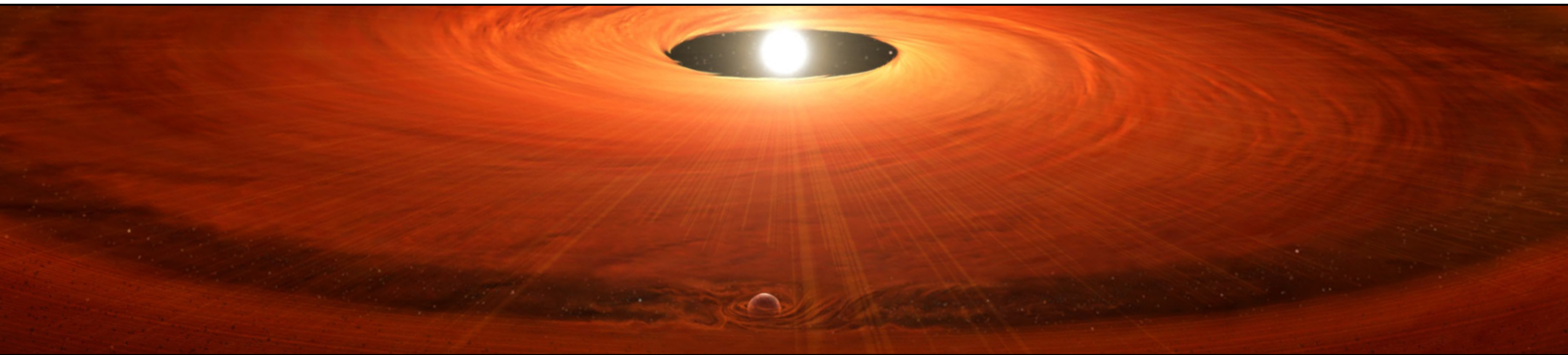


# High Contrast Polarimetry as a Complement for Total Intensity Circumstellar Disk Imaging

Presented by Kellen Lawson  
University of Oklahoma

Work conducted with John Wisniewski, Thayne Currie, and many others.



# Imaging Circumstellar Disks

- Circumstellar disks → the material for planet formation
- Disk features (gaps, spirals) can indicate planet presence
- Strengthened by integral field spectrograph (IFS) data

## Eliminating Starlight at Small Separations

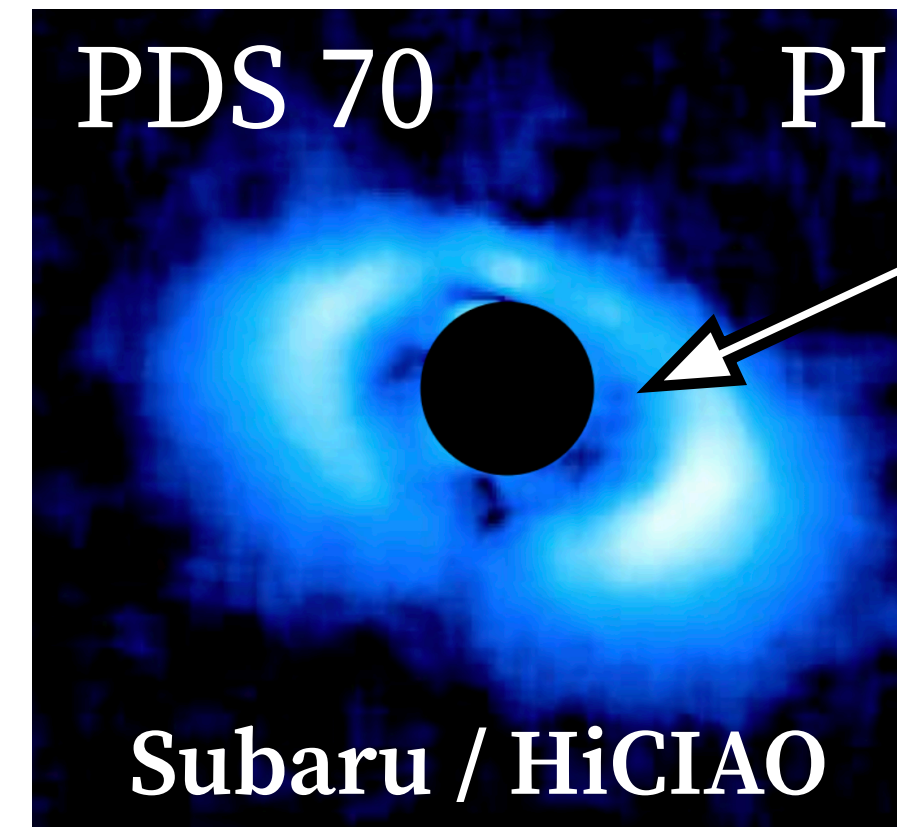
Reference Star Differential Imaging (RDI):

- ▶ spatially & spectrally variable signal loss

Polarimetric Differential Imaging (PDI):

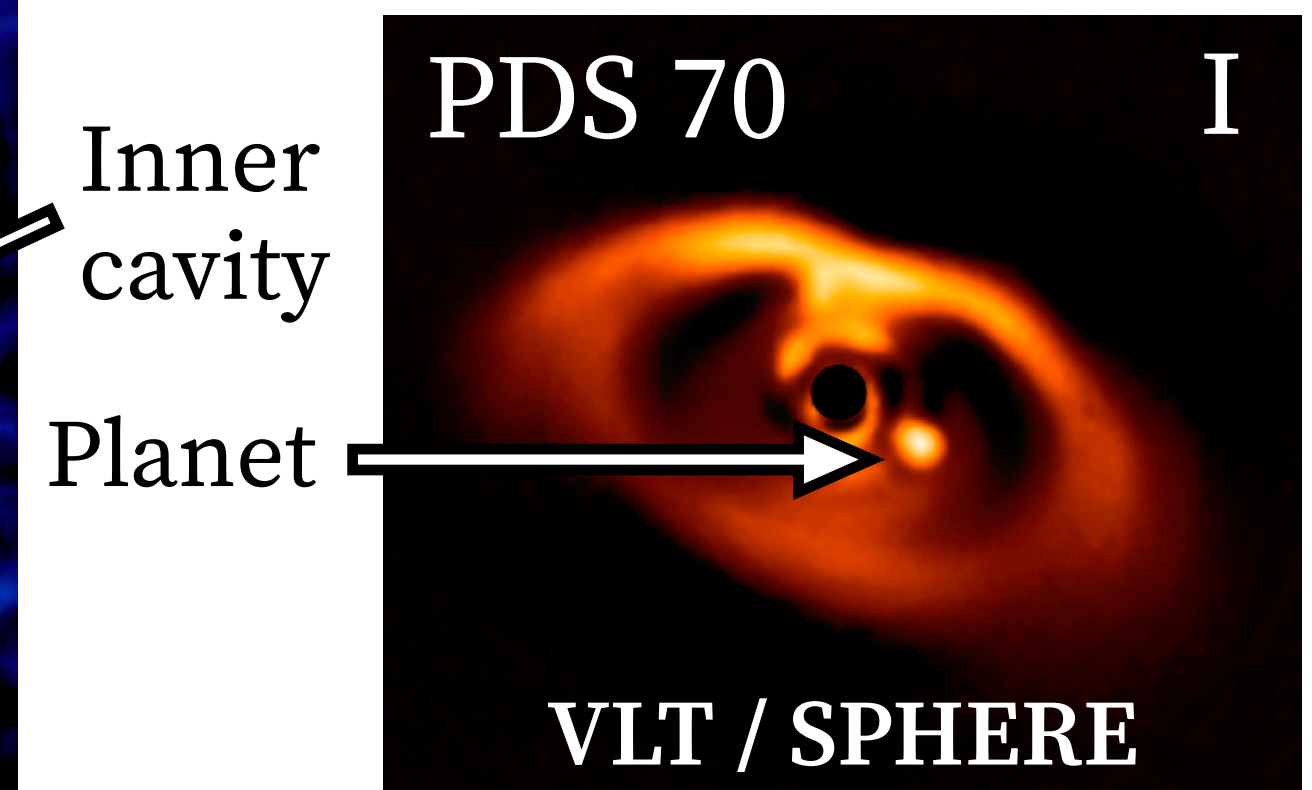
- ▶ unattenuated disk PI
- ▶ no / weak planet signal

Hashimoto et al. (2012)

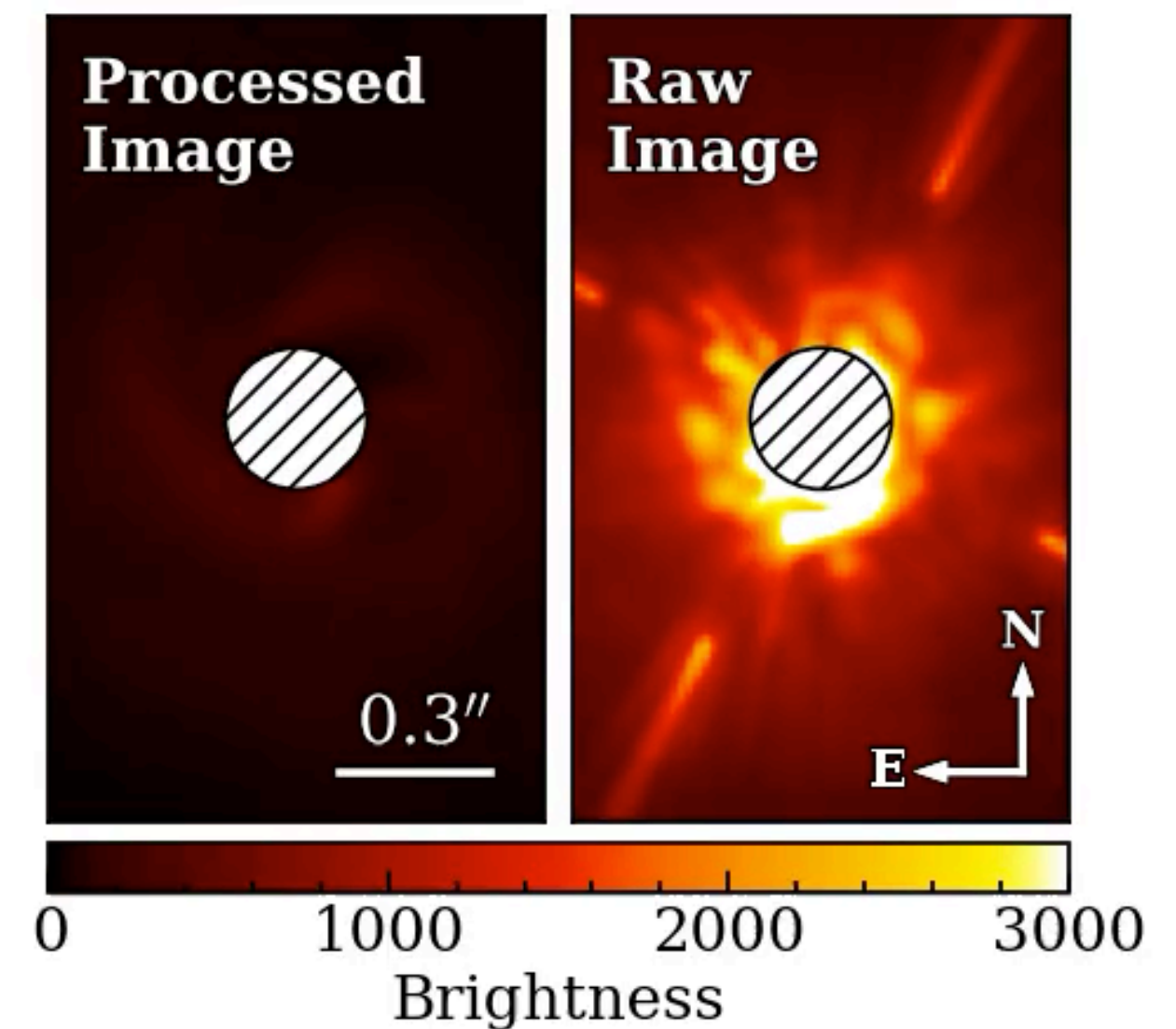
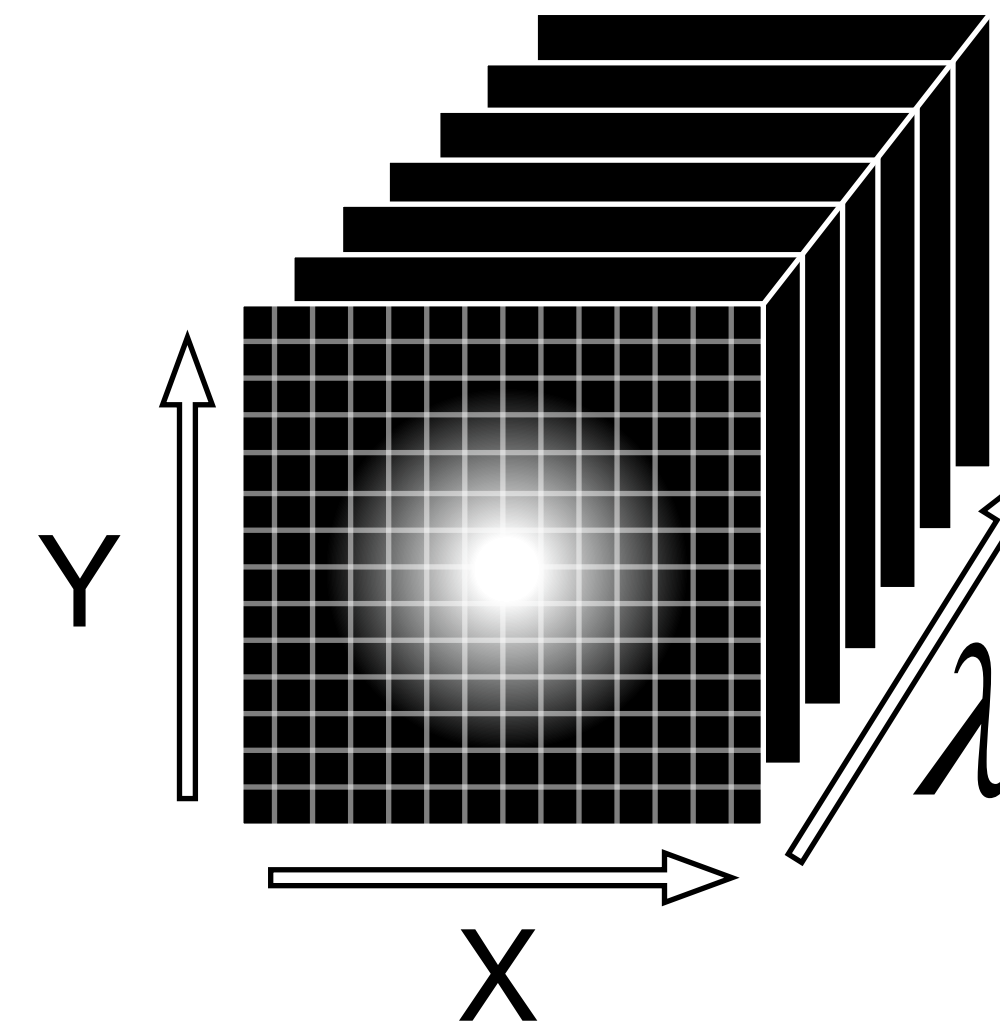


Discovery paper: Keppler et al. (2018)

This image: Müller et al. (2018)

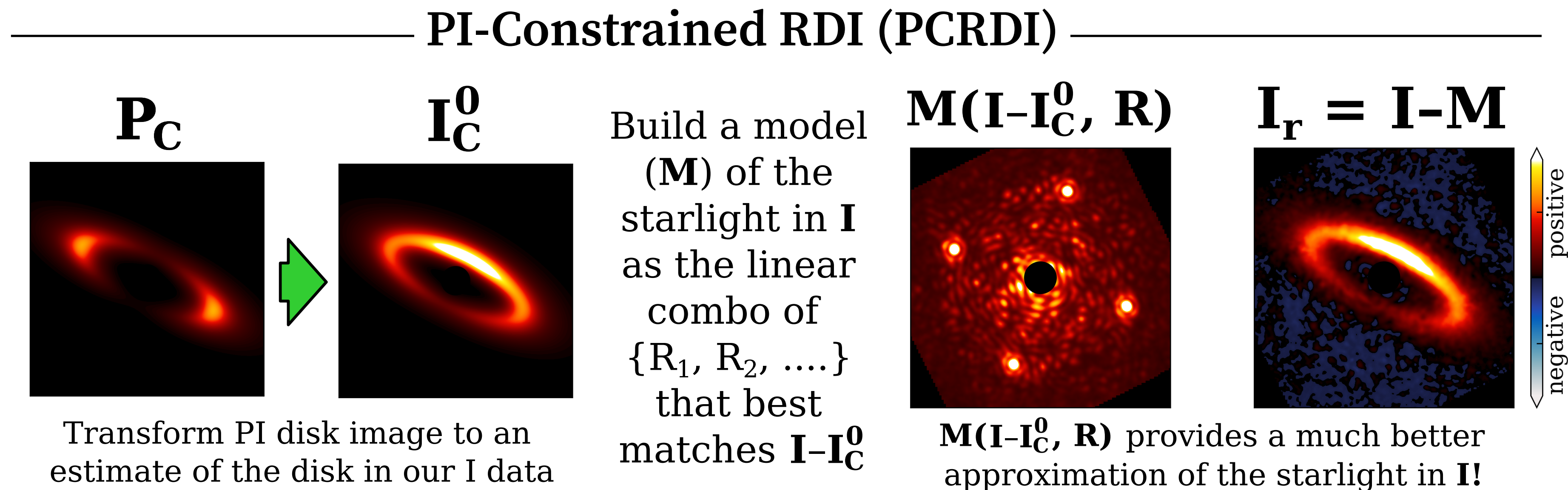
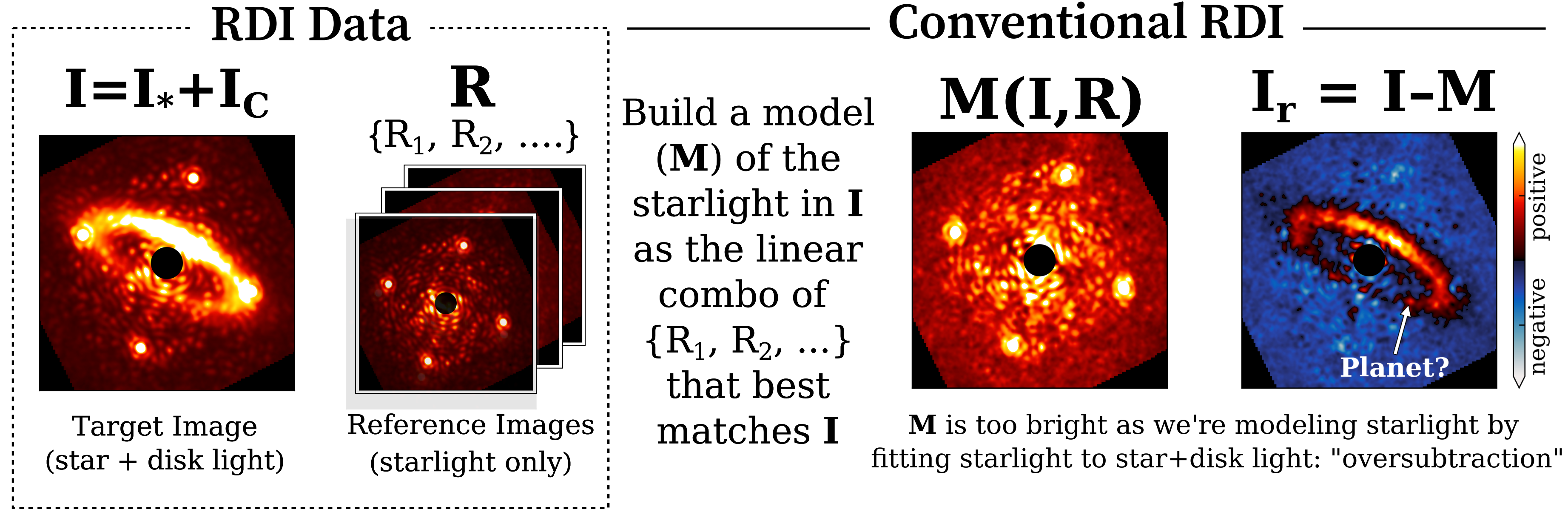


IFS Exposure



**Post-processing signal loss prevents**  
**a) detection of the youngest planets,**  
**b) detailed characterization of disks**

# Eliminating RDI Attenuation



# Constrained RDI: Simulated Data

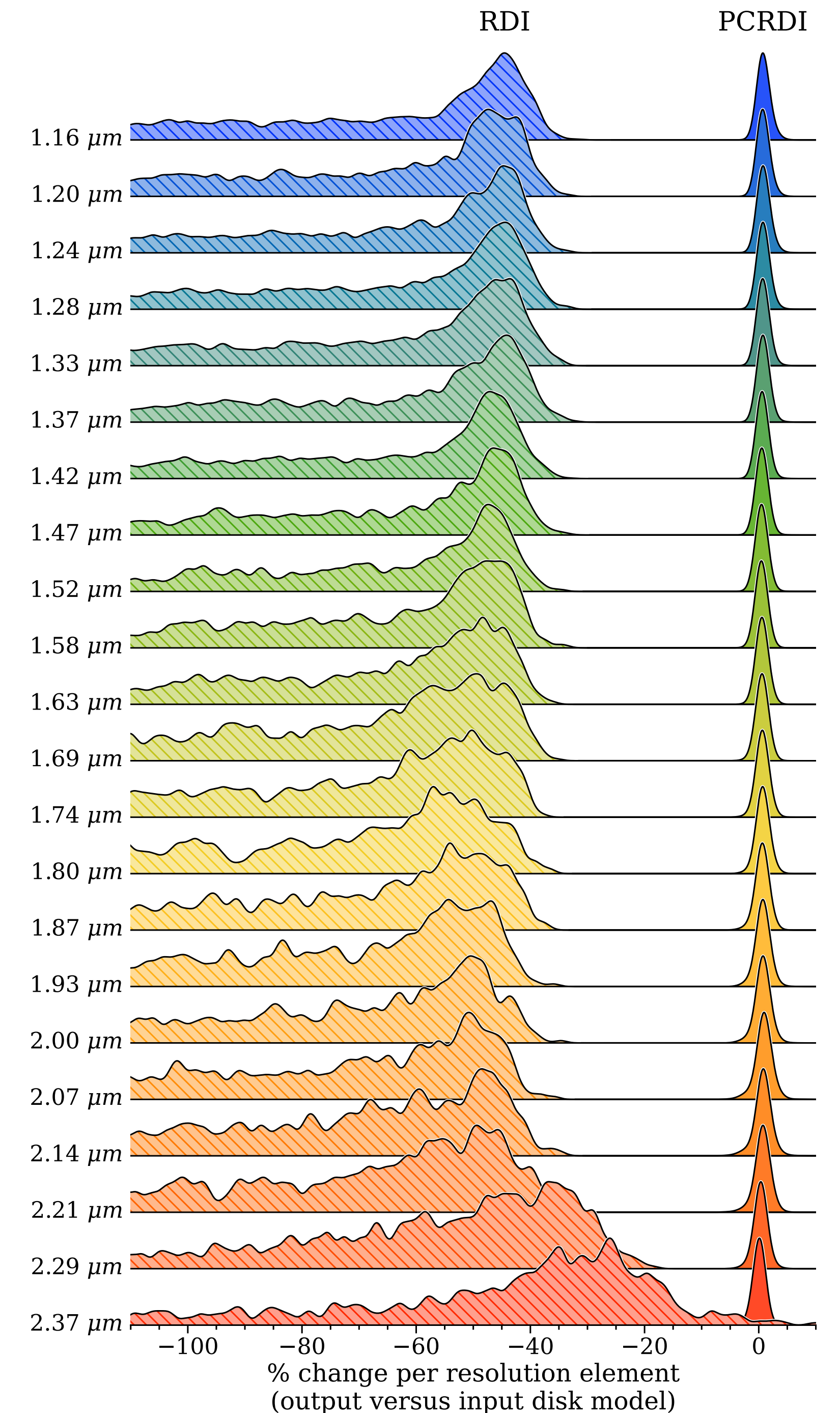
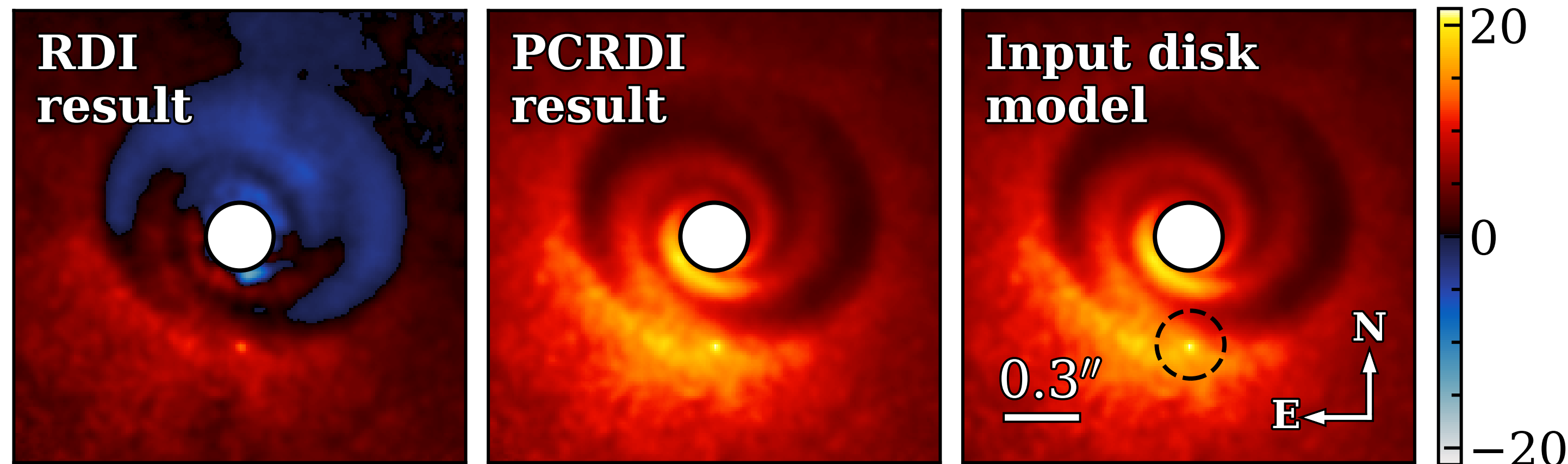
- Applied RDI & PCRDI to synthetic IFS data
- Attenuation — RDI:  $\sim 25\text{--}50\%$  PCRDI:  $\sim 0\%$

PCRDI provides unattenuated total intensity disk imagery

Even in disks that are not feasible to model, we can now:

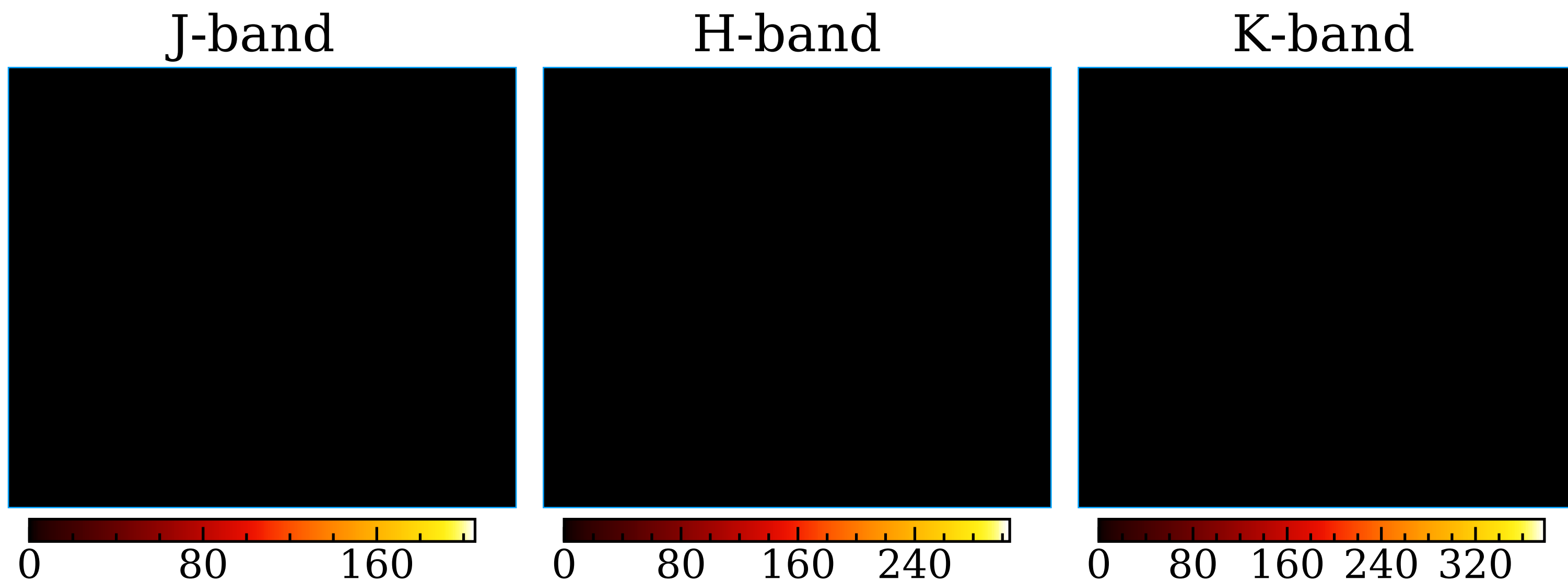
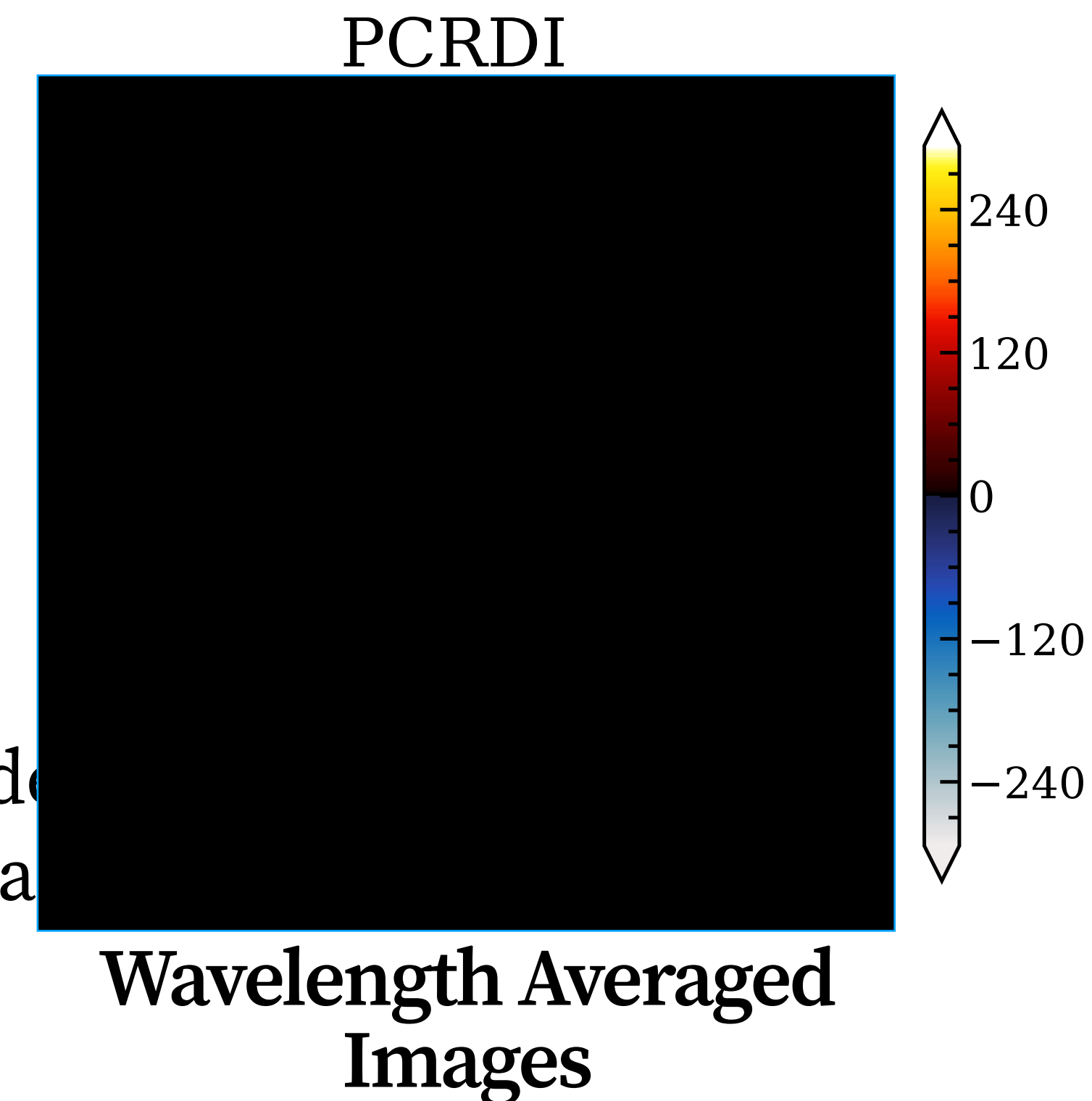
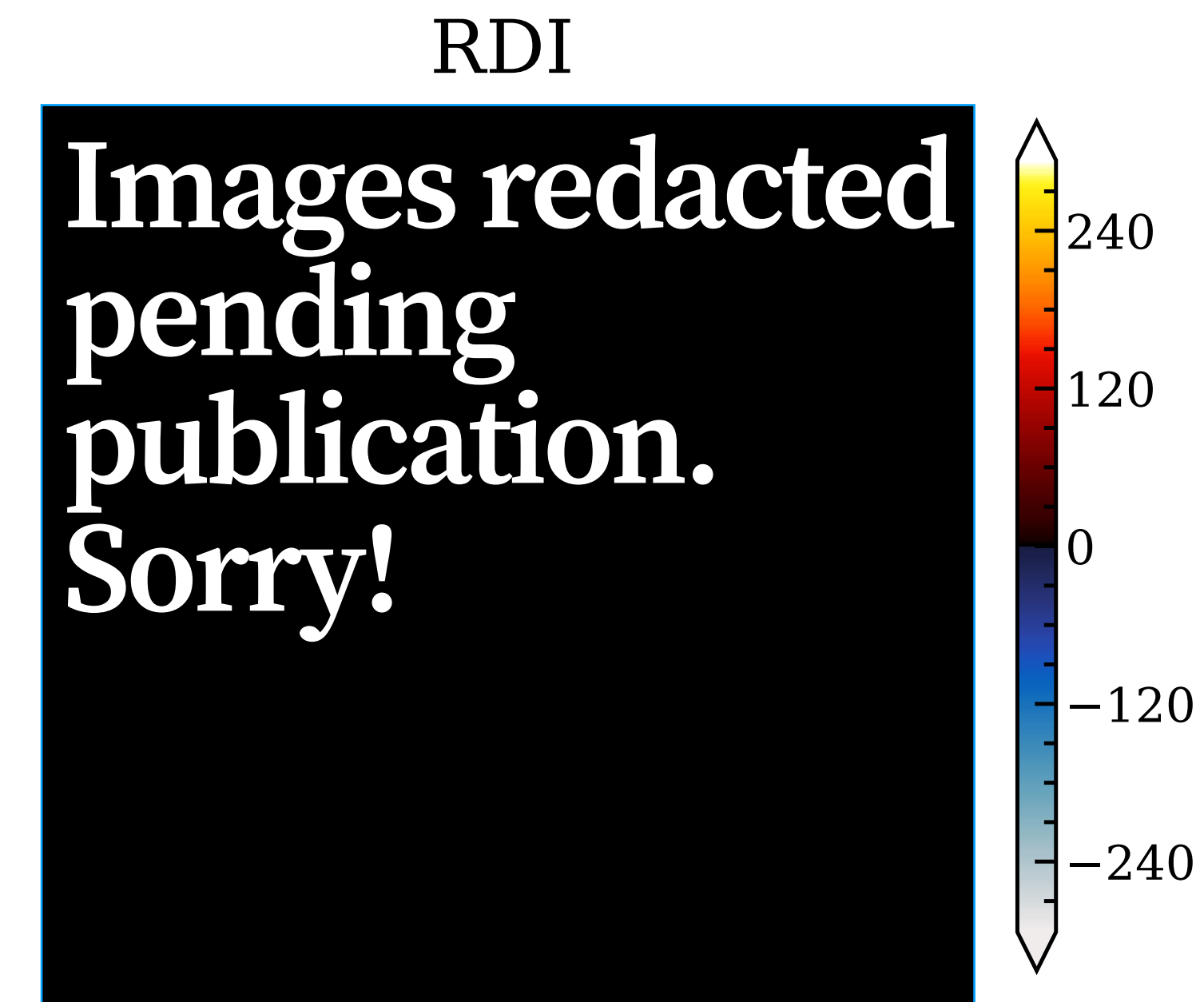
- assess planet candidates
- study local disk properties and exozodiacal dust

## Wavelength Averaged Images



# Constrained RDI: Application

- Applied PCRDI w/ CHARIS RDI & PDI IFS data
- Helped to confirm an embedded protoplanet (1–3 Myr)
  - Currie, Lawson, et al. 2022, Nat. Astron. (under minor rev.)
- Evidence of gas giant planet formation at wide separation (~100 au) — rather than migration
- Possible evidence of disk instability planet formation

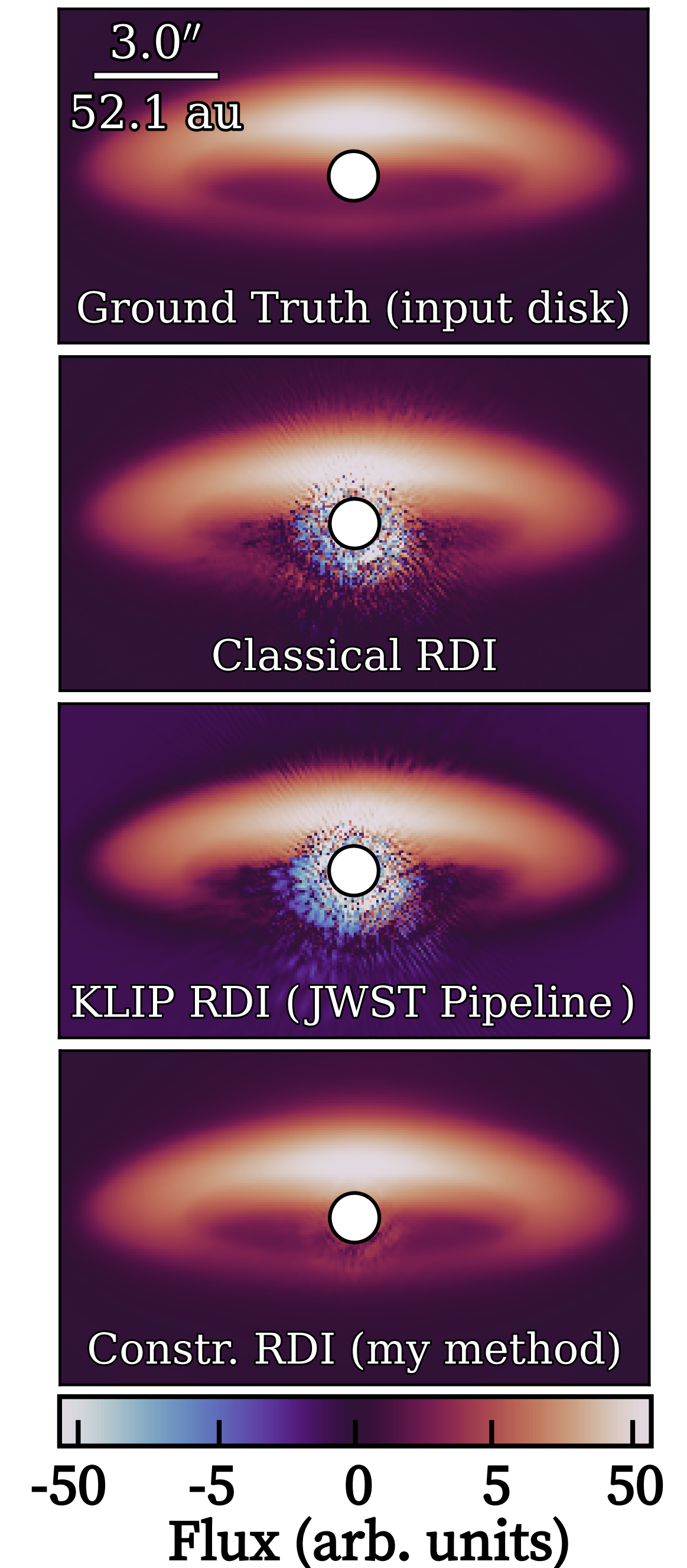


embedded  
protoplanet

# Variants & JWST+ Applications

- Model-Constrained RDI (MCRDI):  
(PCRDI's PI-based disk estimate) → (fully synthetic disk model)
  - Apply to simulated NIRCам disk imagery
  - MCRDI outperforms nominal techniques throughout FOV
  - Thanks to prolific PI disk surveys, PCRDI can also be used to improve JWST results (including early release science disk targets!)
- Also applicable to data from the Roman CGI

Sim. JWST/NIRCам — HD 10647



# Science Impact

By studying young,  
embedded exoplanets . . .

1. How do planets form & evolve?
2. How well does disk structure predict exoplanet occurrence?

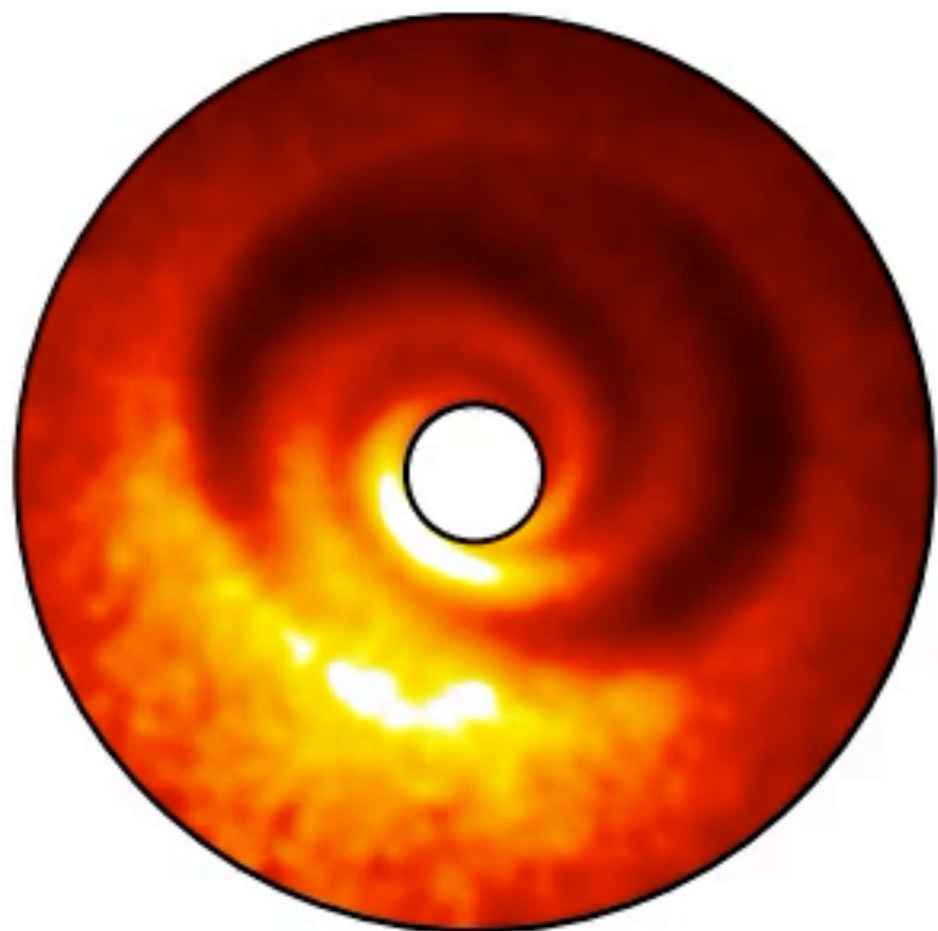
Using detailed spatial+spectral  
disk analysis . . .

1. How do dust properties vary throughout disks?
2. How does exozodiacal dust impact planet detection?

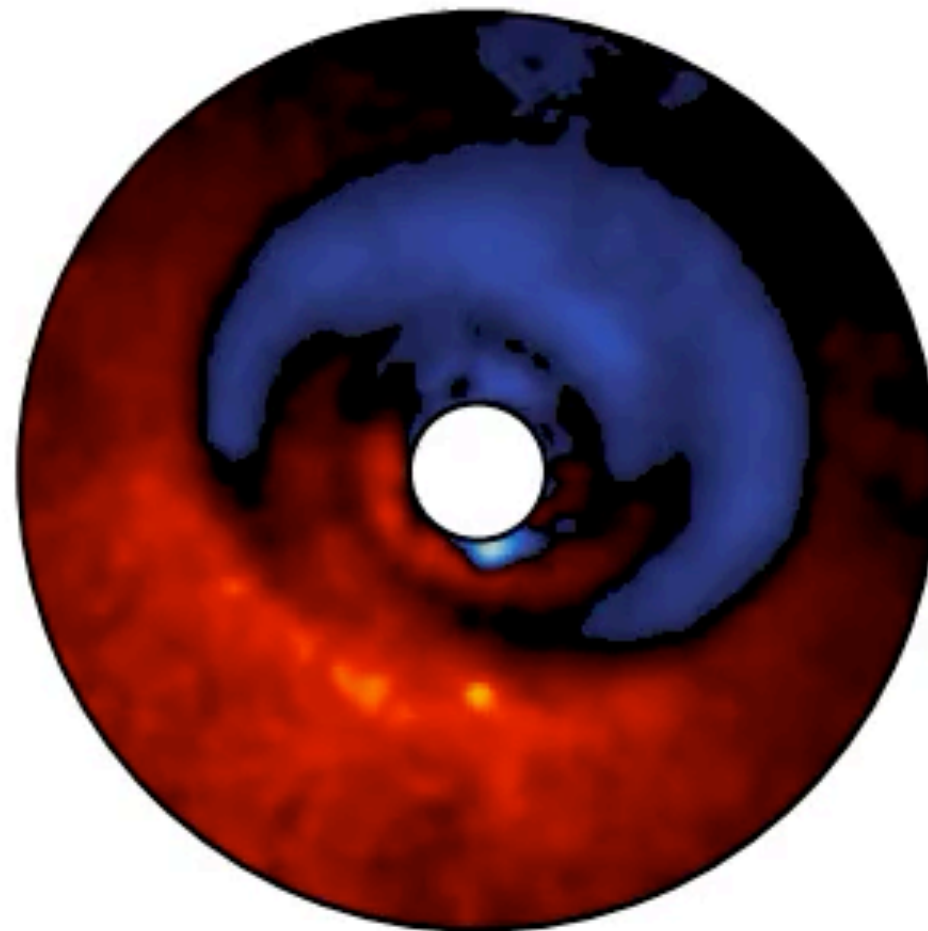
## Thank you!

### Optimizing PCRDI

Input Disk + Planet



Final RDI image:  
0% optimized



Attenuation per resolution element

