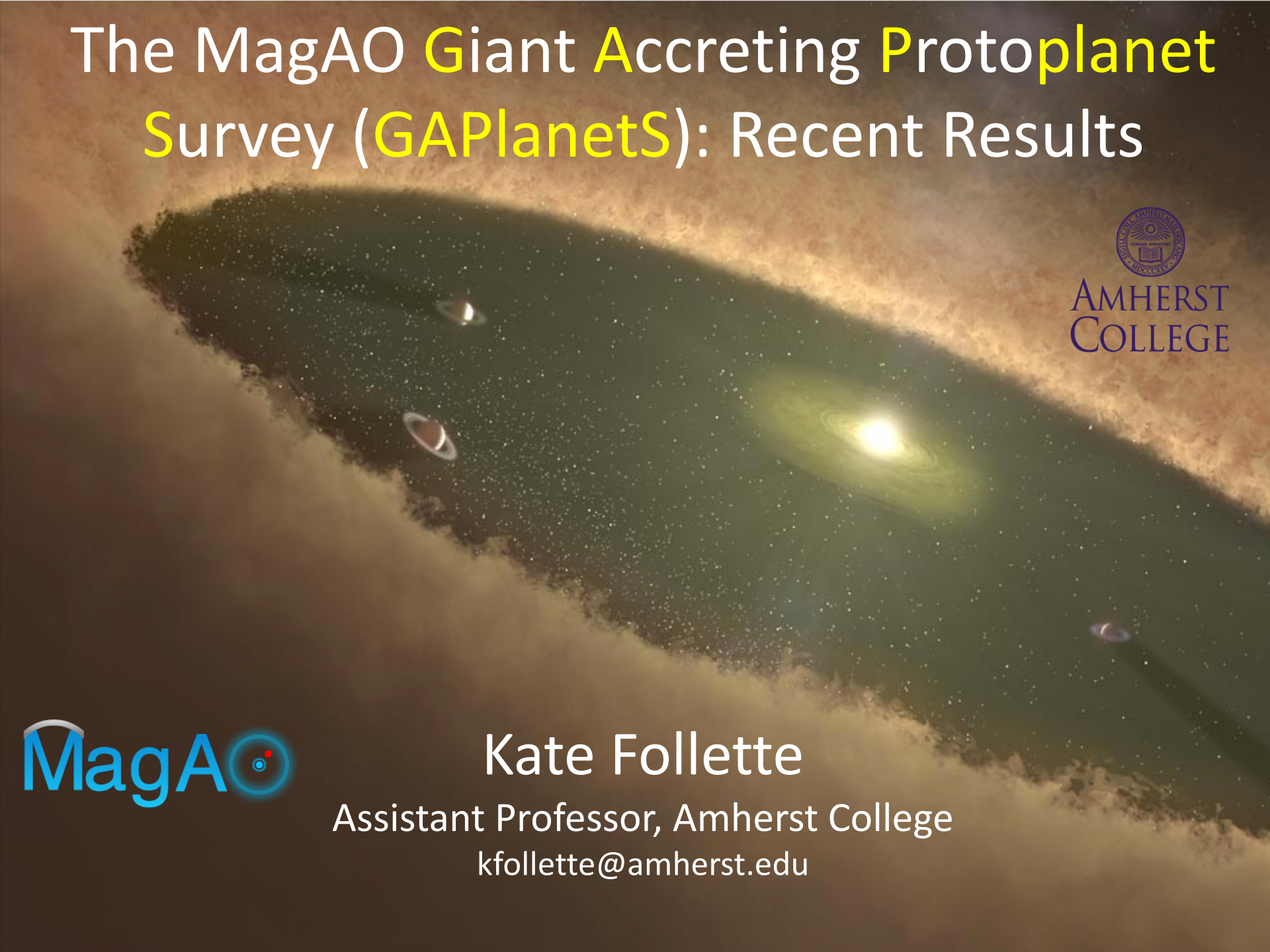
# The MagAO Giant Accreting Protoplanet Survey (GAPlanetS): Recent Results




Kate Follette

Assistant Professor, Amherst College

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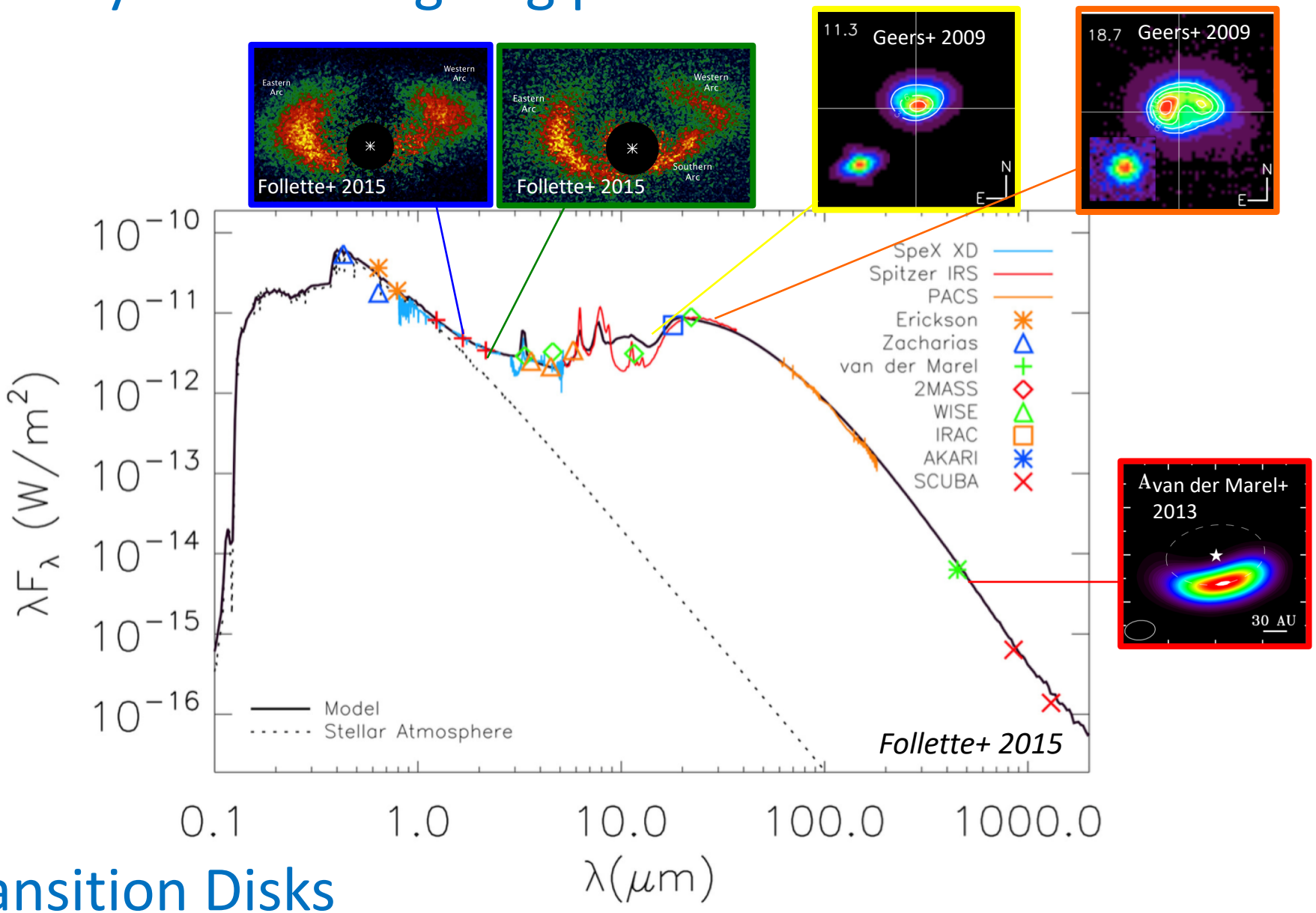
# How do you observe the planet formation process?

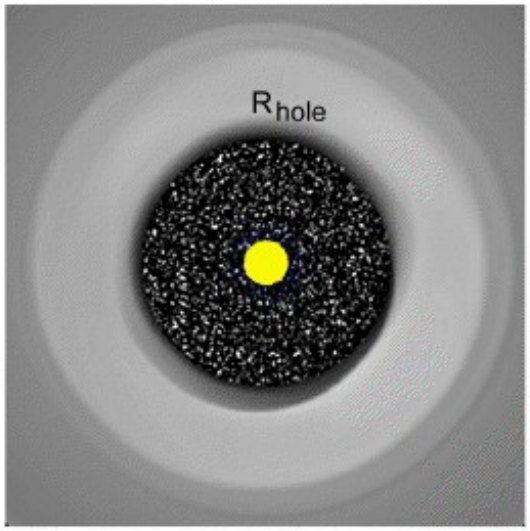
## Identify sites of ongoing planet formation



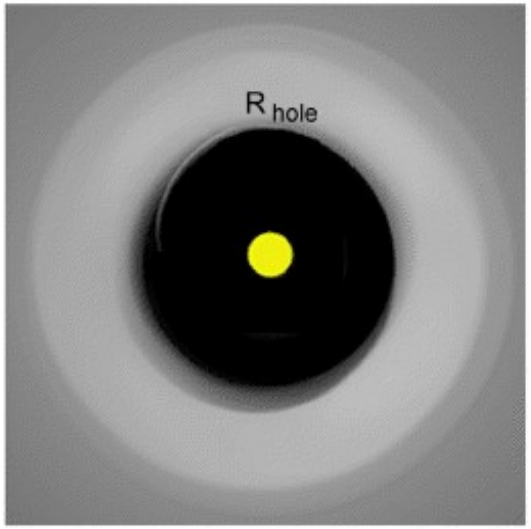

## Transition Disks

# How do you study the planet formation process?

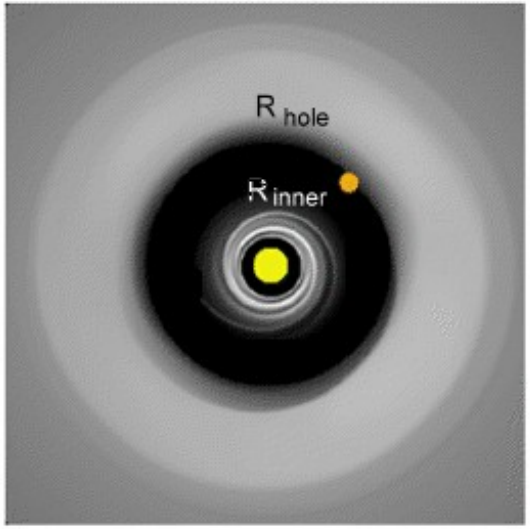
**Grain Growth**




**Photoevaporation**

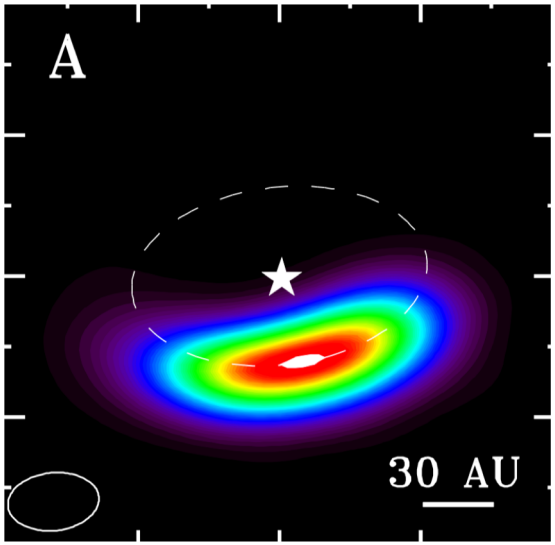


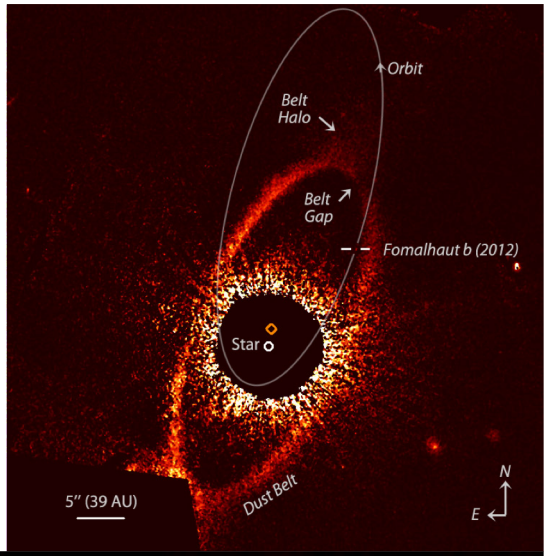

**Planet Formation**

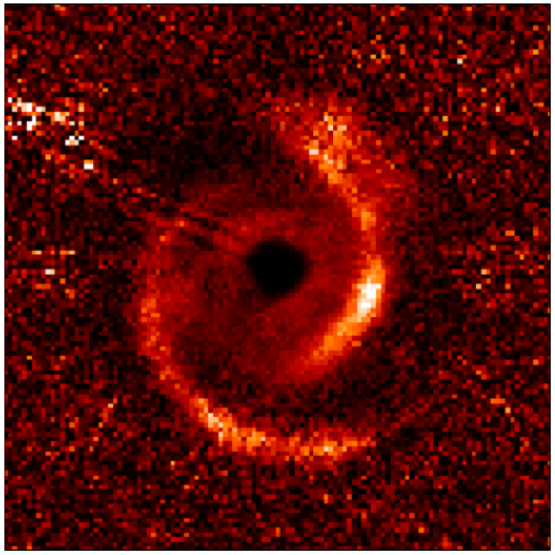


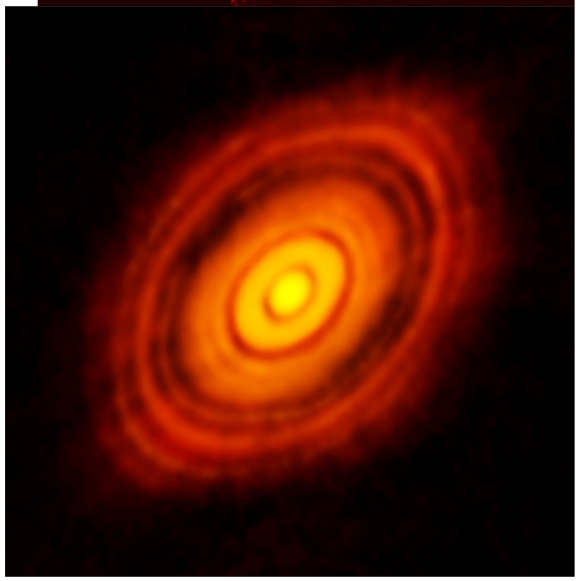

**Strategy 1: Take high resolution, high contrast images of transition disks and look for ”signposts”**

# Disks as “Signposts” of Planets



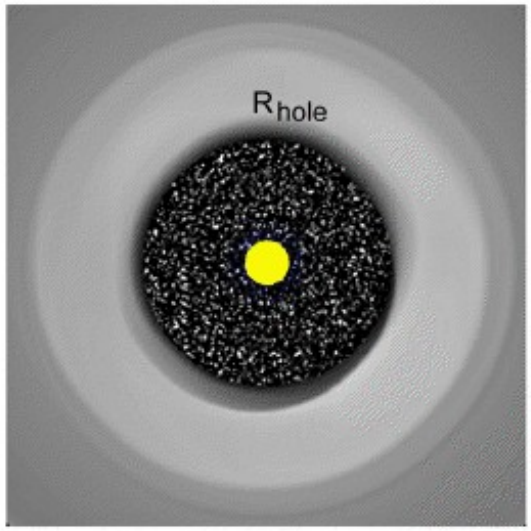



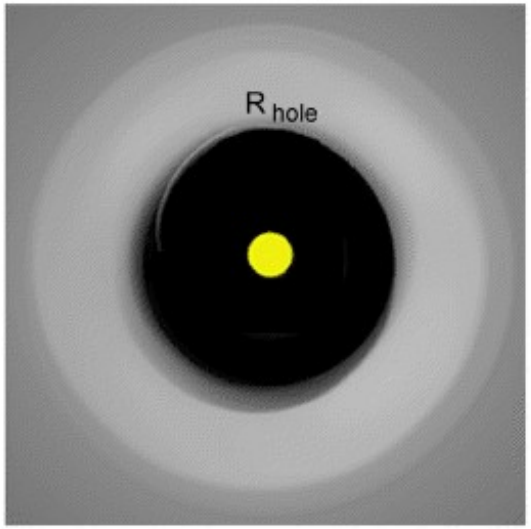


# How do you study the planet formation process?

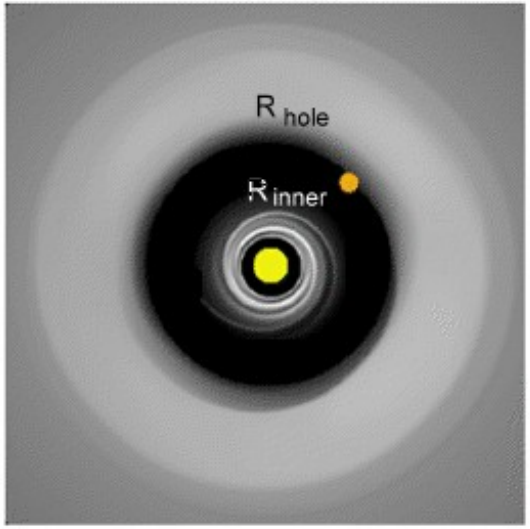
**Grain Growth**




**Photoevaporation**




**Planet Formation**




Strategy 1: Take high resolution, high contrast images of the disks and look for ”signposts”

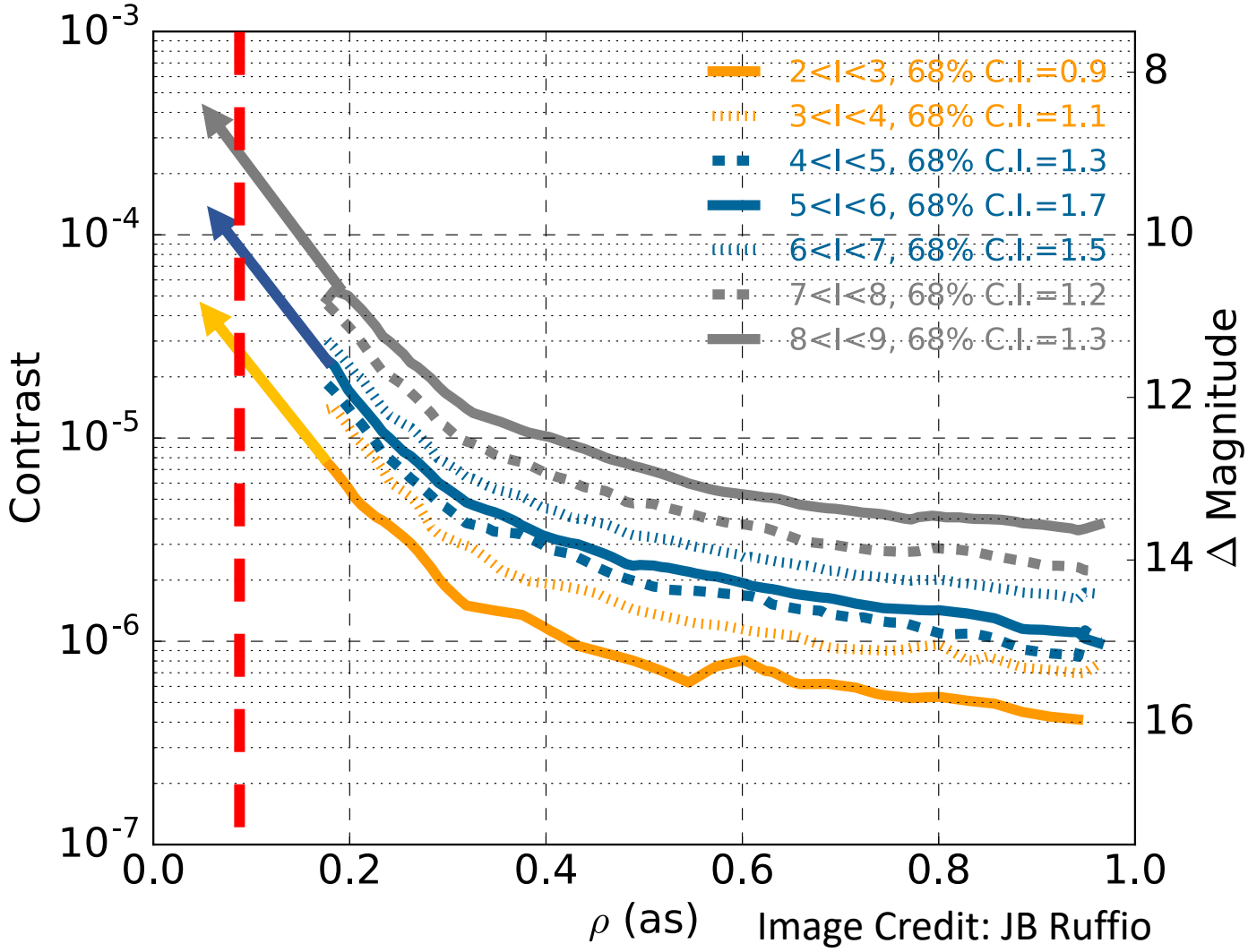
**Strategy 2: Look for the planets themselves!**

**Obstacle 1: Resolution**

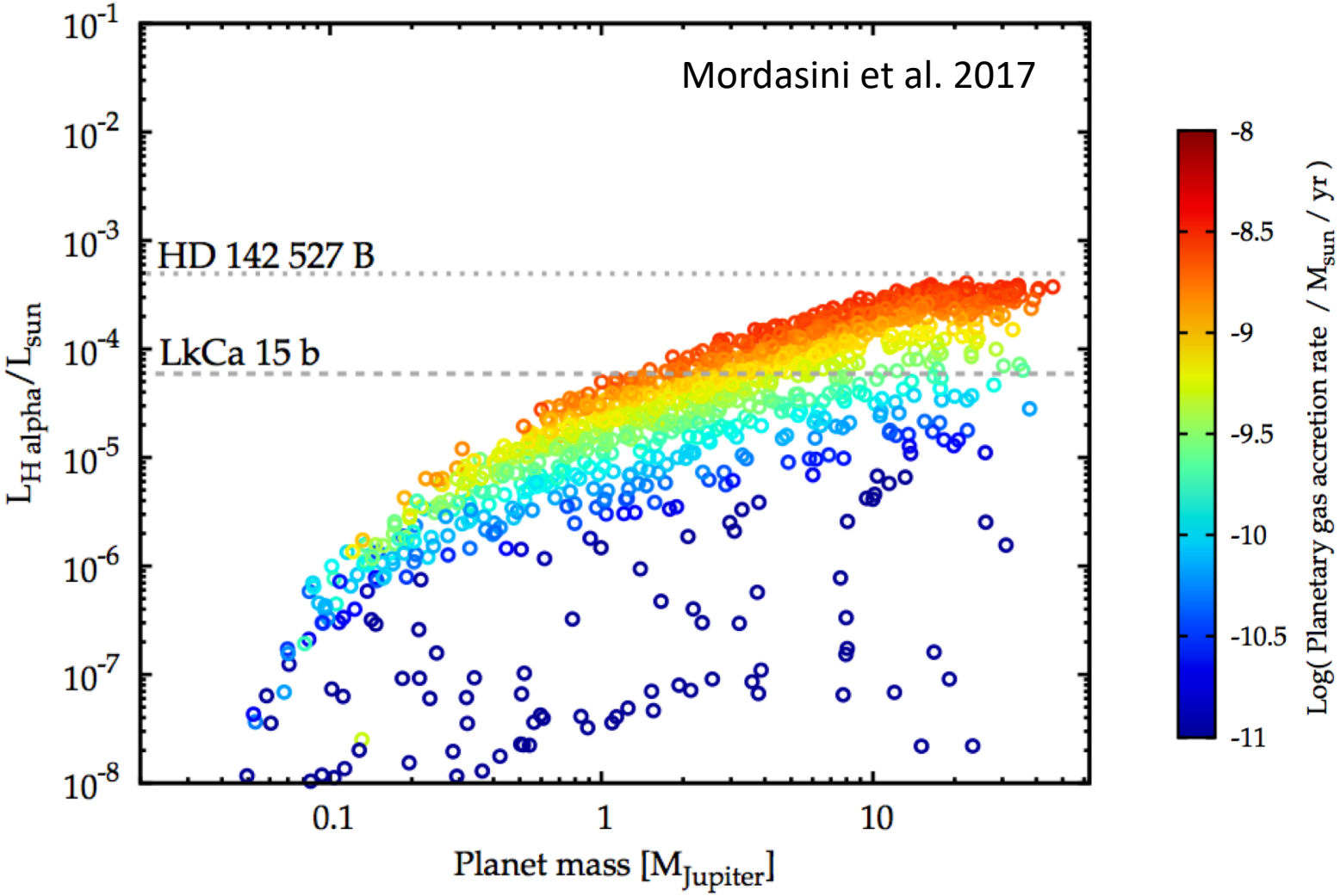
**@ 140pc, a 10AU hole (Saturn-sized orbit) is 0.07”**

$$\theta = 1.22\frac{\lambda}{D}$$ → Bigger telescope or shorter wavelength

# Obstacle 2: Contrast



# Obstacle 2: Contrast



# ADI$^{+}$ Post-Processing = LOCI/KLIP

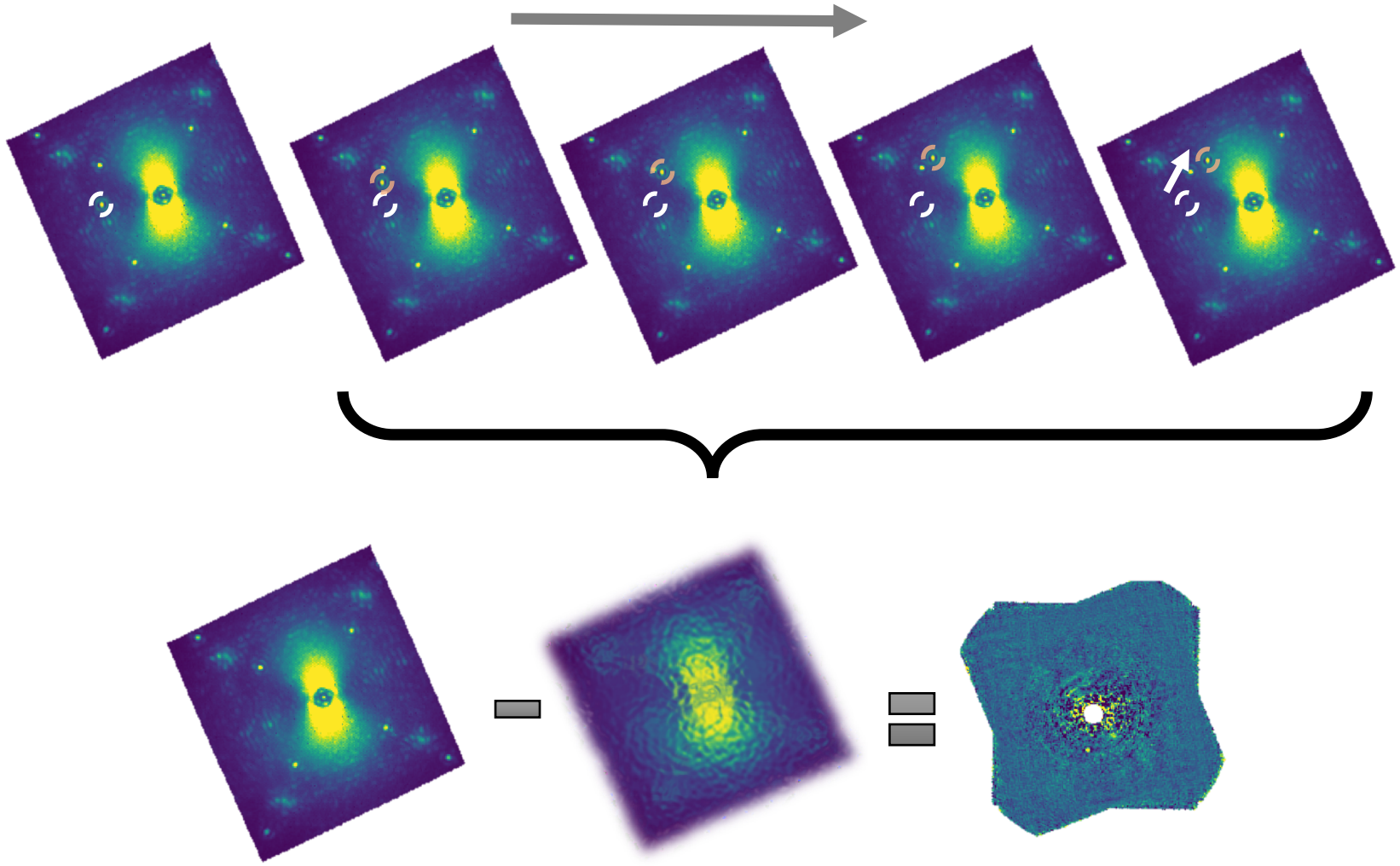
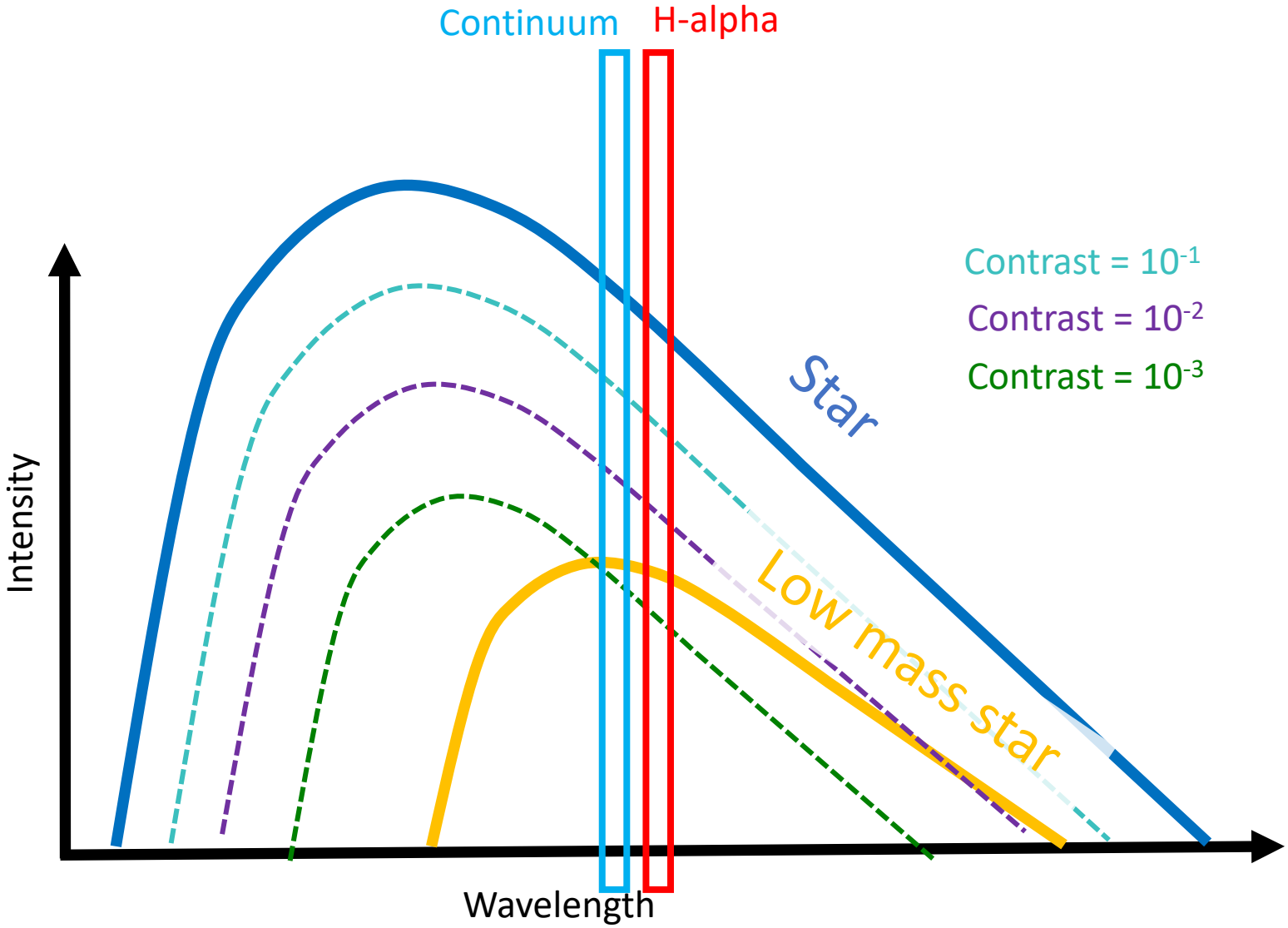
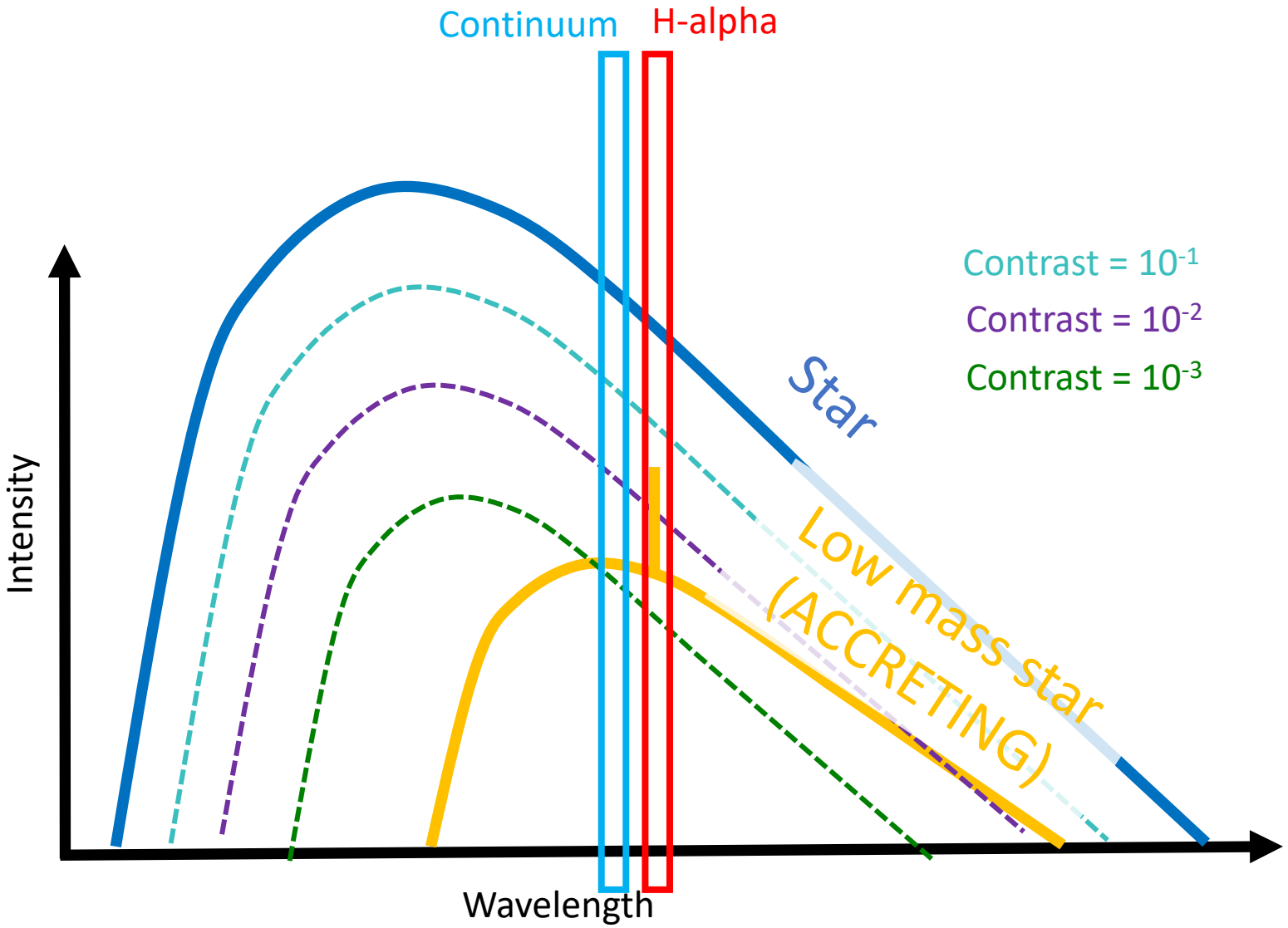


*Image Credit: JB Ruffio*

# Simultaneous (Spectral) Differential Imaging



# Simultaneous (Spectral) Differential Imaging



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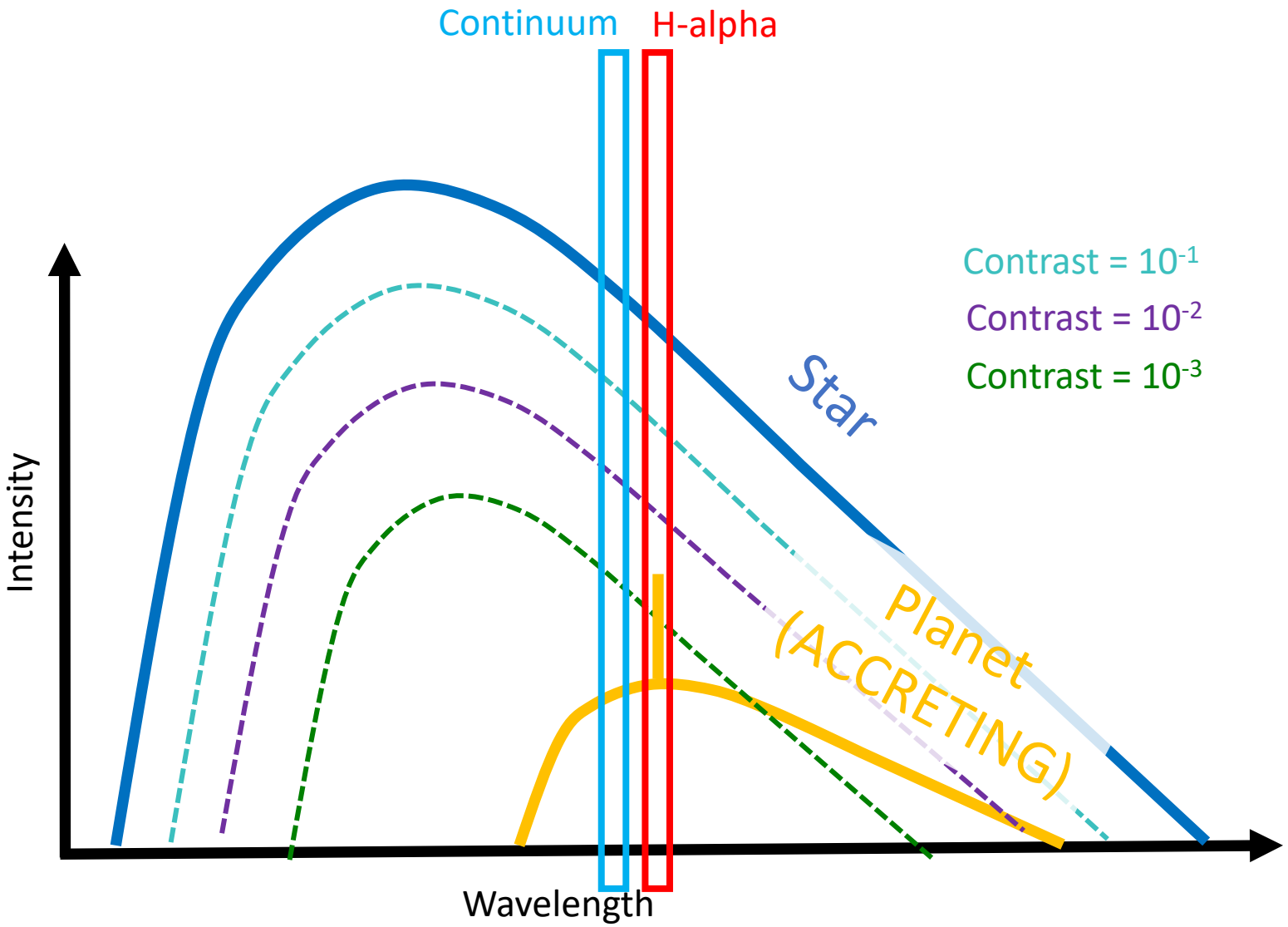


# Giant Accreting Protoplanet Survey (GAP planetS)

| Candidates | Rmag | d (pc) | Rcav (") | Rcav (AU) |
|---|---|---|---|---|
| HD 100546 | 6.7 | 97 | 0.13 | 13 |
| Target 2 | 7.0 | 98 | 0.15 | 15 |
| Target 3 | 8.2 | 145 | 0.16 | 23 |
| HD 142527 | 8.3 | 230 | 0.57 | 130 |
| Target 5 | 8.3 | 200 | 0.37 | 73 |
| Target 6 | 8.4 | 47 | 0.13 | 5.9 |
| Target 7 | 8.4 | 150 | 0.53 | 80 |
| Target 8 | 8.7 | 142 | 0.32 | 46 |
| Target 9 | 9.7 | 385 | 0.12 | 46 |
| Target 9 | 10.7 | 140 | 0.18 | 25 |
| Target 10 | 10.8 | 160 | 0.27 | 43 |
| Target 11 | 10.9 | 56 | 0.82 | 46 |
| Target 12 | 11.2 | 185 | 0.16 | 30 |
| Target 13 | 11.3 | 140 | 0.50 | 70 |
| Target 14 | 11.4 | 160 | 0.11 | 18 |
| LkCa 15 | 11.6 | 140 | 0.36 | 50 |
| Target 16 | 11.7 | 125 | 0.24 | 30 |
| Target 17 | 11.8 | 145 | 0.50 | 72 |
| Target 18 | 11.8 | 145 | 0.48 | 70 |

Distances: mostly ~140pc

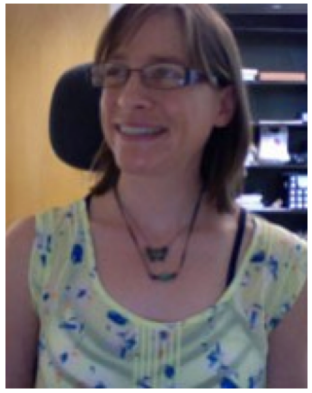
Separations: ~0.1-0.5”

→ ~10-100AU

# GAPlanetS Team

Laird Close
MagAO PI

Jared Males
VisAO PI
MagAOX PI



Katie Morzinski
MagAO Instrument Scientist

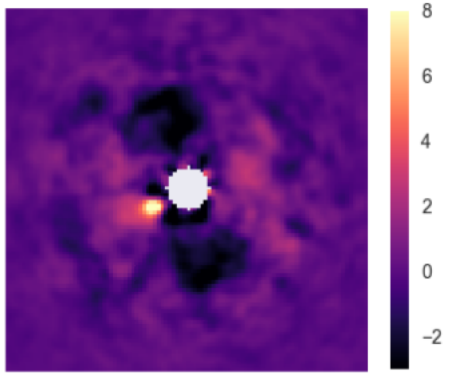

Clare Leonard
Alex Watson
Elijah Spiro
Wyatt Mullen
Ray Saitoti
Jea Adams
William Balmer
Fernando Garcia-Toro
David Wang

Alex Watson
Undergraduate thesis

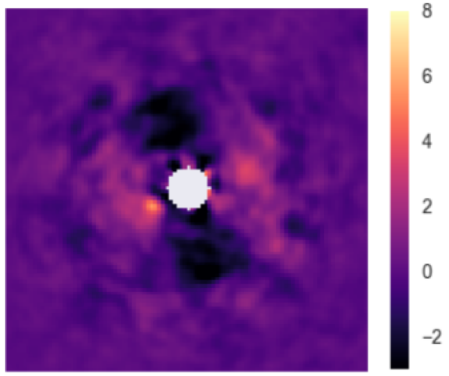
# HD 142527 – An Accreting Stellar Companion

## SDI = H-alpha - Continuum

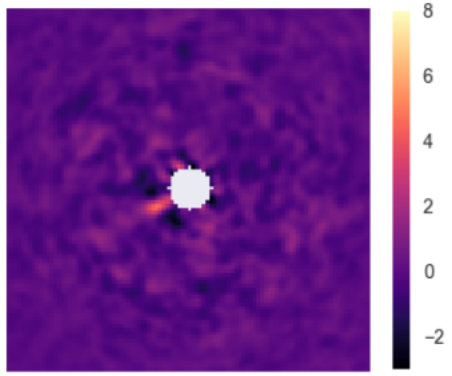
H-alpha



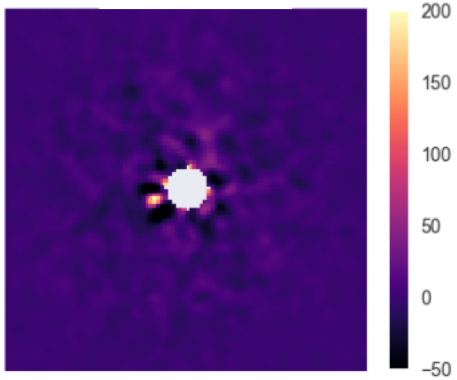

Continuum



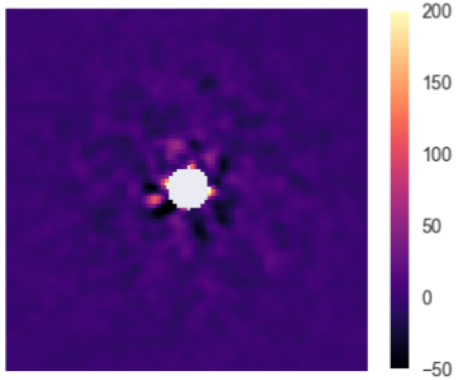

SDI



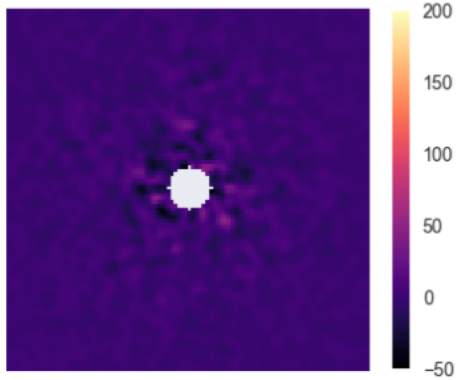

H-alpha




Continuum



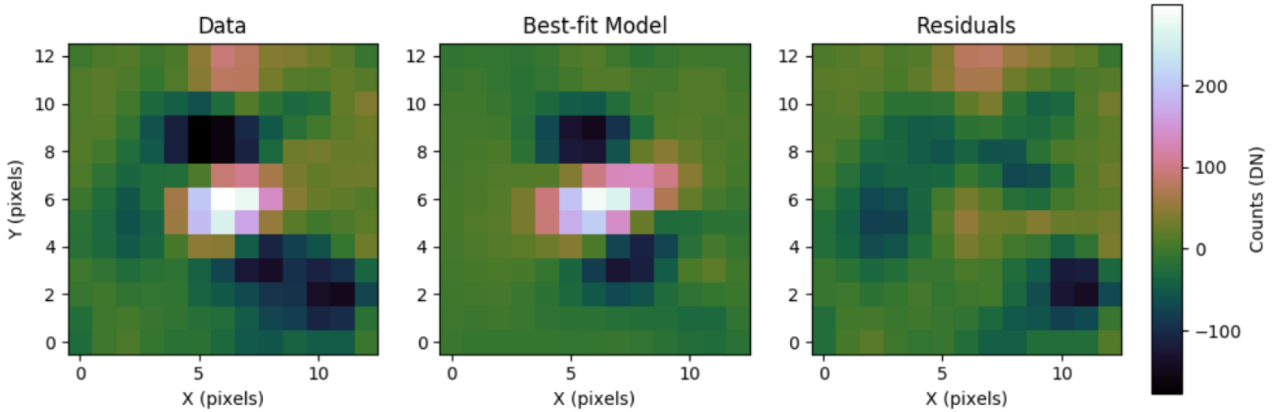

SDI

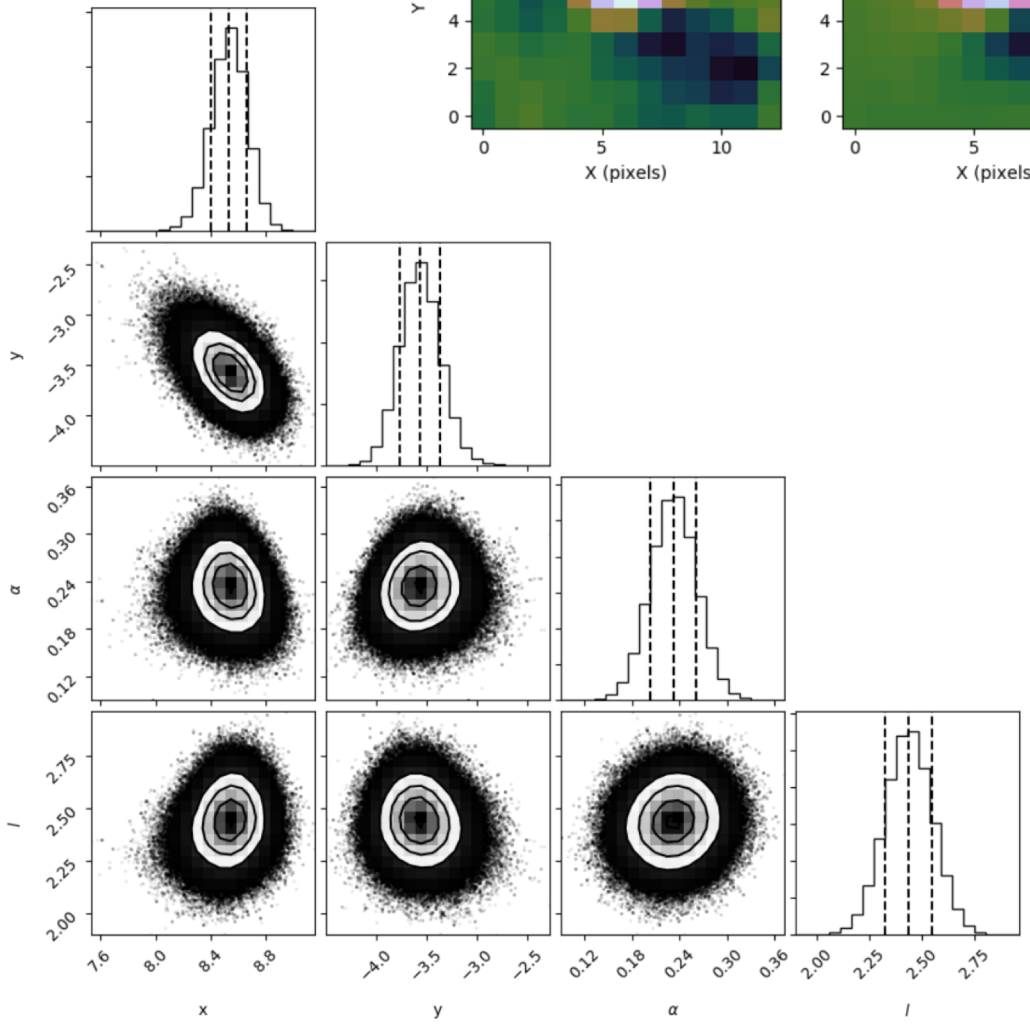



Just 0.086” separation → 12AU!

Brighter in H-alpha
→ accreting

Alex Watson
Undergraduate thesis

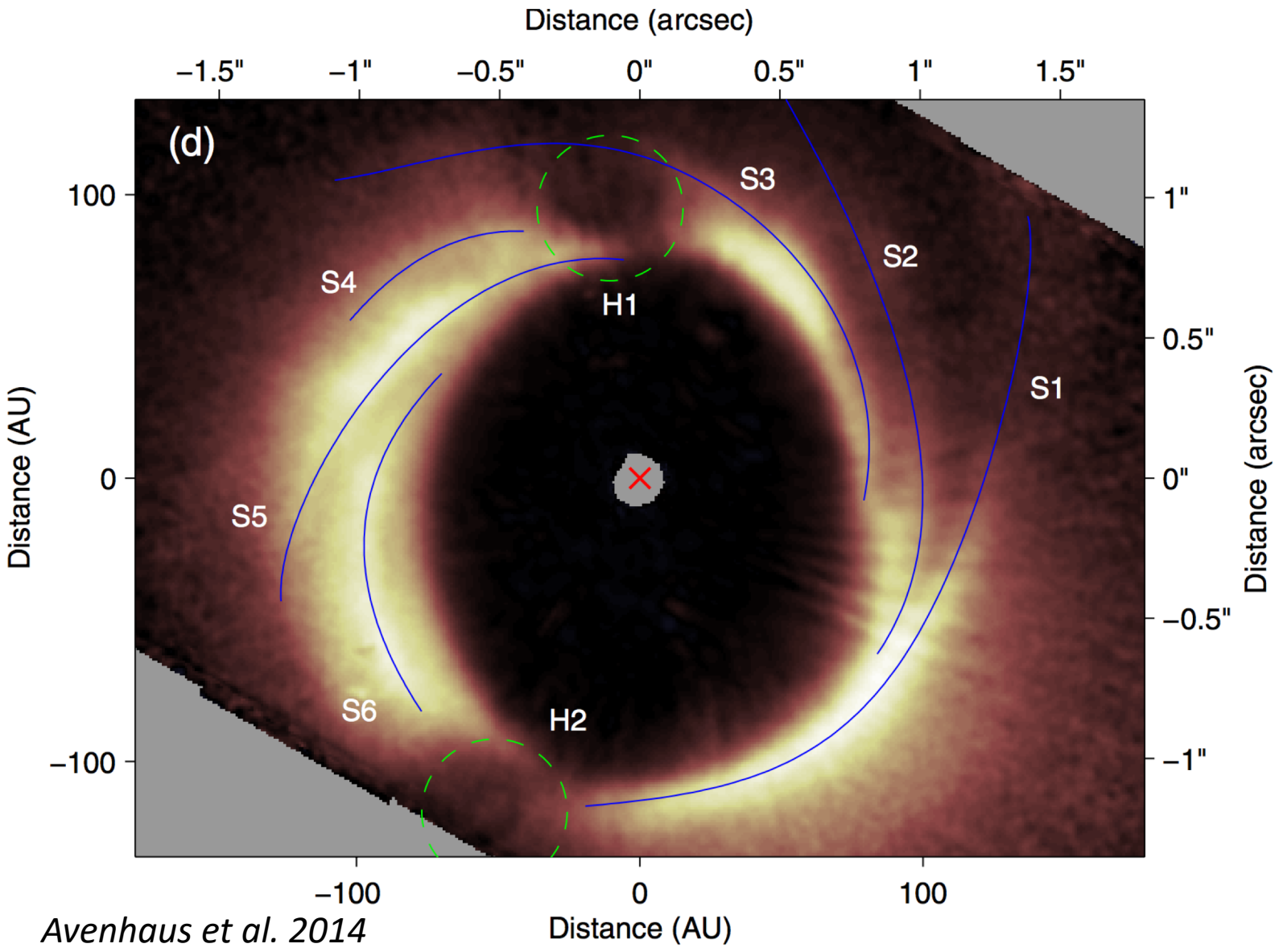



# Bayesian KLIP Astrometry (BKA)

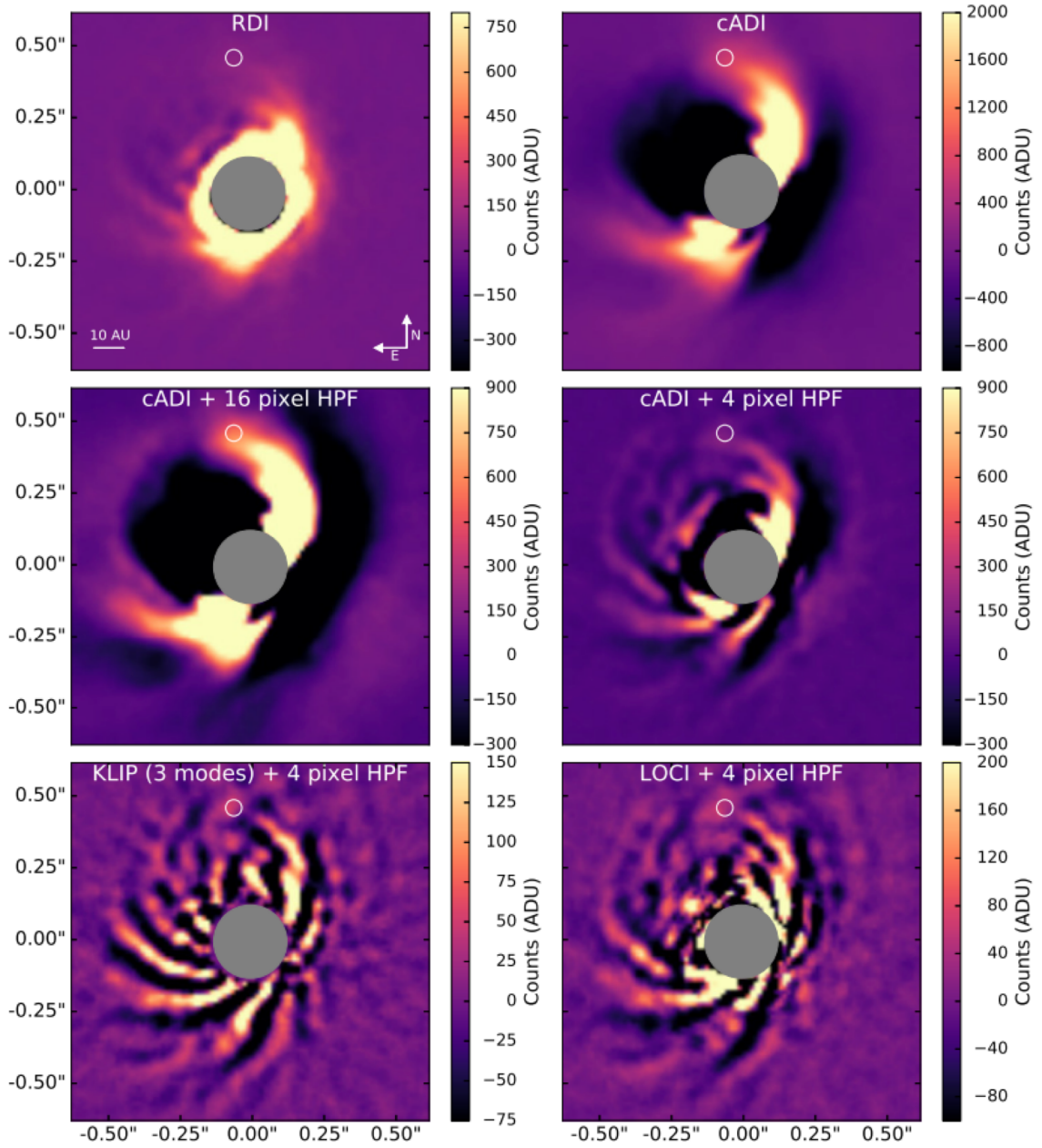
*PyKLIP*
*Jason Wang*

# The HD 142527 Disk/Cavity

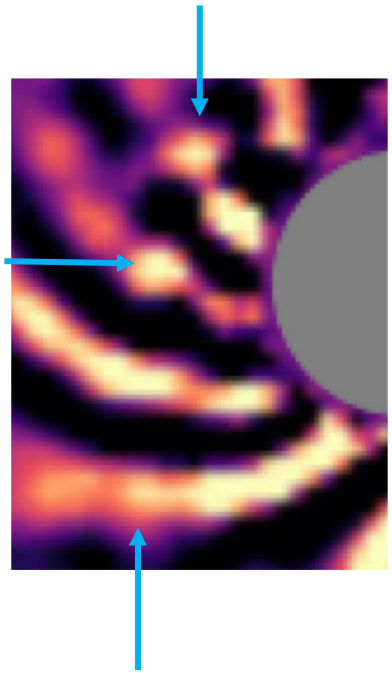



*Avenhaus et al. 2014*

# Continuity of Scattered Light Structures

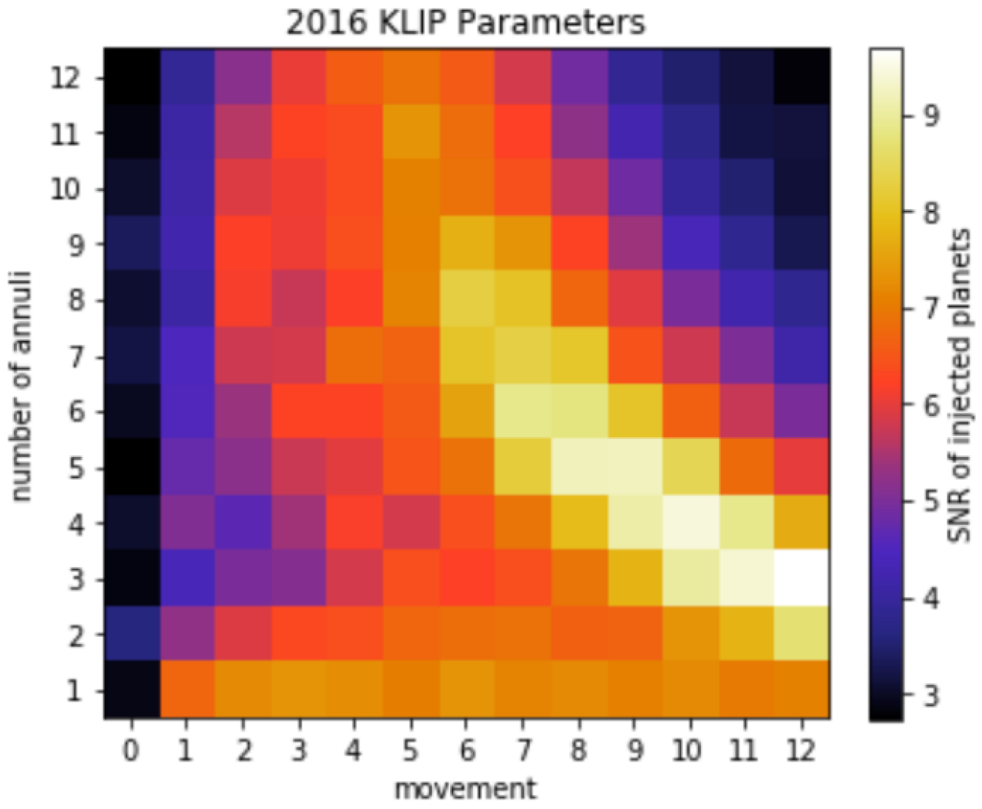


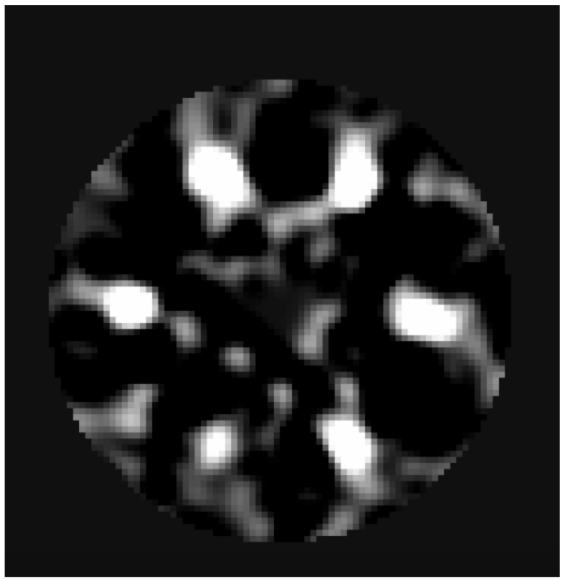

"aggressiveness"



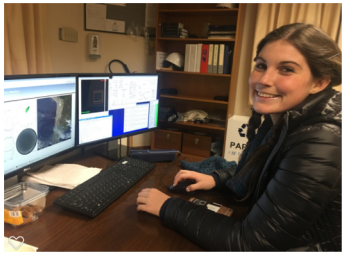
*Follette et al. 2017*

# Optimization of KLIP Parameters



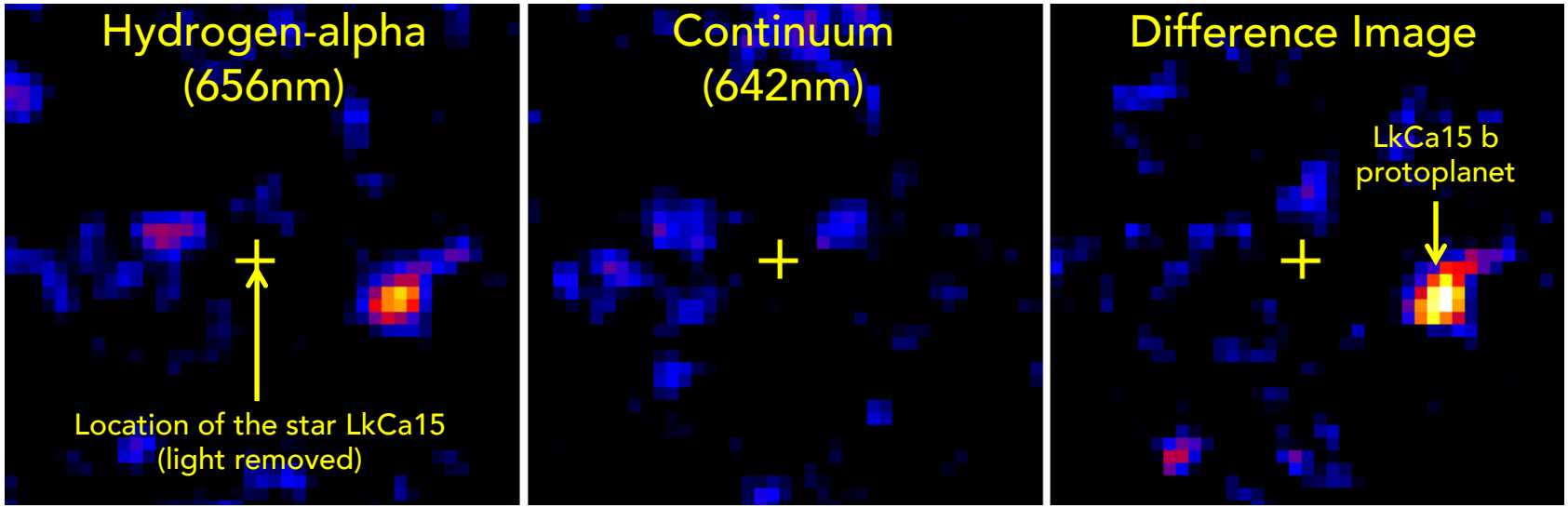



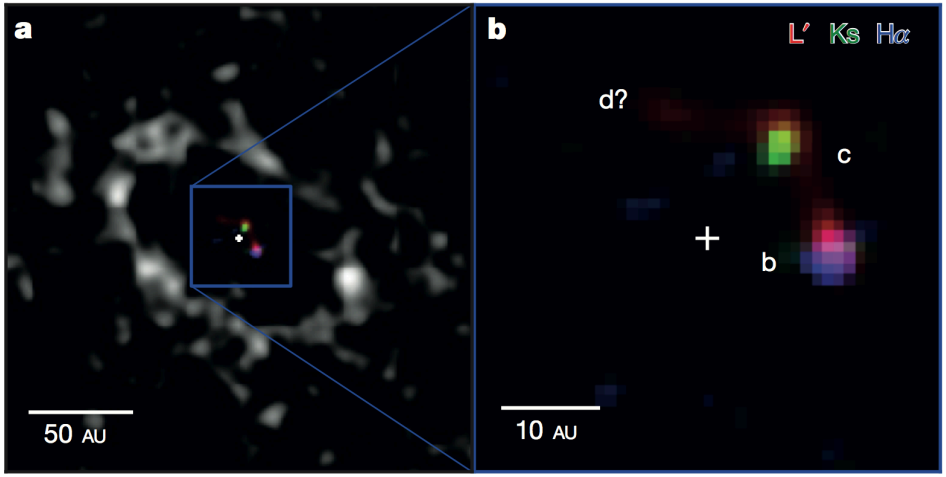
"Annuli" = number of annular zones
"Movement" = rotational mask
"Subsections" = number of azimulthal zones
"KL modes" = number of principal components



Clare Leonard
Undergraduate thesis

# LkCa15 b – An Accreting Protoplanet




*Sallum, Follette et al. 2015 Nature*

## Properties

**Separation:** 93 ± 8 mas

1.3 × FWHM

14.7 ± 2.1AU

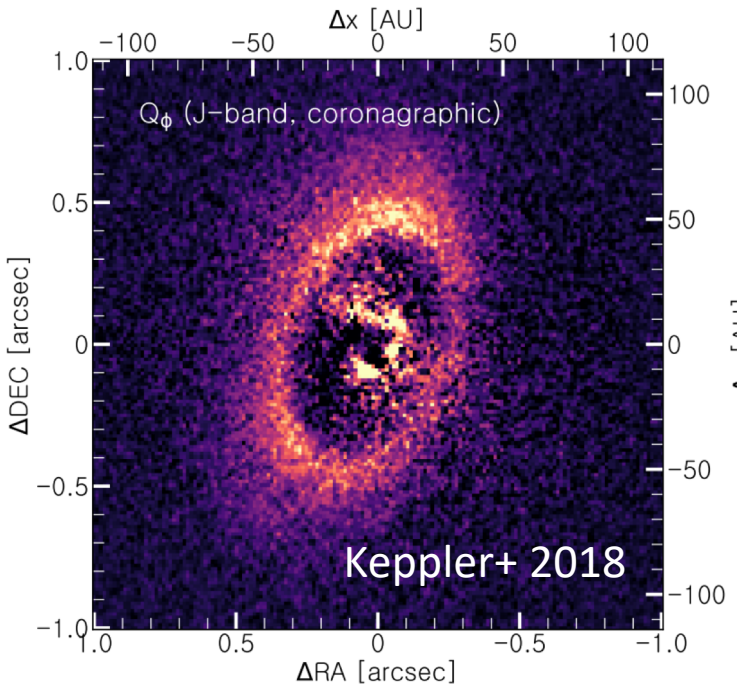
**PA:** -104 ± 3°

**$\Delta_{mag}$:** 5.2 ± 0.3

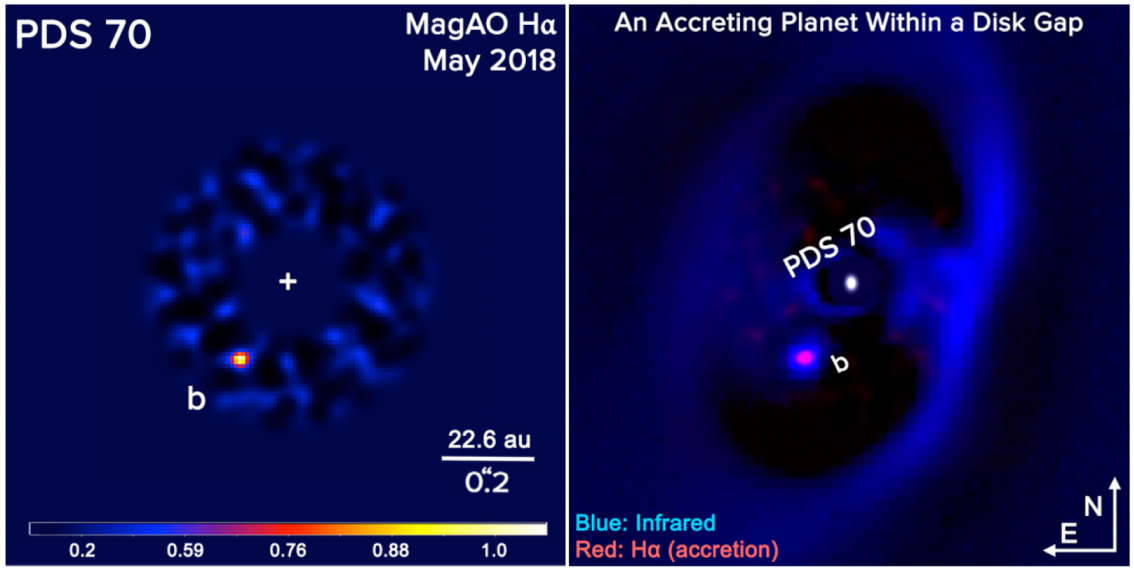
$8 \times 10^{-3}$ contrast

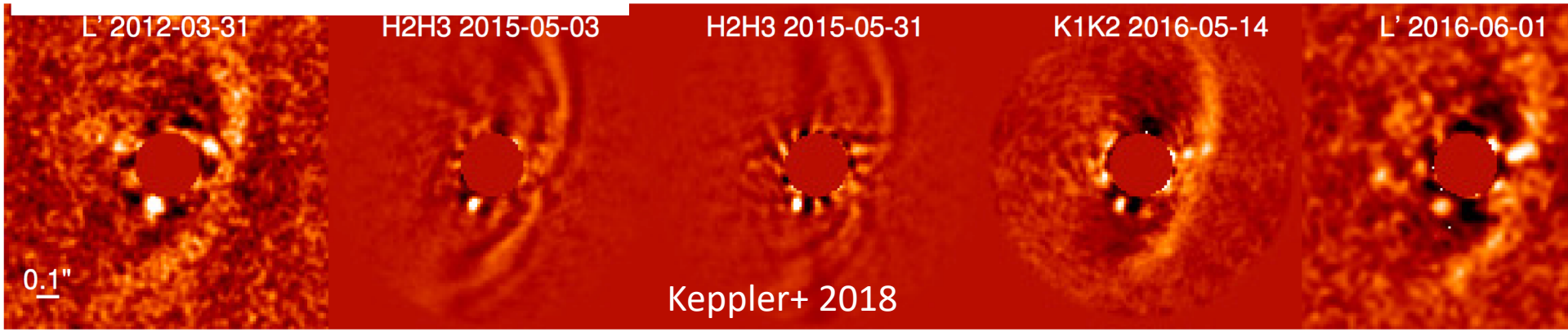
**SNR:** 6.8

# PDS 70 b – Accreting Protoplanet #2

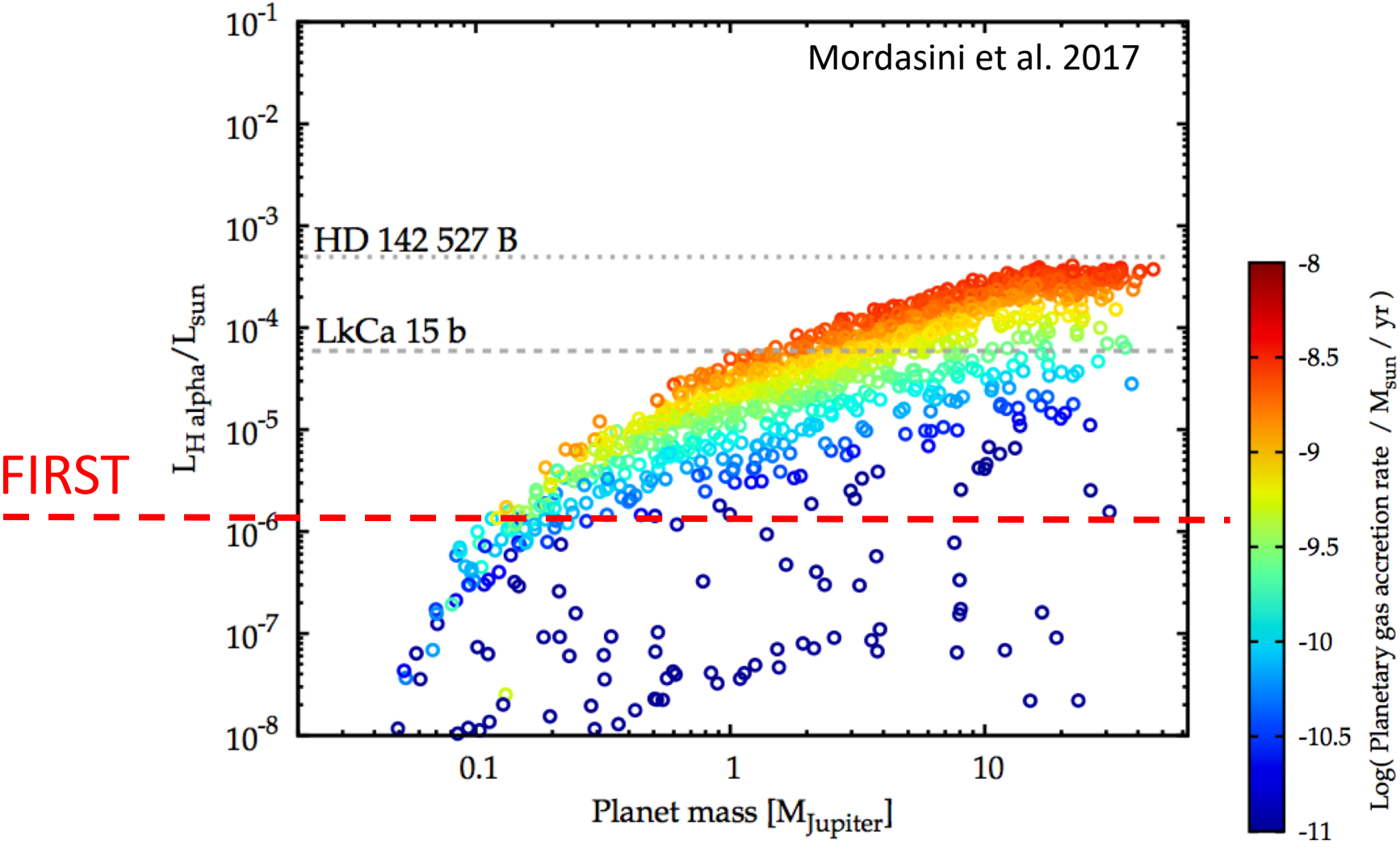



Wagner, Follette et al. 2018

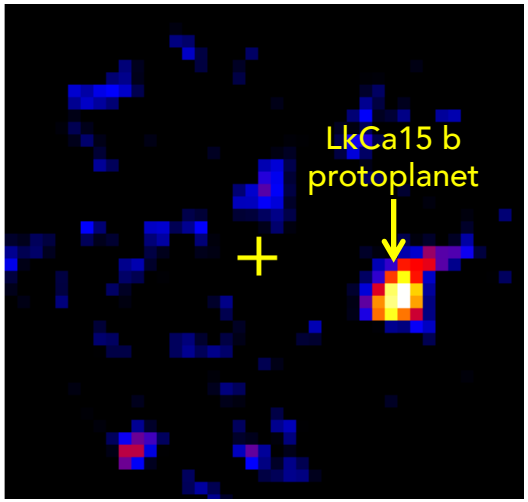


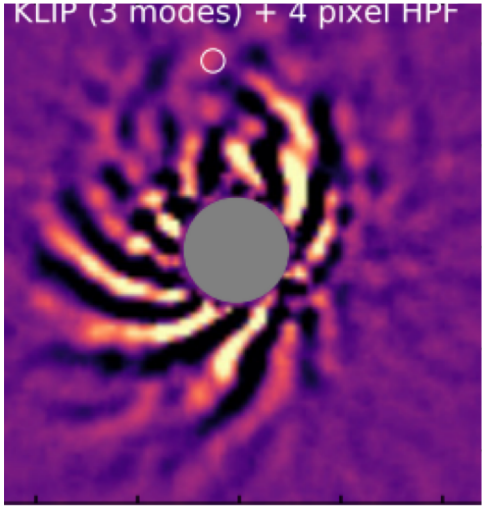
# Improving Sensitivity to Accreting Protoplanets

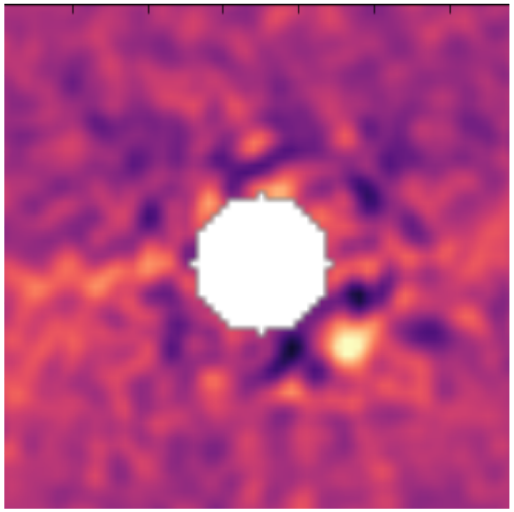
# Conclusions




*Imaging in visible light and at wavelengths that require more moderate contrasts allows for* ***direct detection of planets within disk gaps****…*



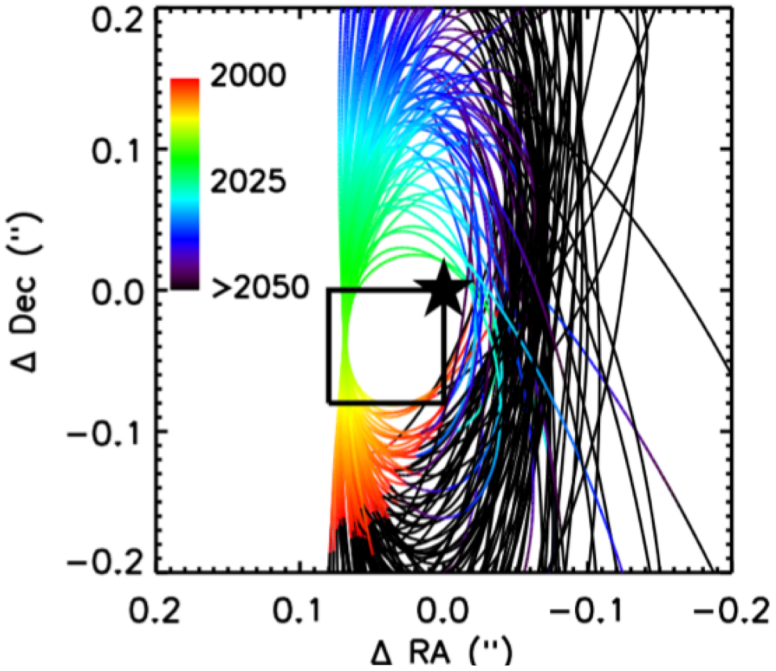

*However* ***interpretation of sources near scattered light features is complicated*** *requires large rotations and thorough exploration of the parameter space*

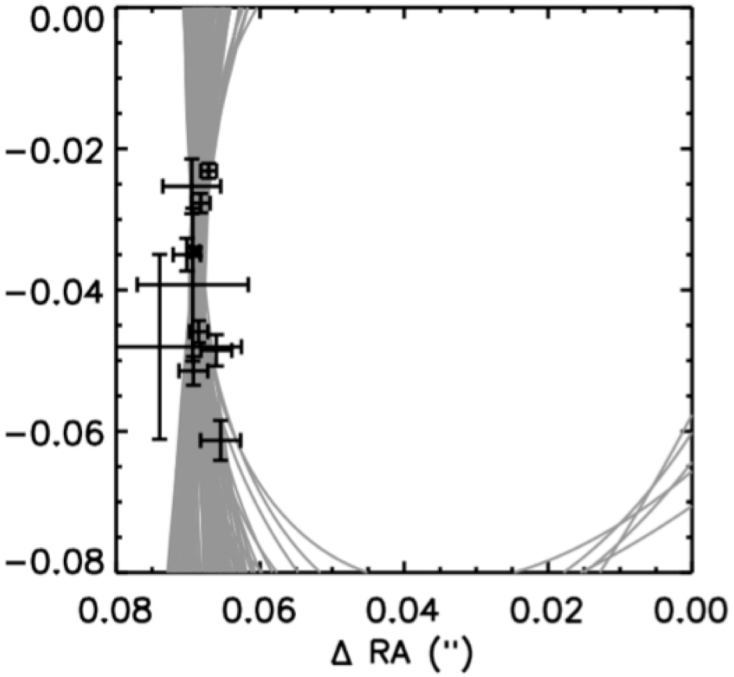


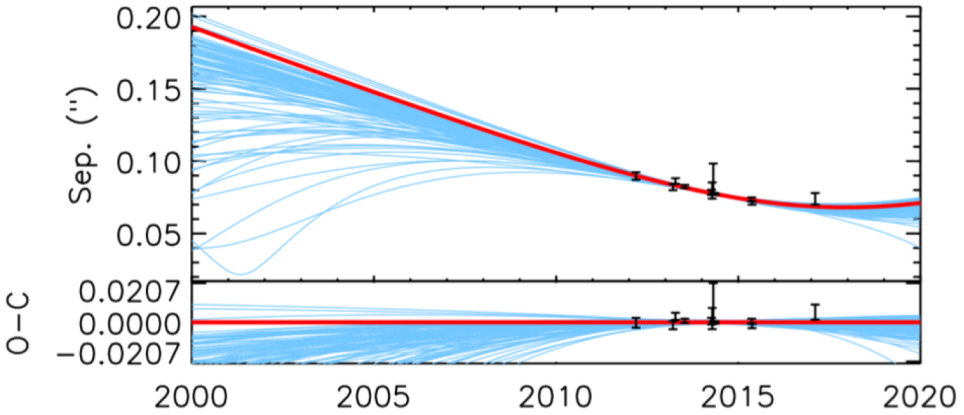
***The future of this technique is bright****, particularly in the context of future space missions*

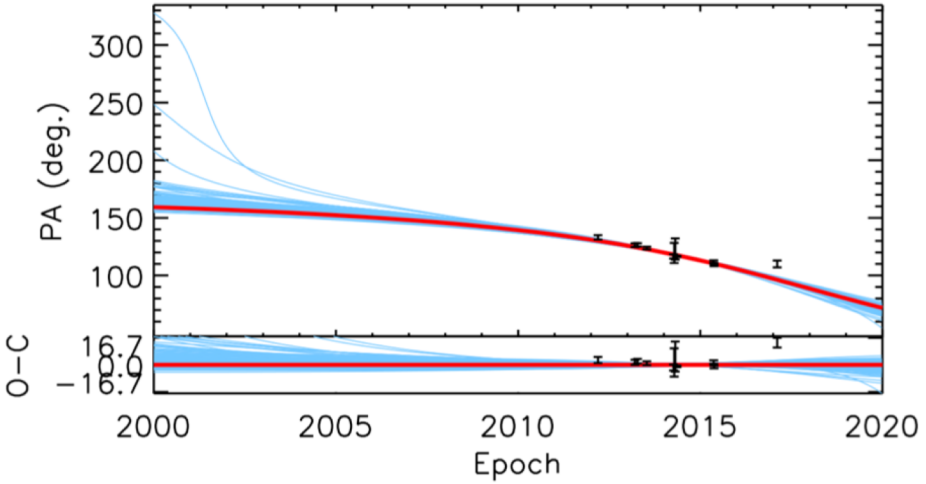
# Orbit Fitting

Alex Watson
Undergraduate thesis



# Orbit Fitting

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Undergraduate thesis