

Missed Objects in the HST archive

An insight of the ALICE project



Elodie Choquet

Hubble Fellow,

Jet Propulsion Laboratory,

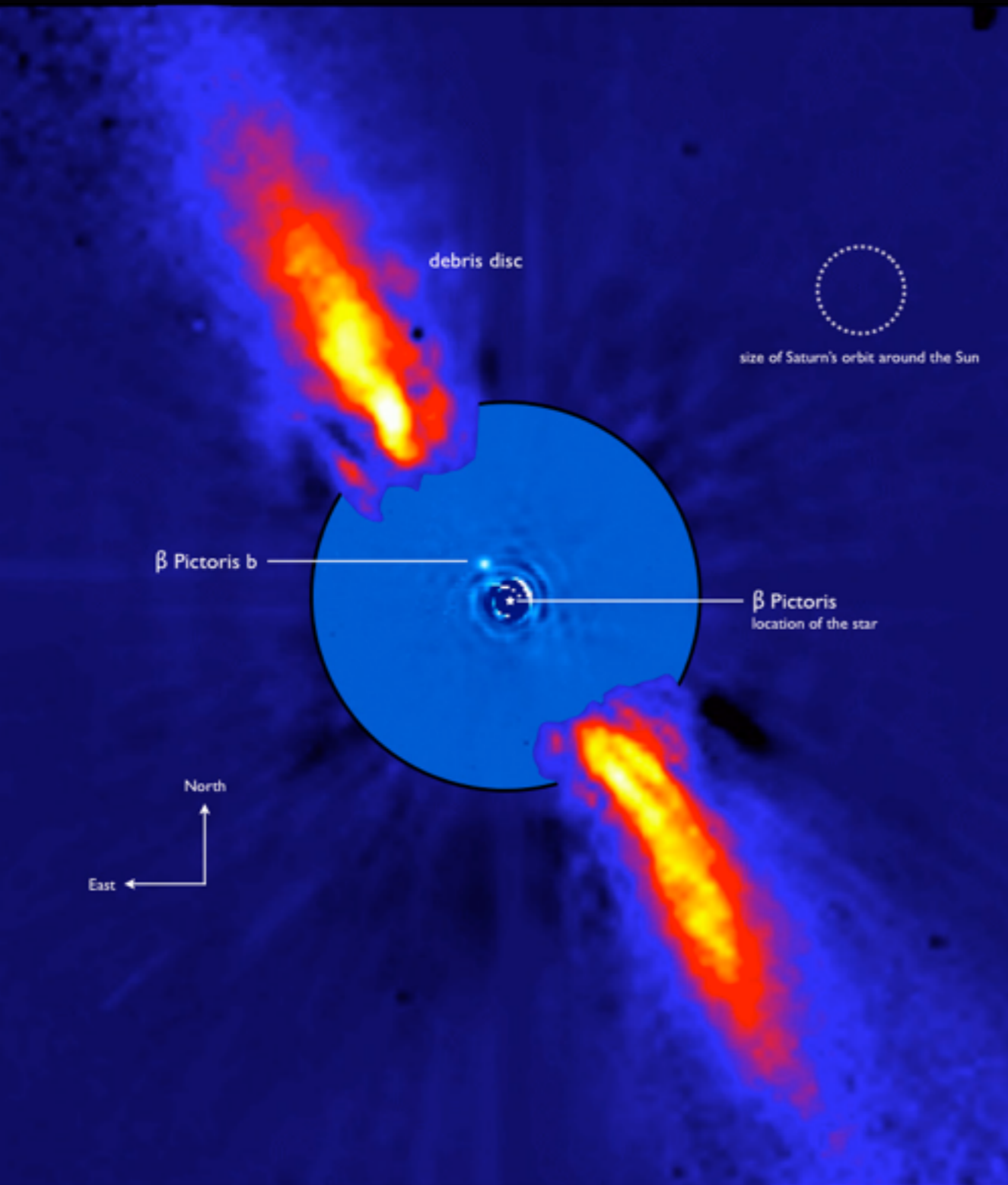
California Institute of Technology

The ALICE Team and collaborators:

R. Soummer (PI), M. Perrin, L. Pueyo, B. Hagan, C. Chen,
D. Golimowski, J. Debes, D. Hines, G. Schneider, C. Stark, A. Moro-Martin, D. Mawet,
E. Gofas-Salas, S. Wolff, J. Mazoyer, M. N'Diaye, M. Ygouf, A. Greenbaum, B. Ren, J. Milli



Imaging of Outer Regions



Atmospheric analysis of planets

Orbital analysis of planets

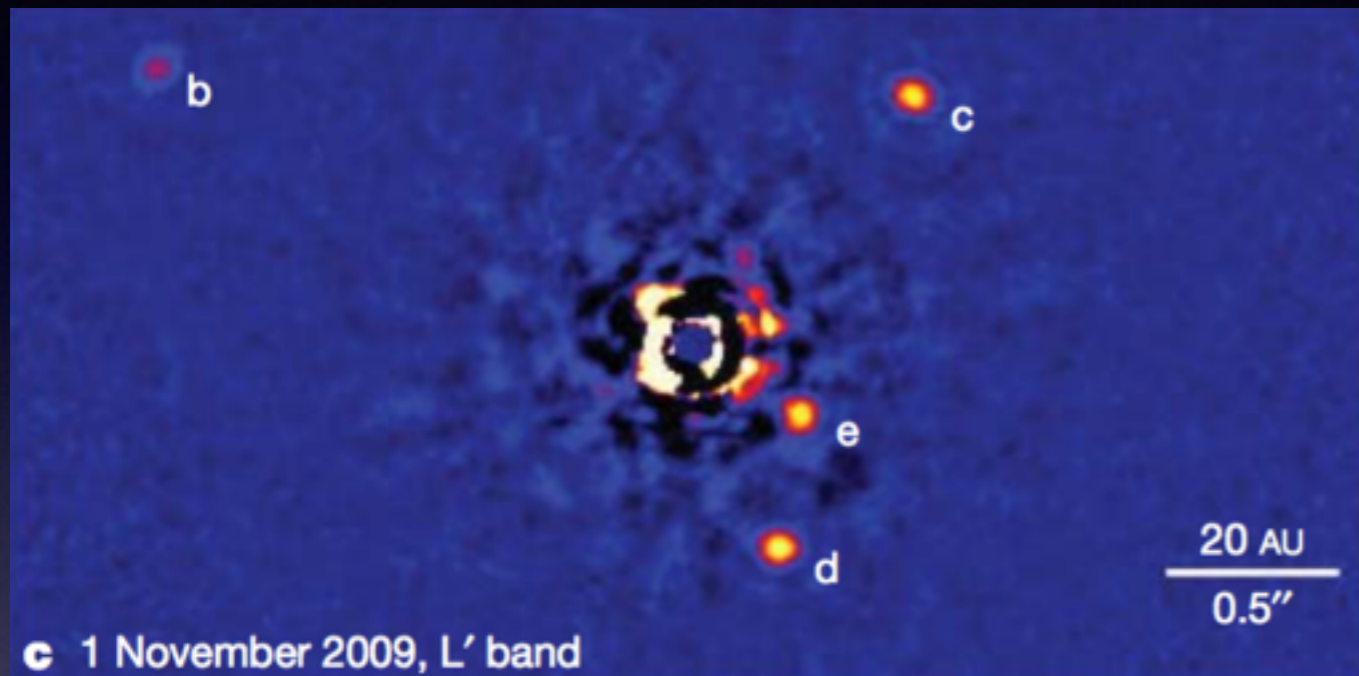
Morphologic analysis of disks

Dust properties of disks

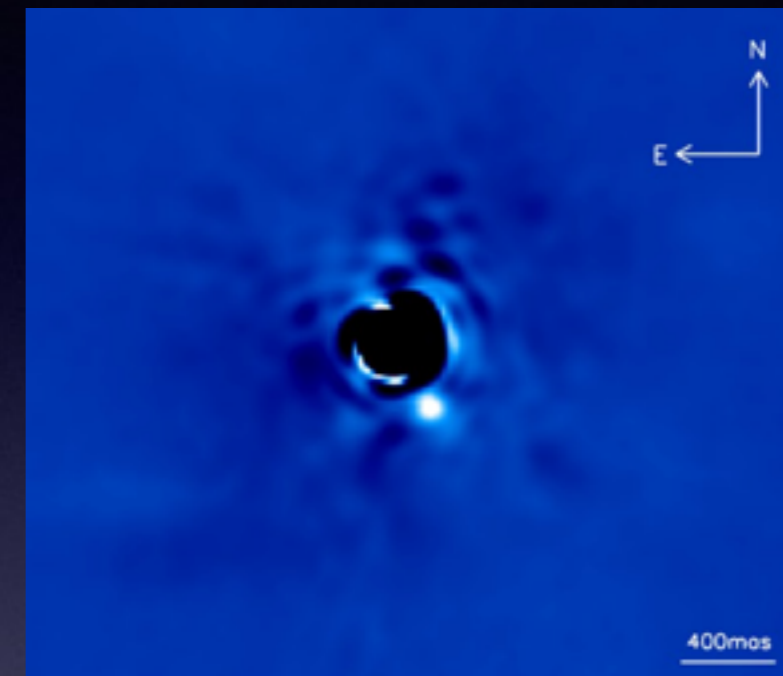
Planet-dust interactions

Exoplanet gallery

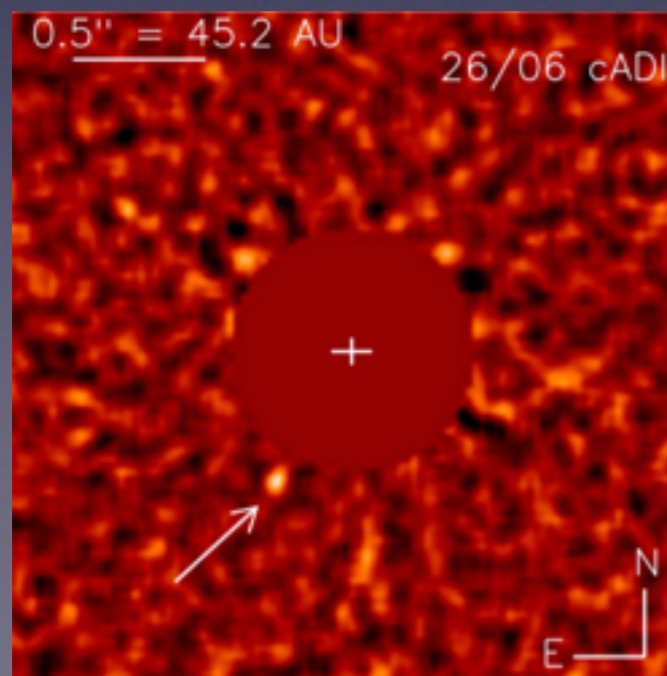
HR 8799 b, c, d, e



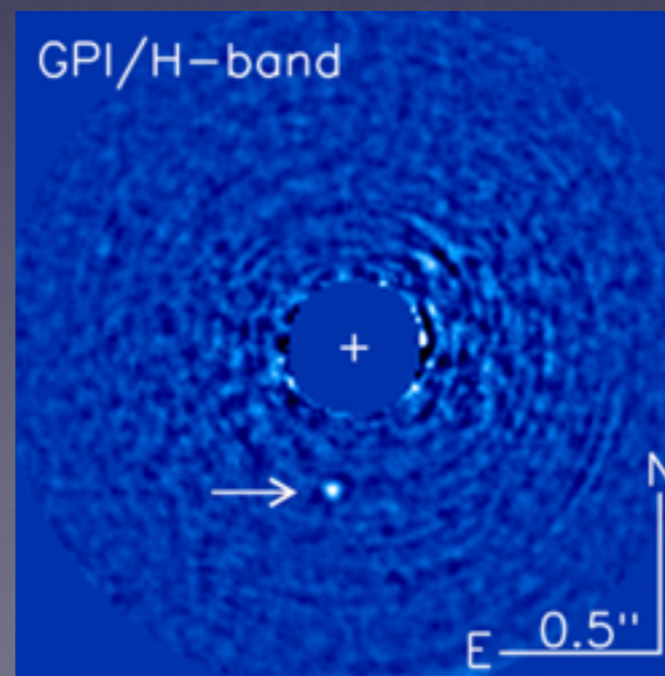
beta Pic b



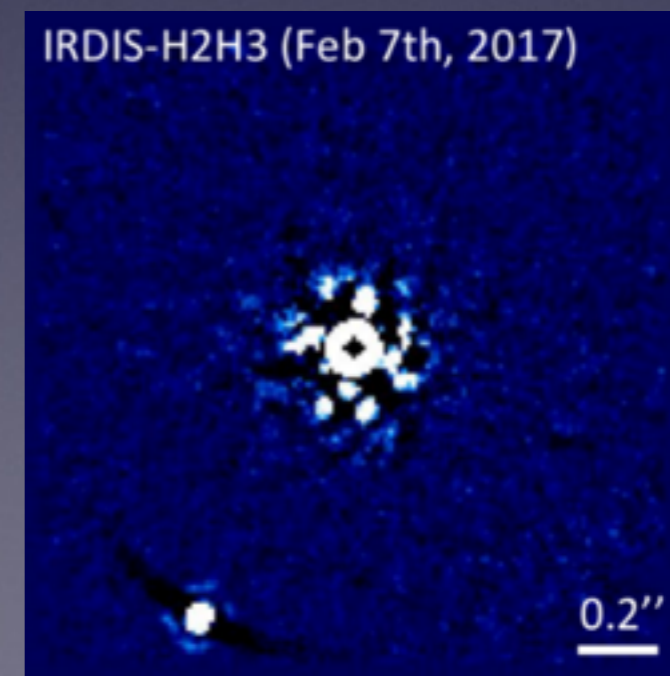
HR 95086 b



51 Eri b



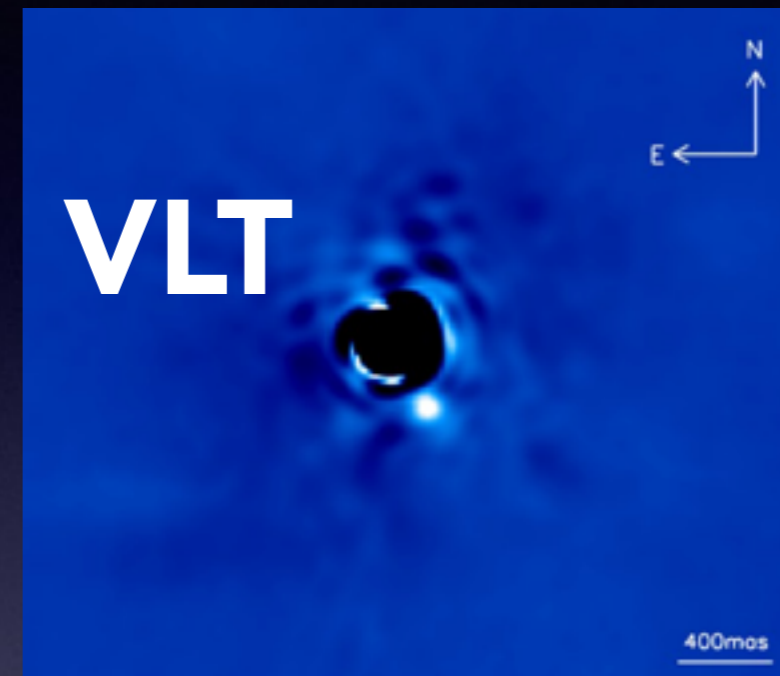
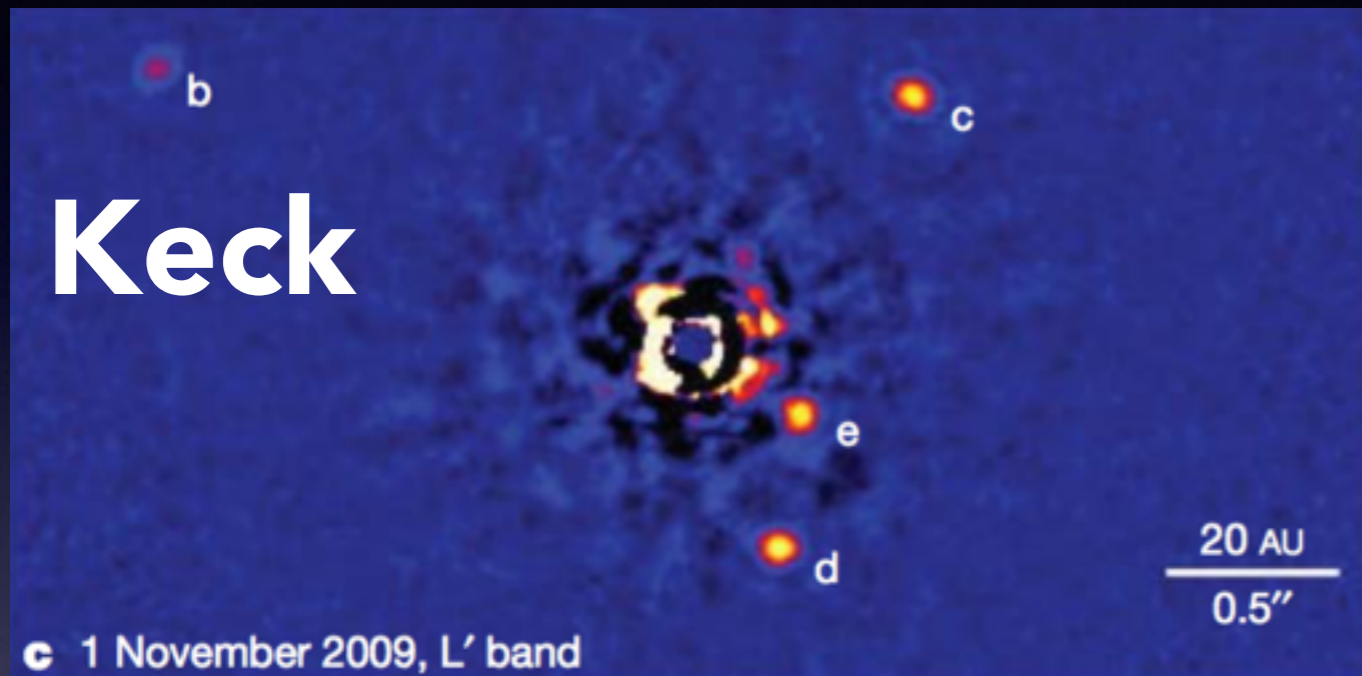
HIP 65426



Exoplanet gallery

HR 8799 b, c, d, e

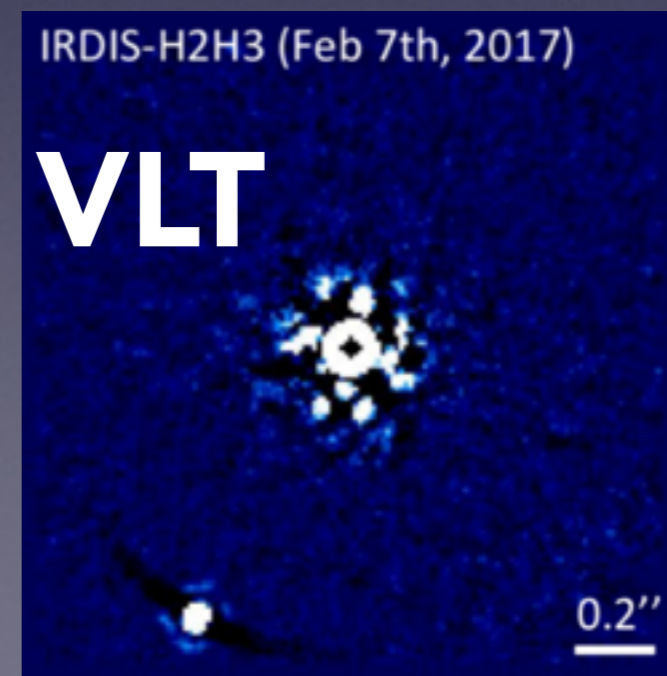
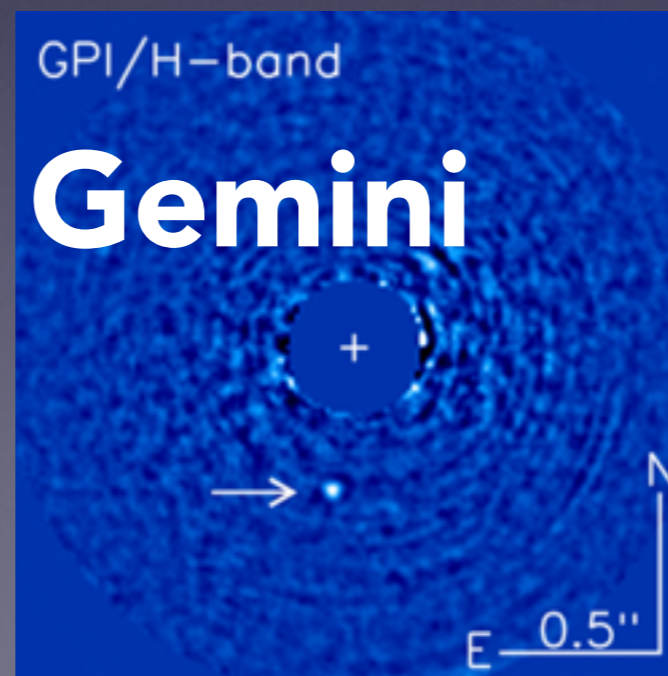
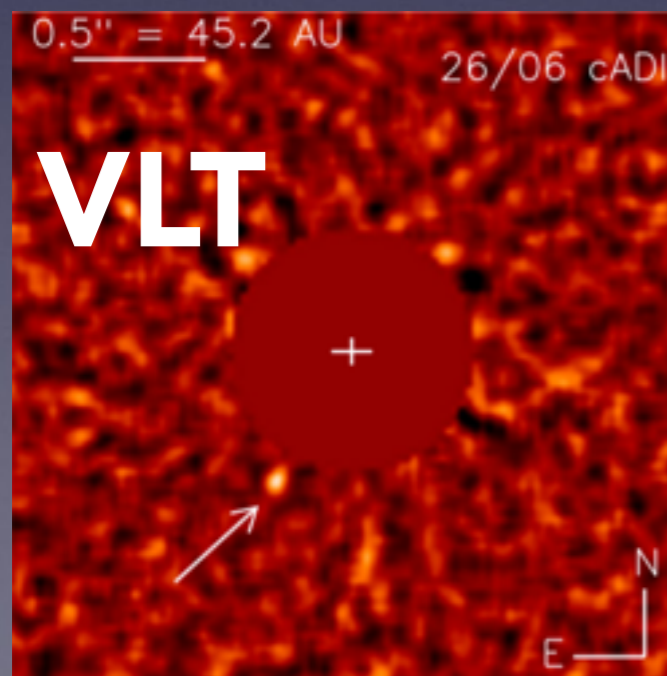
beta Pic b



HR 95086 b

51 Eri b

HIP 65426



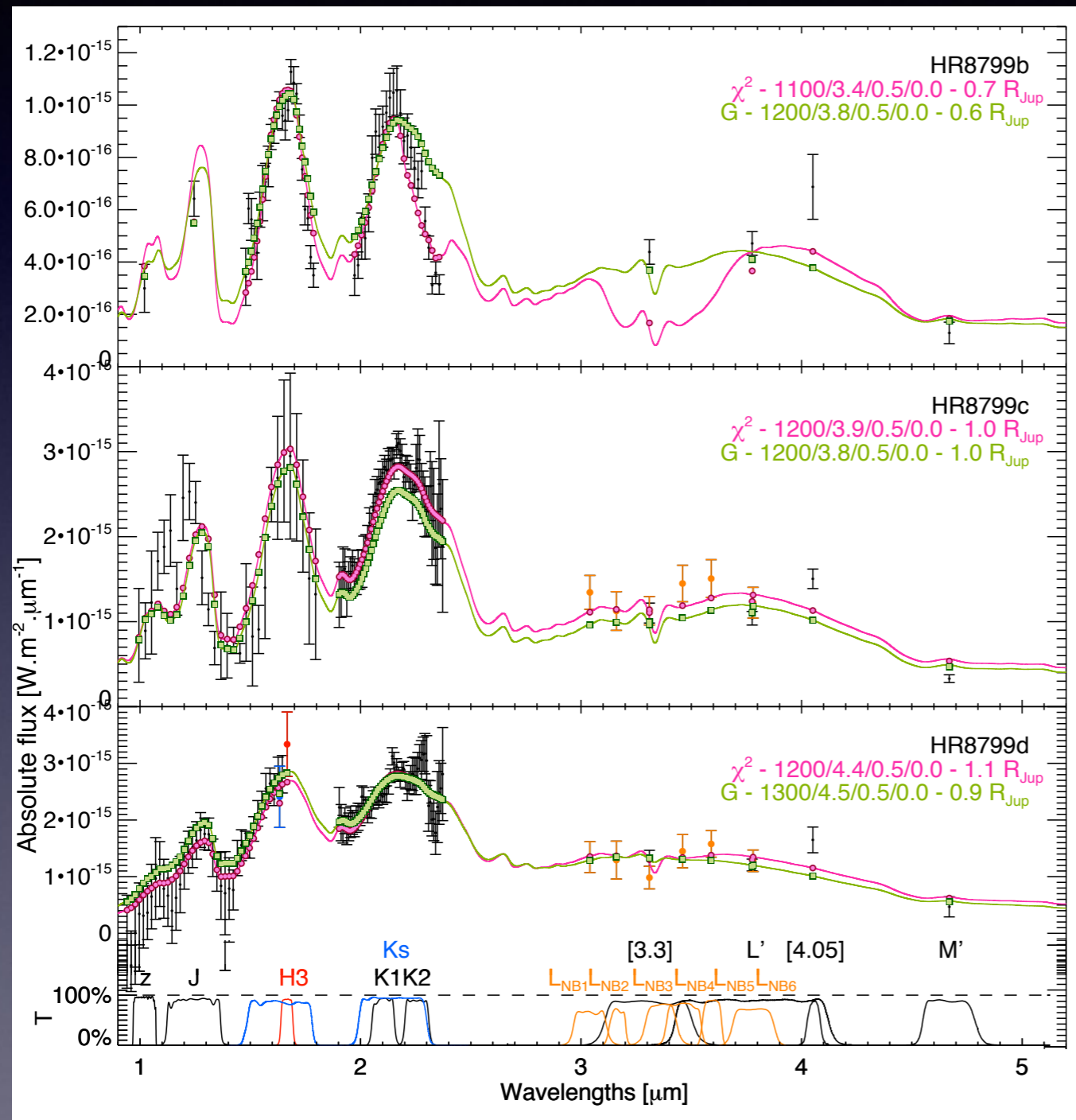
"Hubble can't image exoplanets"

"Hubble can't image exoplanets"

WRONG!

HR 8799 - Planets b, c, d

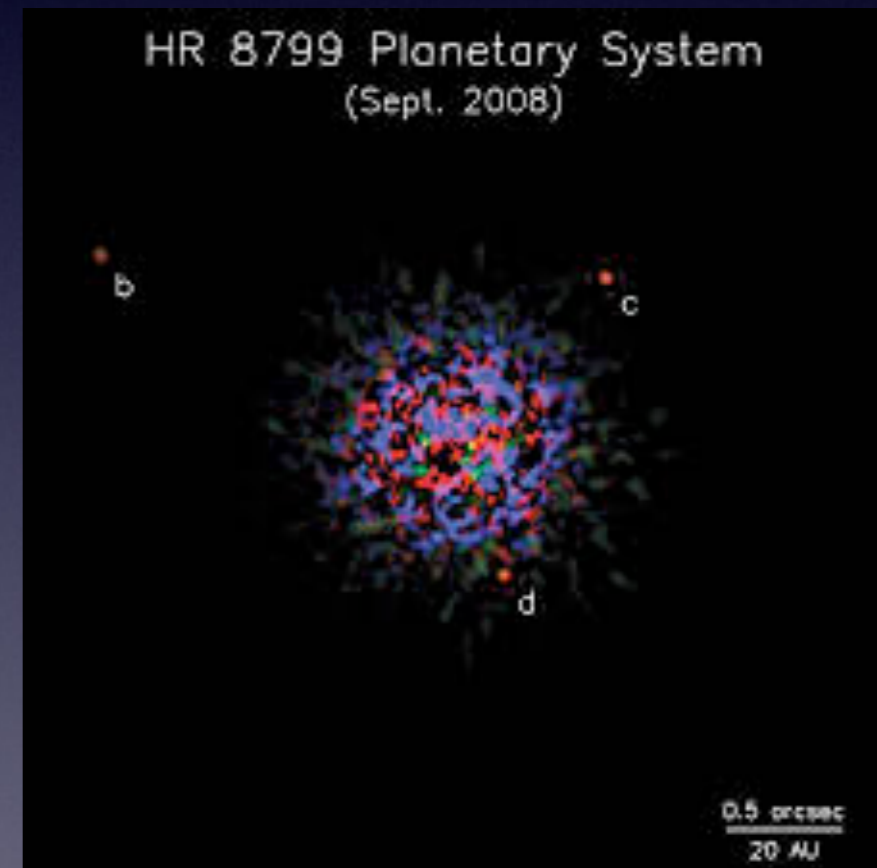
Best direct spectro-photometry



Bonnefoy et al. 2016

2008

Keck Telescope



Marois et al. 2008

Discovery

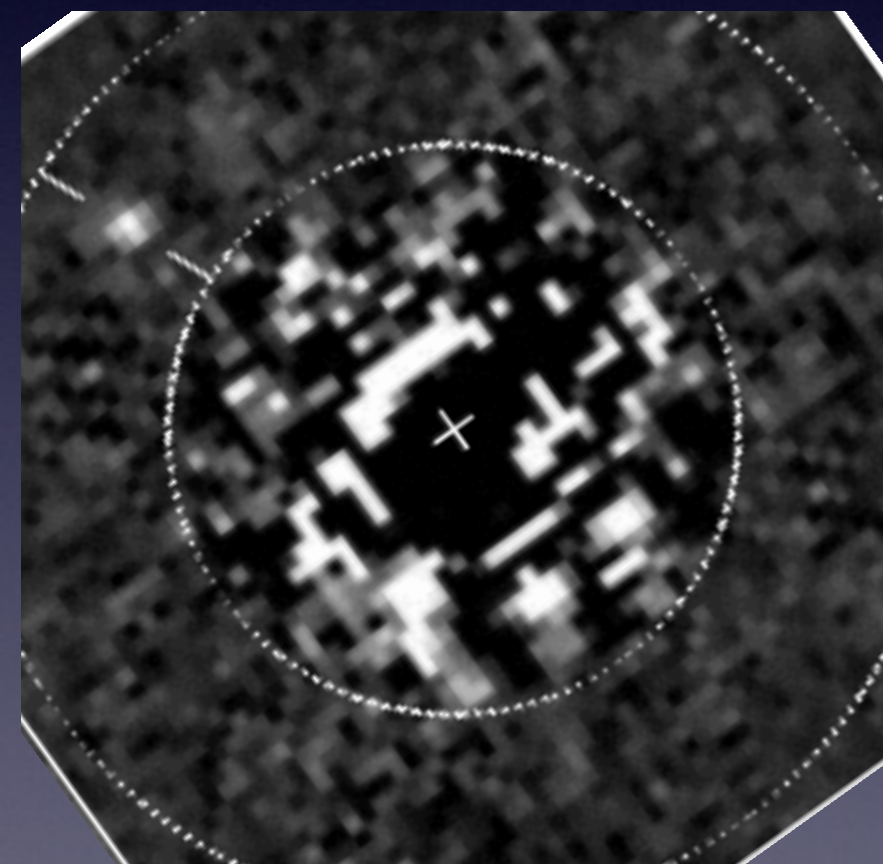
HR 8799 - Planets b, c, d

1998

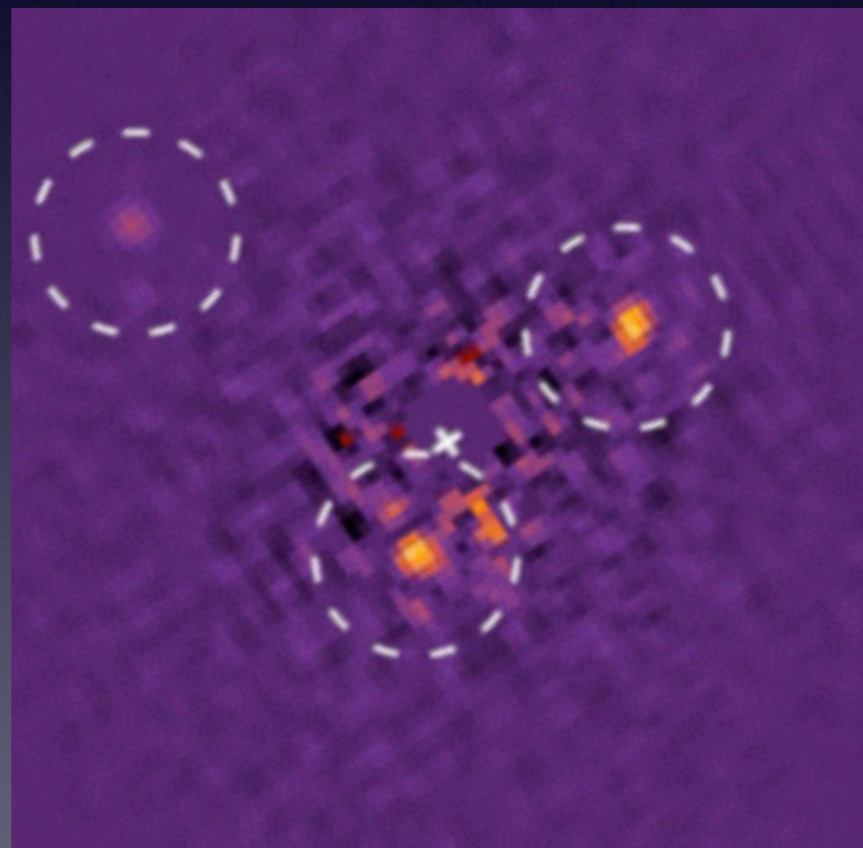
Hubble Space Telescope

2008

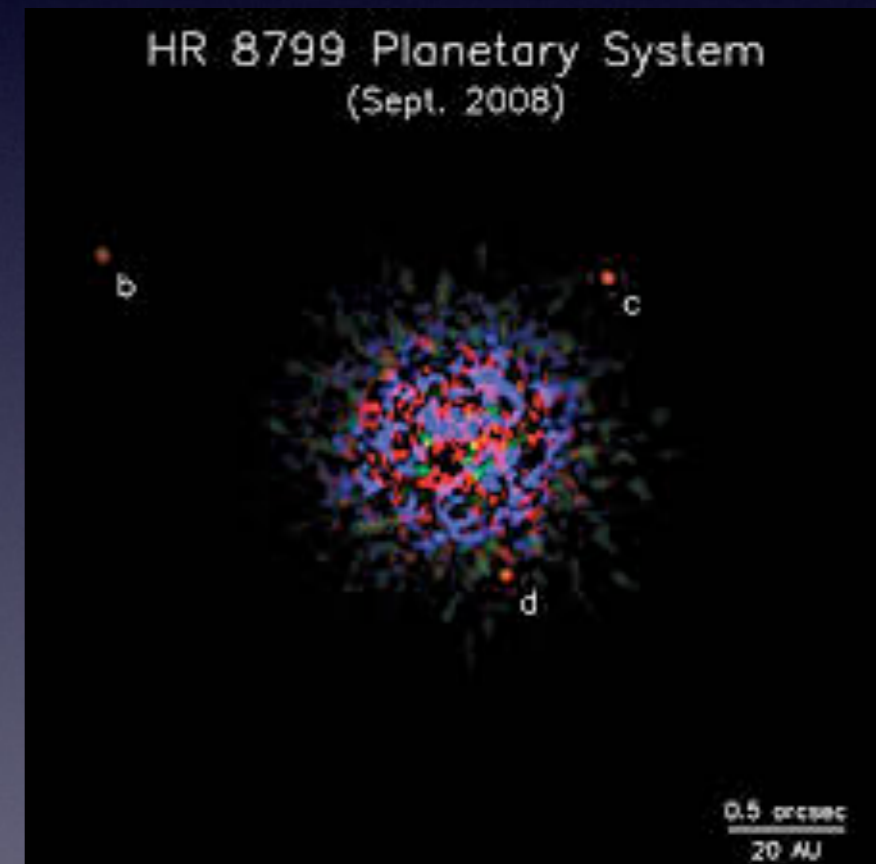
Keck Telescope



Lafrenière et al. 2009



Soummer et al. 2011



Marois et al. 2008

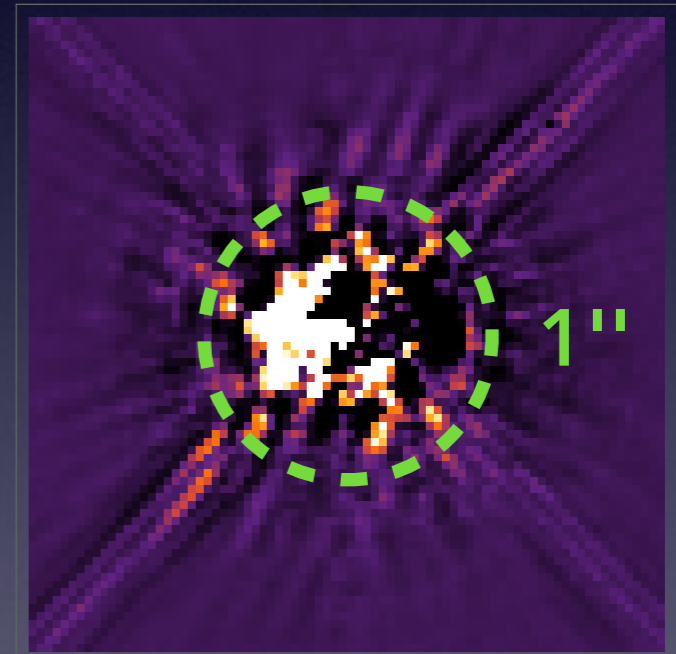
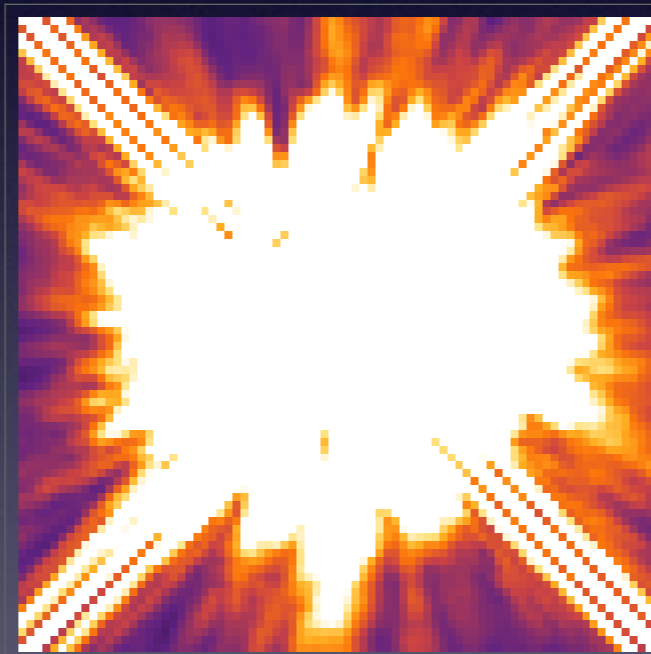
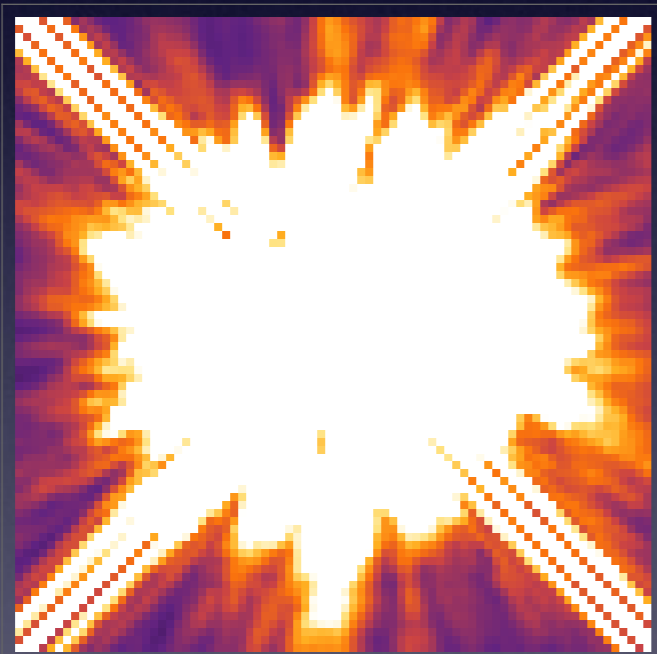
RE-Discovery

Discovery

Starlight Subtraction Methods

Classical Subtraction

$$T - R = \text{Residuals}$$

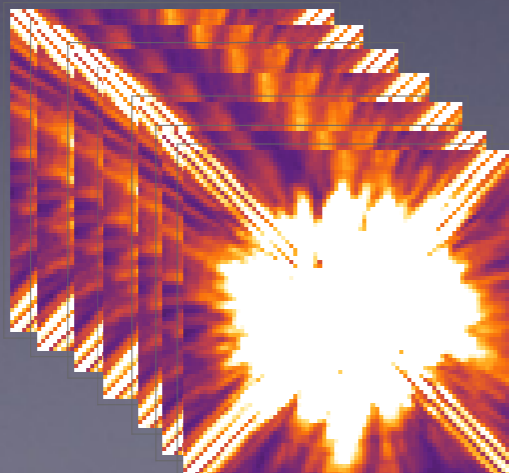
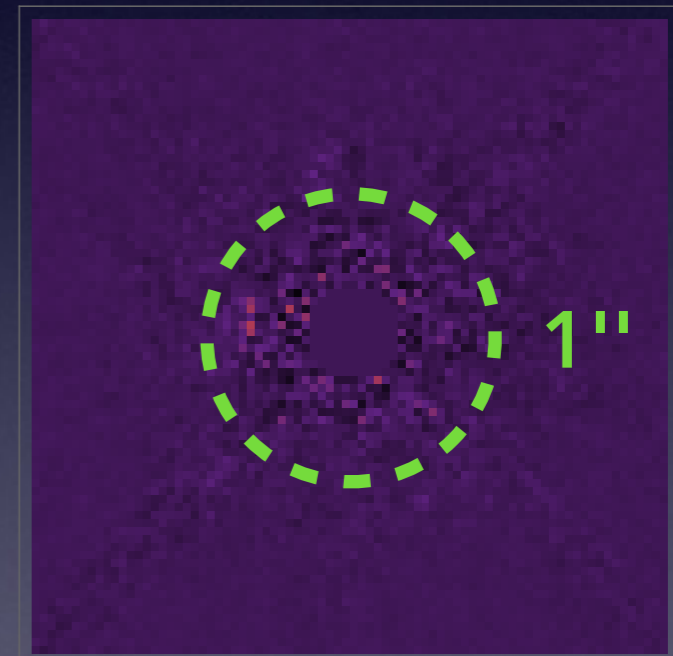
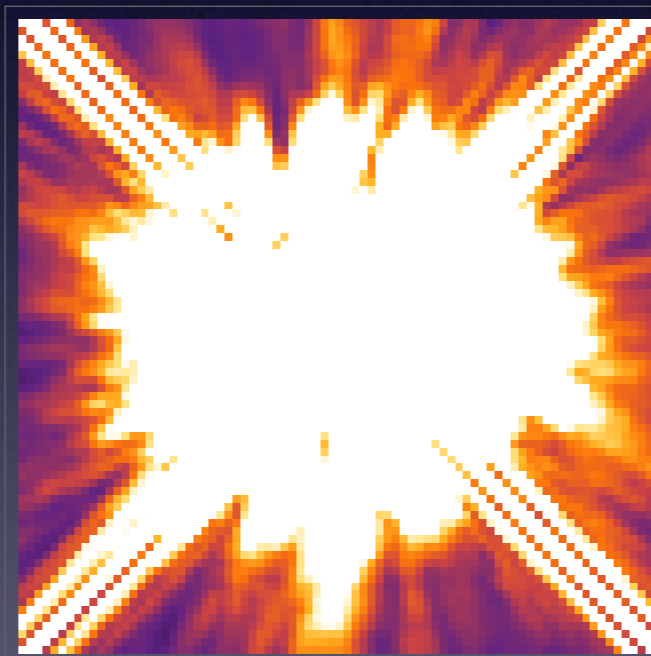
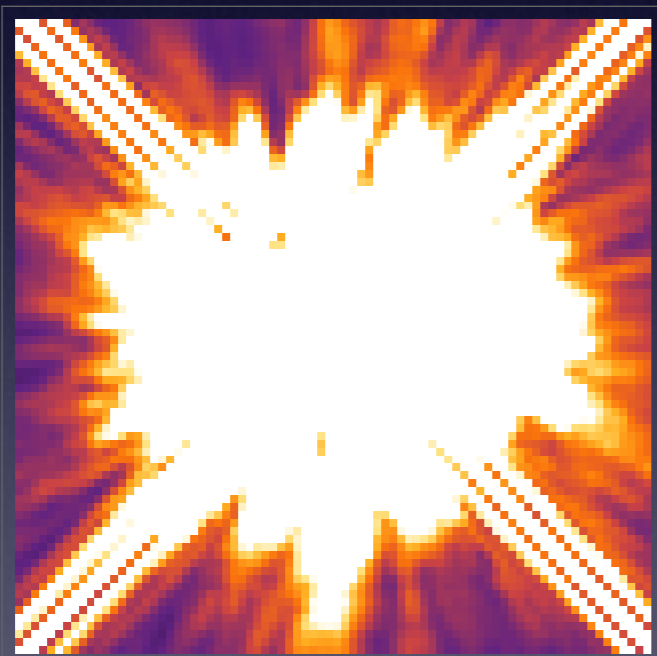


Telescope Roll
Reference star

Starlight Subtraction Methods

Advanced Subtraction

$$T - R = \text{Residuals}$$



Synthetic image

$$\min_{c_k} \left\| T - \sum_k^n c_k R_k \right\|^2$$

Lafrenière et al. 2007
Soummer et al. 2012
Marois et al. 2014

Creating PSF libraries for HST

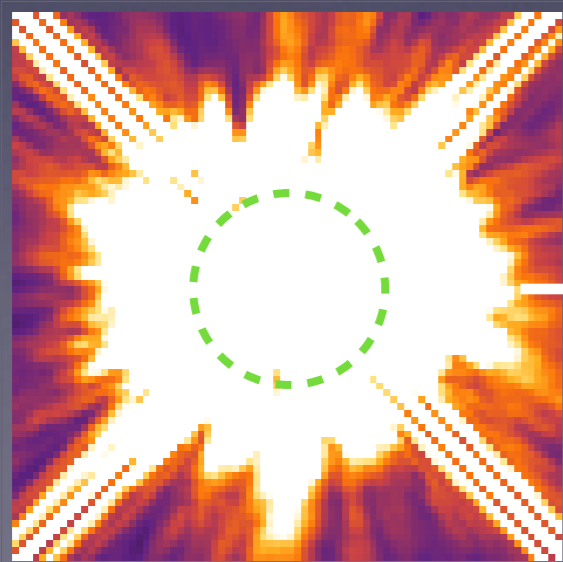
Pupil Tracking Strategy
Short Exposures



10+yr Archives
Long-term stability

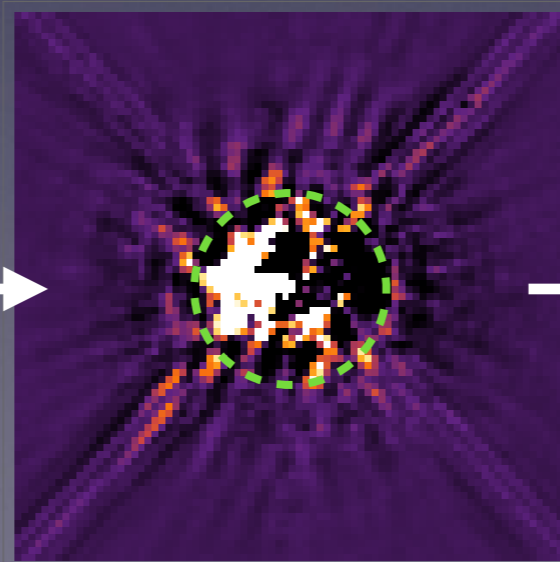


Raw image



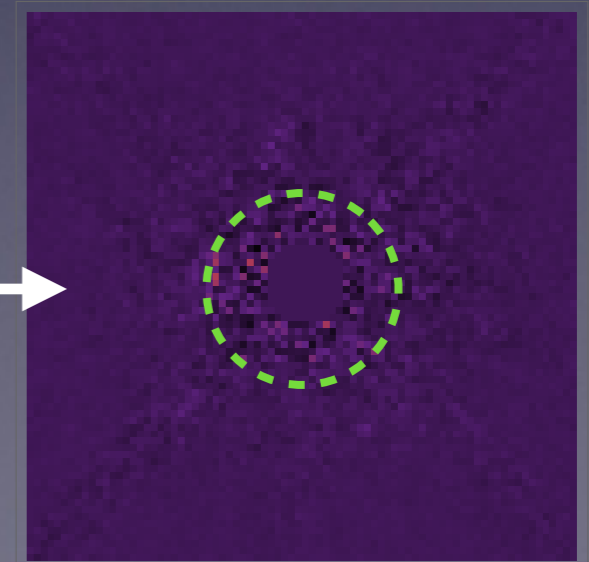
$\sim 10^{-4}$

Classical



$\sim 10^{-5}$

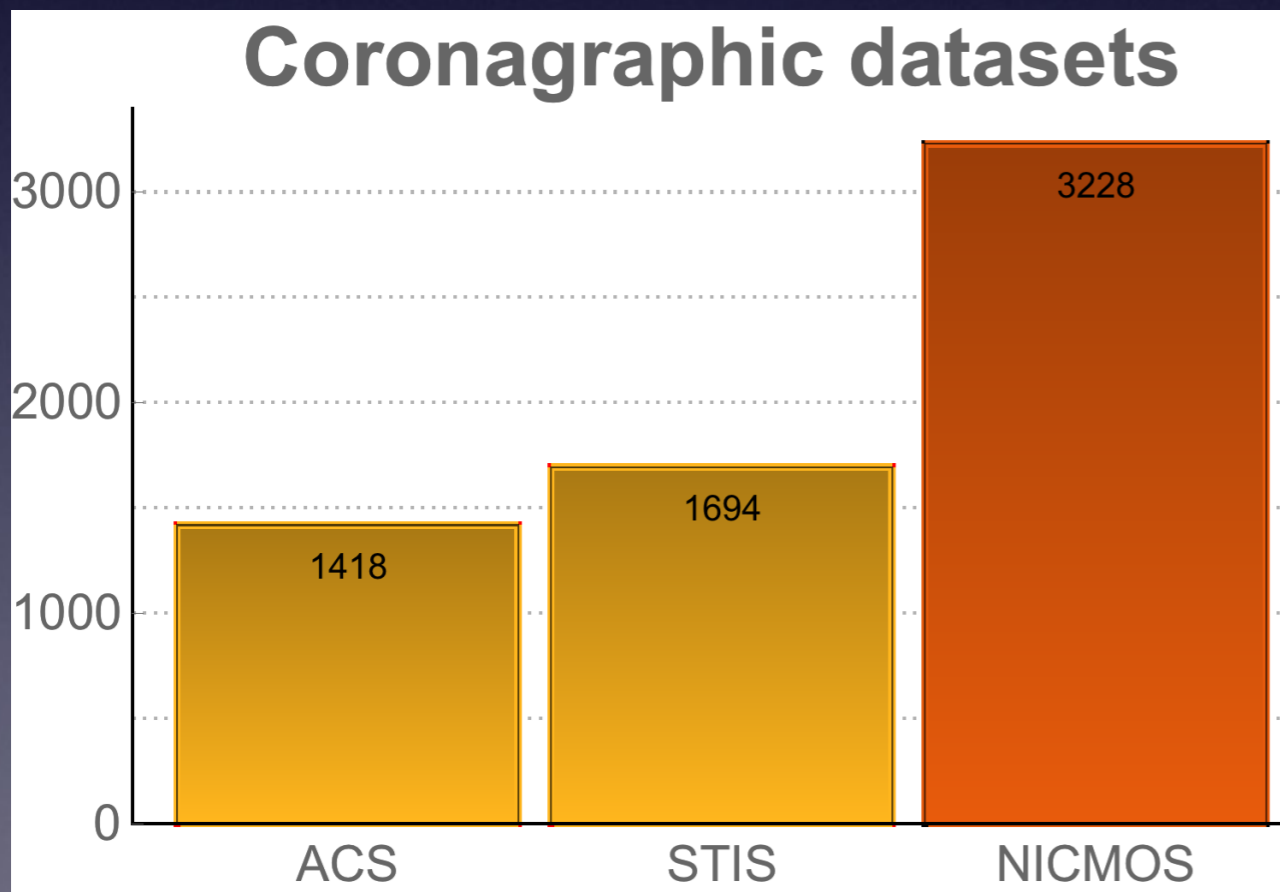
Advanced



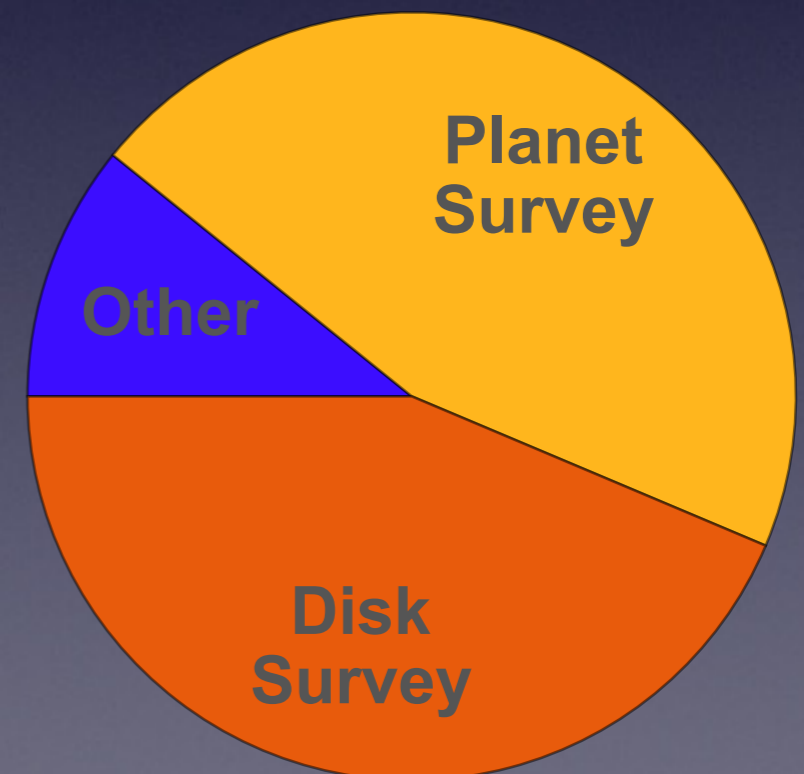
The **ALICE** Program

Archival **L**egacy **I**nvestigations of **C**ircumstellar **E**nvironments

Generalization to the **whole** NICMOS archive



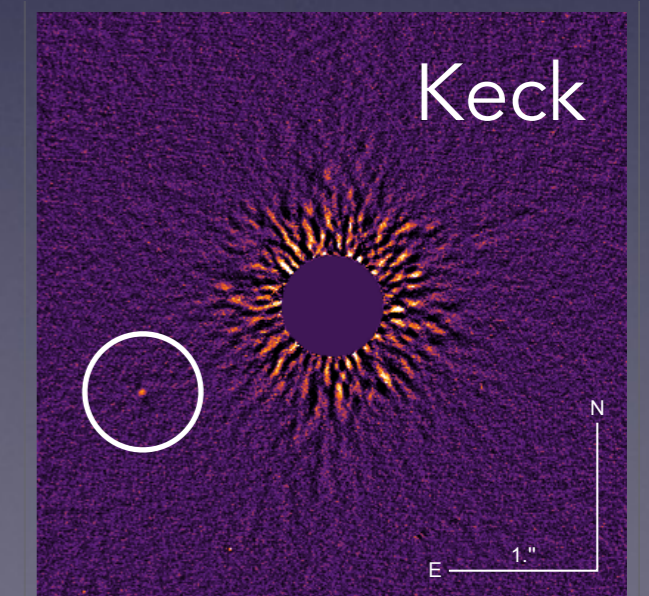
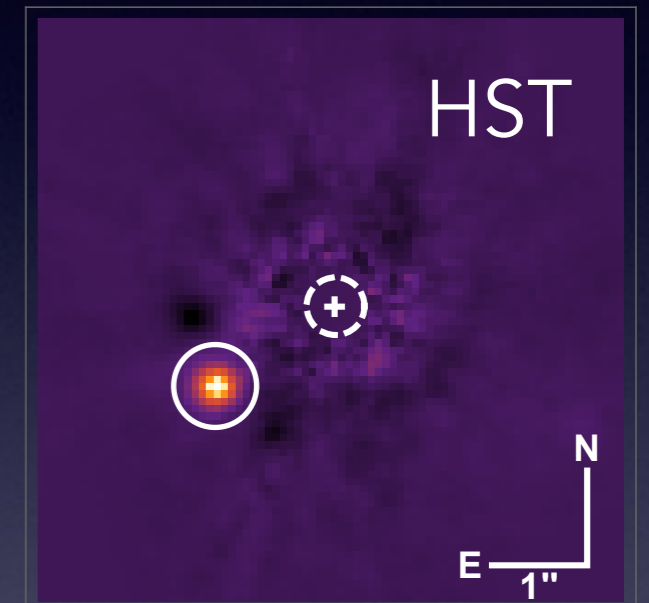
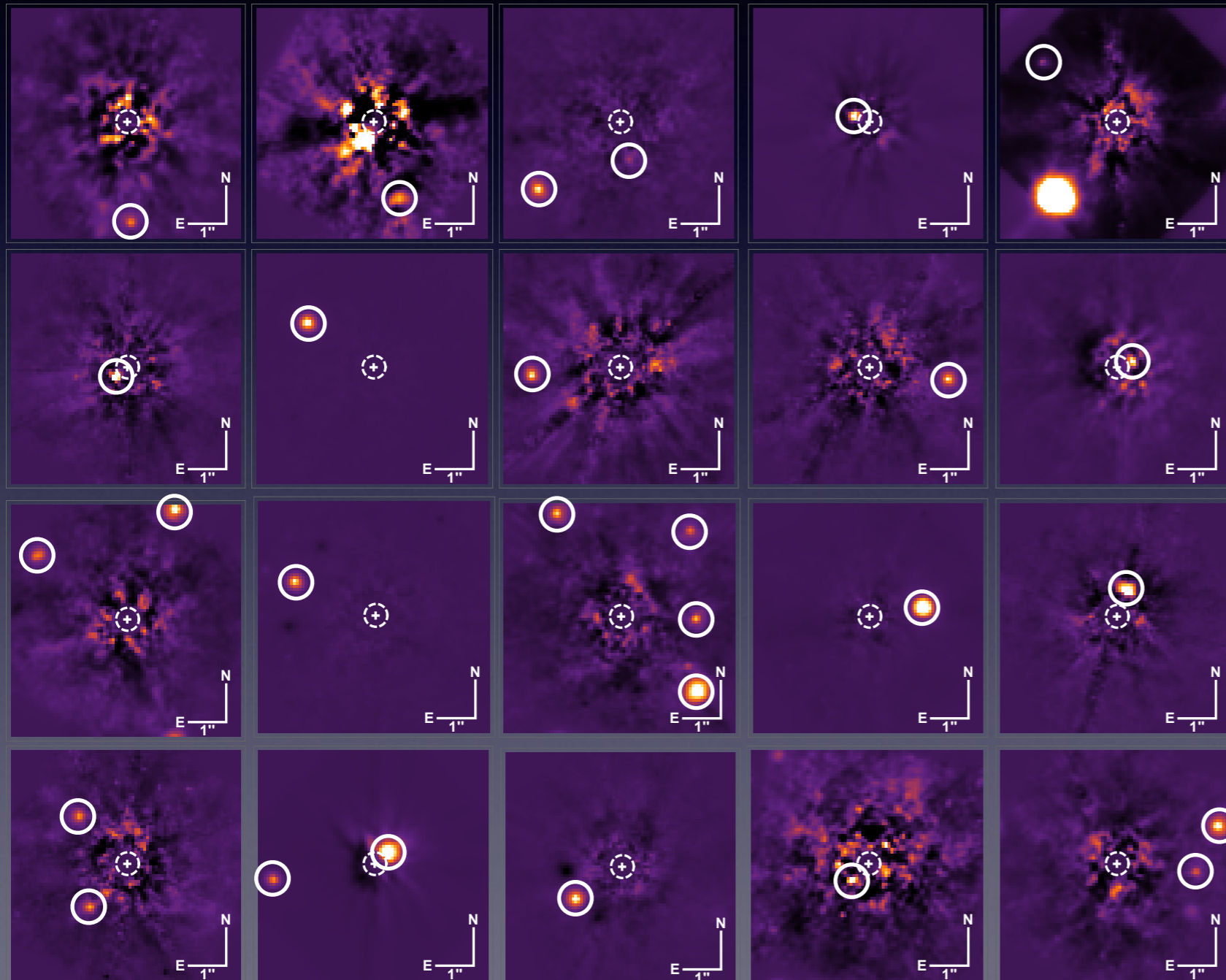
400 targets



ALICE Point Source Detections

New planet / BD candidates

Keck Followup
campaign



NICMOS Debris Disks Detections

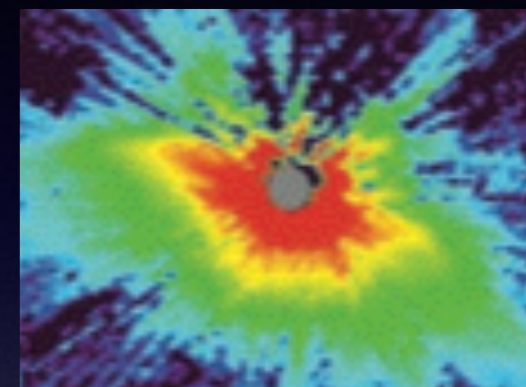
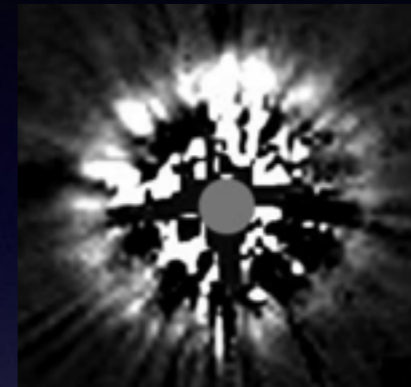
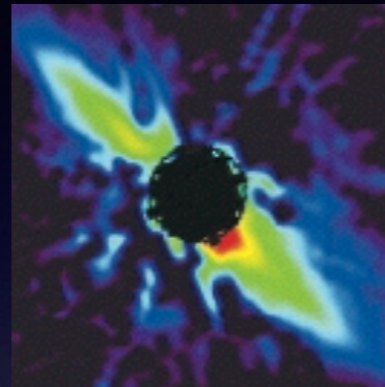
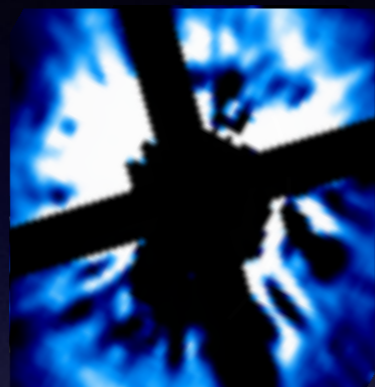
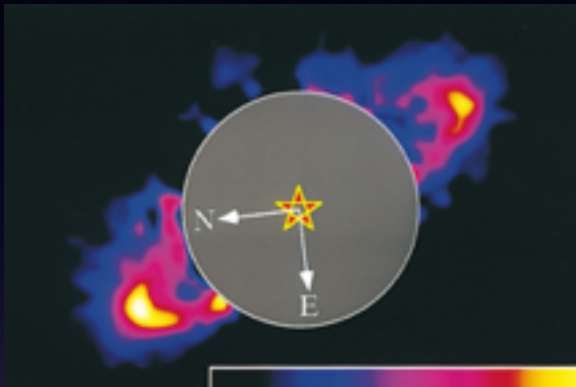
HR 4796

HD 141569

HD 32297

HD 181327

HD 61005



Schneider et al.

Augereau et al.
Weinberger et al.

Schneider et al.

Schneider et al.

Hines et al.

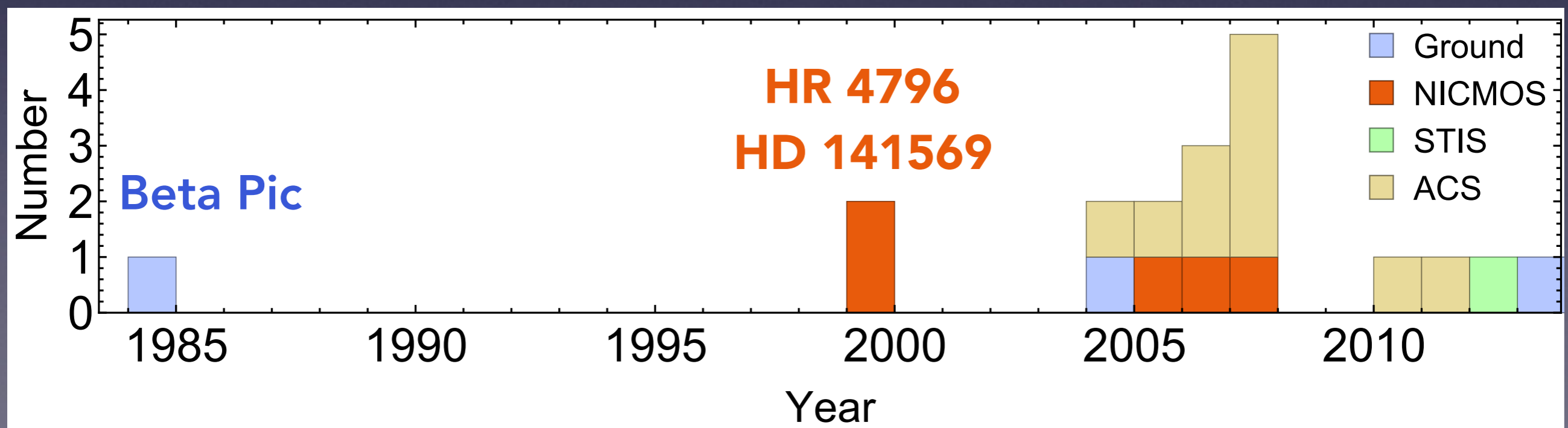
1999

1999

2005

2006

2007



NICMOS Debris Disks Detections

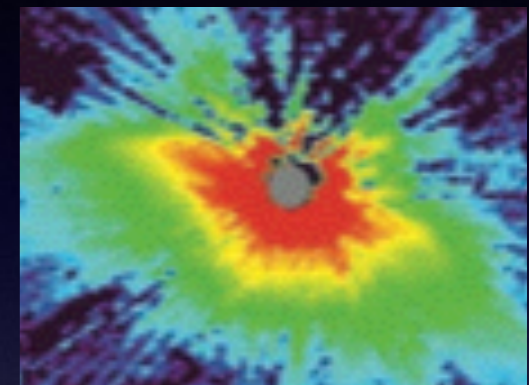
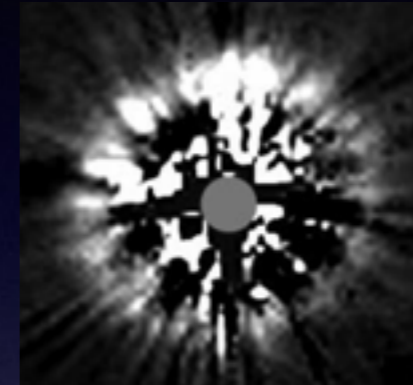
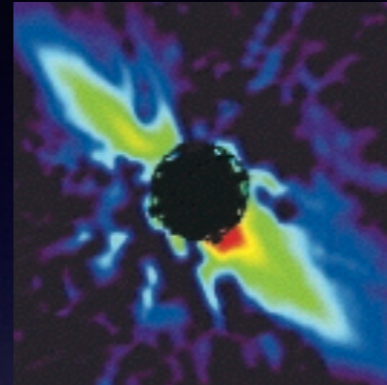
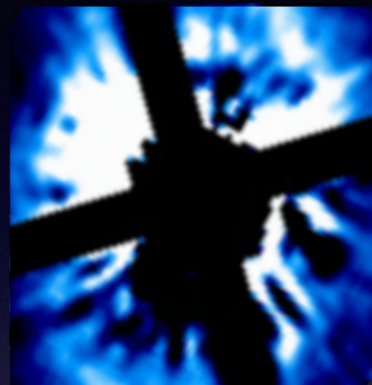
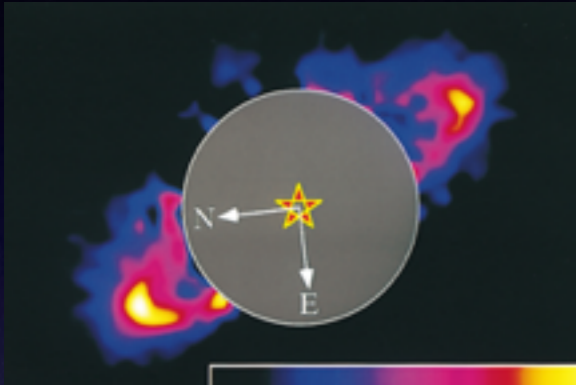
HR 4796A

HD 141569

HD 32297

HD 181327

HD 61005



Schneider et al.

Augereau et al.
Weinberger et al.

Schneider et al.

Schneider et al.

Hines et al.

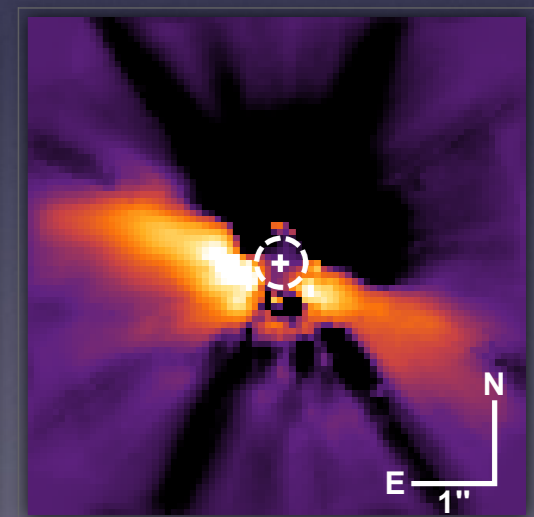
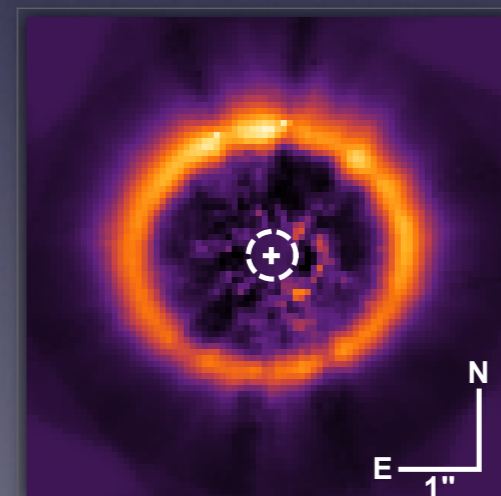
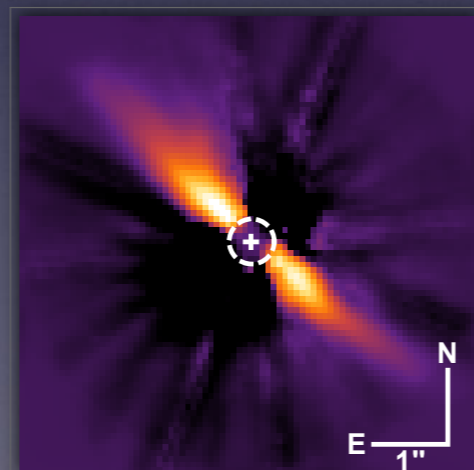
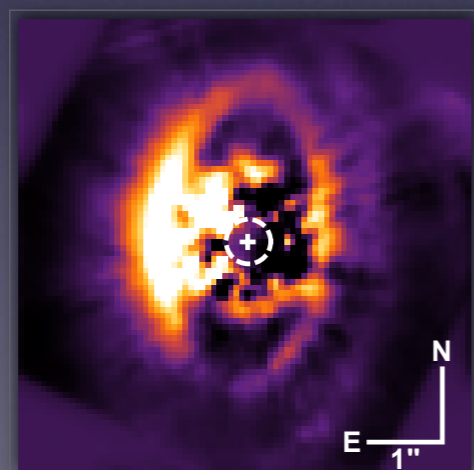
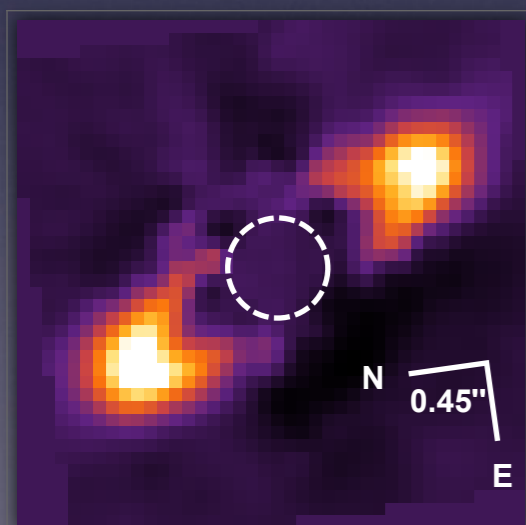
1999

1999

2005

2006

2007

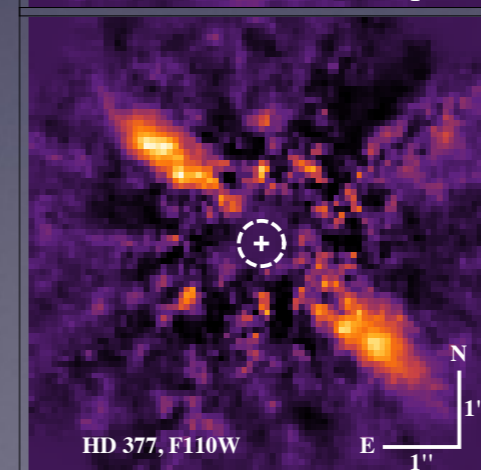
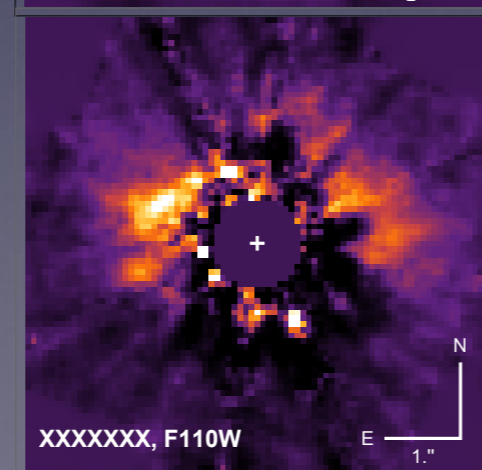
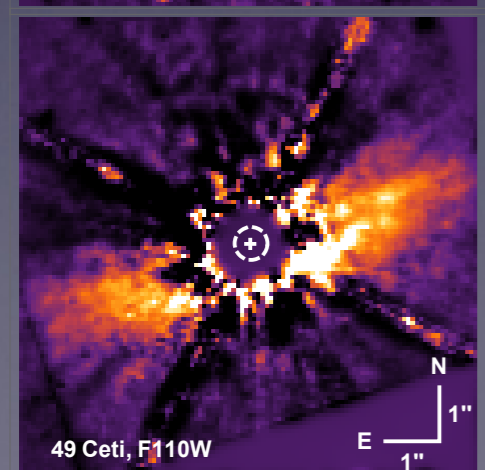
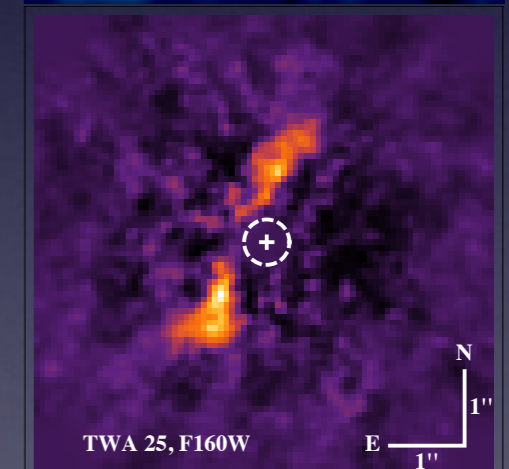
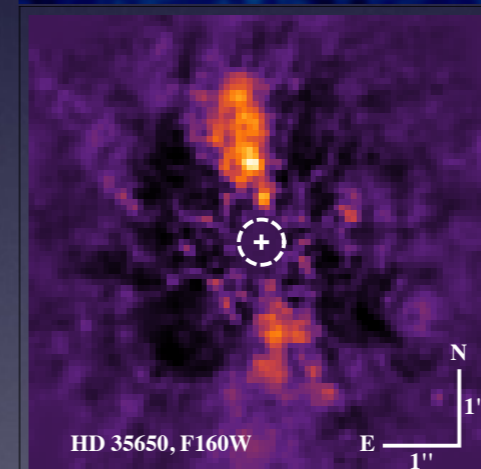
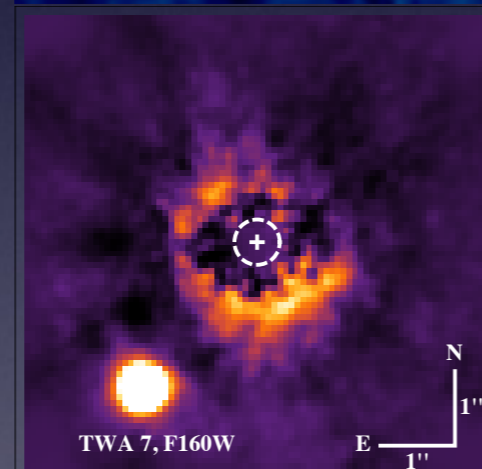
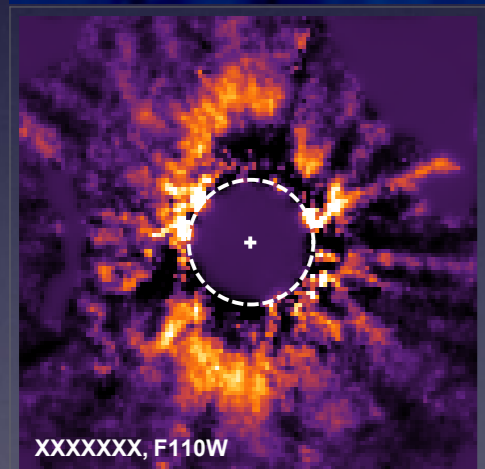
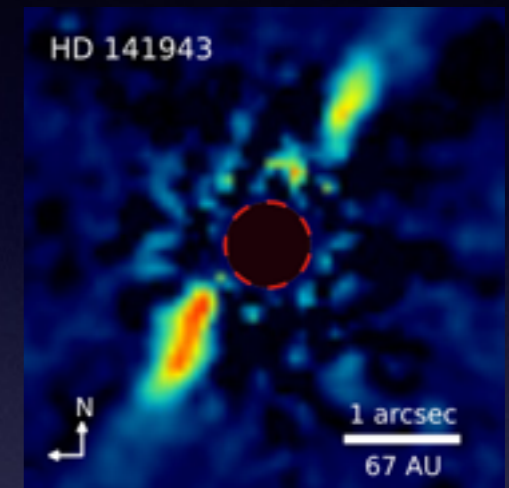
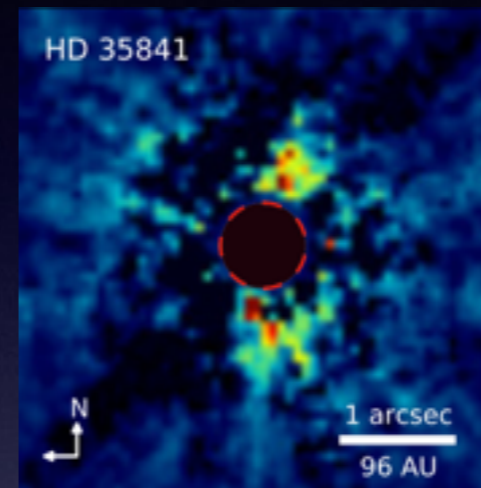
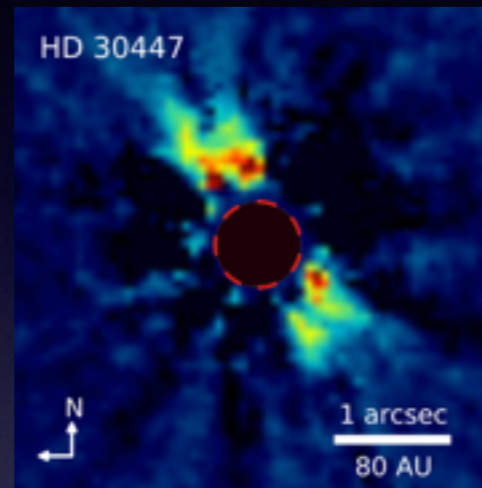
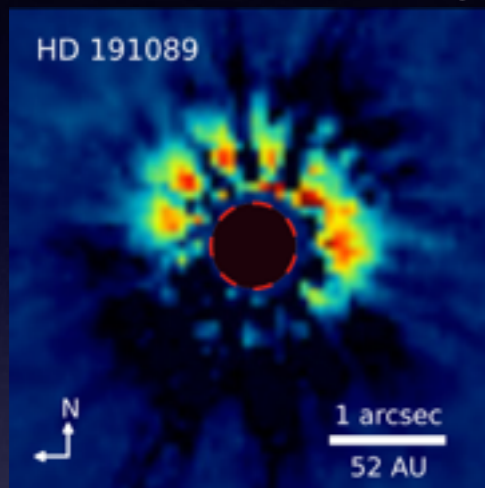


ALICE processing, same dataset

ALICE Debris Disks Detections

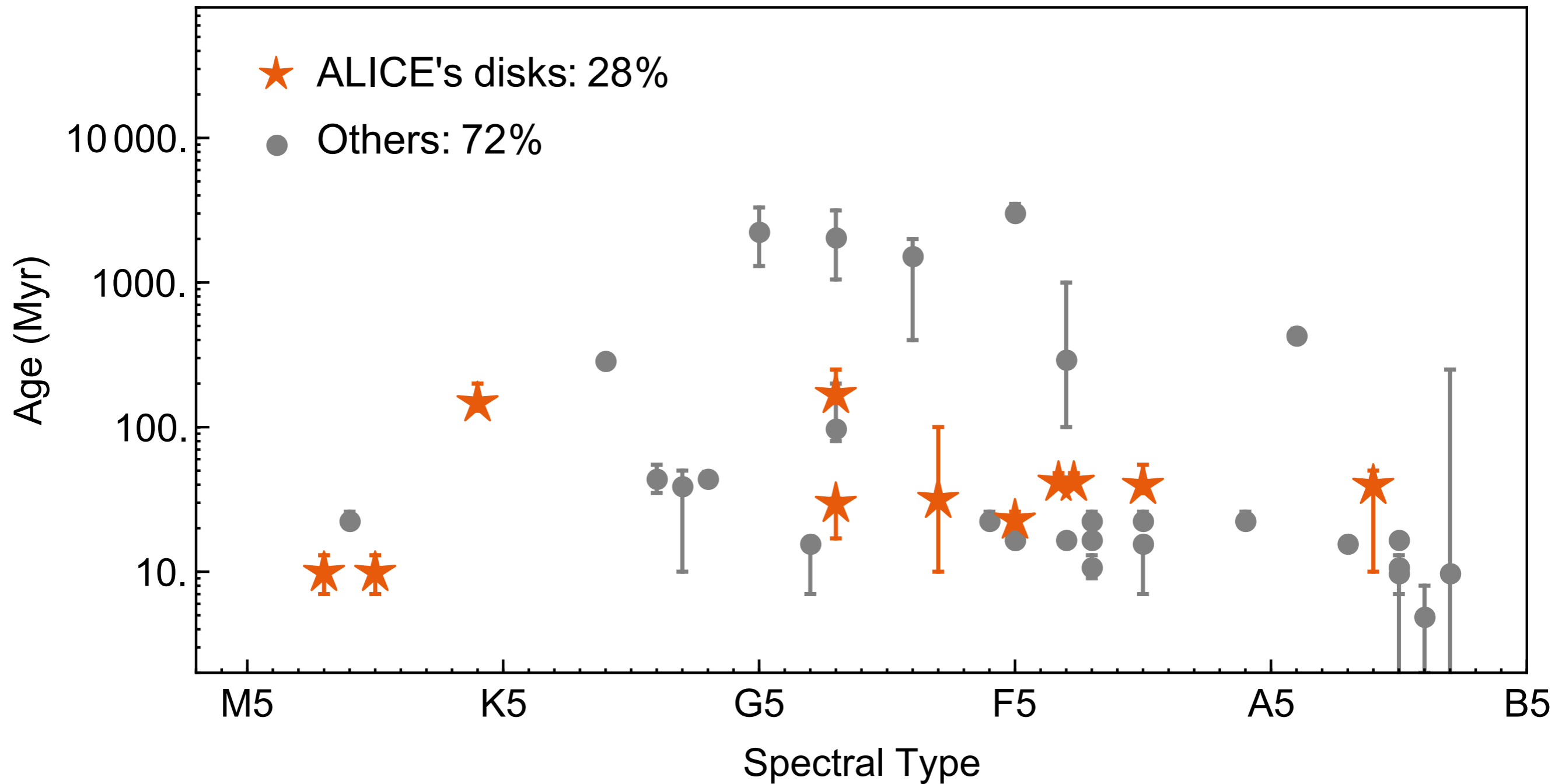
First Image
in scattered-light

Very First Image



Soummer et al. 2014
Choquet et al. 2016
Choquet et al. 2017
Choquet et al. in prep

Debris Disks in Scattered-Light

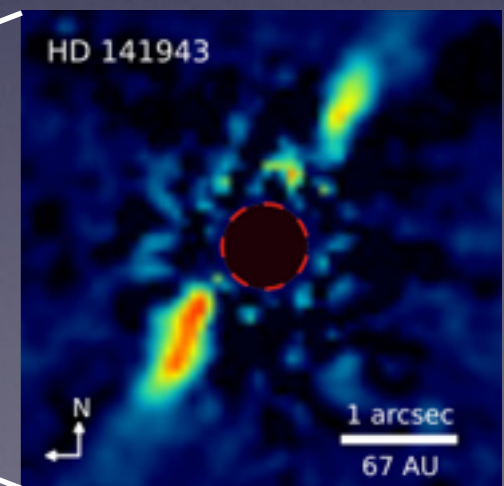
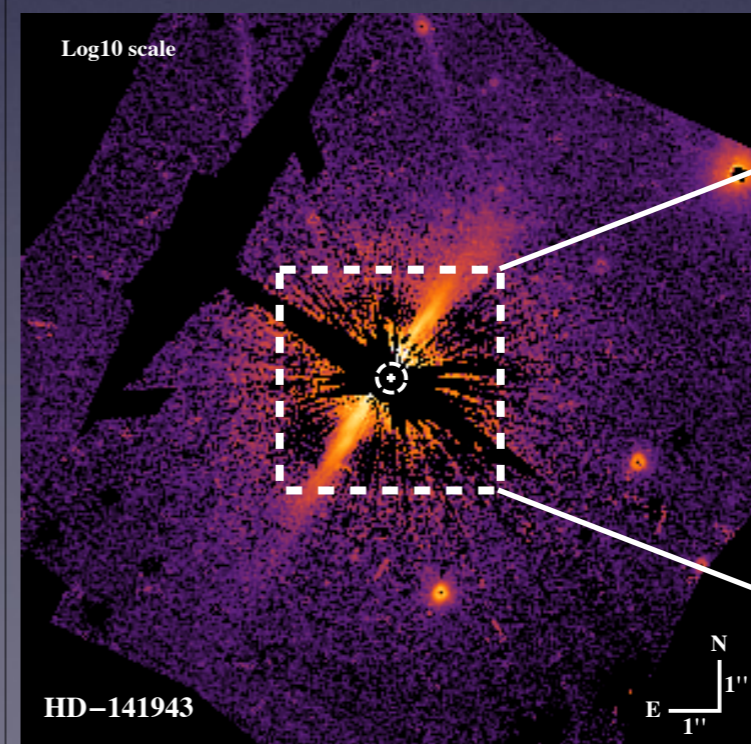
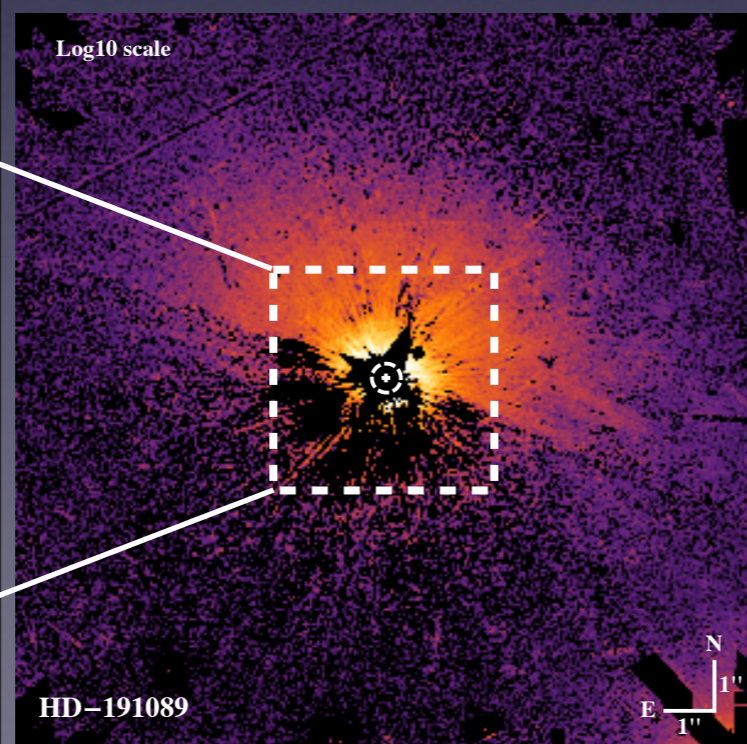
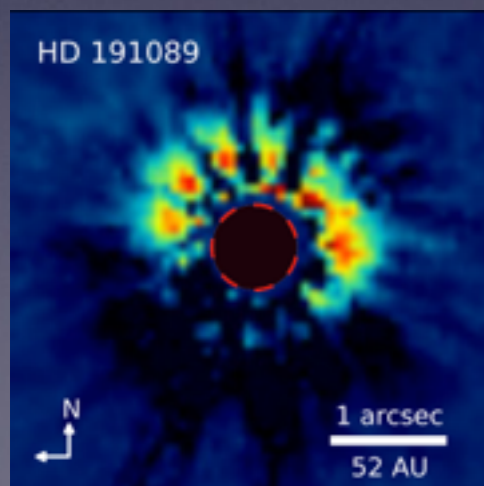
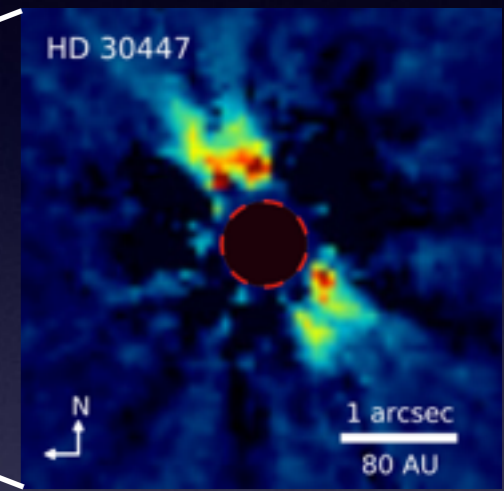
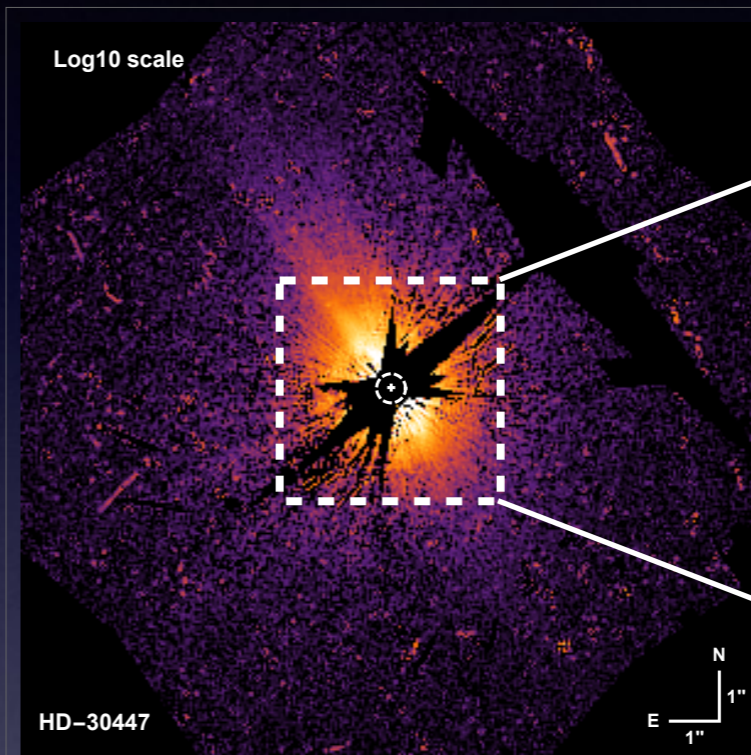
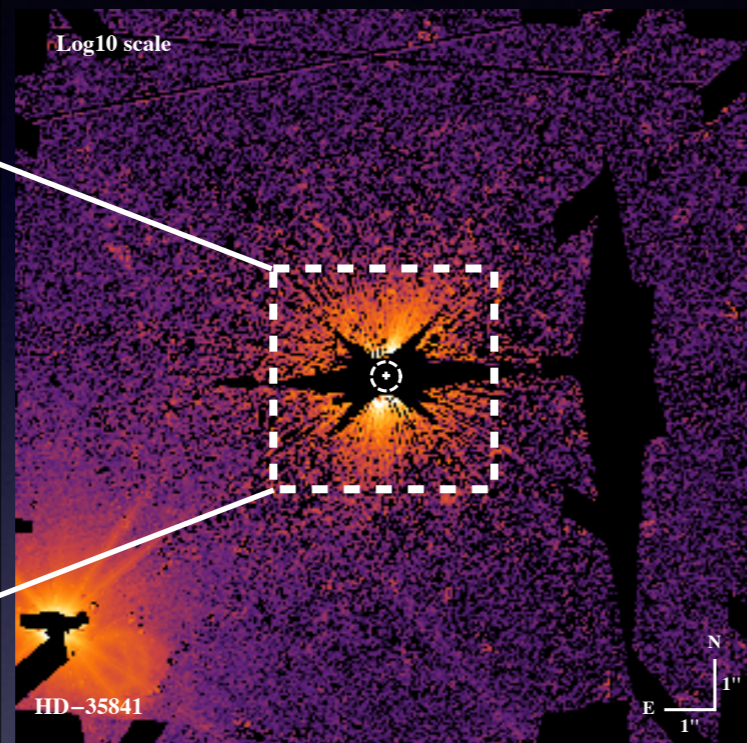
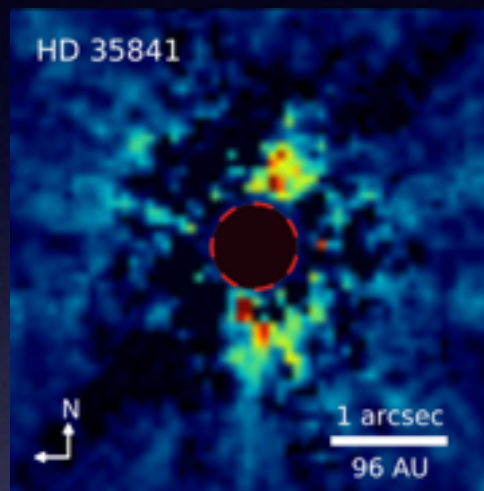


Blown-out Particles Detection

NICMOS
near-IR

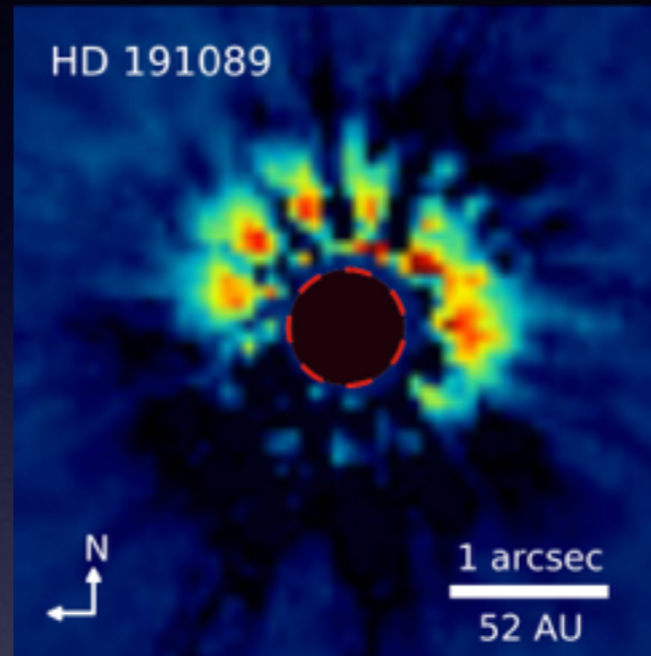
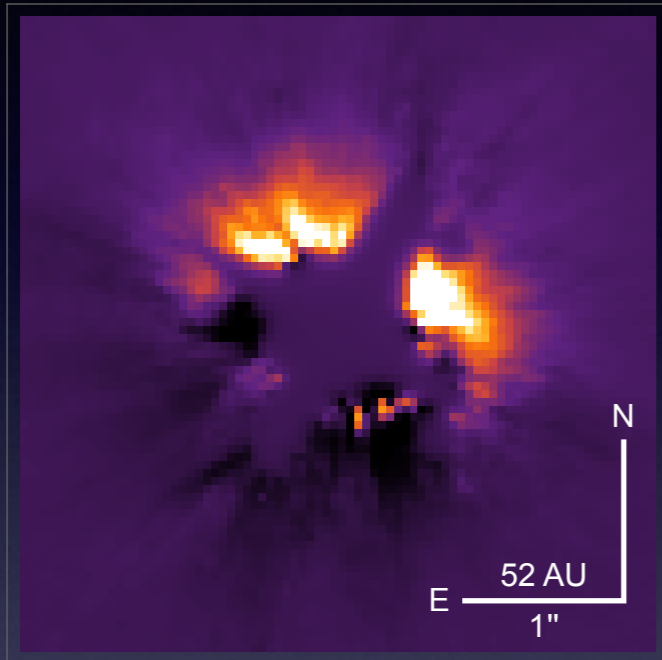
STIS - visible-light

NICMOS
near-IR



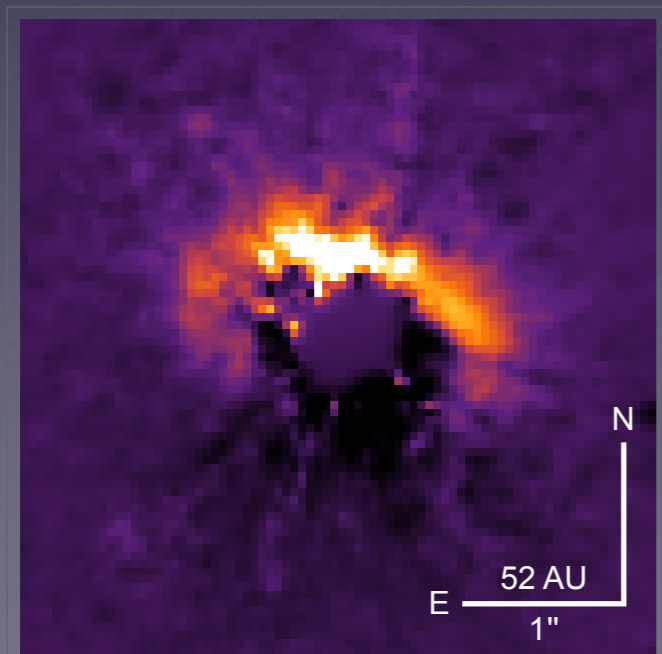
Parent Belt color/near-IR color

Classical Subtraction

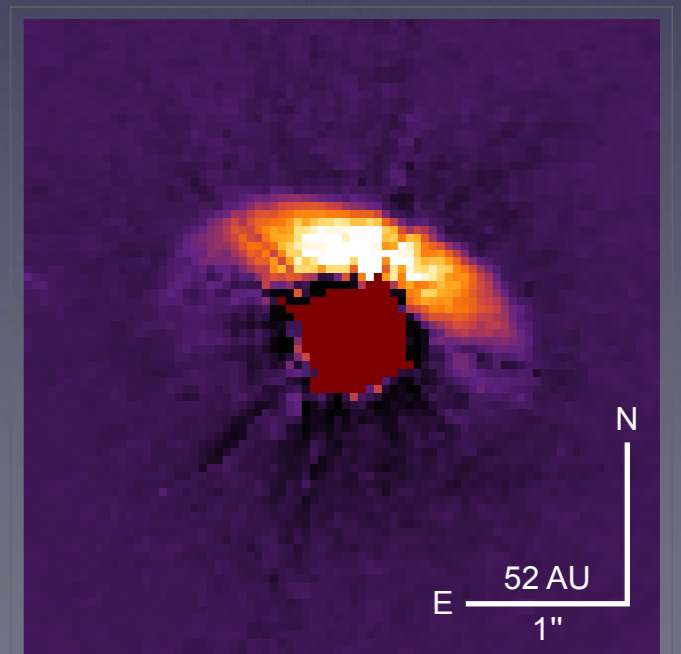
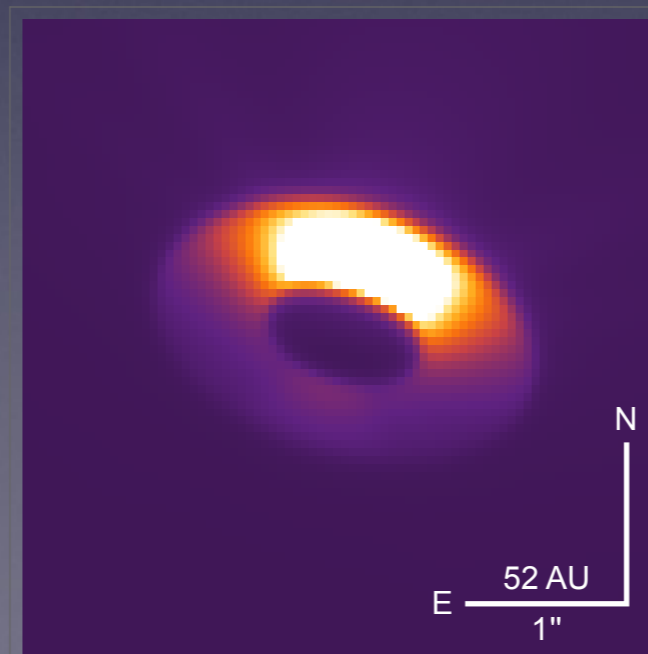


B. Ren (JHU)

Advanced Subtraction



Forward Modeling



Conclusion & Prospects

- 1: Pushing detection limits reveals a faint disks
- 2: New population of disks with low albedos
- 3: Complementary data to constrain the composition

