High-contrast Imaging Exploration for Exoplanet around Young Stellar Objects with Subaru/HiCIAO+AO188

Uyama et al., 2017a, AJ, 153, 106

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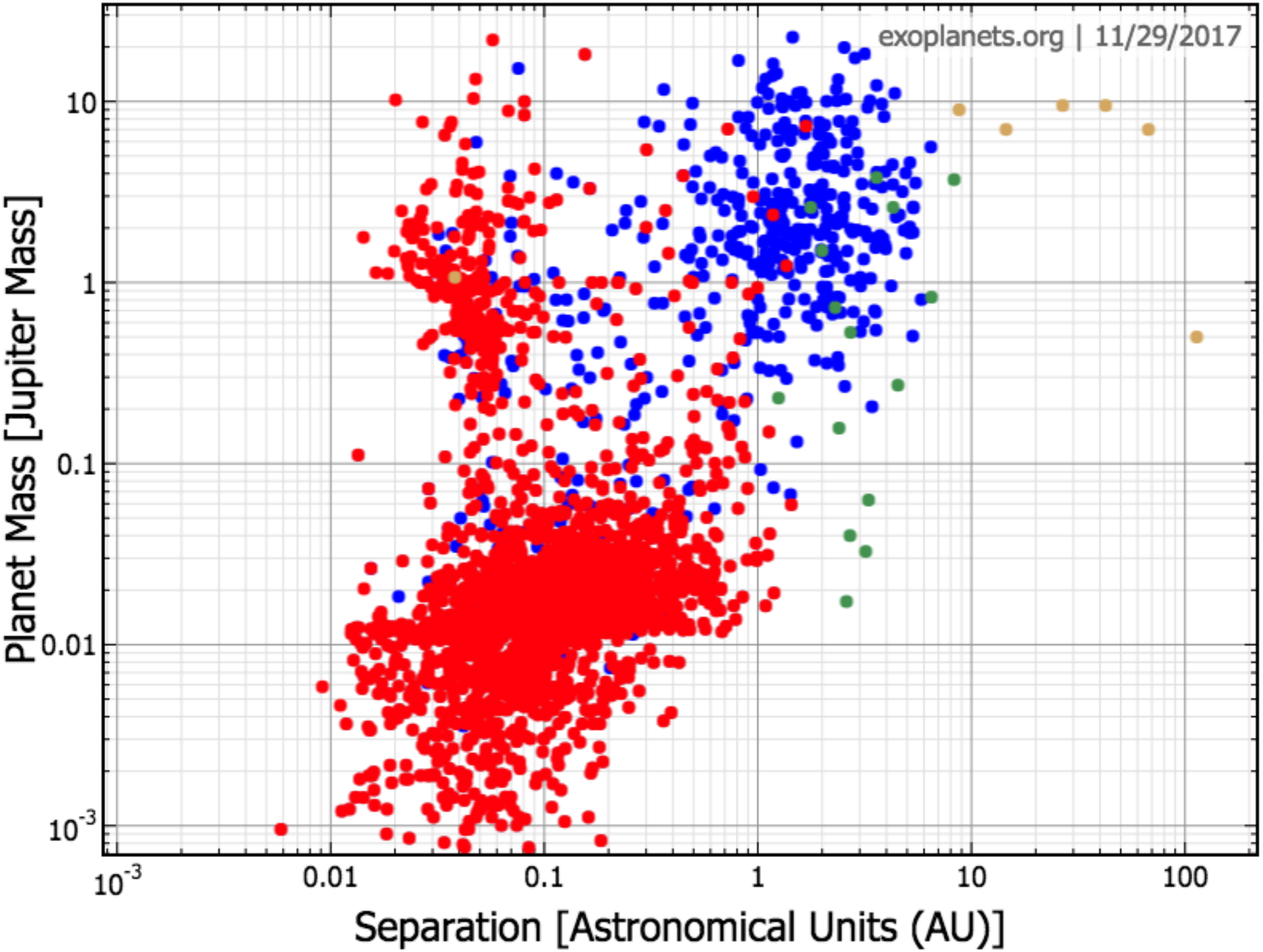
1/17 @Subaru User's Meeting

Introduction - Exoplanet

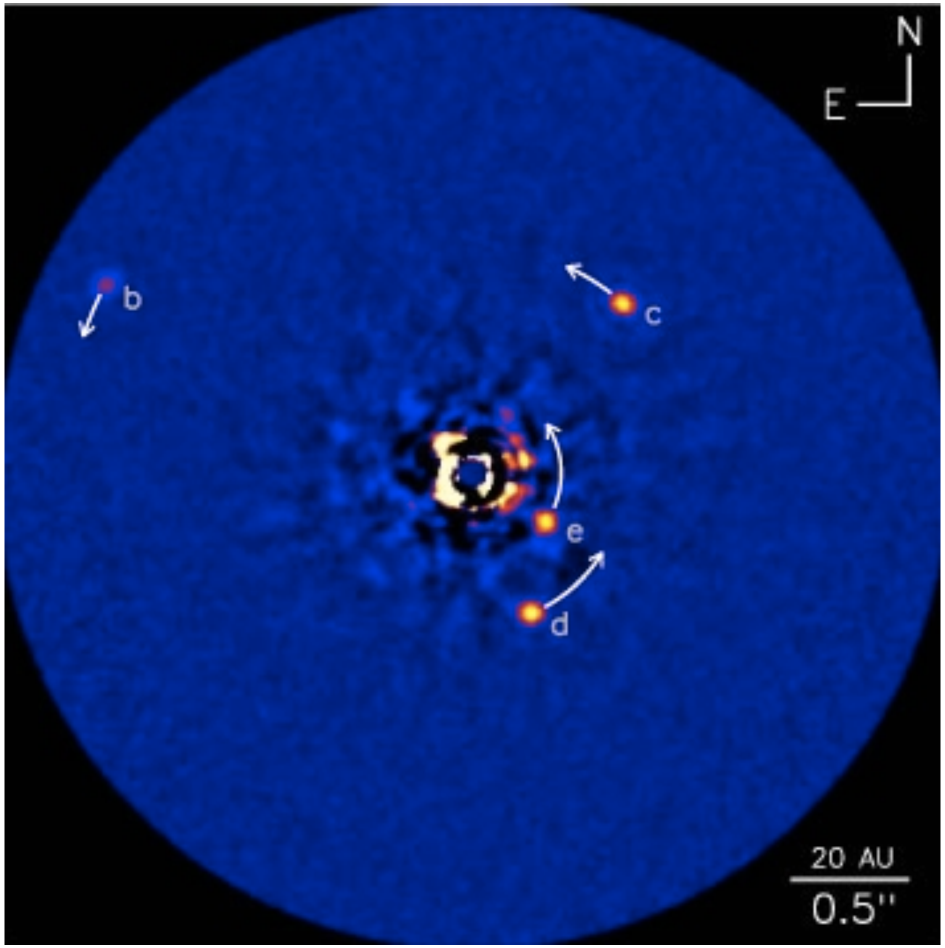


Introduction - Direct Imaging

▪More sensitive to wide-orbit (>10AU) and young (<a few Gyr) gas giants

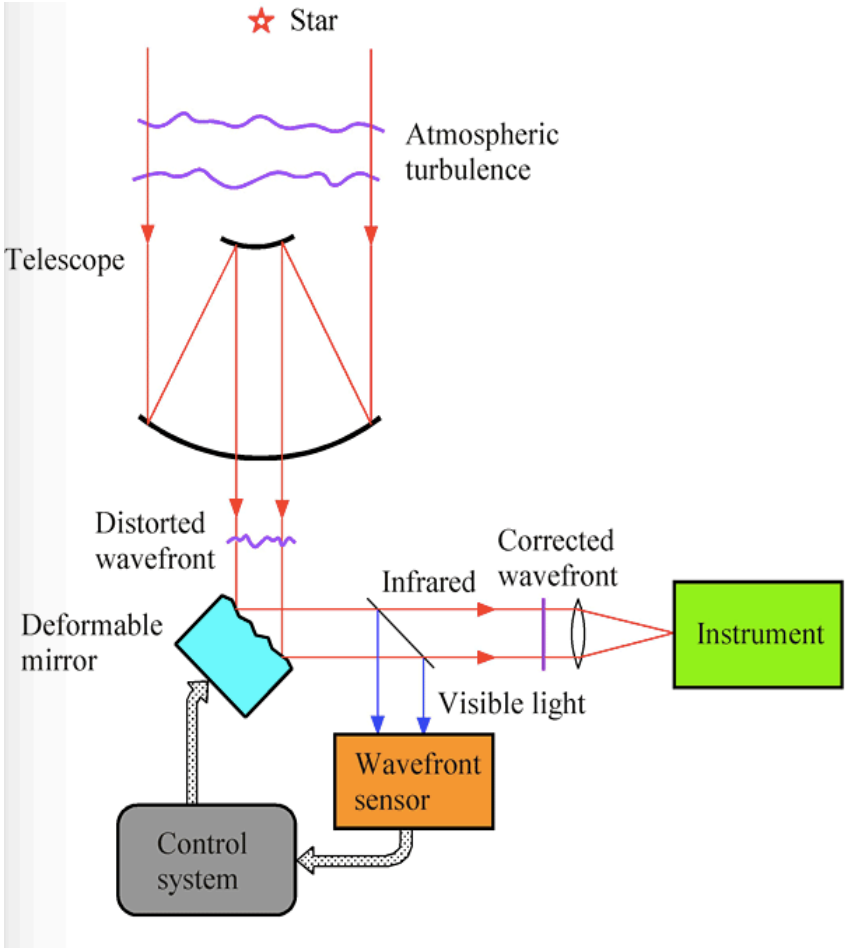
▪Science: planet formation, orbital evolution, atmosphere

▪High contrast problem
- adaptive optics
- coronagraph
- differential imaging



HR8799 (a multi-planetary system; Marois et al. 2008)

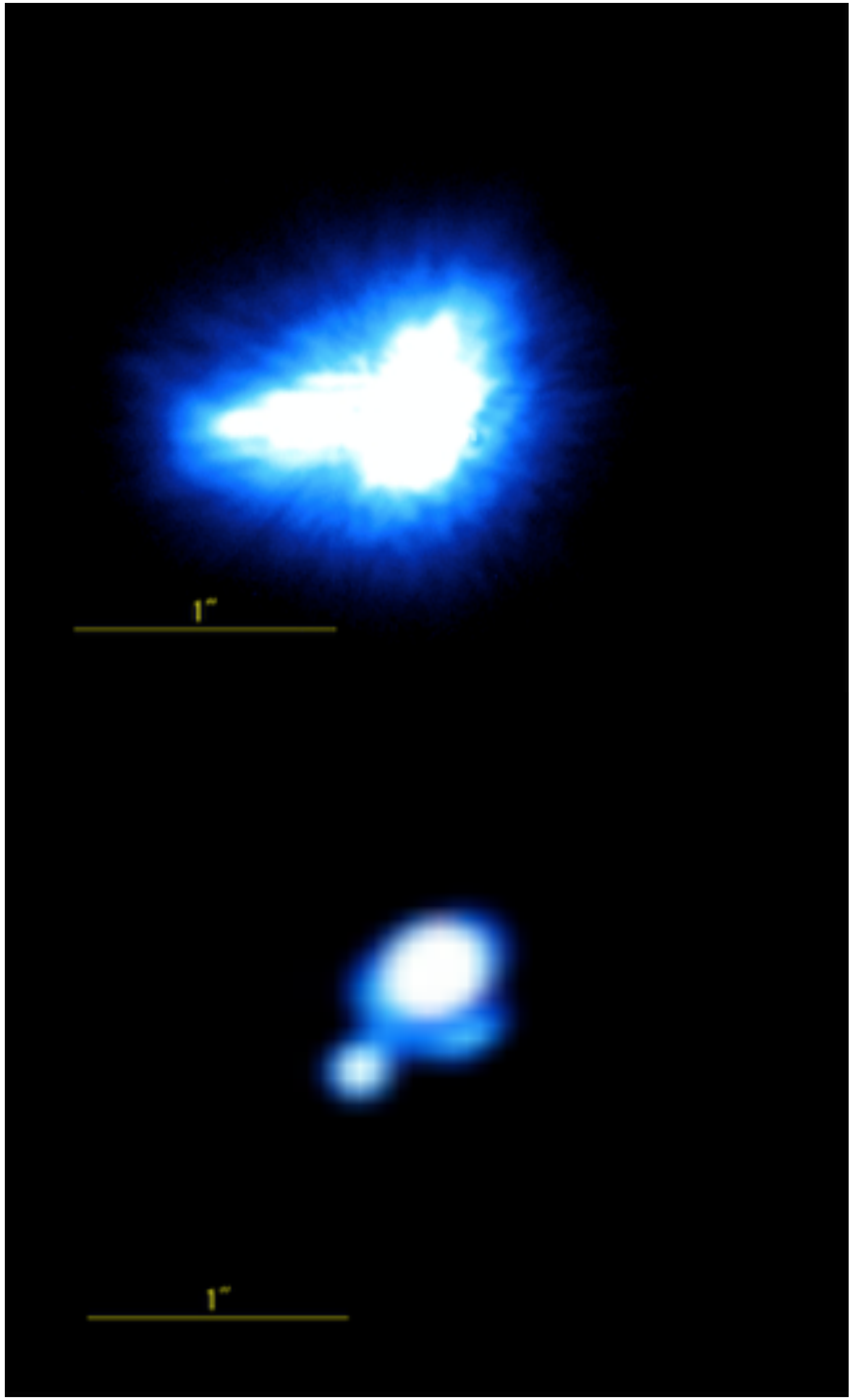
Adaptive Optics (AO)



Schematic diagram of adaptive optics

(left) The schematic of AO ©NAOJ

A binary system (upper right) without AO (lower right) with AO ©Subaru

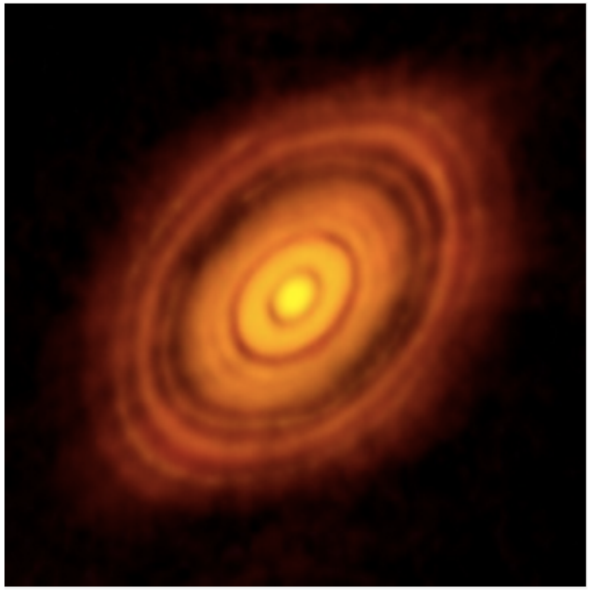


Young Stellar Object

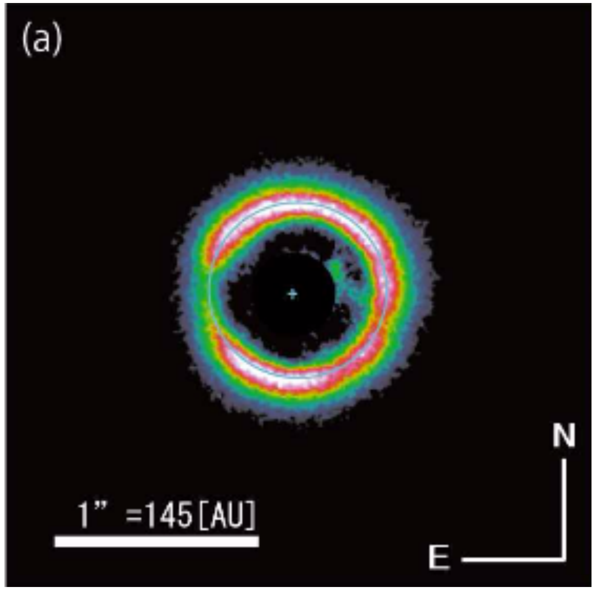
- Transitional disk
  - IR excess and a dent at mid-IR region
  - suggestion of an inner gap and planet formation

- Disk observations
  - Asymmetric disks are hopeful planet factories

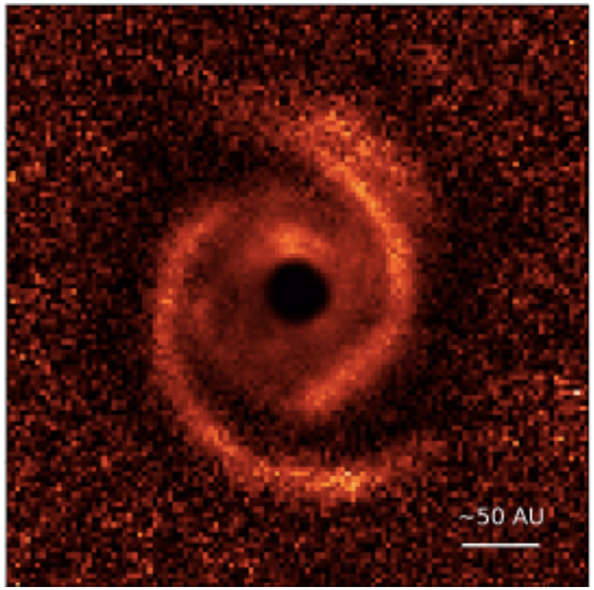
- Motivation
  - To discuss a relationship between planet formation and disk evolution.



ALMA partnership et al. 2015



Mayama et al. 2012



Benisty et al. 2015

Observations

- We observed 68 YSOs (99 data in total) with Subaru/HiCIAO+AO188 in SEEDS project (Tamura2009)
  - the first large-scale statistic exploration around YSOs
  - basically H (1.6μm) or Ks (2.2μm) band

- effective imaging modes are different
  - Polarization differential imaging (PDI) for disk survey
  - Angular differential imaging (ADI) for companion survey

- HiCIAO observations can discuss companions beyond 50 AU
  - distances of the targets
  - instrumental specifications

Group	Age (Myr)	Dsitance (pc)
Taurus-Auriga	1−13	140
Upper-Sco	9-13	145
Lupus	0.1-10	155
Ophiucus	0.3-3	120

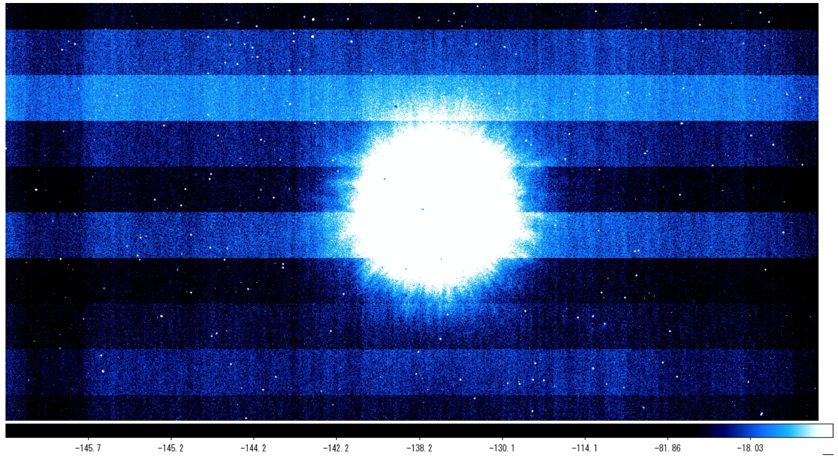
Main star-forming regions

arcsec	AU
0.5	70
1	140
2	280

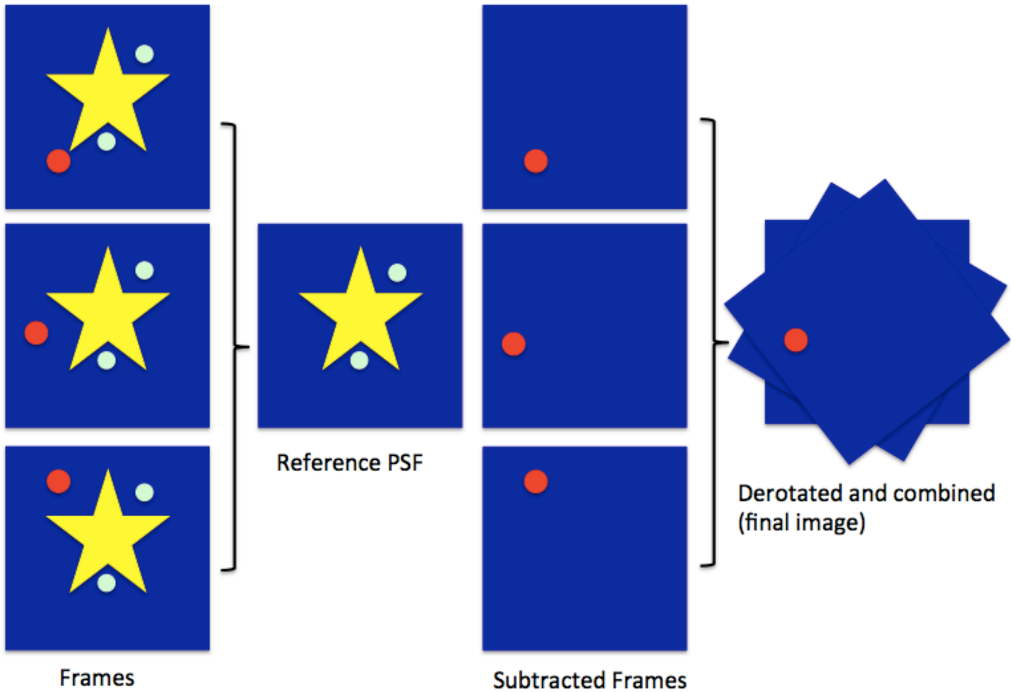
separations at 140 pc

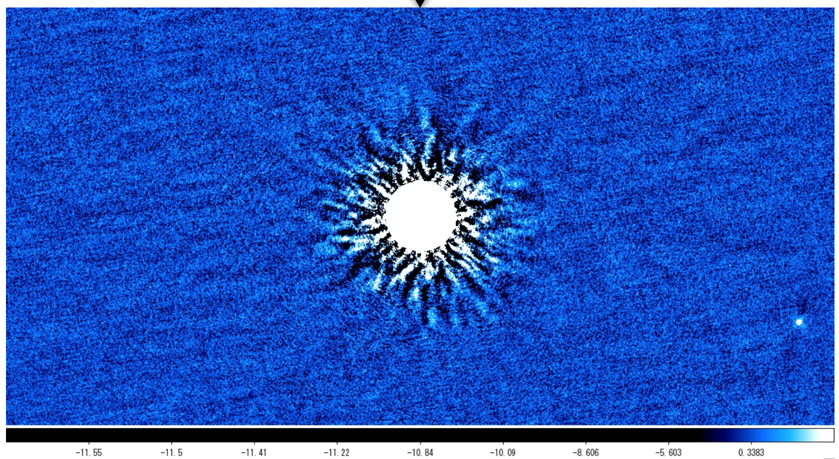
Observations

▪ Angular Differential Imaging (ADI; Marois et al. 2006)
 - subtract stellar halo and speckles by rotating FOV
 - suitable for point source detection
 - available with other differential techniques



Raw image





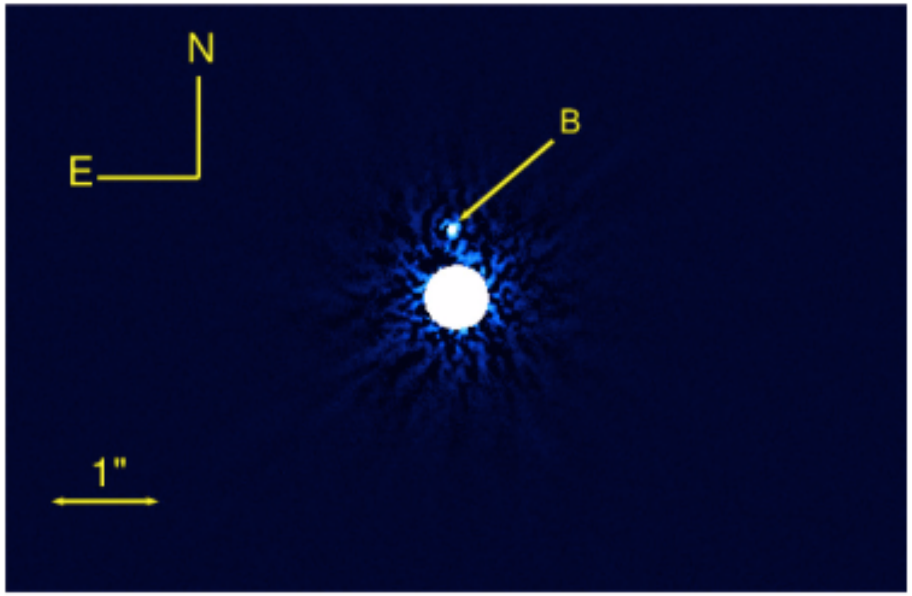
ADI-reduced image

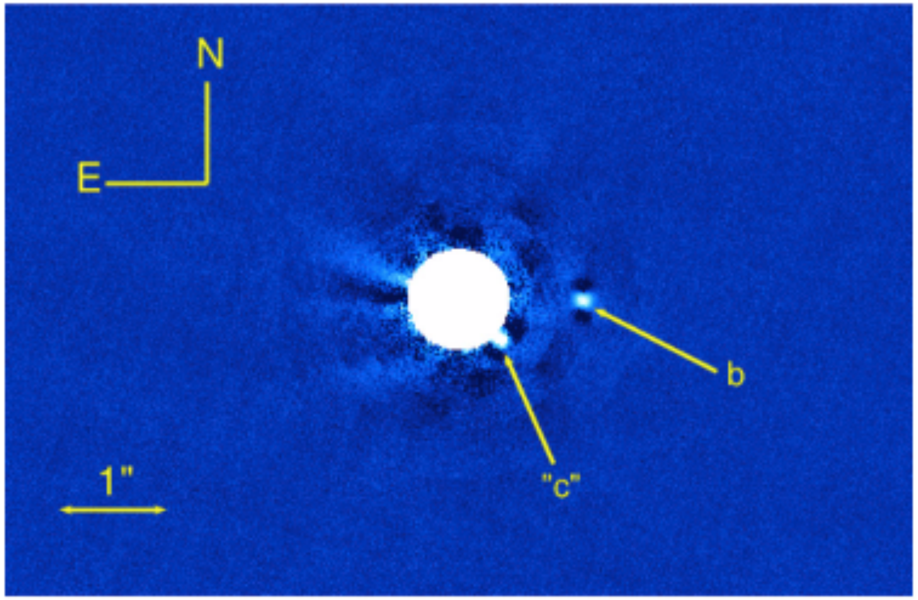
Results – Case for Companions

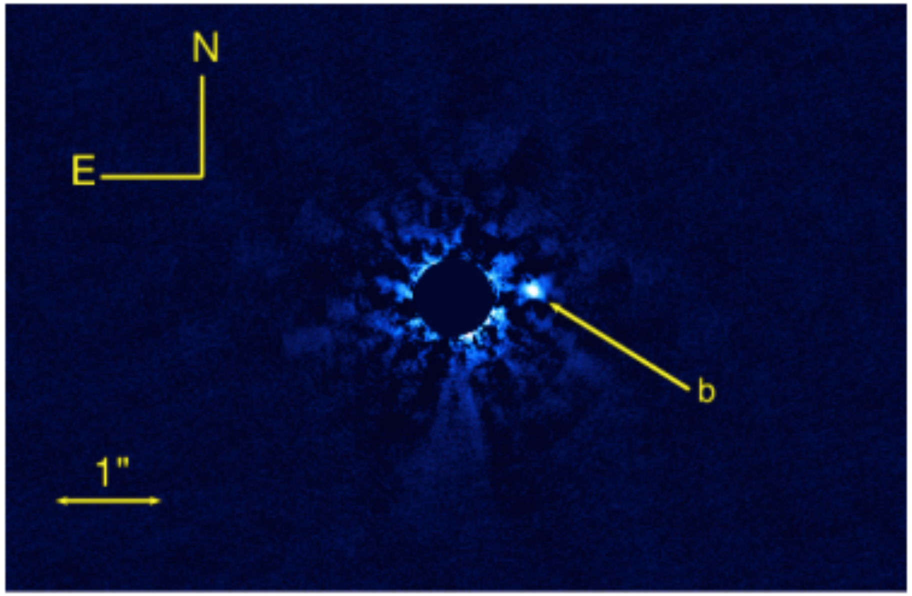
Upper right: HIP 79462 (a new stellar–mass companoin)

Lower right: GQ Lup (the known substellar-mass companion)

Lower left: ROXs 42B (the known substellar-mass companion)

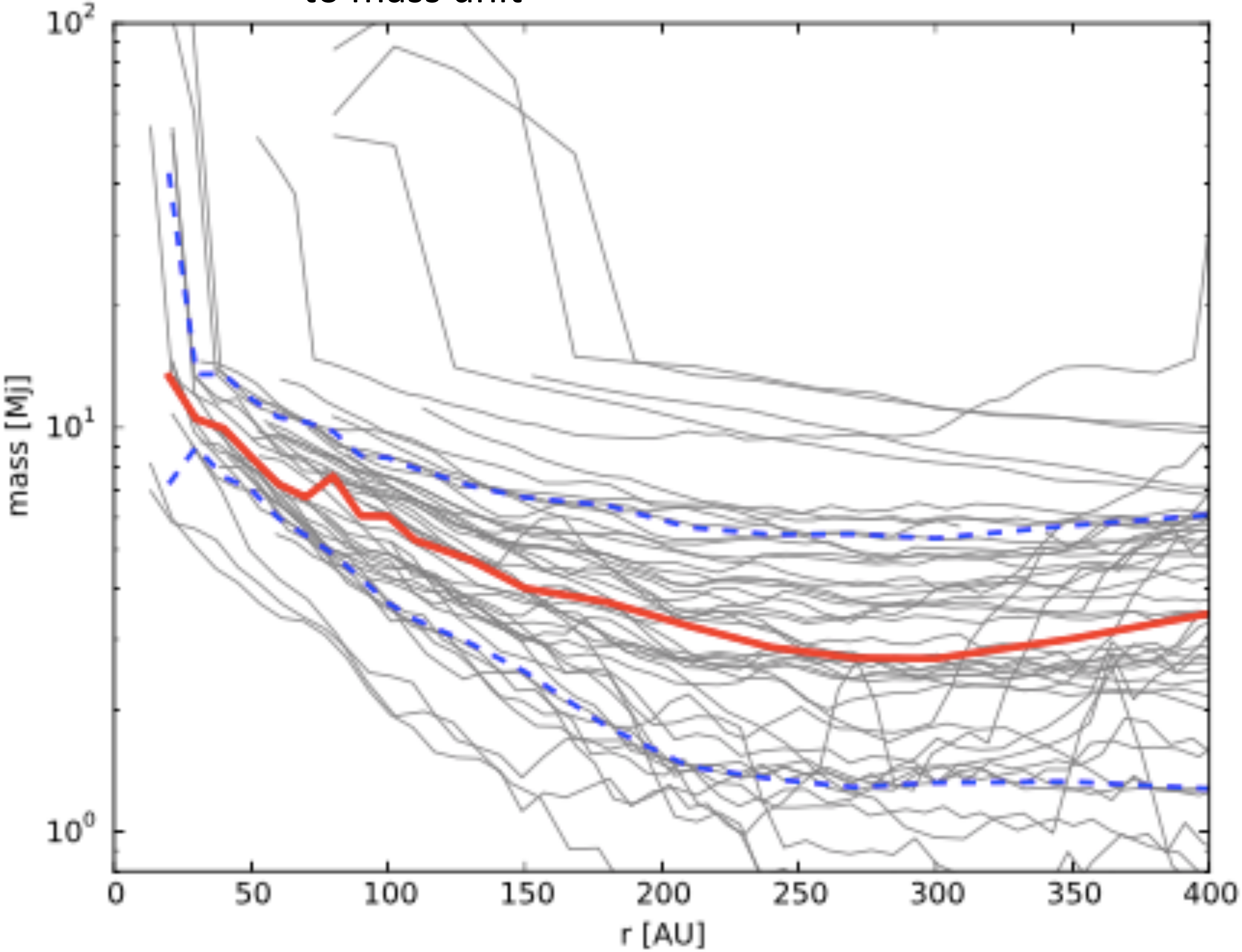






Detection Limits

- typical contrast; $10^{-3.5}$ at 0.5”, 10^{-4}-10^{-5} at 1.0”, and $10^{-4.5}$-10^{-6} beyond 2”
- COND03 model (Baraffe et al. 2003) is used for conversion to mass unit



Results and Discussions

・We observed 68 YSOs and found 15 companion candidates between 50 AU and 400 AU. We also confirmed 2 known substellar-mass companions (GQ Lup b and ROXs 42Bb).

- 7 objects: background stars
- 1 object: a stellar-mass companion (HIP 79462 B)
- 1 object: a stellar-mass companion or a background star (not exoplanet)
- 6 objects: low-mass companion candidates (need for follow-up observations)

・Our observations achieved typical detection limits of ~10M_J at 70 AU and ~6M_J at 140 AU.

・preliminary discussion

Simply speaking, frequency of 1-70M_J companions at 50-400 AU is 2.9%.

- c.f., SEEDS/Moving Group; the frequency of 5-70M_J objects between 10 and 100AU 1.0-3.1% (68% confidence) and 0.92-11% (97% confidence) (Brandt et al. 2014a).

・Compared to recent disk observations that reported asymmetric features at smaller than 50 AU, we should improve high-contrast observations at very inner region.

Summary

・YSOs are suitable target to discuss a relationship between planet formation and disk evolution.

・Our observation is the first large-scale statistic exploration of YSOs. We confirmed 2 known substellar-mass companions (GQ Lup b and ROXs 42Bb) and found a new stellar-mass companion (HIP 79462B).

・Our preliminary results show the frequency of 1-70M_J companions at 50-400 AU is 2.9%, which does not deviate from statistical results of SEEDS/Moving Group observations.

Future works

How can we overcome the high-contrast problem?

1) Instrumental development

→ Extreme AO and IFU (Subaru/CHARIS+SCExAO, Gemini/GPI, and VLT/SPHERE)

2) Focusing on potentially more bright signals

→ Search for accretion signatures

(only for YSO targets – see Uyama et al. 2017b for details)

post SEEDS - Subaru/CHARIS+SCExAO

- SCExAO+CHARIS observations are expected to detect a companion down to ~1M_J at 20 AU, which value is much better than that of SEEDS.