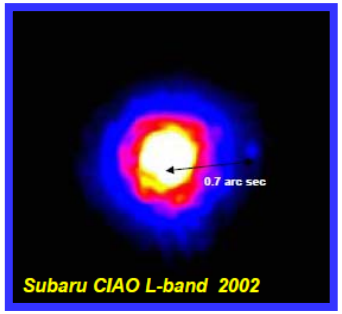
SEEDS

Strategic Explorations of Exoplanets and Disks with Subaru

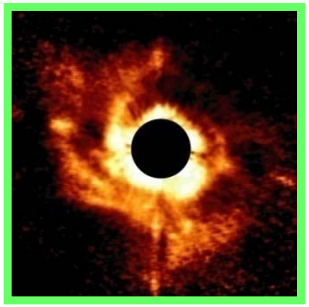
2011.1.20 Thu 11:05-11:25
M. Tamura
on behalf of
the HiCIAO/AO/
SEEDS team

SEEDS – Strategic Exploration of Exoplanets and Disks with Subaru

- First “Subaru Strategic Program (SSP)” – a new open-use category
- 120 Subaru nights in 5 years
- Direct imaging and census of giant planets in the outer regions (a few - 40 AU) around ~500 solar-type and massive stars
- Exploring protoplanetary disks and debris disks for the origin of their diversity and evolution at the same radial regions
- Direct linking between planets and protoplanetary disks



>100AU scale w/ CIAO



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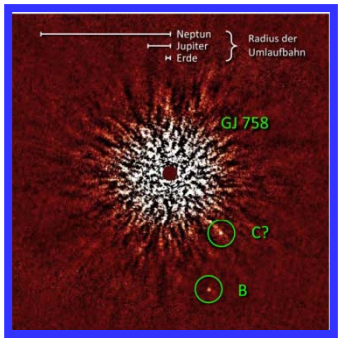


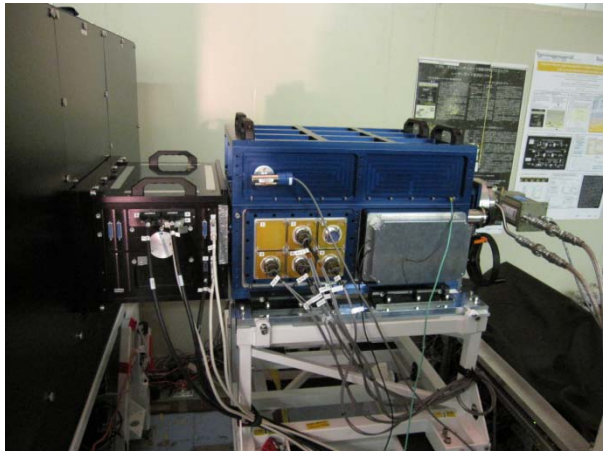
Solar-System Scale (<50AU) w/ HiCIAO

disk data shown later

Subaru/HiCIAO+AO188+SCExAO

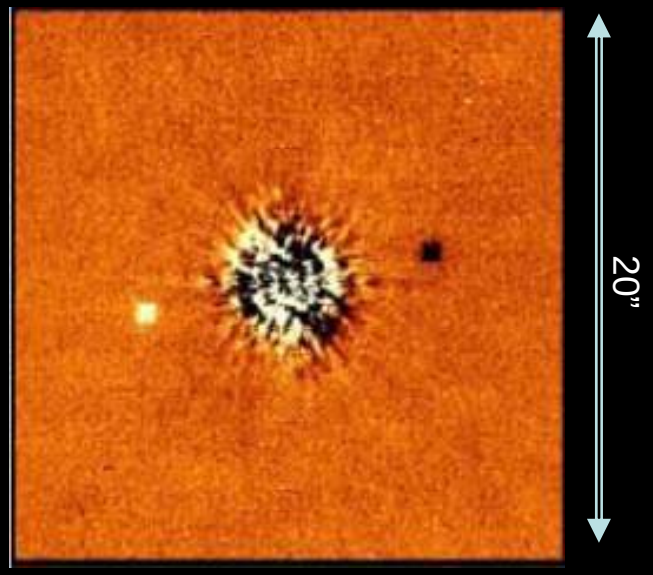
- HiCIAO: High Contrast Instrument for the next generation Adaptive Optics
  - For Subaru 8.2m telescope
  - PI & CoPIs: Motohide Tamura (NAOJ), Klaus Hodapp (UH), Ryuji Suzuki (NAOJ; now TMT)
  - Based on a previous Japan/MEXT grant
- Combined with the curvature-sensing AO with 188 elements (Hayano, Takami et al.) and SCExAO1024 upgrade (Guyon, Martinache)
- Commissioned mainly in 2009 with AO188 (including Princeton/MPIA teams for angular differential imaging and commissioning)

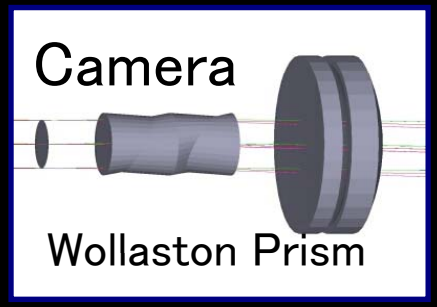
- Specification and Performance
  - 2048x2048 HgCdTe detector and ASIC readout
  - Wavelengths: 1 – 2.5 microns (NIR)
  - Observing modes: DI, PDI (dual beam), SDI (quad beam), & ADI; w/wo occulting masks (>=0.1"ϕ); 10mas/pixel
  - Contrasts on-sky: 10^-6 at 1", 10^-4 at 0.15"
    - Roughly 10 times better than CIAO, as specified



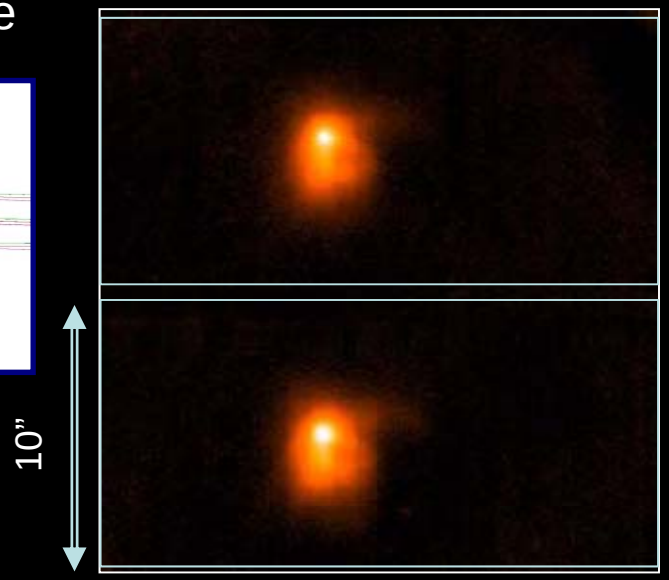
Four observation modes of HiCIAO: DI, PDI, SDI, ADI

Direct Imaging (DI) mode

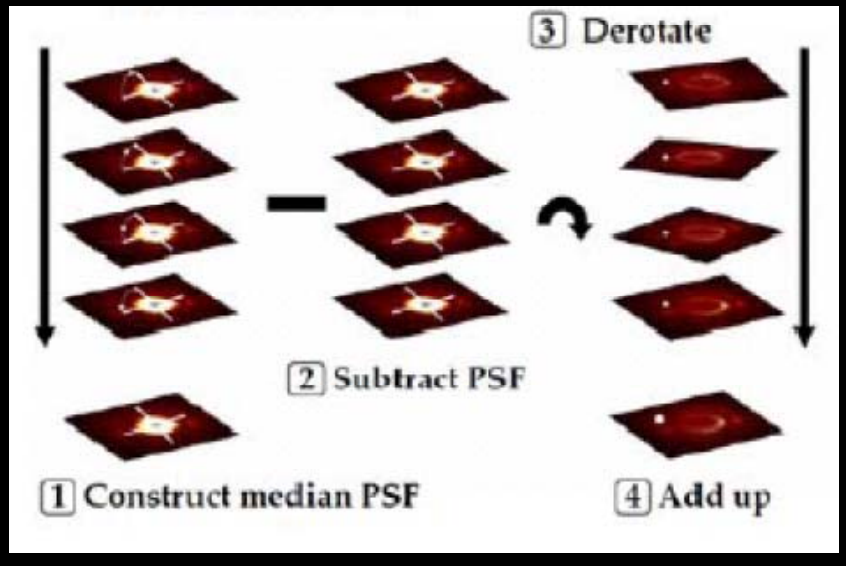




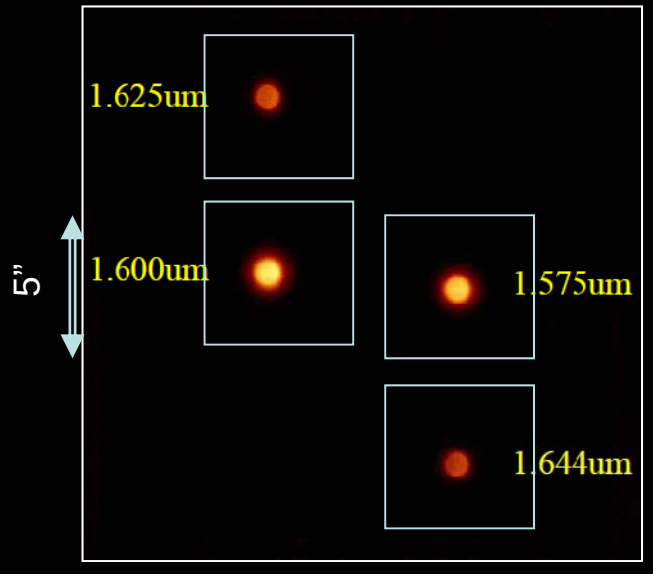
Polarization Differential Imaging (PDI) mode



Angular Differential Imaging (ADI) mode



Spectral Differential Imaging (SDI) mode



SEEDS Target/Observation Summary

Category	Planet searches			Disk searches		Total number
	(a)	(b)	(c)	(d)	(e)	
	SFR YSOs	Open cluster & Moving Group	Nearby stars & WDs	Protoplanetary disks	Debris disks	
Target #	210	60+40	140+37	Same targets as (a)	70	557 Target balance can change
Distance	~140 pc	<~125 pc	<~30 pc	~140 pc	<~130 pc	
Age	1-10 Myr	10~100 Myr	100 Myr - 1 Gyr	1-10 Myr	5 Myr - 6 Gyr	
Observed in 9 nights	11	10+11	19+1	Same targets as (a)	8	60 Including multiple observations
Refereed Publications			HAT-P-7, GJ758x2	LkCa15, AB Aur		5

Adaptive Optics-Deformable mirror broken in 2009 Jan,
but fully recovered.
SEEDS runs have resumed in this November.
We already have some notable results as described below.

Summary of Early Results

- Direct imaging of planet candidates around an old G-type star GJ758,

  Thalmann et al. 2009, ApJL, 707, 123.

- Search for outer massive bodies around transiting planetary systems: Candidates of faint stellar companions around HAT-P-7,

  Narita et al. 2010, PASJ, 62, 779

- Imaging of a transitional disk gap in reflected light: Indications of planet formation around the young solar analog LkCa 15,

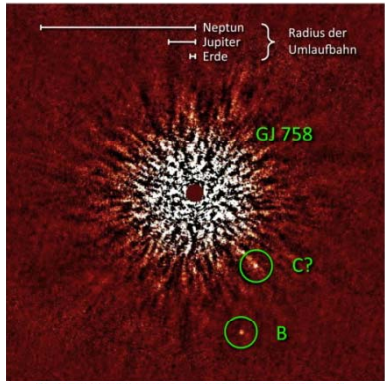
  Thalmann et al. 2010, ApJL, 718, L87.

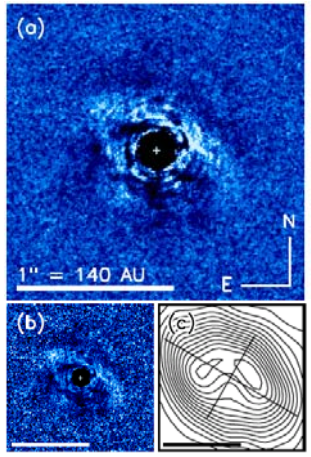
- Near-infrared multi-band photometry of the substellar companion GJ 758b,

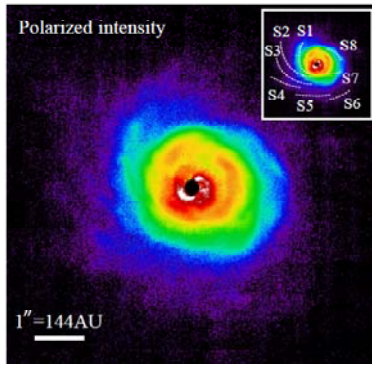
  Janson et al. 2011, ApJL, in press.

- Direct imaging of fine structures in giant planet forming regions of a protoplanetary disk around AB Aur,

  Hashimoto et al. 2011, ApJL, in press





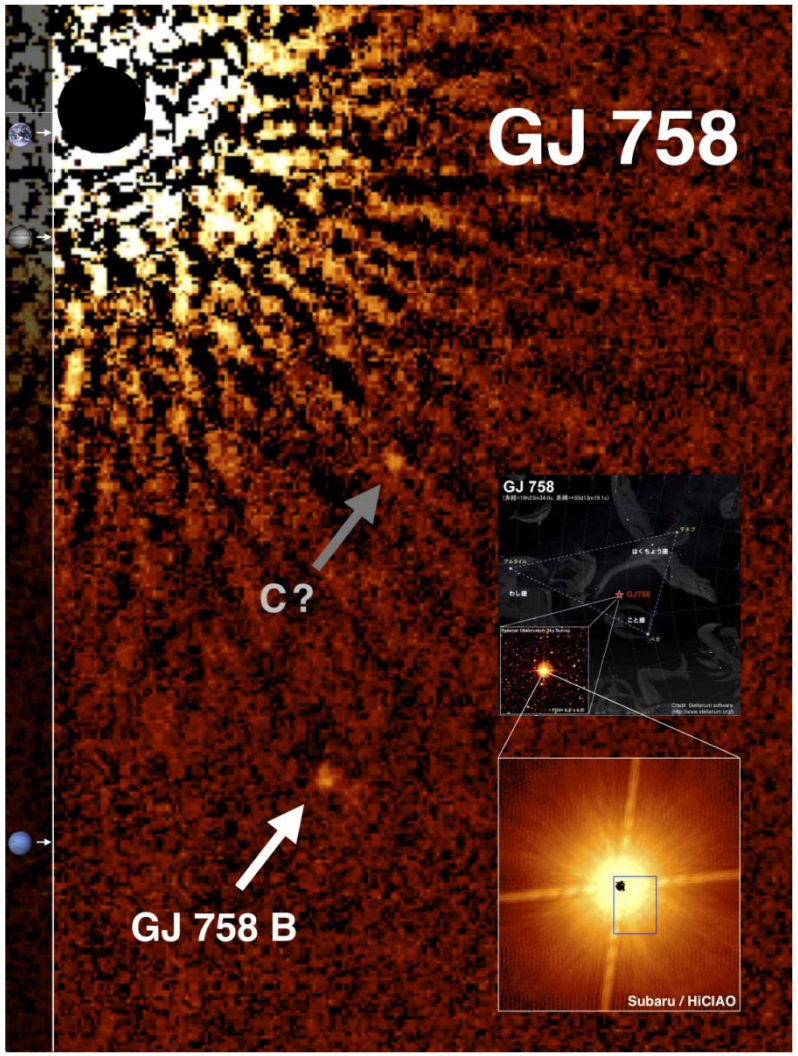


Direct Imaging of Planet Candidates around a G Star GJ 758

- G9 Type
  - V=6; Mass=0.97Mo
- Distance: 16pc
- Age
  - Isochrone estimate: 700Myr (Takeda et al. 2007; isochrone)
- GJ 758B
  - Common proper motion
  - Possible orbital motion
  - 10-30MJupiter (age uncertainty)

- Follow-up with Keck, Gemini
  - Narrow-band spectroscopic confirmation
  - Methane feature
  - Janson et al. 2011

GJ758=HD182488=HIP95319



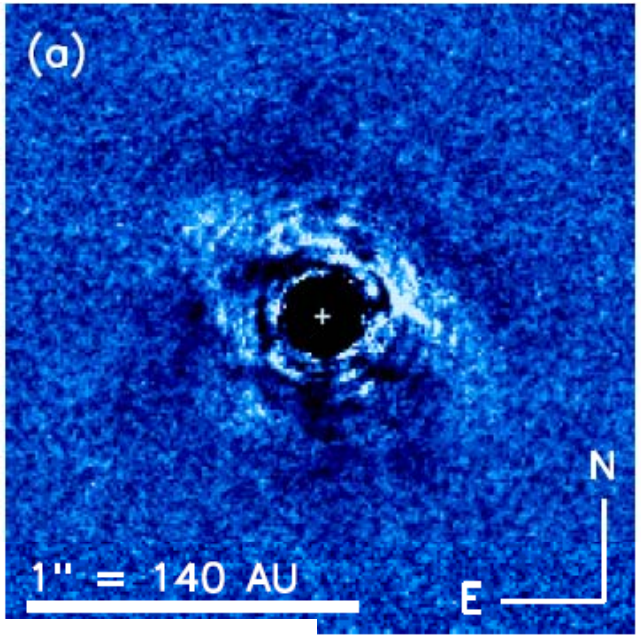
1.6 micron image with ADI

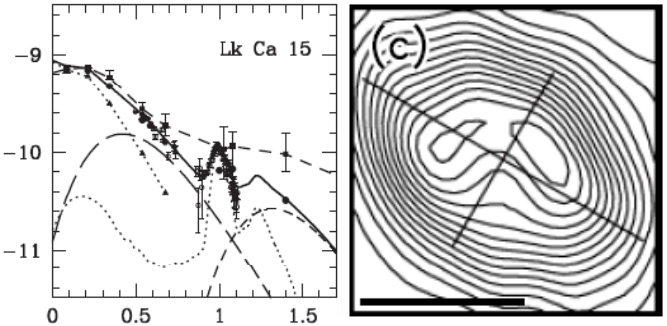
Thalmann et al. 2009

Imaging of transitional disk gap of a WTTS " LkCa 15 " in reflected light

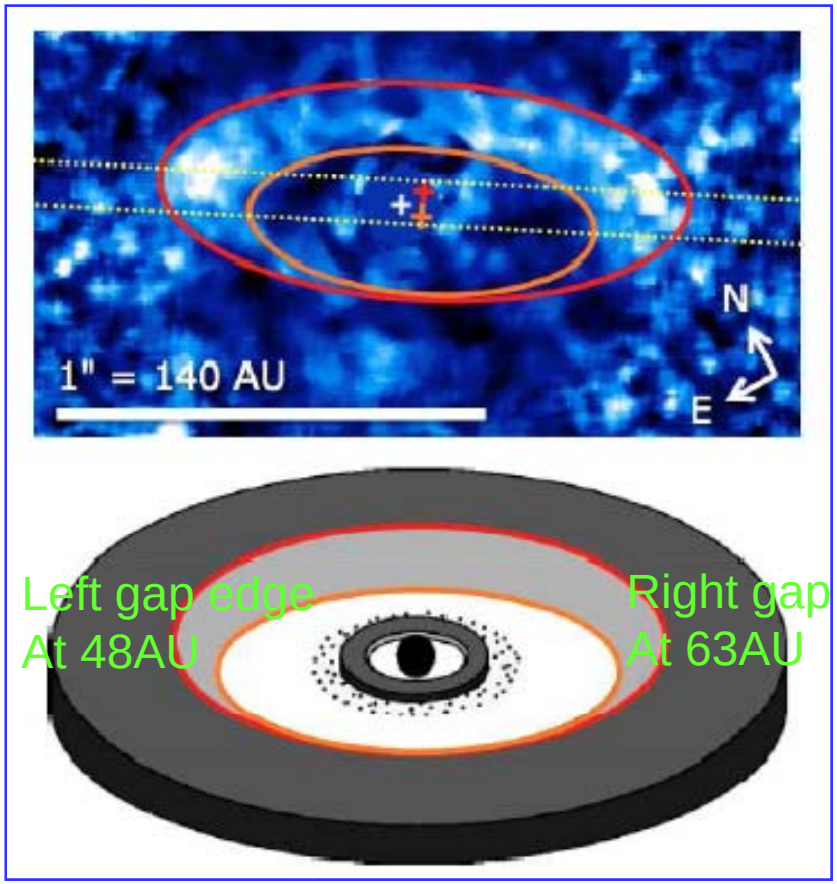
0.97Mo, 1.5-5Myr

(Thalmann et al. 2010)





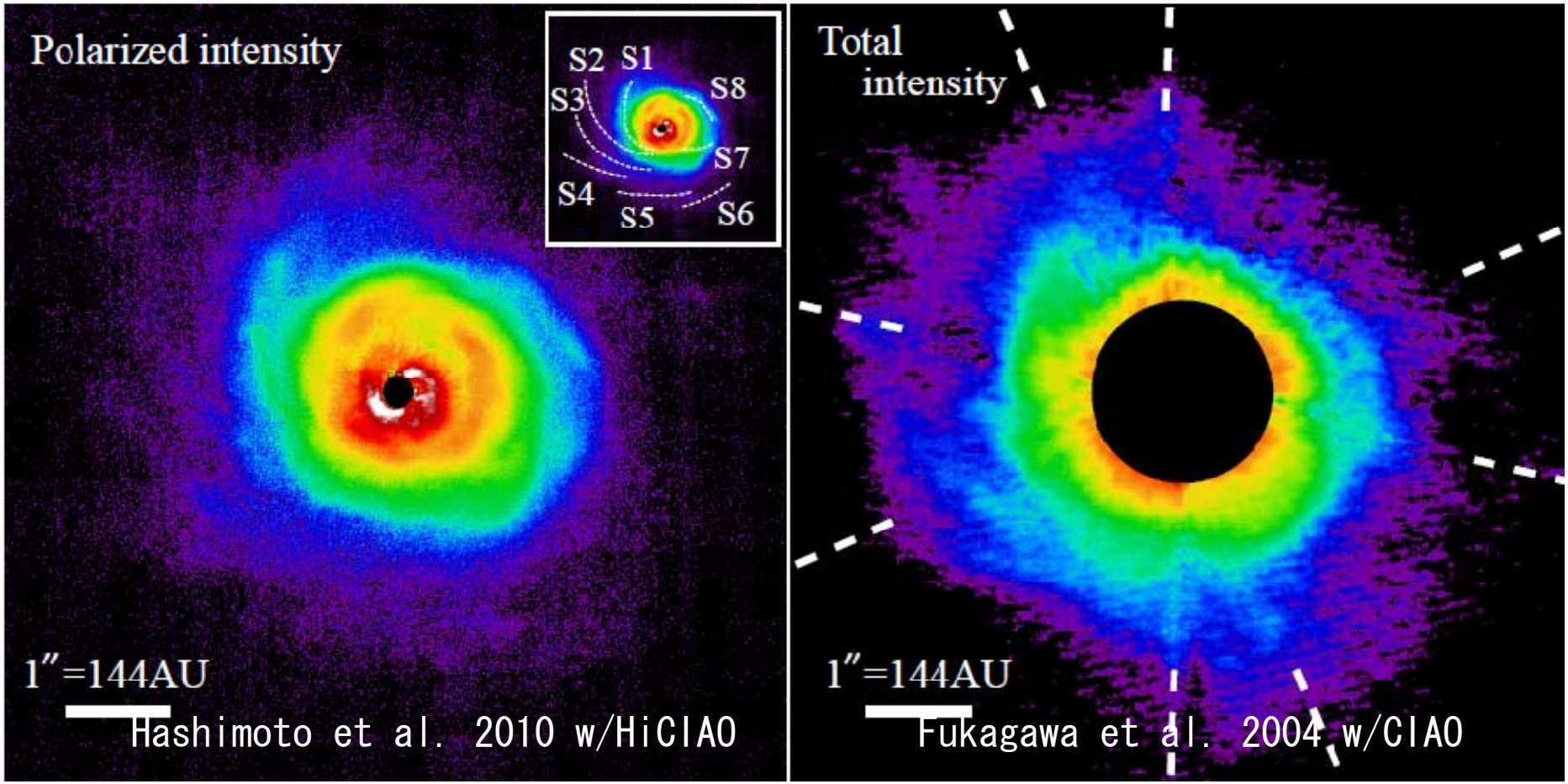
1.6 um image, SED (Bergin+04), 1.4mm continuum map (Pietu+08)



(Top) Ellipse fits to the inner and outer boundaries of the illuminated disk wall.
(Bottom) Sketch of the disk architecture.

Sharpest and closest image of AB Aur Disk

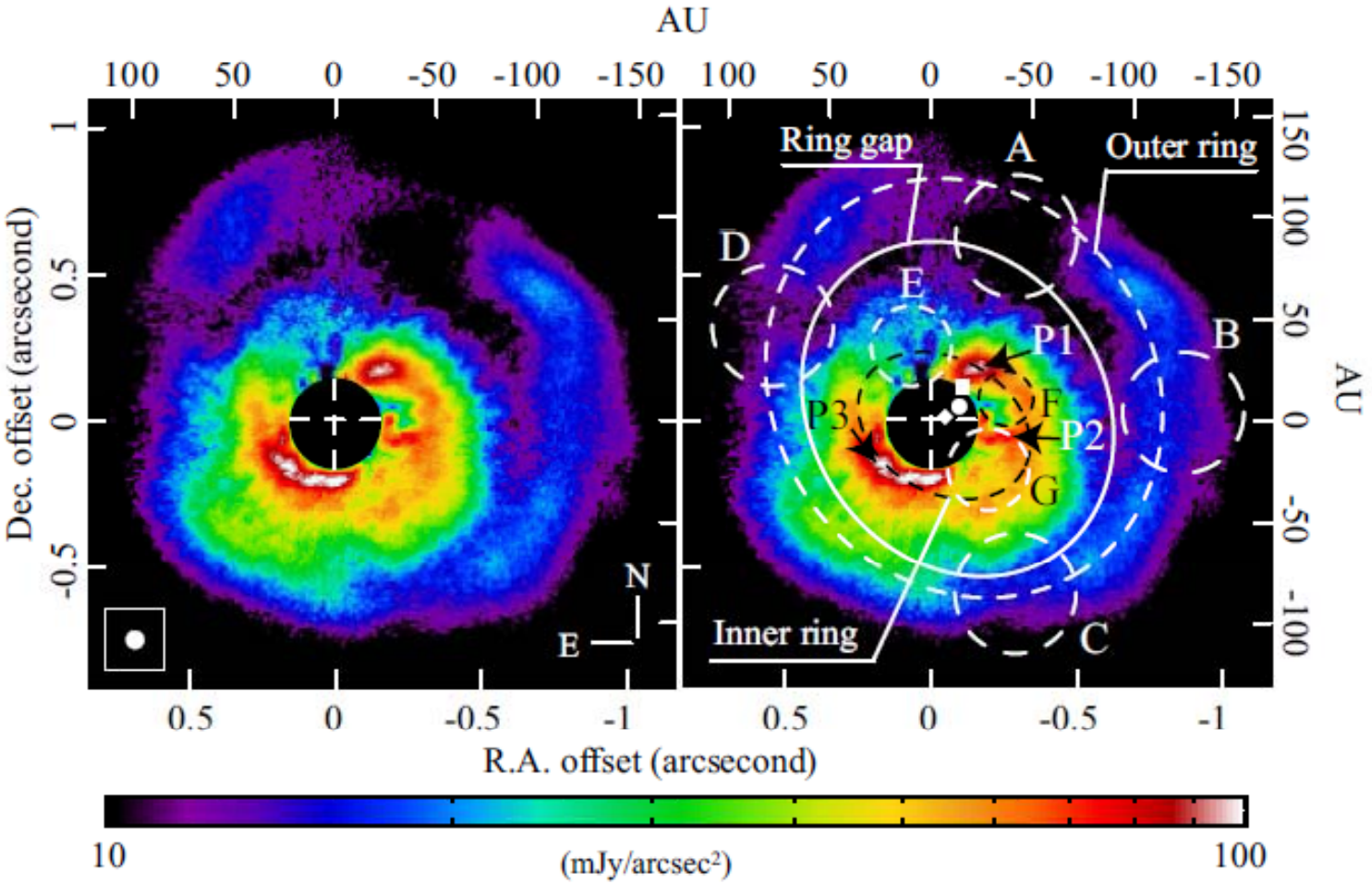
- AB Aur: Herbig Ae star, age=4Myr, mass=2.4Mo, distance=144pc
- The first r<40 AU & 8 AU resolution images (1.6um)
- PI image, but not POL pattern but mostly INTENSITY pattern (see Figure)
- Hashimoto, Tamura, Muto et al. 2011



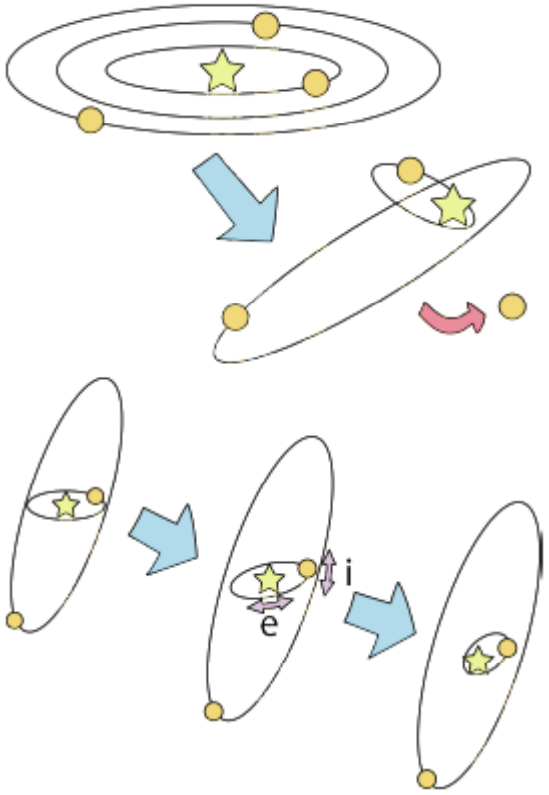
Sharpest and closest image of AB Aur Disk

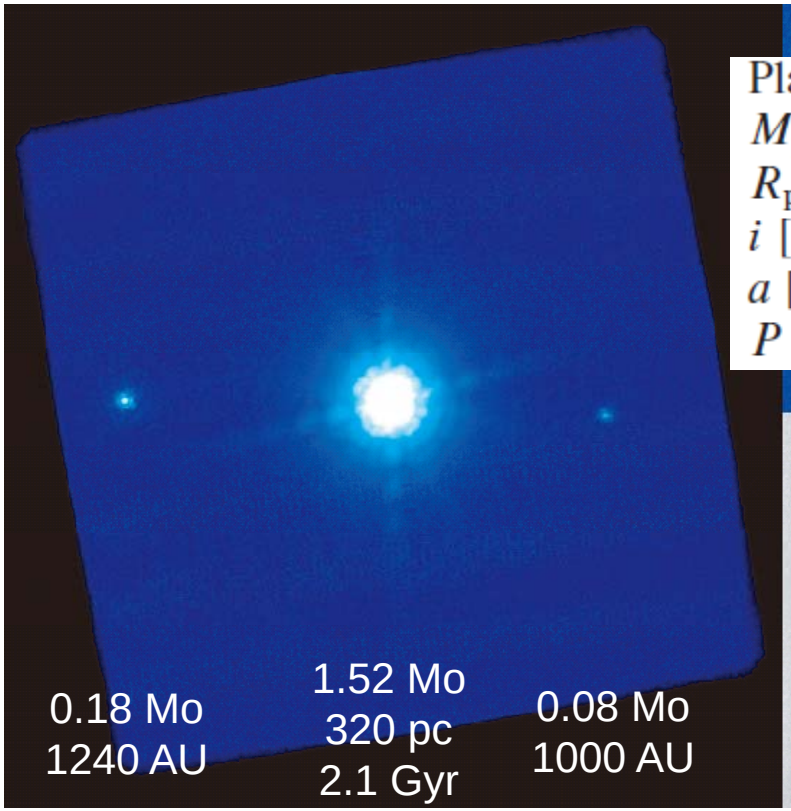
- PI image, but not POL pattern but mostly INTENSITY pattern (see Figure)
- Double & bumpy “rings” as well as ring-like “gap”
- Possible disk “warp” and “offset”

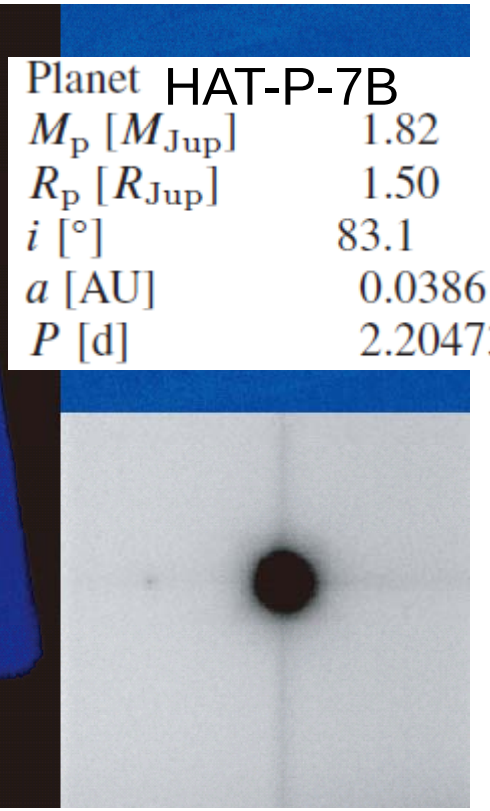
Disk Fine Structures
-> Planet existence



Search for Outer Massive Bodies around Transiting Planetary Systems: Candidates of Faint Stellar Companions around HAT-P-7 (320pc) (Narita et al. 2010)







Planet	HAT-P-7B
M_p [M_{Jup}]	1.82
R_p [R_{Jup}]	1.50
i [°]	83.1
a [AU]	0.0386
P [d]	2.204733

Left: 1.6 um image of HAT-P-7 (12"x12"). Upper right: A ADI/LOCI reduced Subaru image (6"x6"). Lower right: AstraLux z' band image of HAT-P-7 and the eastern companion candidate.

Seeking for evidence for planet scattering or migration

SEEDS Members

- 26 institutes 110 members (36 international).

- Principal Investigator (PI): M. Tamura (NAOJ)
- Co-PI: T. Usuda, H. Takami (NAOJ)
- MOU w/ Princeton, soon w/ MPIA

Runs in S10B & Plan for S11A

- ~12 nights per semester allocation continues.
- 11/29: HiCIAO+AO188 engineering; successful !
- 11/30-12/2: SEEDS run#4; poor weather
- 12/25-12/28: SEEDS run#5; extreme bad weather
- 1/27-1/31: SEEDS run#6; next week !

- Three runs in S11A (Mar, May, Jul).

How to manage the SEEDS project

- The “Rule” book
  - Membership
  - Observations
  - Data
  - Publications
  - Follow-ups,
- All category meetings (monthly)
  - 5/6, 6/3, 7/5-9(Princeton workshop), 7/29, 9/2, 10/7, 11/4, 12/9, 1/13 in this school year 2010
- Each category meetings
  - YSO, OC, NS, DD, MG, WD
  - weekly to monthly, depending on each category
- Data reduction workshop
  - LOCI workshops
  - PDI workshop in plan

Memorandum: Rules for SEEDS collaborations Ver. 3.0

M. Tamura

2008.5.9; 2009.11.2, 11.21, 11.30, 12.1, 12.25; 2010.2.16, 6.1

This document describes the general rules on the SEEDS collaborations. This version is not for complete agreement but rather for agreeing general policy on rules and making necessary items.

I. SEEDS Membership

1. New Japanese collaborators

A) SEEDS (Strategic Explorations of Exoplanets and Disks with Subaru) is the Strategic Observations project that encourages collaborations, in particular among Japanese researchers. Therefore, new Japanese members are welcome even after the start of the SEEDS observations. If the SEEDS PI is contacted by a Japanese researcher, the PI will report it to the core member (currently the SEEDS proposal core composed of the instrument and observatory key persons) for permission.

2. Membership of students (both Japanese and international)

Students are not permanent and new students might join the SEEDS project at any time. Therefore, different rules are necessary.

A) New students can join the SEEDS project if they have appropriate supervisor(s). The student supervisor should contact with the SEEDS PI for permission.

B) If there is no appropriate supervisor, the student can contact with the SEEDS PI.

C) The students moving to new positions can keep the SEEDS membership, if they wish.

3. New foreign collaborators

A) Institutional-partnership foreign collaborators (currently Princeton with MOU, and MPIA planning to make MOU with NAOJ eventually) are regarded as the Japanese collaborators that do not always make MOU with NAOJ. They basically have the same duty and right with the Japanese member.

B) Other new foreign collaborators are not based on institutional-partnership but rather are individual researcher-based. In this case, each member should

Summary

- Direct imaging techniques for exoplanet studies are important for detecting wide orbit planets and studying their properties such as atmospheres.
- First Subaru Strategic Program “SEEDS” of a direct imaging survey for exoplanets/disks has started (120 nights for 5 years) in 2009.
- Early results on planet candidates and protoplanetary disk fine structures are introduced.
  - GJ758, HAT-P-7: SUGGESTION OF OUTER PLANETS
  - AB Aur, LkCa15: DISK SIGNPOST OF PLANETS
- Some 110 people including 25% international member are now involved in SEEDS.
- Lots of management experiences in a large international science project (e.g., “Rules”).