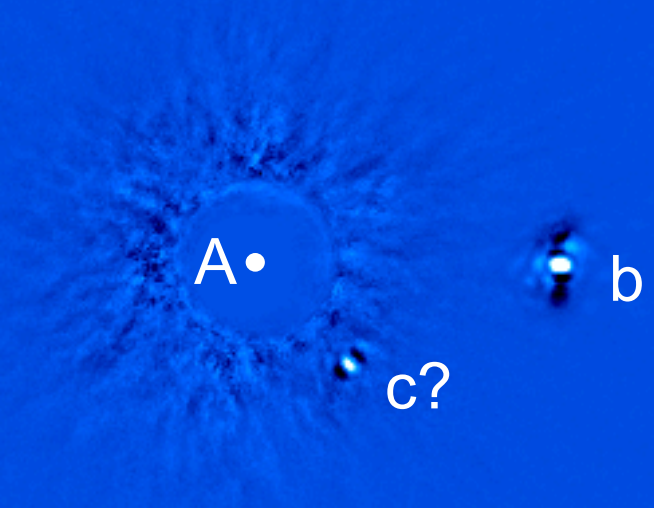
Searching for Scatterers:

High Contrast Imaging of Wide-Separation Planetary Mass Companions

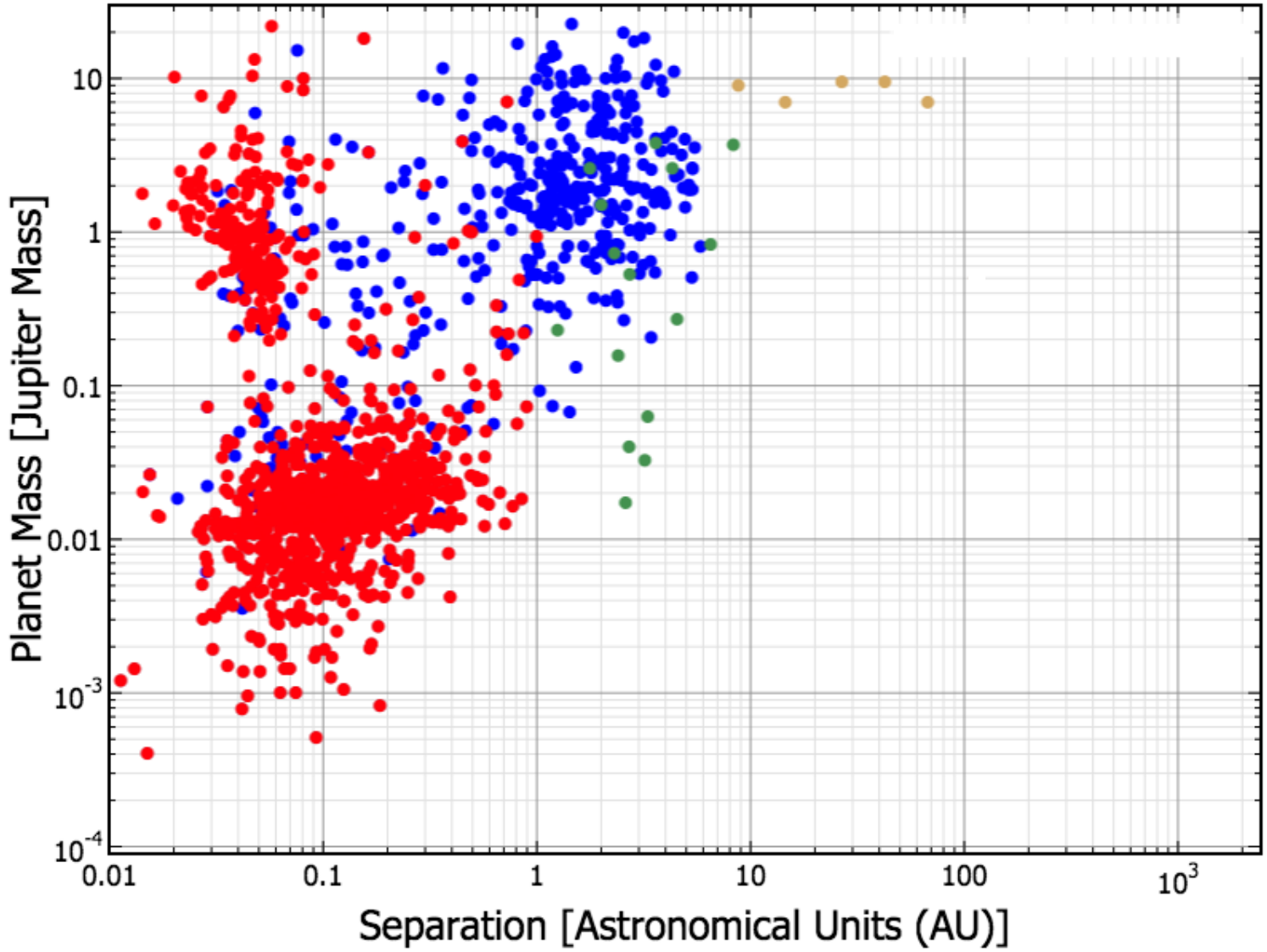


Marta Bryan
Caltech

Collaborators: Brendan Bowler (Caltech)
Heather Knutson (Caltech)
Dimitri Mawet (Caltech)
Sasha Hinkley (U. Exeter)
Adam Kraus (UT Austin)

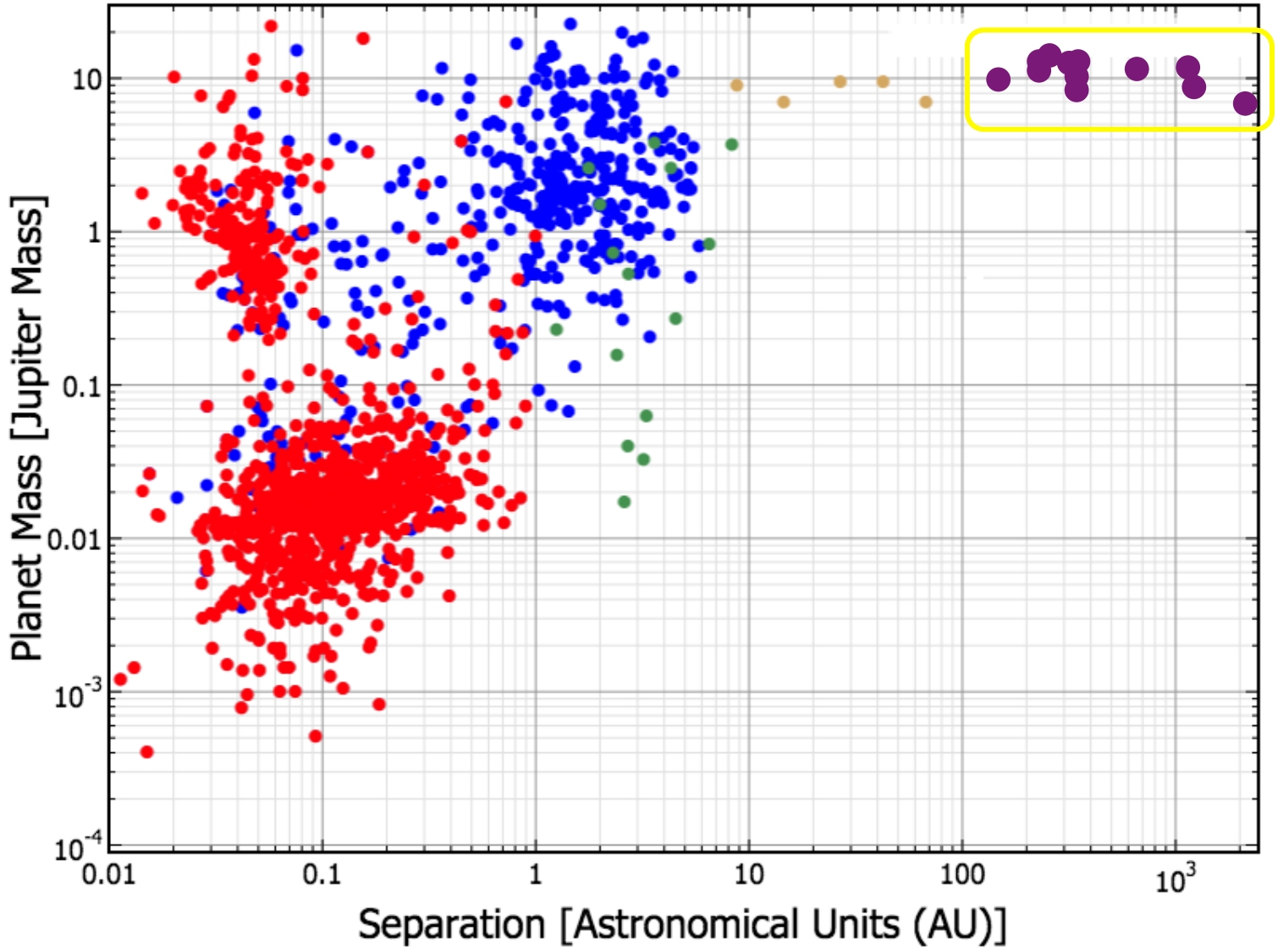
Thursday 2 July 2015

A New Population of Planetary Mass Companions



exoplanets.org

A New Population of Planetary Mass Companions



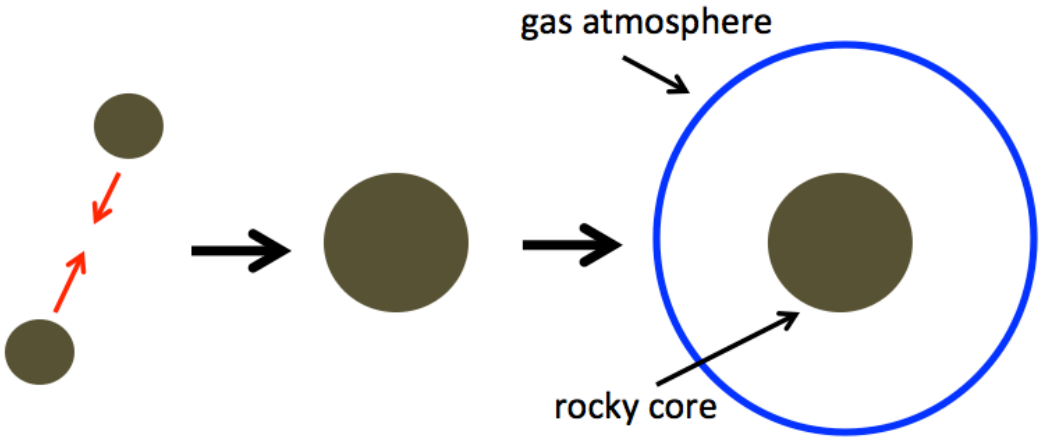
exoplanets.org

How do they form?

1. Core accretion + gas capture
2. Disk instability
3. Turbulent fragmentation

How do they form?

1. Core accretion + gas capture
2. Disk instability
3. Turbulent fragmentation



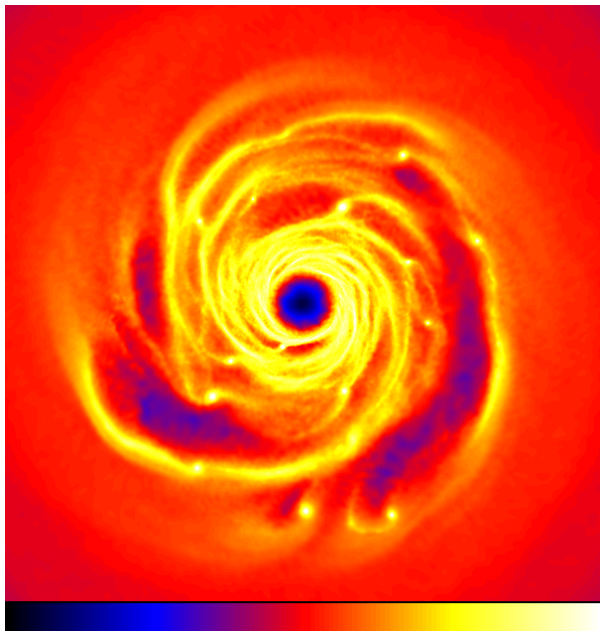
Problem:

timescale to grow massive cores >>
lifetimes of protoplanetary disks

Pollack et al (1996)
Alibert et al (2005)

How do they form?

1. Core accretion + gas capture
2. Disk instability
3. Turbulent fragmentation



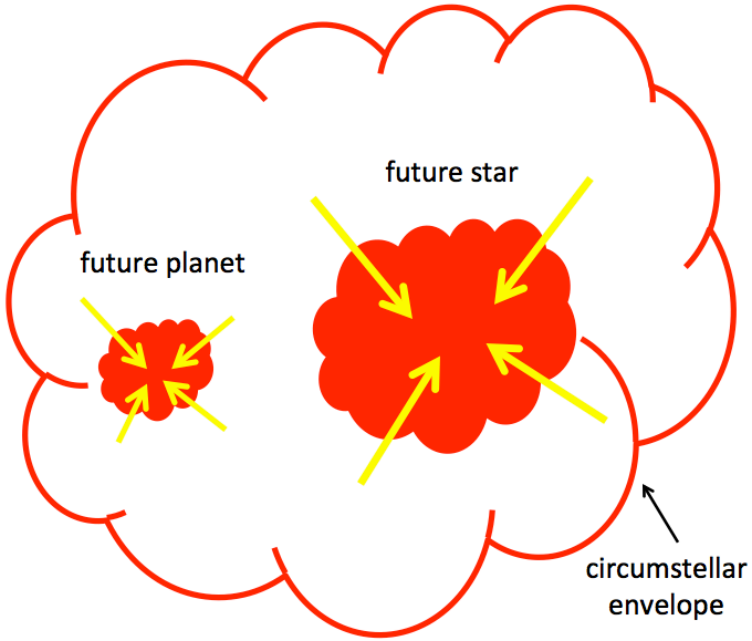
Problem:

disk surface densities beyond 100 AU are too low for gravitational instability to operate

Boss (1997)
Vorobyov (2013)
Dodson-Robinson et al (2009)
Boss(2006)

How do they form?

1. Core accretion + gas capture
2. Disk instability
3. Turbulent fragmentation

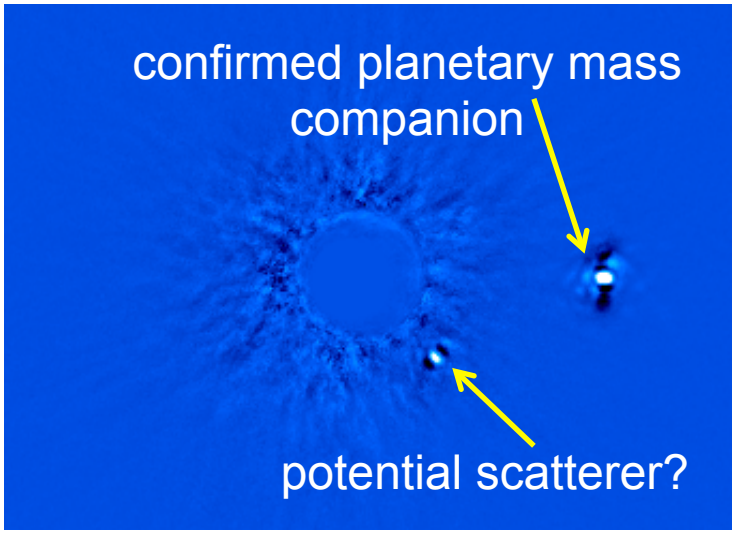


Problem:
unlikely to stop accretion at planetary masses

Bate et al (2002)
Bate (2009)

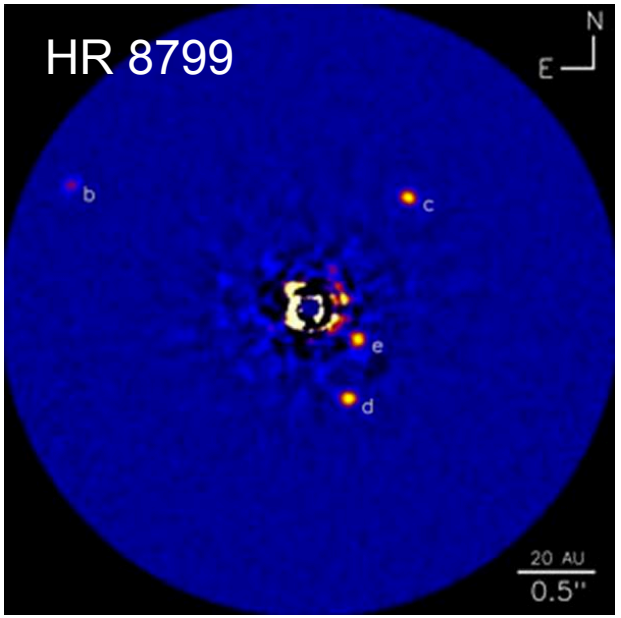
Searching for Scatterers

We test the possibility that the observed wide-separation PMCs formed closer in and were scattered out to their present day locations by looking for other massive bodies in the system

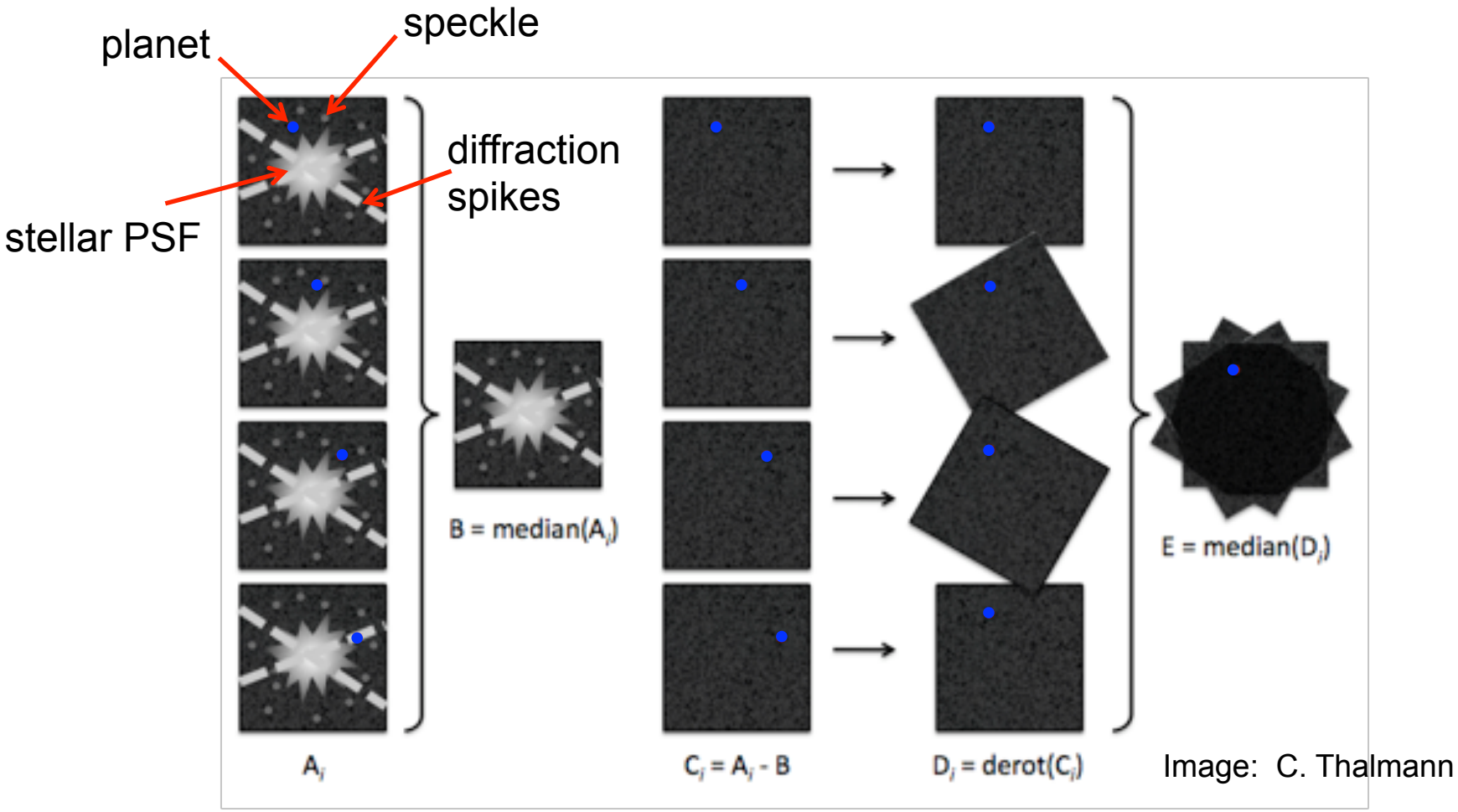


- Sample size: 7 confirmed PMC systems
- Deep (30-40 min) ADI imaging
- NIRC2/Keck

Deep imaging opens up the possibility to find the next HR 8799

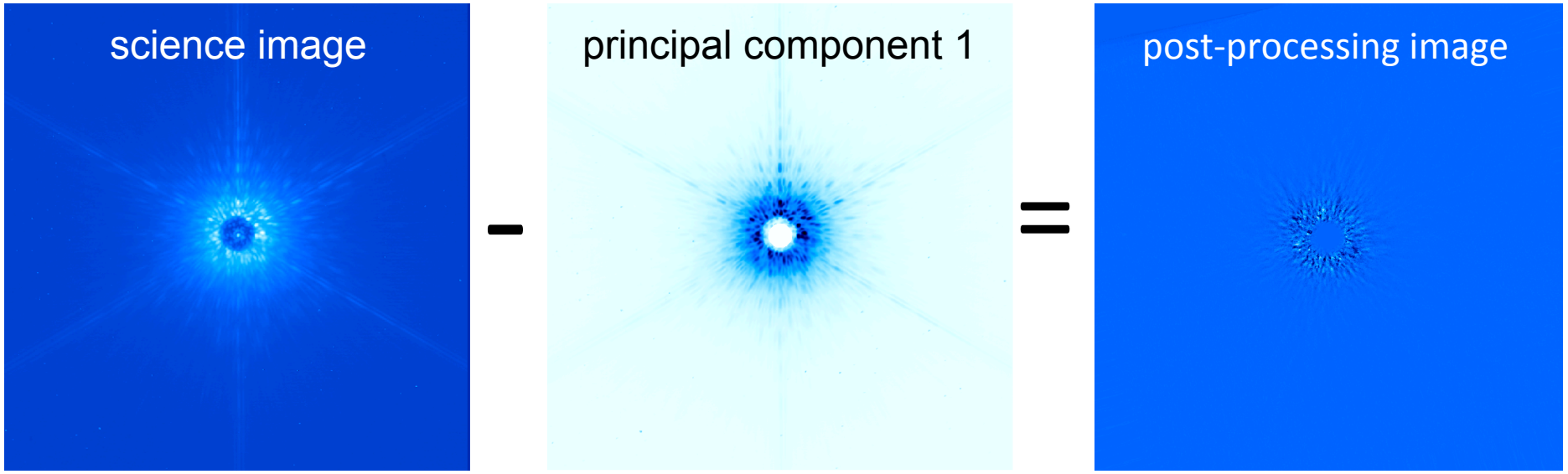


Angular Differential Imaging (ADI)



Pupil orientation is kept constant →
quasi-static speckles remain as stable as possible

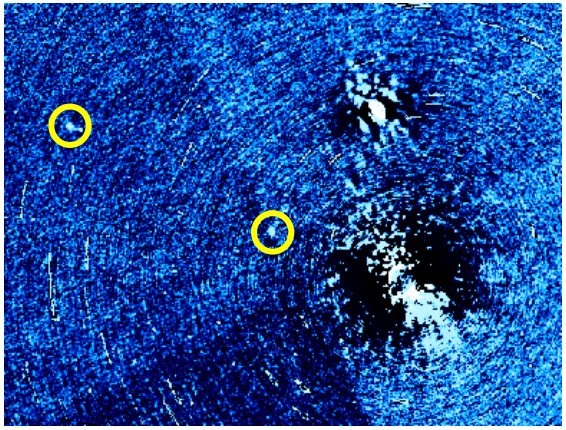
Principal Component Analysis (PCA)

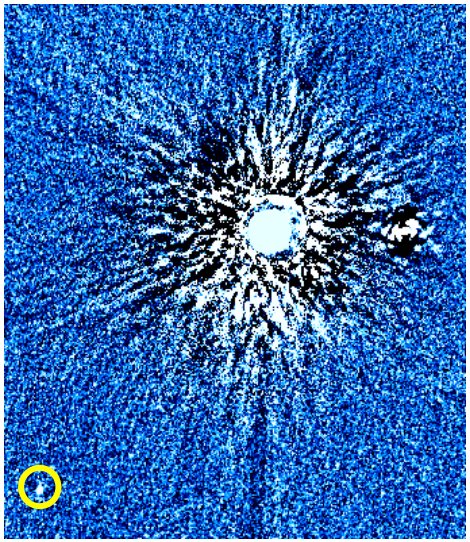


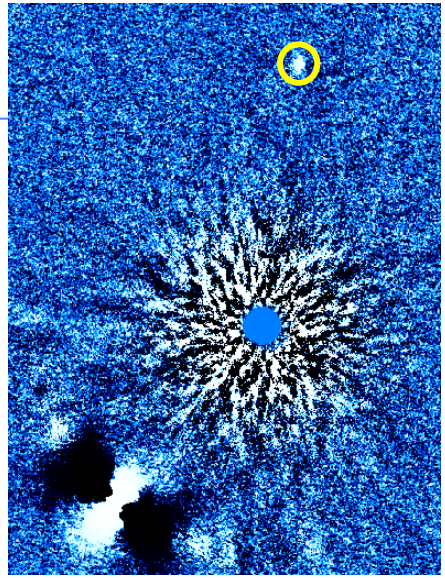
Subtract linear combinations of principal components from the science images to search for faint companions

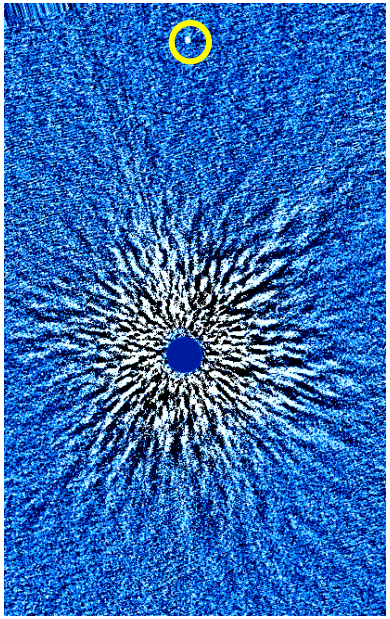
Soummer et al (2012)

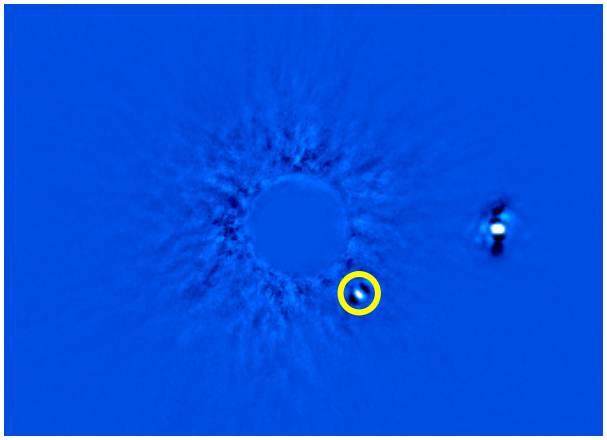
Candidate Companions

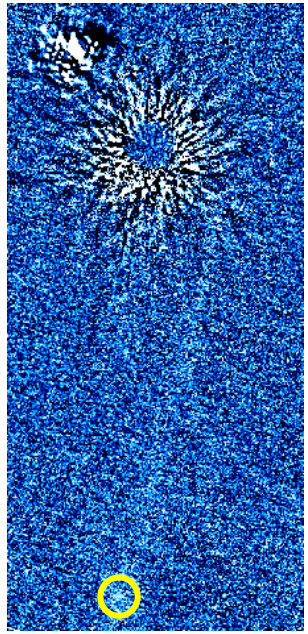


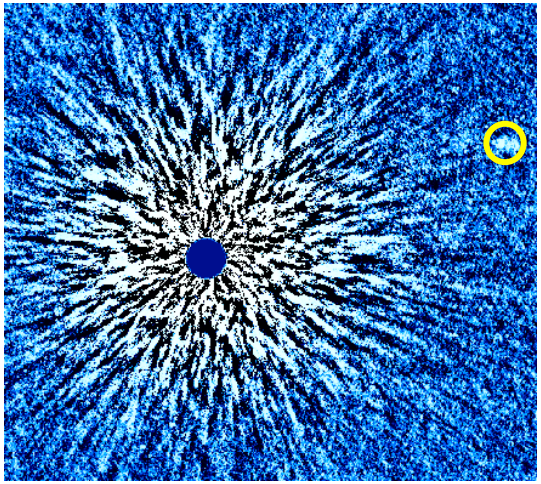






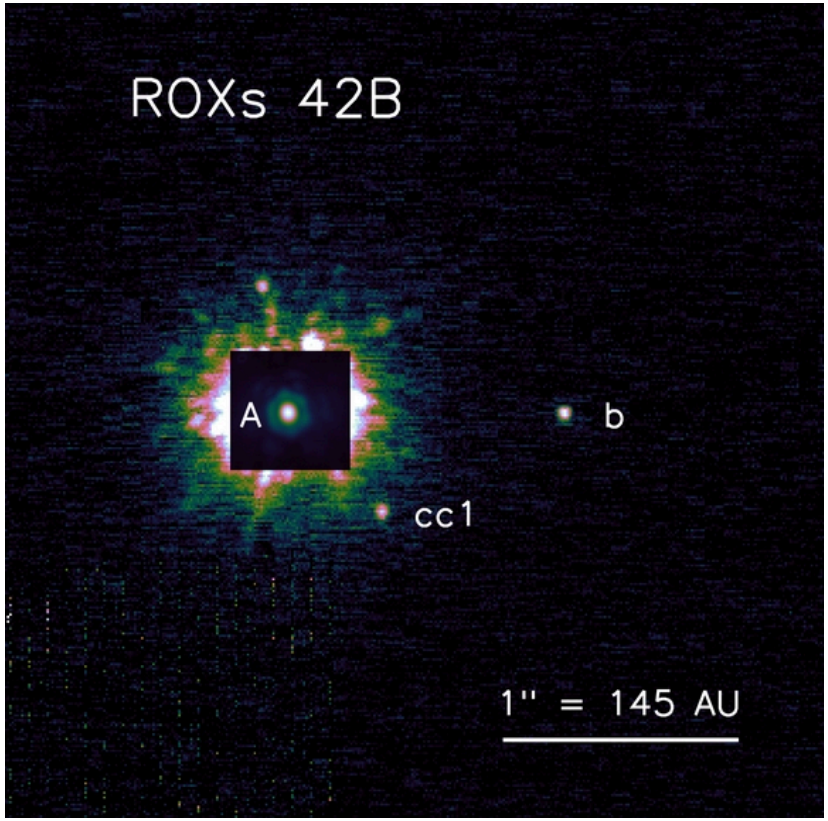






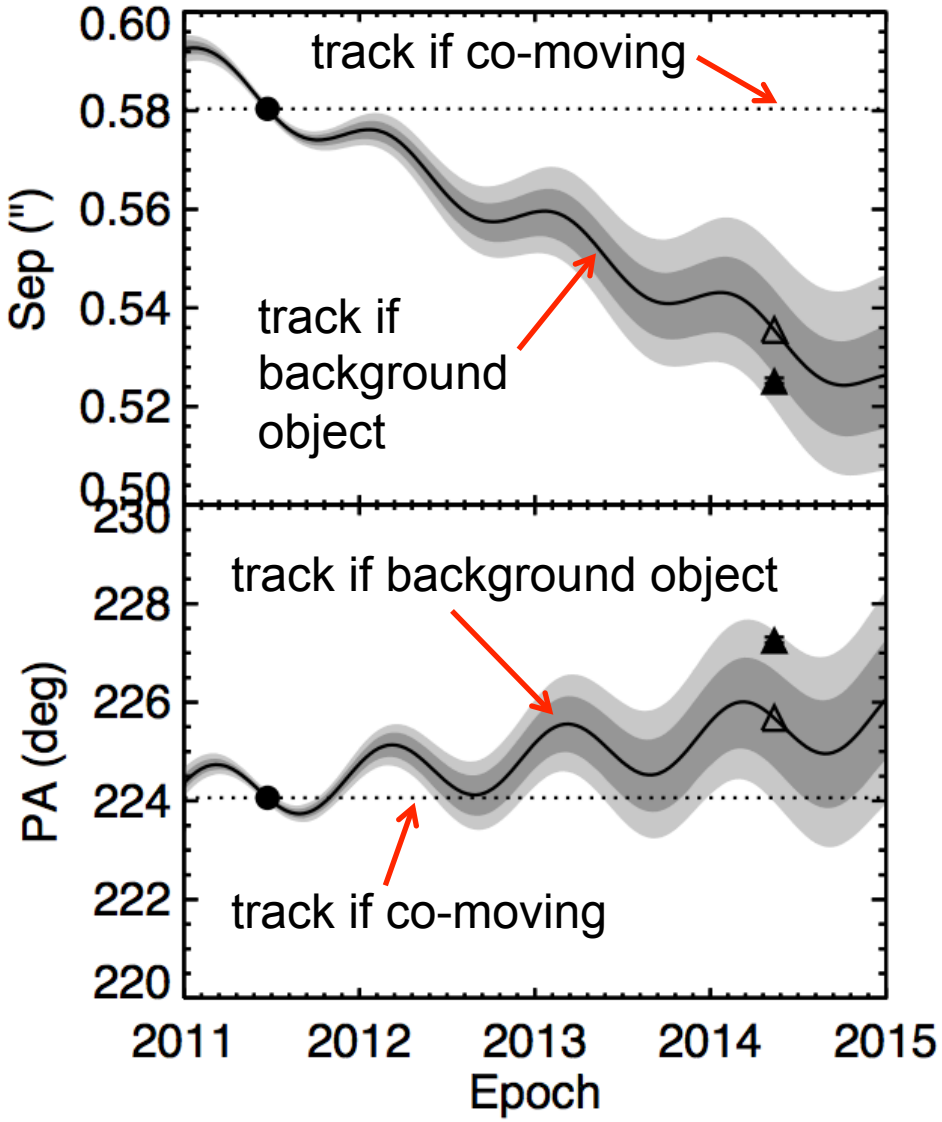
ROXS 42B

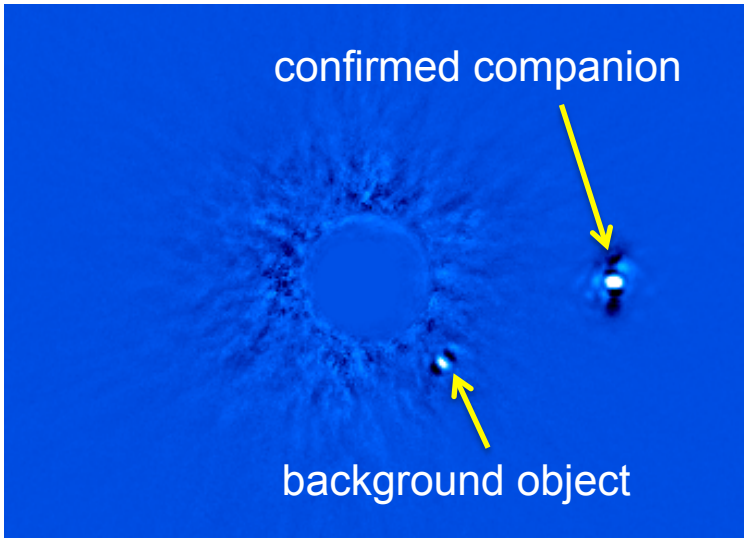
- Primary is a close binary in the Ophiuchus star forming region
- Confirmed companion discovered by Ratzka et al in 2005, independently confirmed by Kraus et al and Currie et al in 2014
- Confirmed companion mass 6-14 M_{jup}
- Confirmed companion separation 140 AU
- Additional candidate companion at ~0.55 arcsec



Kraus et al (2014)
Bowler et al (2014)

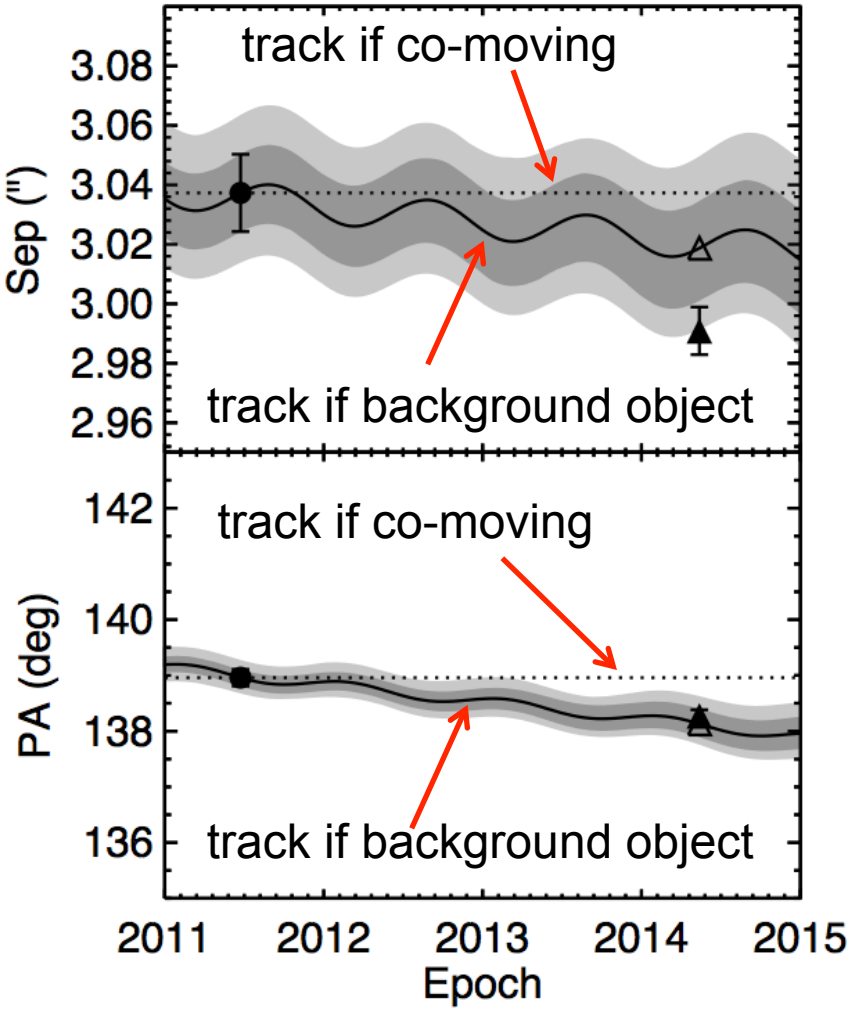
ROXS 42B Candidate Companion #1

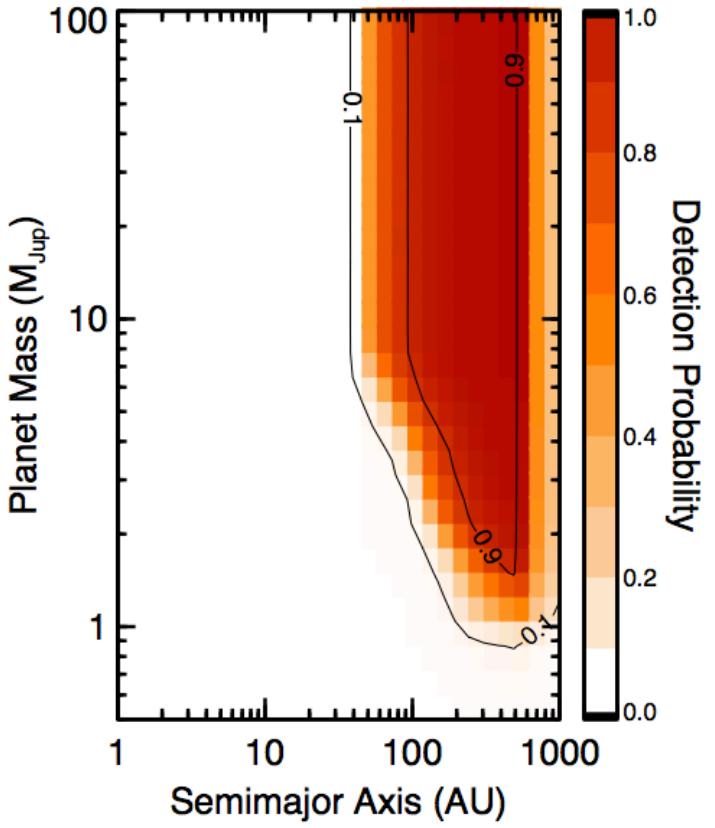




The astrometry conclusively shows that this candidate companion is a background object

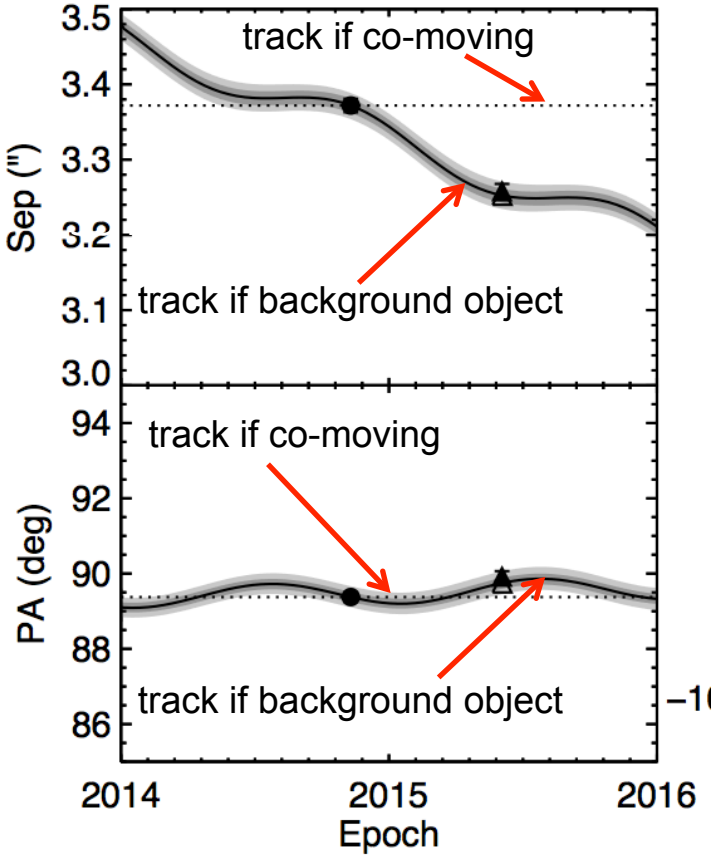
ROXS 42B Candidate Companion #2

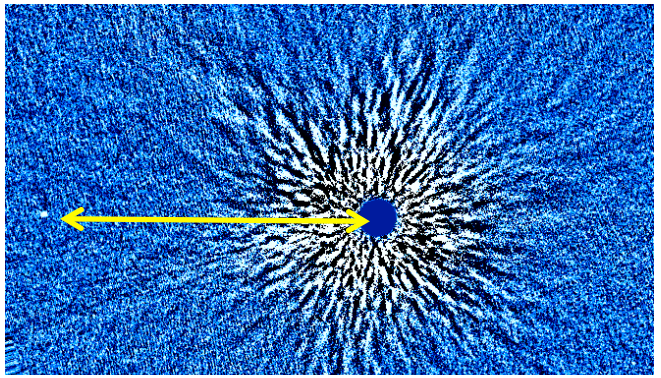


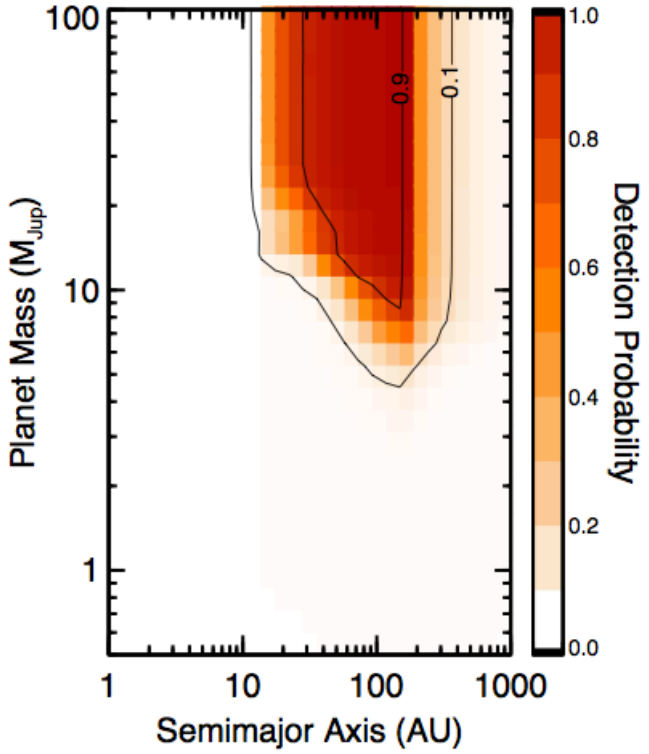


HD 203030 Candidate Companion

- Confirmed companion discovered and confirmed by Metchev et al 2006
- Companion mass 12-30 M_{jup}
- Companion separation 487 AU

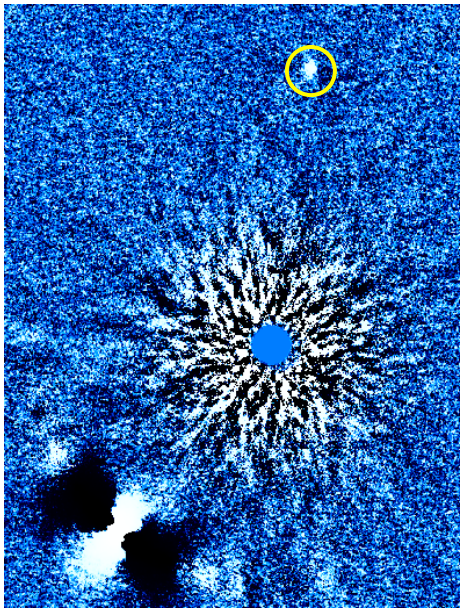


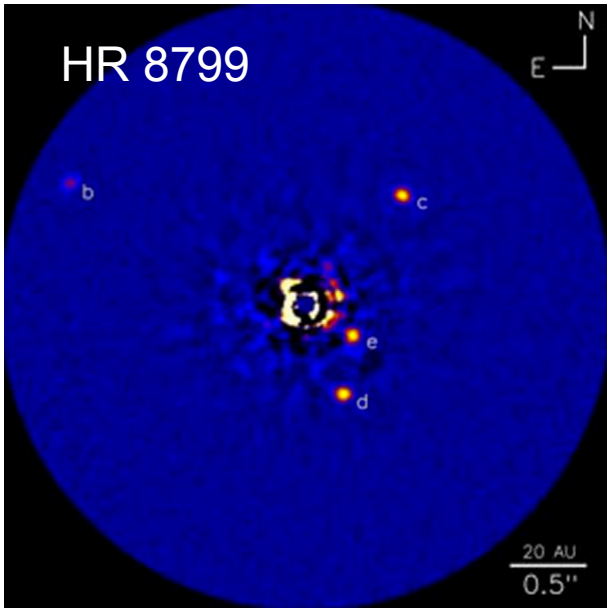




Future Work/Implications

- Following up remaining candidate companions
- Two implications if a candidate companion is bound:
  - could have scattered wide-separation PMC to present location → potential solution to PMC formation dilemma
  - This system would be only the second multi-planet system discovered via direct imaging other than HR 8799

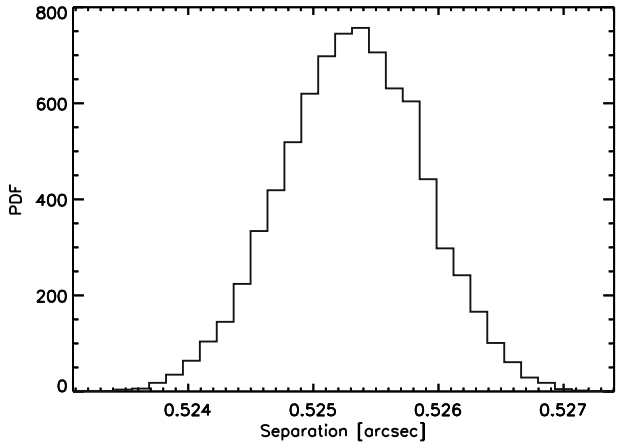


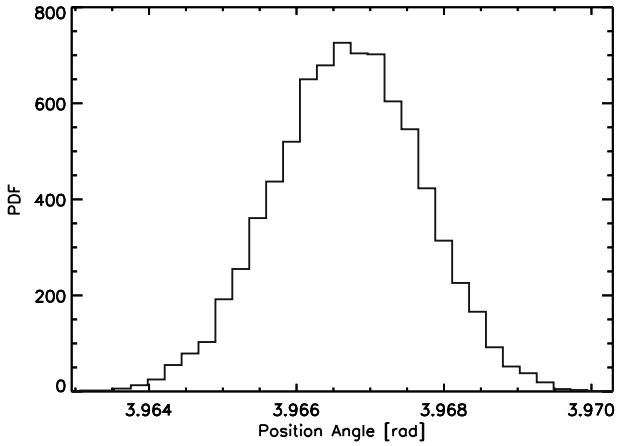


Summary

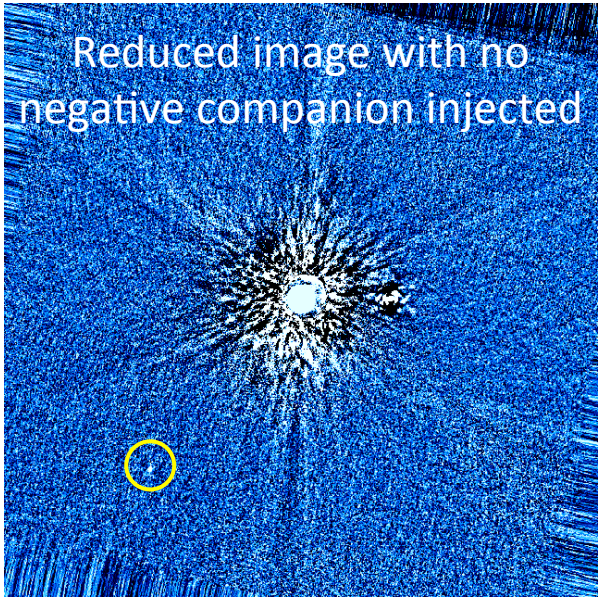
- We conducted a deep ADI imaging survey with NIRC2 at Keck to look for potential scatterers in a sample of seven systems with confirmed wide-separation PMCs
- Reductions using principal component analysis (PCA) revealed 9 candidate companions
- An MCMC program simultaneously solved for companion candidate astrometry and relative photometry
- Astrometry conclusively shows that the candidate companions in ROXS 42B and HD 203030 are background objects
- We are following up remaining candidate companions

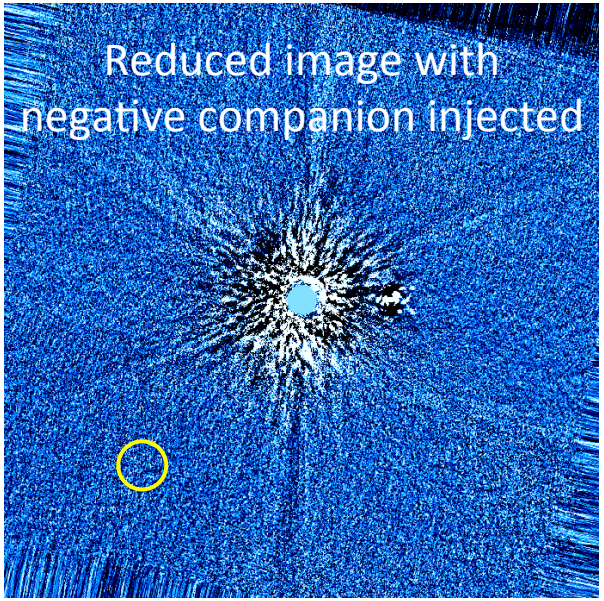
Candidate Companion Astrometry



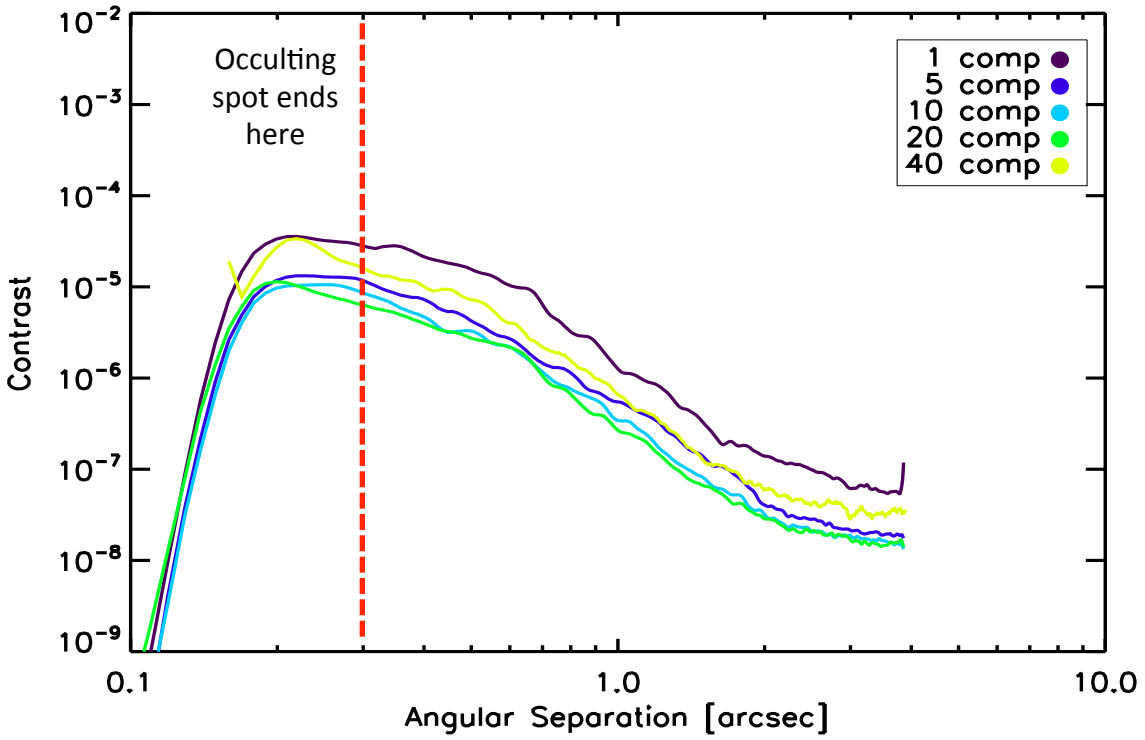


MCMC program simultaneously calculates the astrometry and relative photometry of candidate companions





Optimized Number of PCA Components



- Number of principal components determines how well the stellar PSF is modeled
- Optimized number of principle components used by comparing contrast curves