES

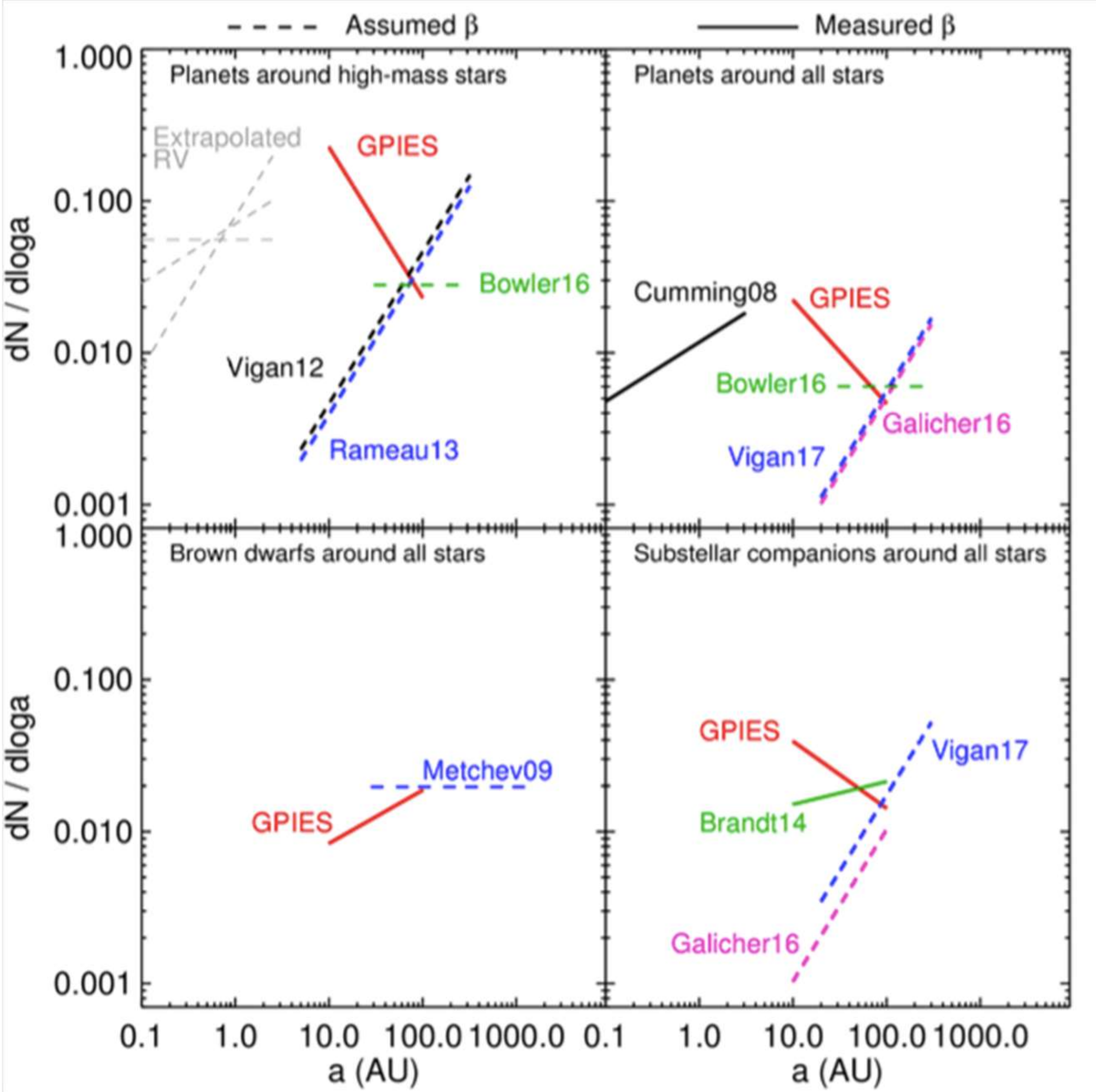
With first 300 stars observed with GPI survey, we are beginning to see important trends.



Nielsen et al. submitted

- Gas giant planets between 3-100 AU are much more likely around stars with >1.5 $M_\odot$
- Occurrence rate of gas giants between 5-13 M_{jup} between 10-100 AU around stars >1.5 $M_\odot$ is 9^{+5}_{-4}%
- Occurrence rate of brown dwarfs 13-80 M_{Jup} is $0.8^{+0.8}_{-0.5}$% (similar to previous estimates)

We have tentative evidence for different populations of objects (planets vs. brown dwarfs)



- Rising number of planets with decreasing semi-major axis could suggest **a peak between 3-10 AU**
- Such a peak is consistent with notional core accretion models of planet formation
- Brown dwarf distribution does the opposite, suggesting distinct populations
- Number of giant planets per star overall <0.25

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Nielsen et al. submitted

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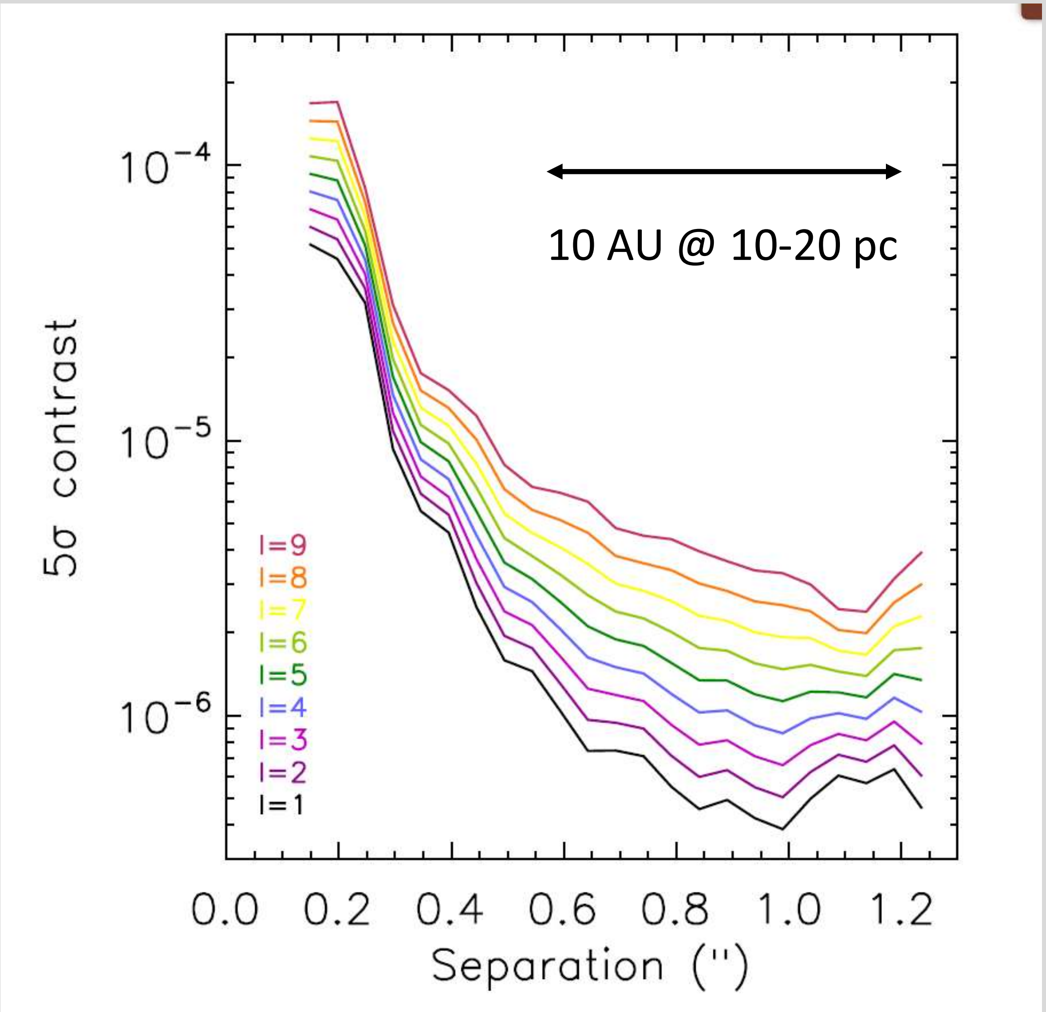
Confirming this with current systems will require studies of closer stars.

- Closer stars are generally not part of moving groups – need additional age identifications
- Improving contrast for these sources is essential for detections



GPI Contrast curves

Summary and Shameless Plugs

- **Low yield of current direct imaging surveys has revealed possible fundamentally important information about exoplanetary system architectures**
  - **Next generation of instruments and surveys can probe these relationships**
- **Sessions and talks to advertise!**
  - **The Future of Ground Based High-Contrast Imaging, Wednesday, 10-11:30 am, Room 304**
    - **www.highcontrastimaging.rocks**
  - **US ELTP Session, Monday, 9:30 – 11:30 am, Room 4C-4**
  - **Gemini Open House, Tuesday, 5:30 - 6:30, Room 305**
  - **GPI-related talks and posters: 140.38 (Mullen et al.); 104.01 (Macintosh et al.); 163.04 (Shirman et al.); 163.14 (Wolff et al.); 259.14 (Ward-Duong et al.); 340.05 (Esposito et al.); 163.13 (Zhang et al.); 140.34 (Meiji et al.); 226.01 (Wang et al.)**