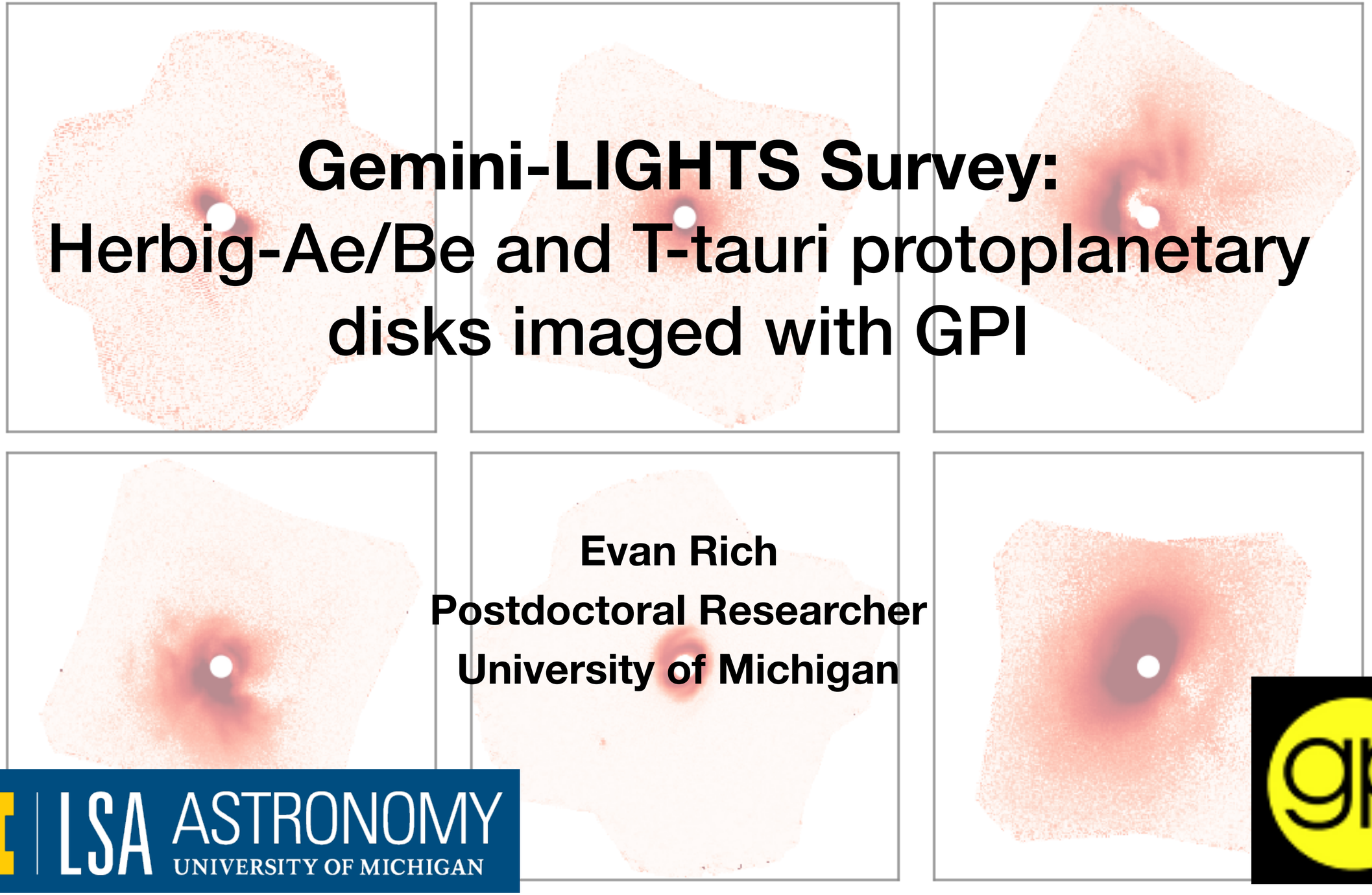


Gemini-LIGHTS Survey: Herbig-Ae/Be and T-tauri protoplanetary disks imaged with GPI

Evan Rich
Postdoctoral Researcher
University of Michigan

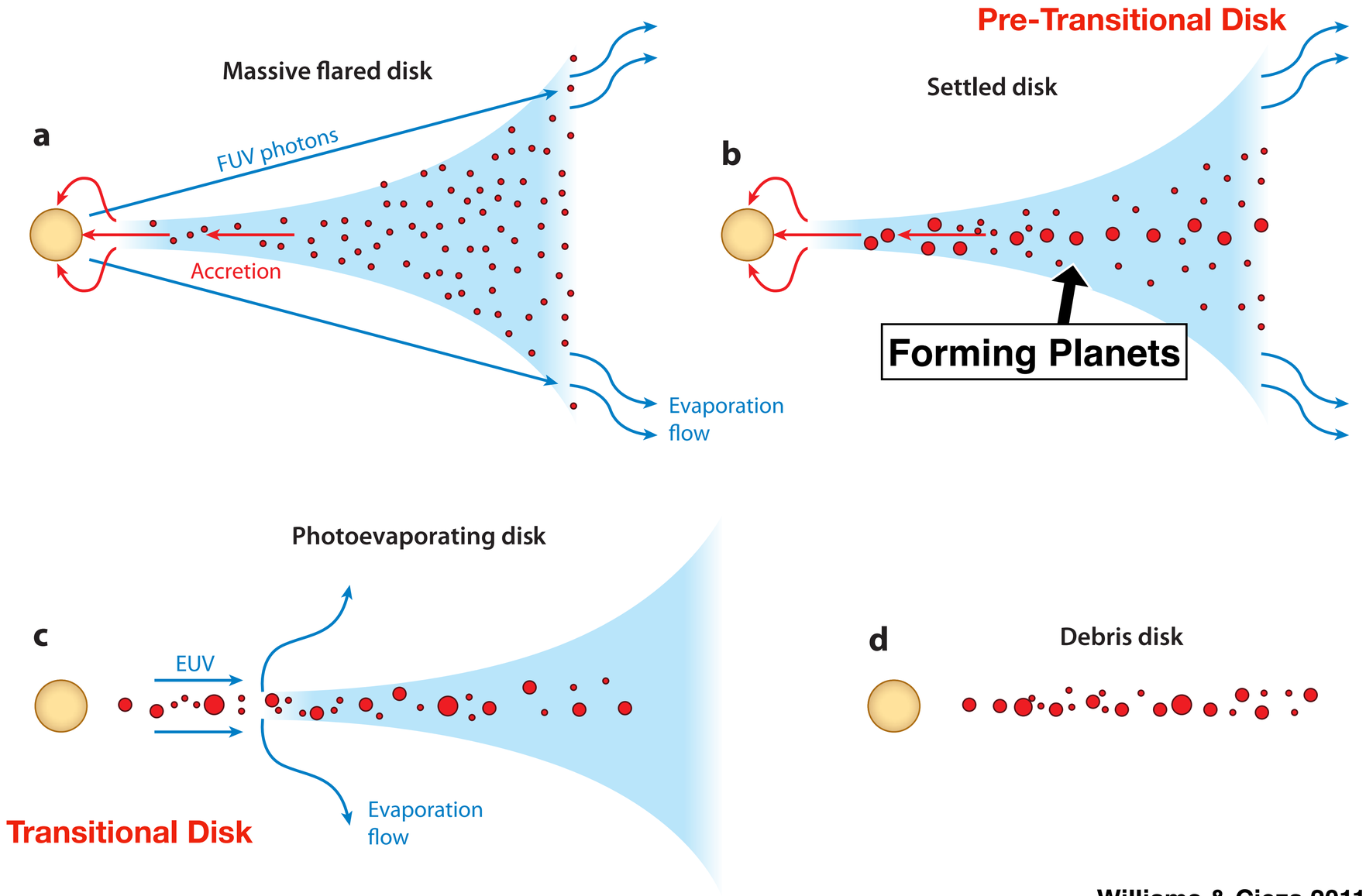
LSA ASTRONOMY
UNIVERSITY OF MICHIGAN

gpi

Summary/Conclusion

- Complete scattered light sample of 44 Herbig and T-Tarui disks at variety of evolutionary states with Gemini Planet Imager (GPI).
- Improvements to reducing polarization data from GPI.
- Discovery of interesting disk features (spiral arms) around HD 34700 A (Monnier et al. 2019).
- Irregular dust features around some of our sample targets along with strong U_ϕ flux (Laws et al. 2019).
- Currently working on modeling the sample with MCRT code TORUS

Protoplanetary Disk: Evolution/Planet Formation



Williams & Cieza 2011

What remains to be answered about Protoplanetary disks?

- How common are complex scattered-light features within 20-100au of disks?
- Transition disks w/o planets?
- Do disks develop non-smooth structures with age?
- Can we solidify links between SED shape and disk characteristics, e.g., rings, spirals, etc.

Need a uniform sample of Protoplanetary disks, especially for protoplantary disks around more massive disks.

Gemini - Large and Long Proposal

"Scattered Light imaging of YSO's: Probing the Fundamental Stages of Planet Formation"

Team:

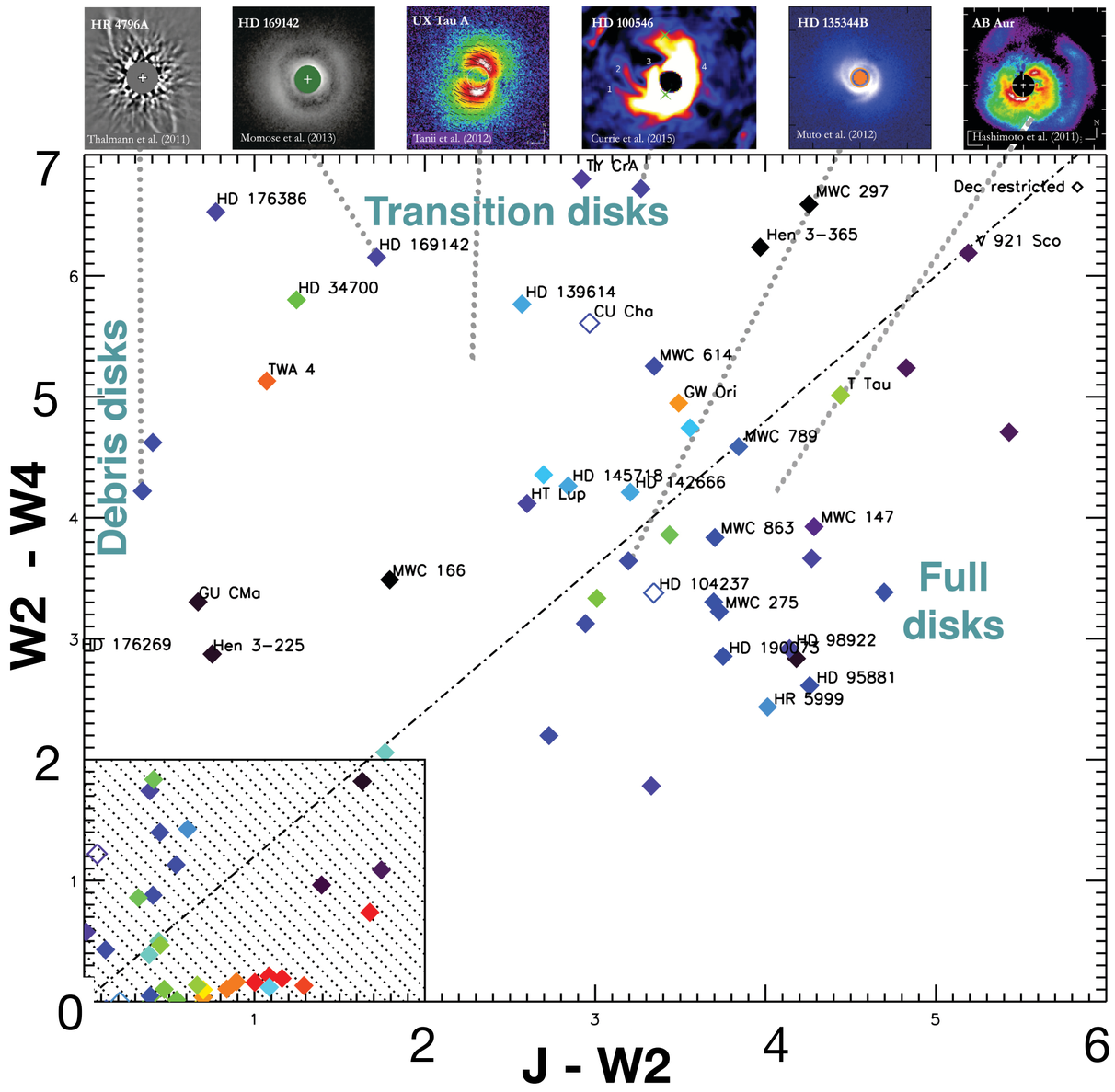
- John Monnier (PI), Alicia Aarnio, Jaehan Bae, Tim Harries, Anna Laws, Benjamin Setterholm, Fred Adams, Sean Andrews, Doug Brenner, Nuria Calvet, Statia Cook, Catherine Espaillat, Alexandra Greenbaum, Lee Hartmann, Sasha Hinkley, Andrea Isella, Stefan Kraus, Melissa McClure, Chris Miller, Rebecca Oppenheimer, Laura Perez, David Wilner, Zhaohuan Zhu

Survey Basics:

- Expand sample to ~30 YSOs with range of disk properties
  - Do not focus ONLY of those with HUGE far-IR excesses.
  - Vast majority of targets are Herbig Ae/Be stars
- Generate multi-wavelength follow-up, e.g. ALMA, SPHERE, SCExAO
- Awarded 80 hours evenly spread over 2017A,B, 2018A,B

Gemini-LIGHTS: Gemini Large Imaging with Gpi: Herbig/T-tauri Survey

- Disks at a range of disk evolution stages.
- Bright enough to be observed with GPI
- If a Binary, cannot interfer with AO-loop
- Close by to resolve disk (This was pre-GAIA DR2)
- Primarily observed in J-band with some observations in H-band.



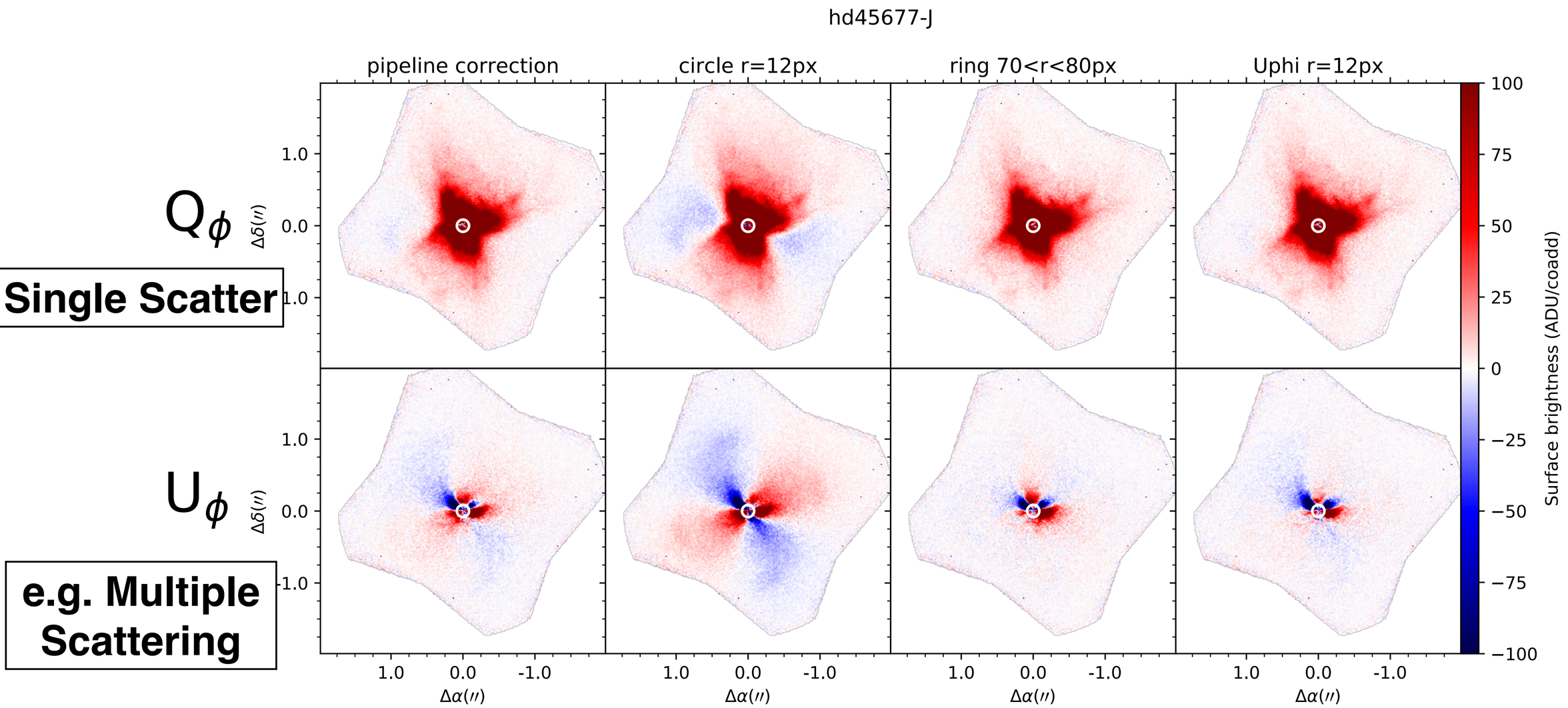
Data Reduction:
GRP (IDL) + Python

- We primarily used the written GPI Reduction Pipeline (version 1.5) but implemented a python wrapper to speed up reductions and include:
  - Removal of linear stellar/instrumental polarization
  - Centering of stars with bright companions

- First version of GRP + python discussed in **Laws et al. 2019** (arxiv: 1911.04214)
- Full version to be discusses in upcoming paper and will be code available online.

Data Reduction:

Removing Stellar/Instrumental Polarization



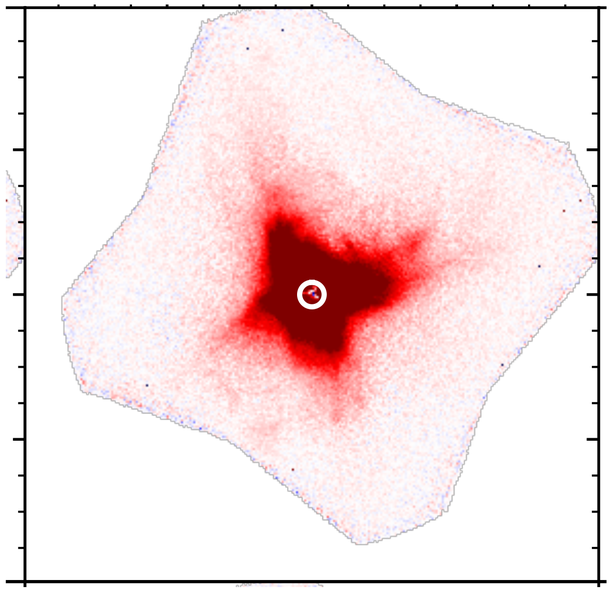
Single Scatter

e.g. Multiple Scattering

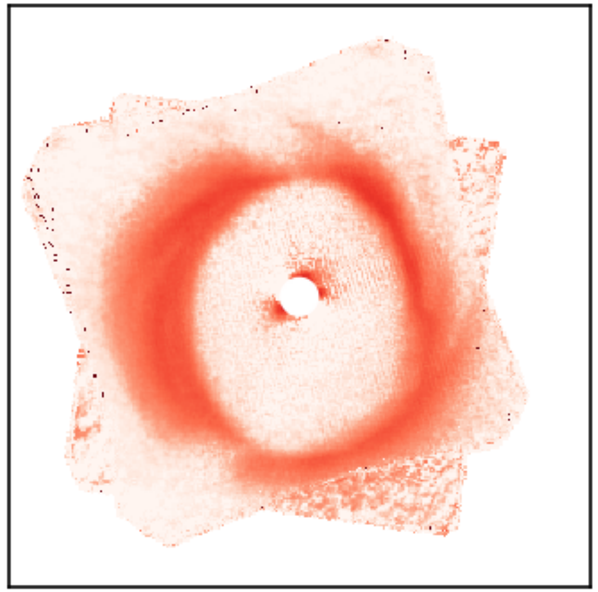
Laws et al. 2019 arxiv: 1911.04214

Data Reduction: Generalize

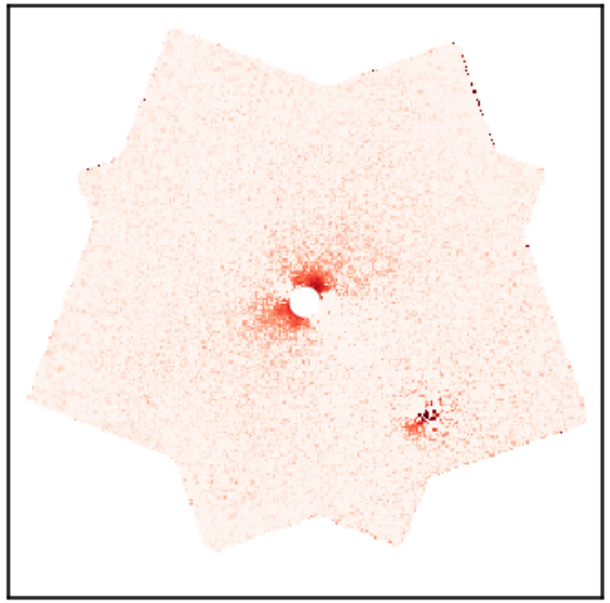
Use the entire CCD



Laws et al. Example



Disk strays into annulus region

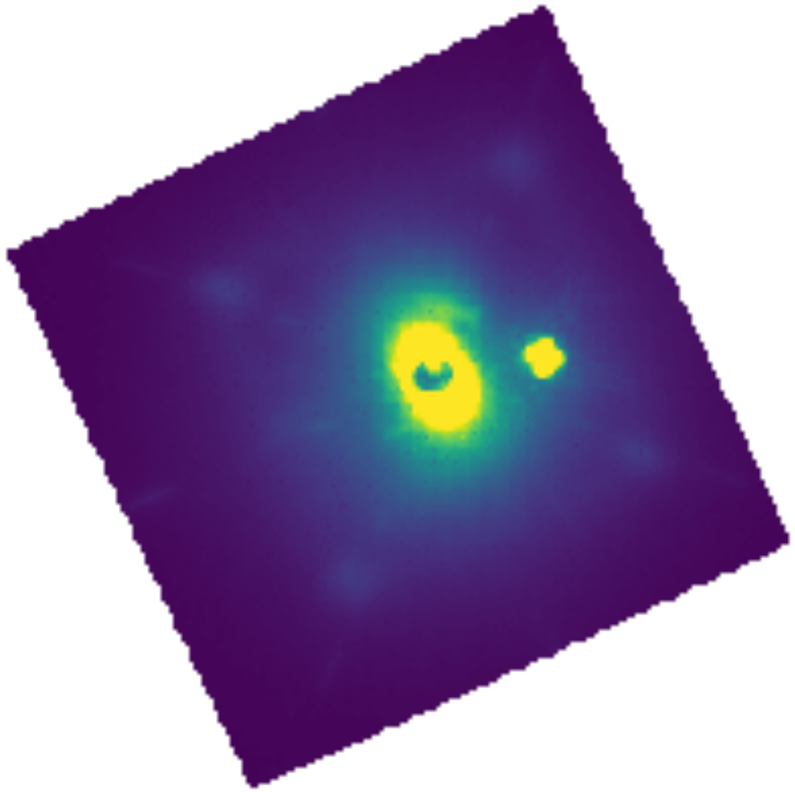


Bright companions

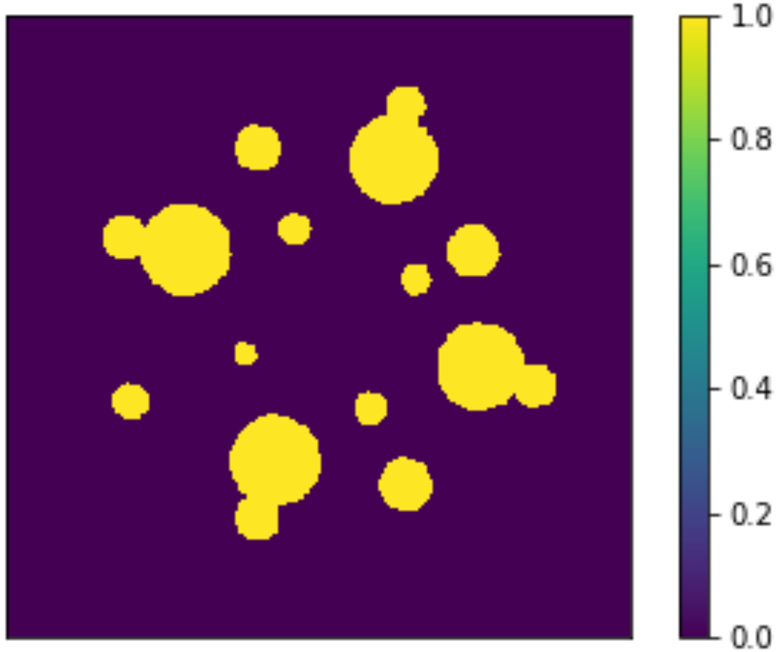
Mask out Disk using Q_ϕ/I ratio
Mask out Binary
Mask out low SNR

Data Reduction:
True Center of the Star

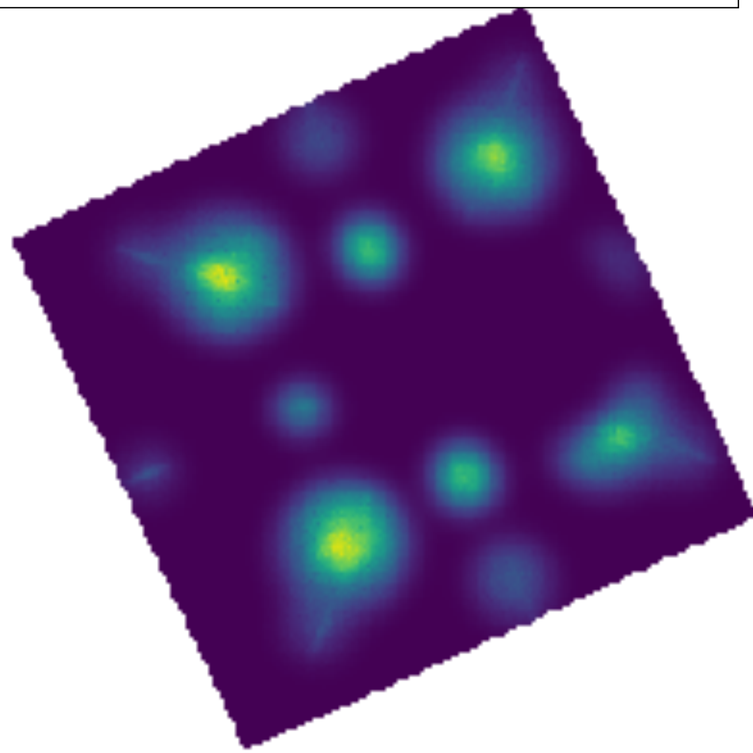
FU Ori Polarization Frame



Mask



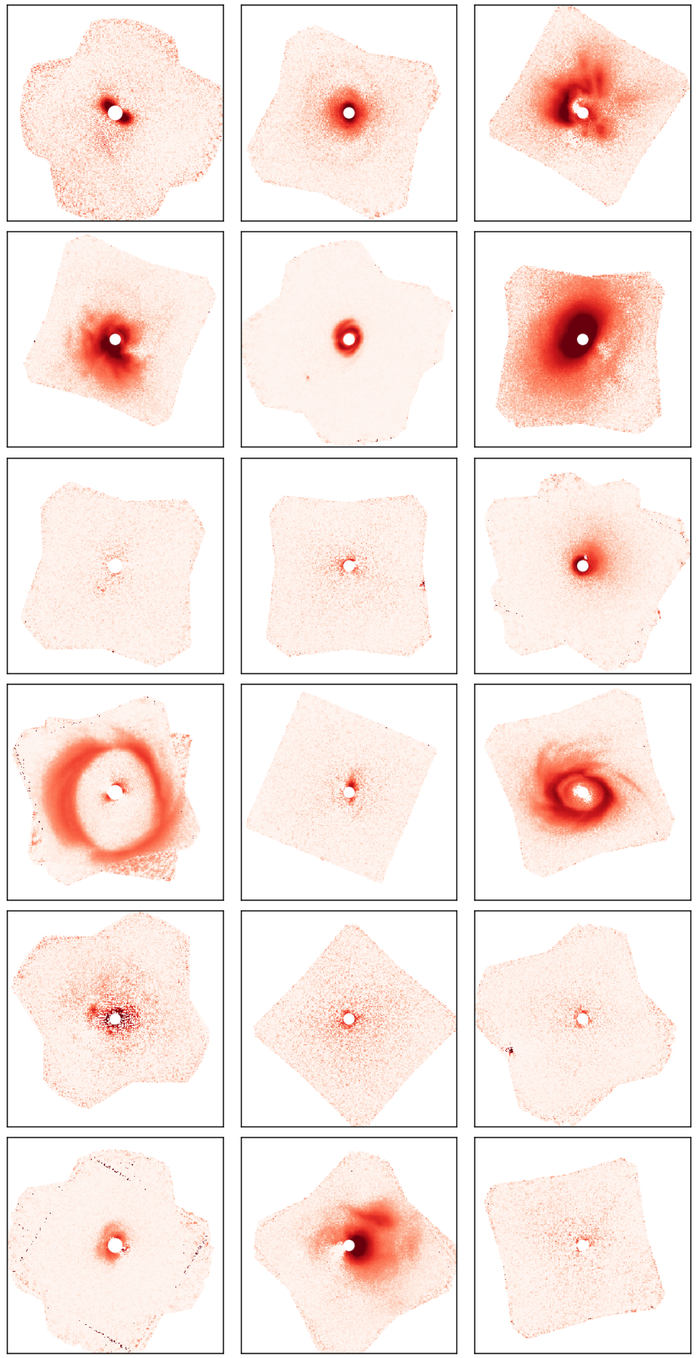
FU Ori Polarization Frame + Mask + Companion Mask

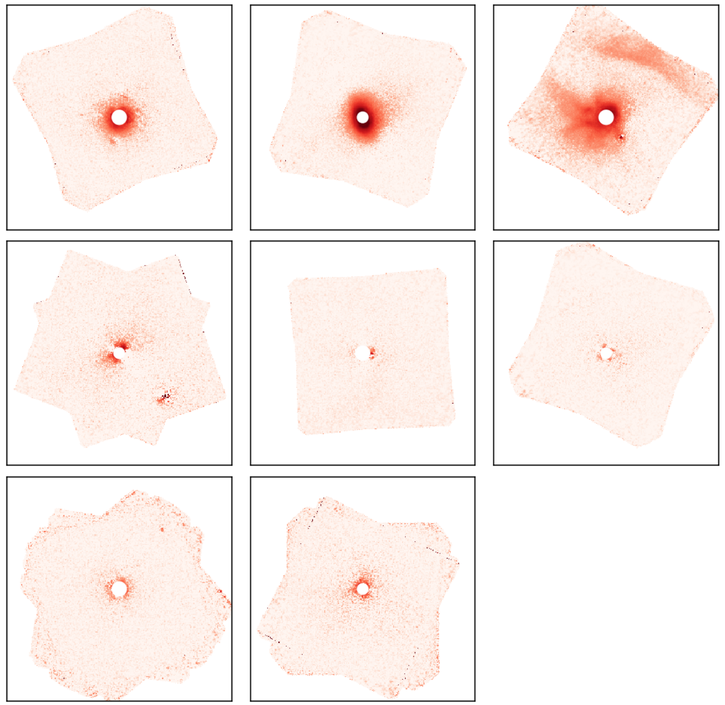


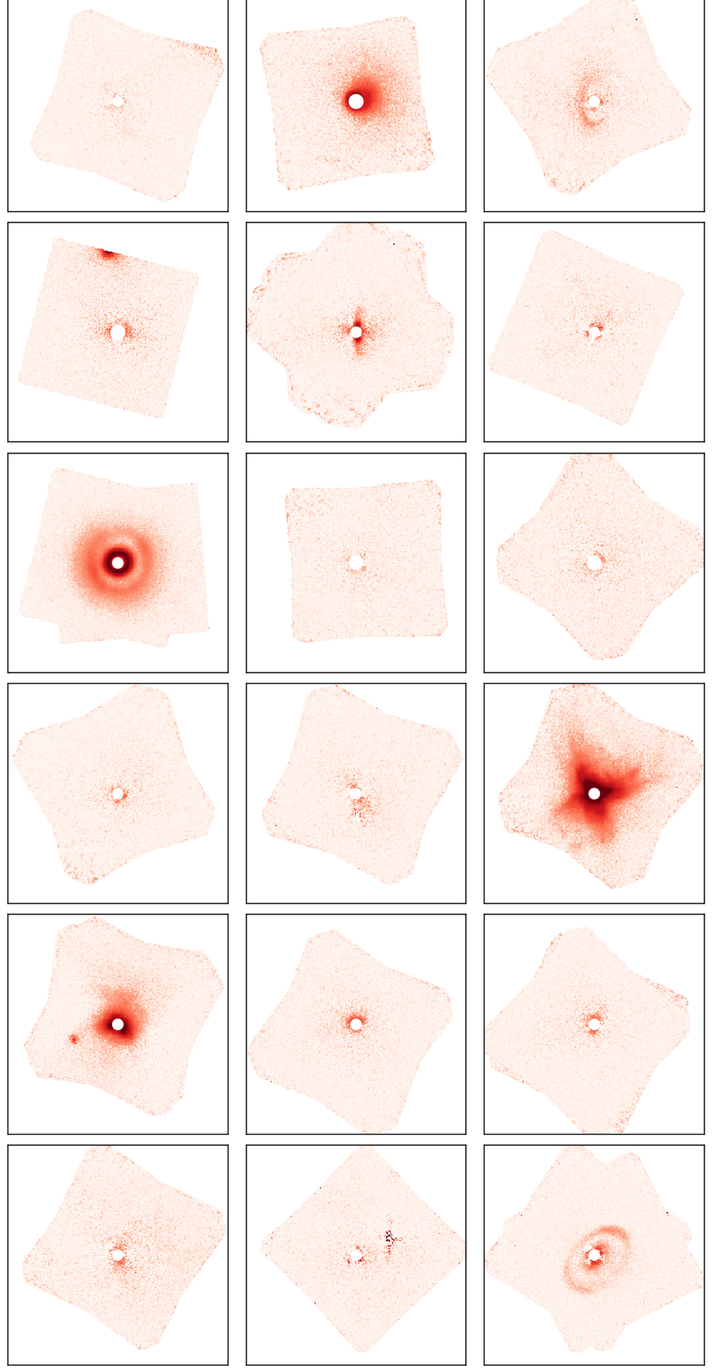
Gemini-LIGHTS:
Entire Sample

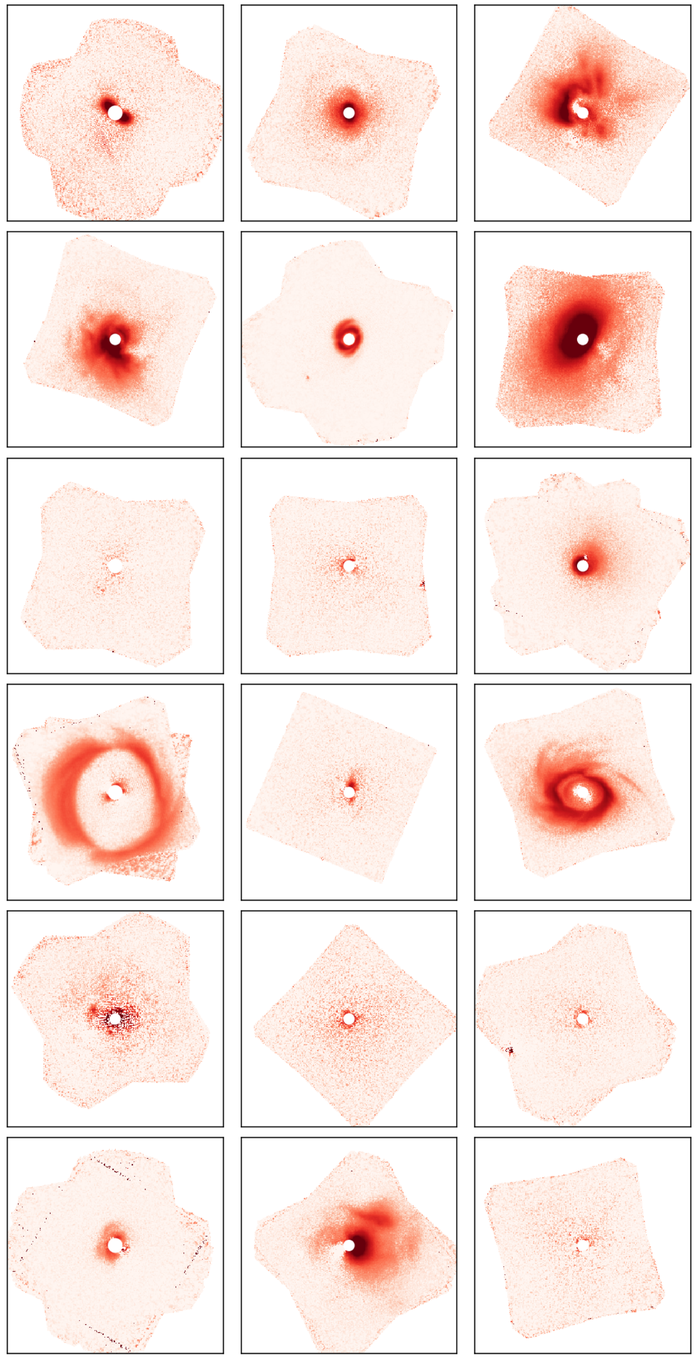
Observations Completed
44 Targets in Total

Observed in J- and/or H-bands



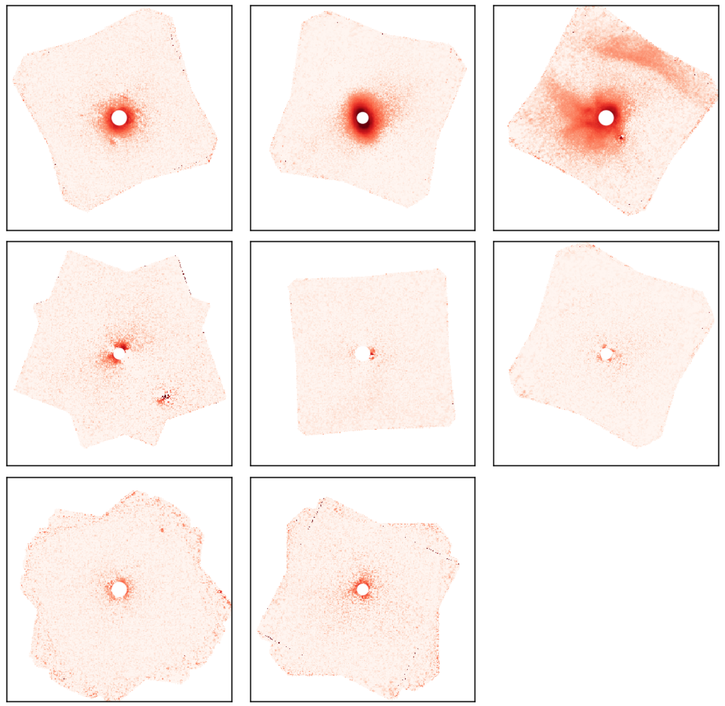


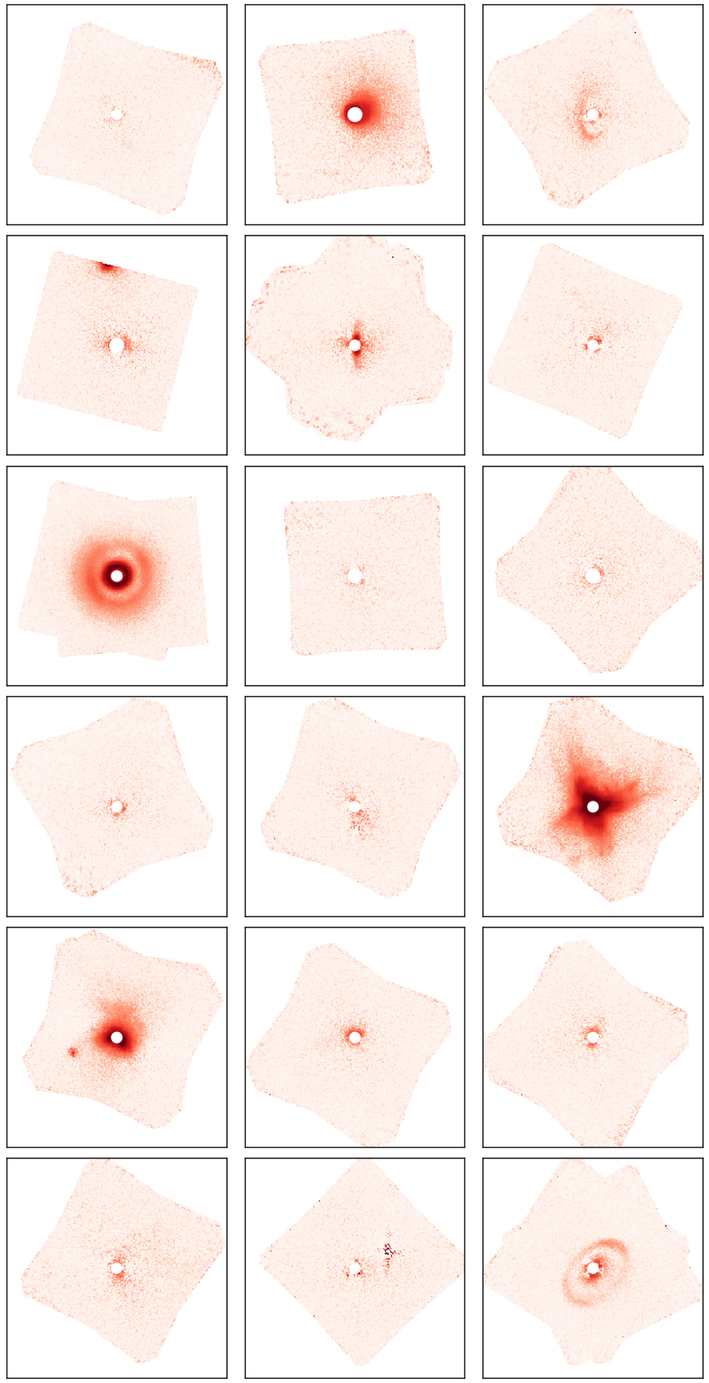


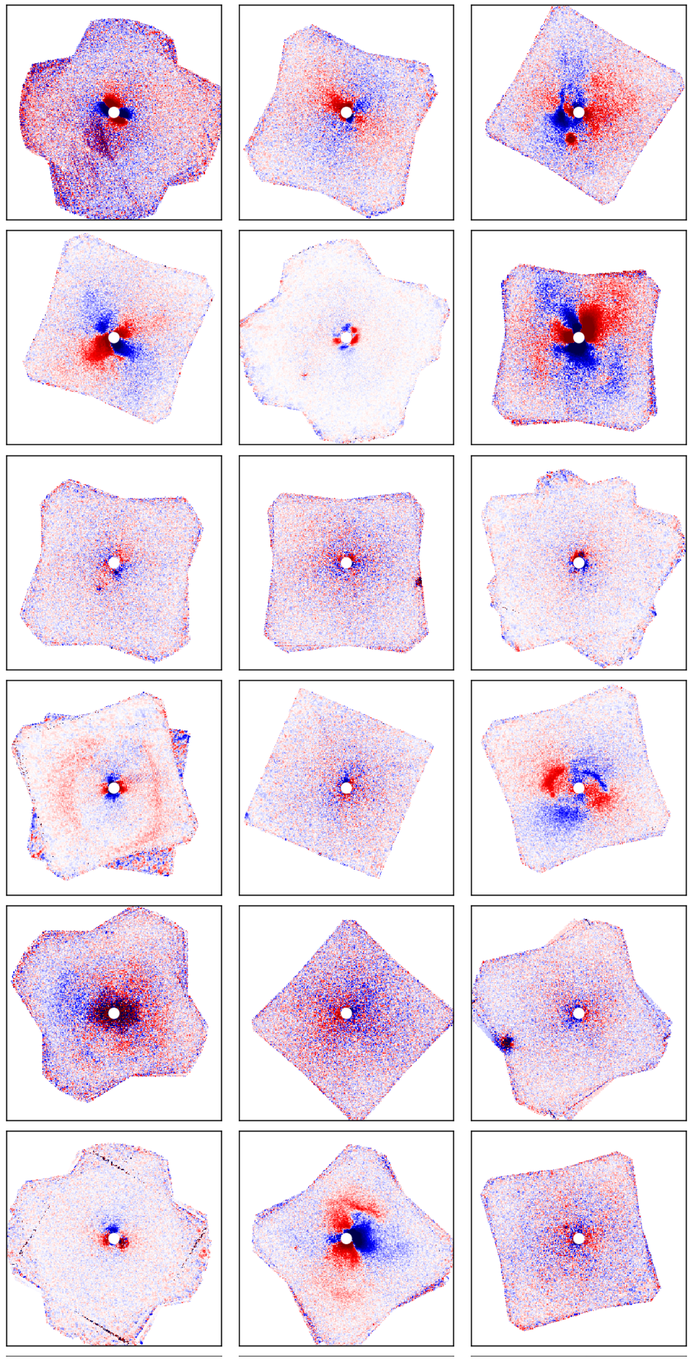


44 Targets in Total

- 19 have bright companions
- 8 Rings
- 4 Spiral Arms

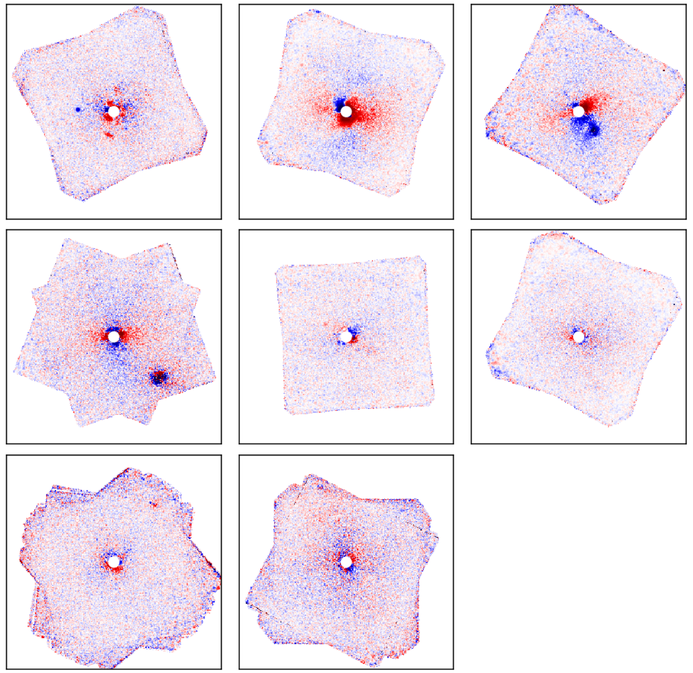


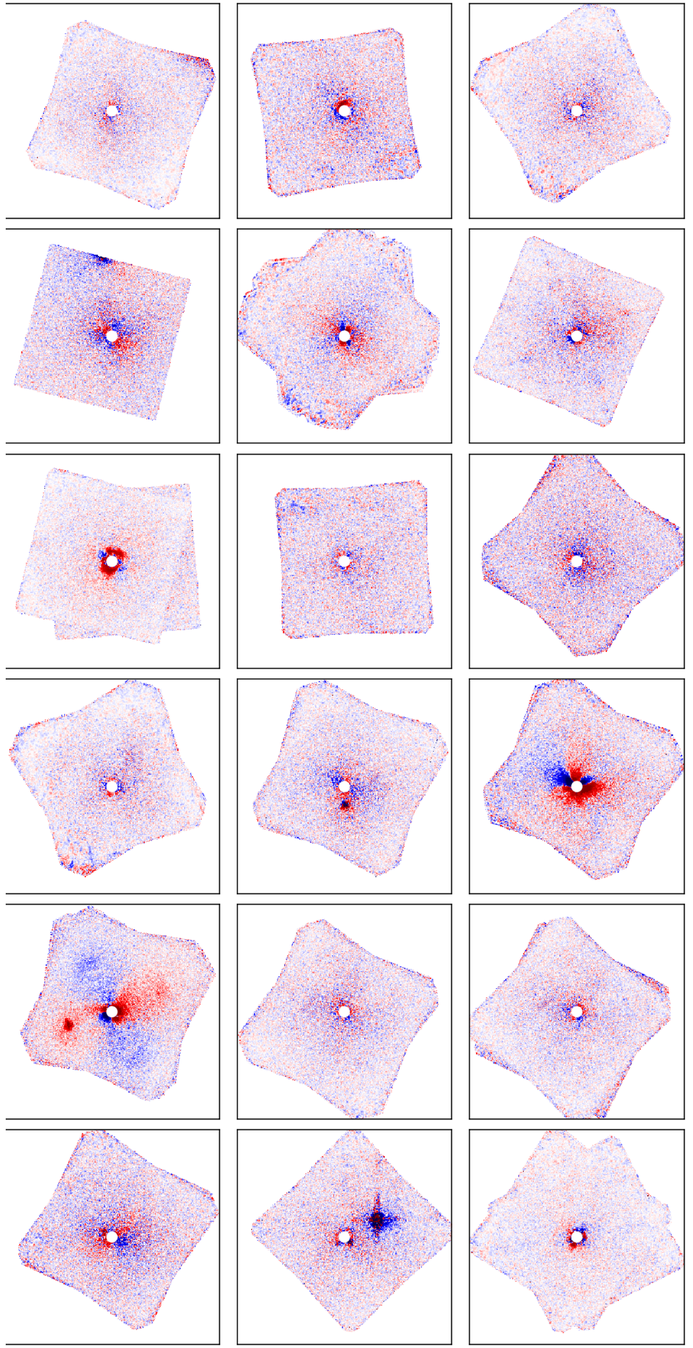




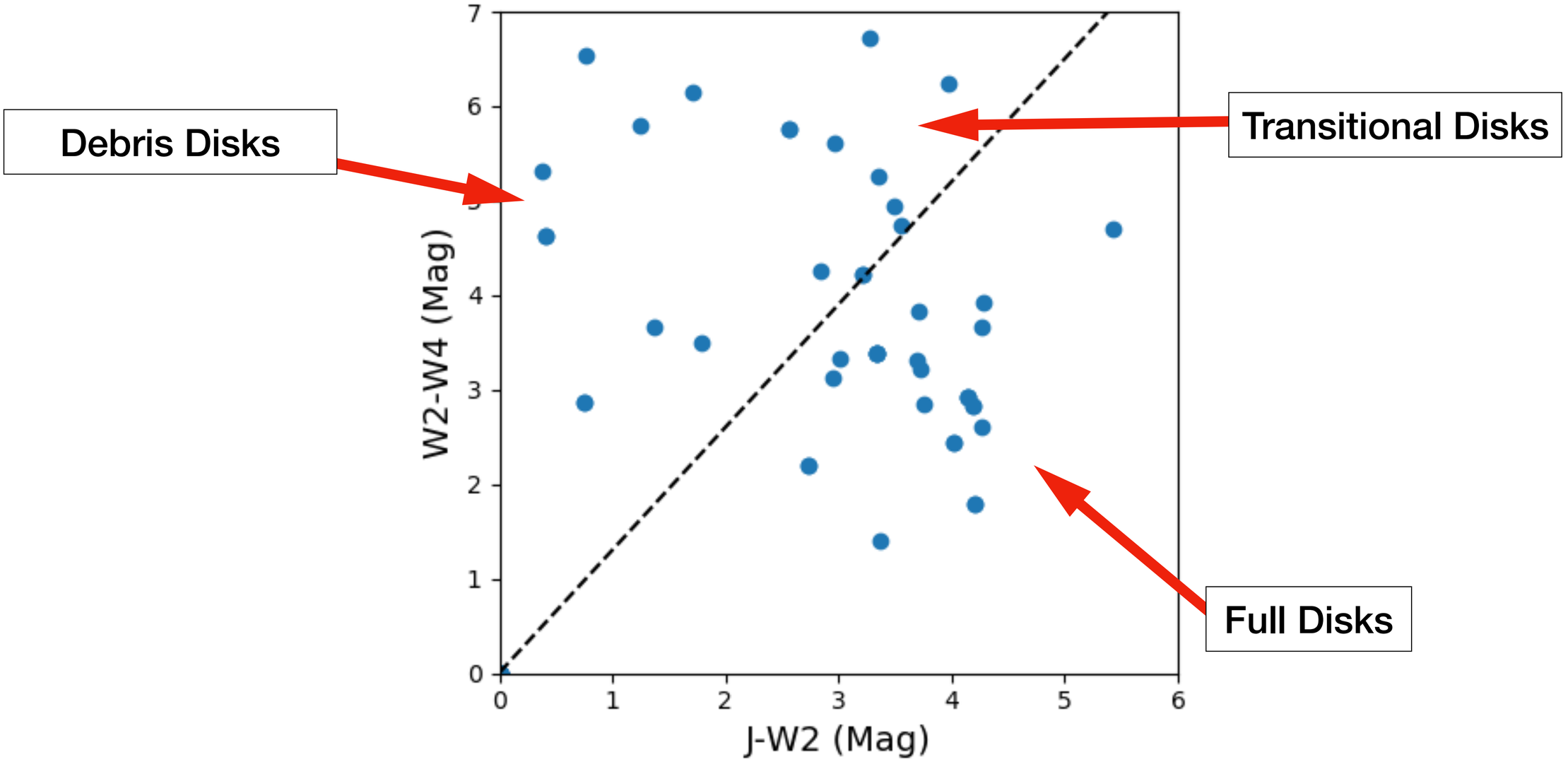
U_ϕ Observations

- Many observations have significant U_ϕ flux.
- Suggests that these disks are optically thick, or have bright companions

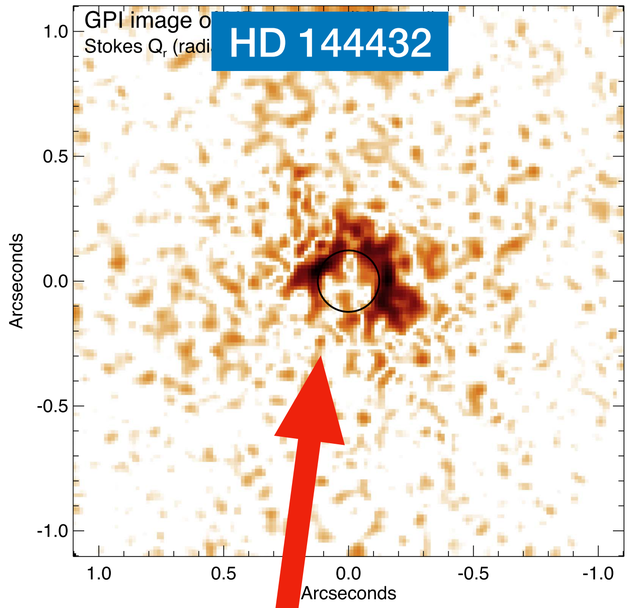




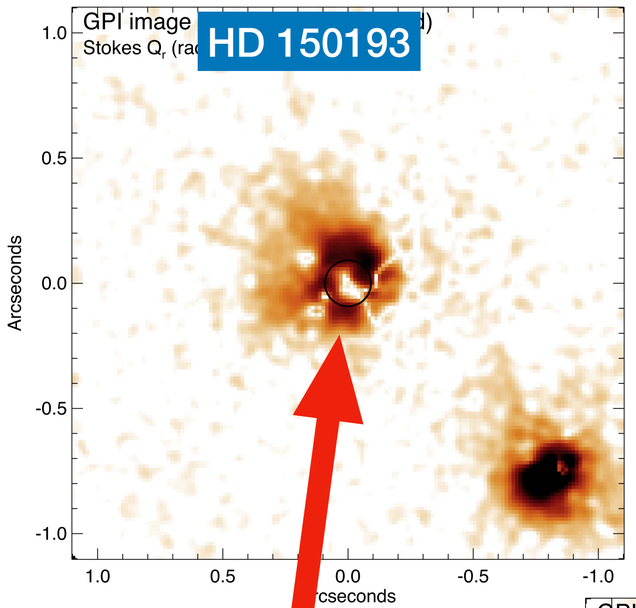
Well Sampled Survey of Different Evolutionary States of Disks



Paper 1: Early GPI Science Results



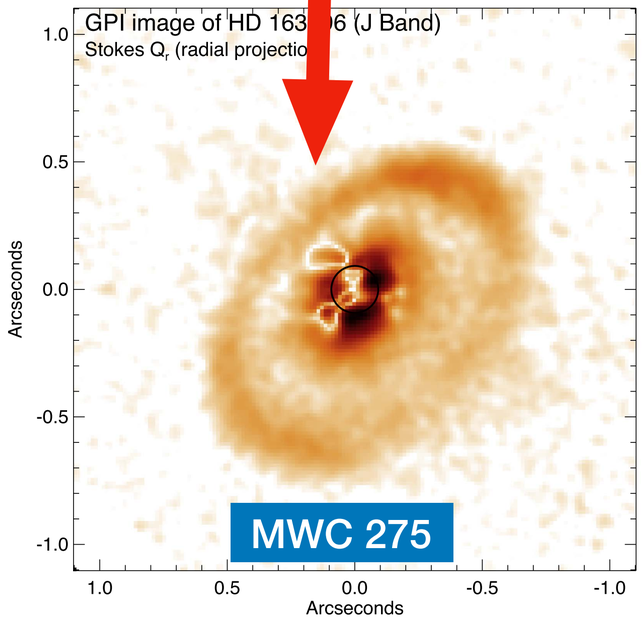
Non-Detection



Weak Detection

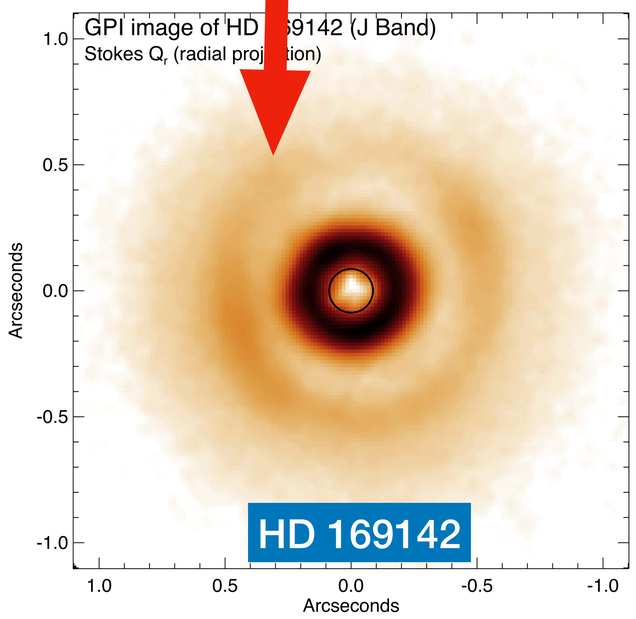
Monnier et al. 2017

Offset disk along minor axis due to scattering surface

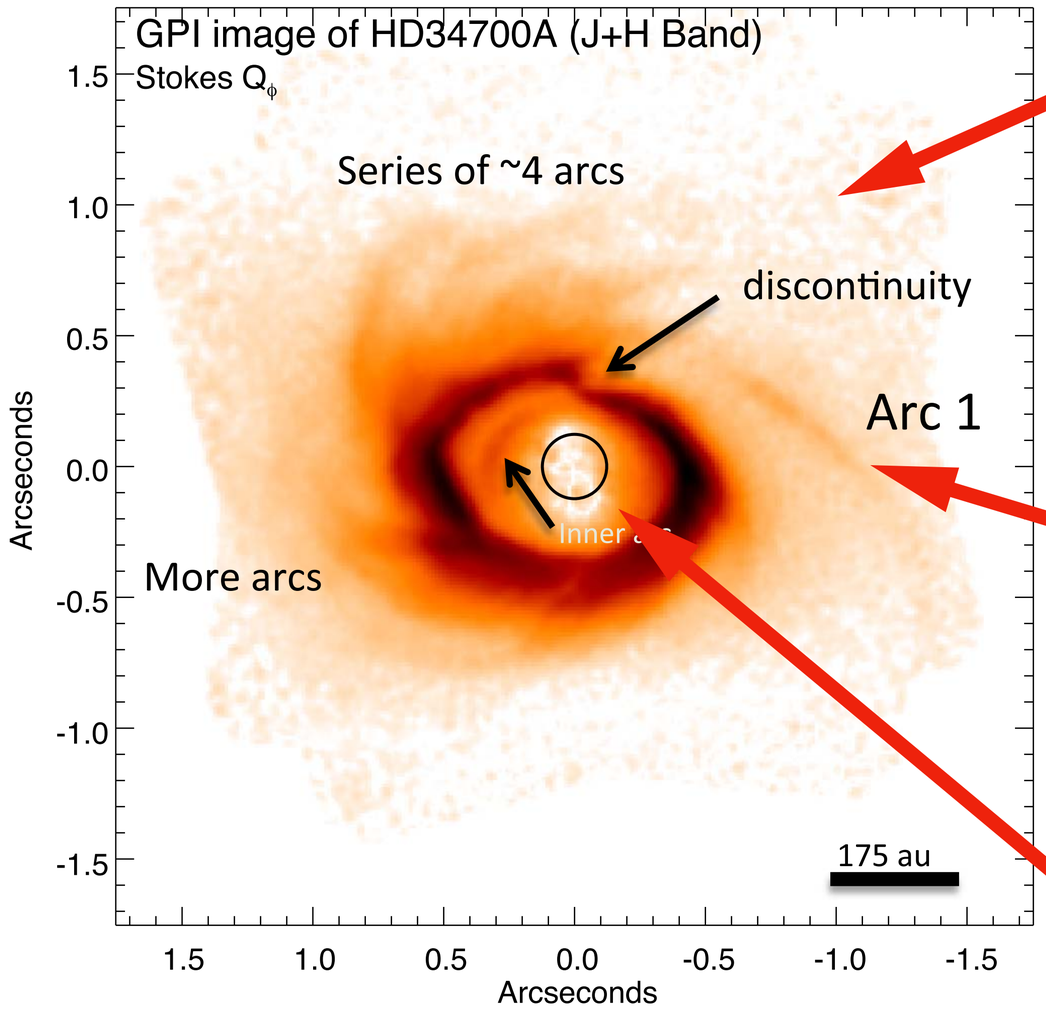


Two face-on rings.

Outer ring much redder than inner ring.



Paper 2: Multiple Spiral Arms in Binary HD 34700 A



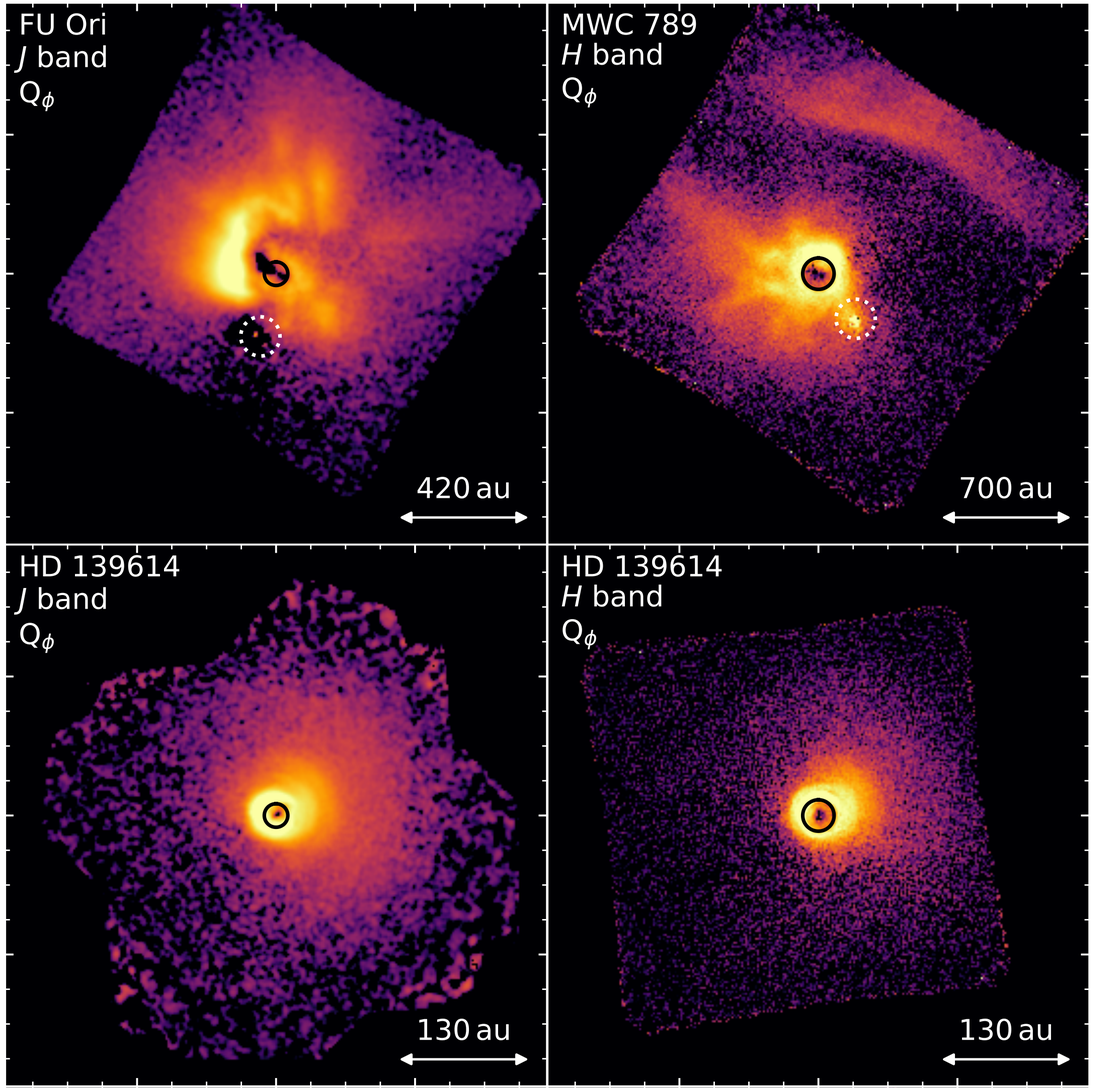
Monnier et al. 2019

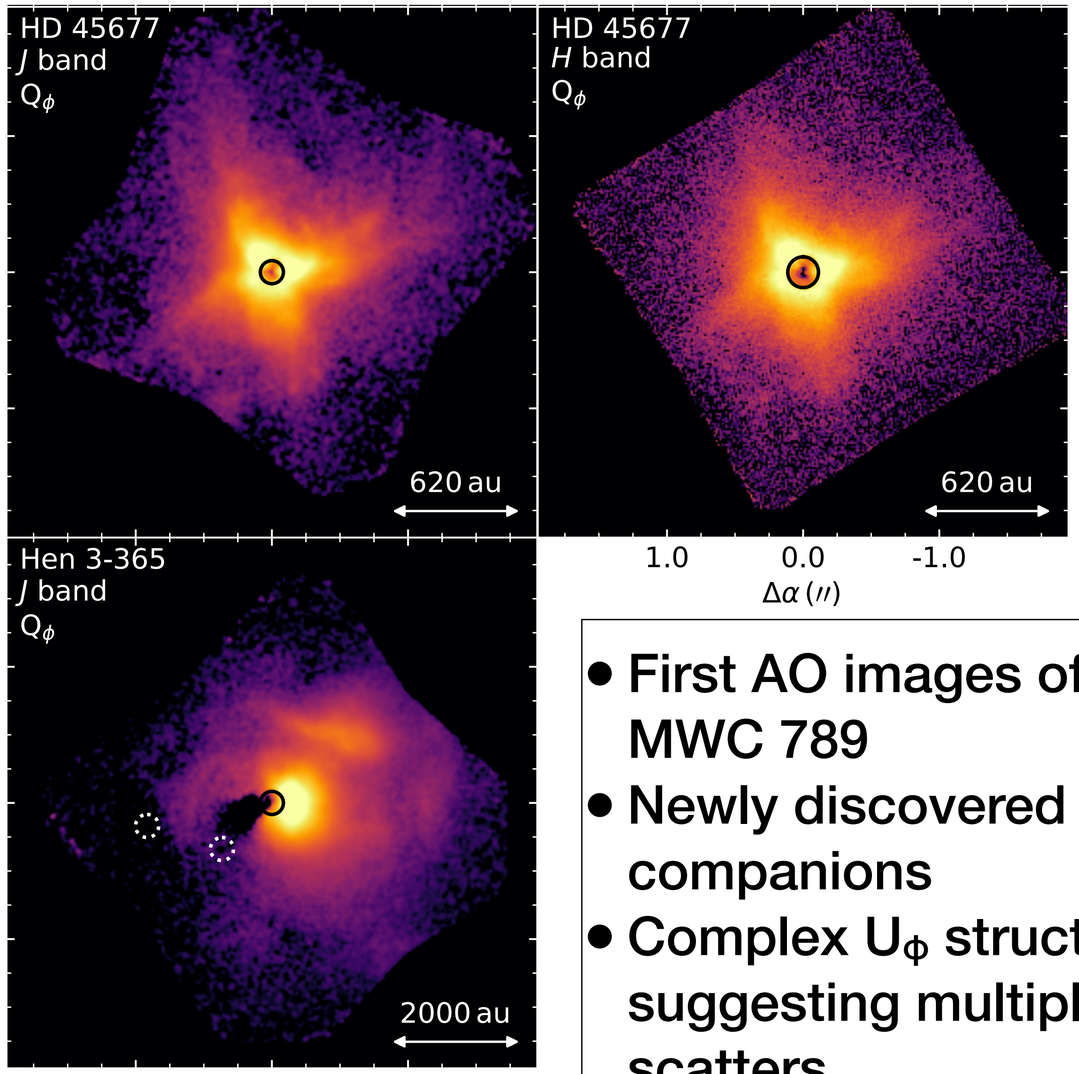
Previously classified as Debris Disk...
Really a Transitional Disk

Spiral arms most likely not caused by gravitational instability

Central Binary of two 2 Msol stars

Paper 3: Irregular dust features around intermediate-mass stars



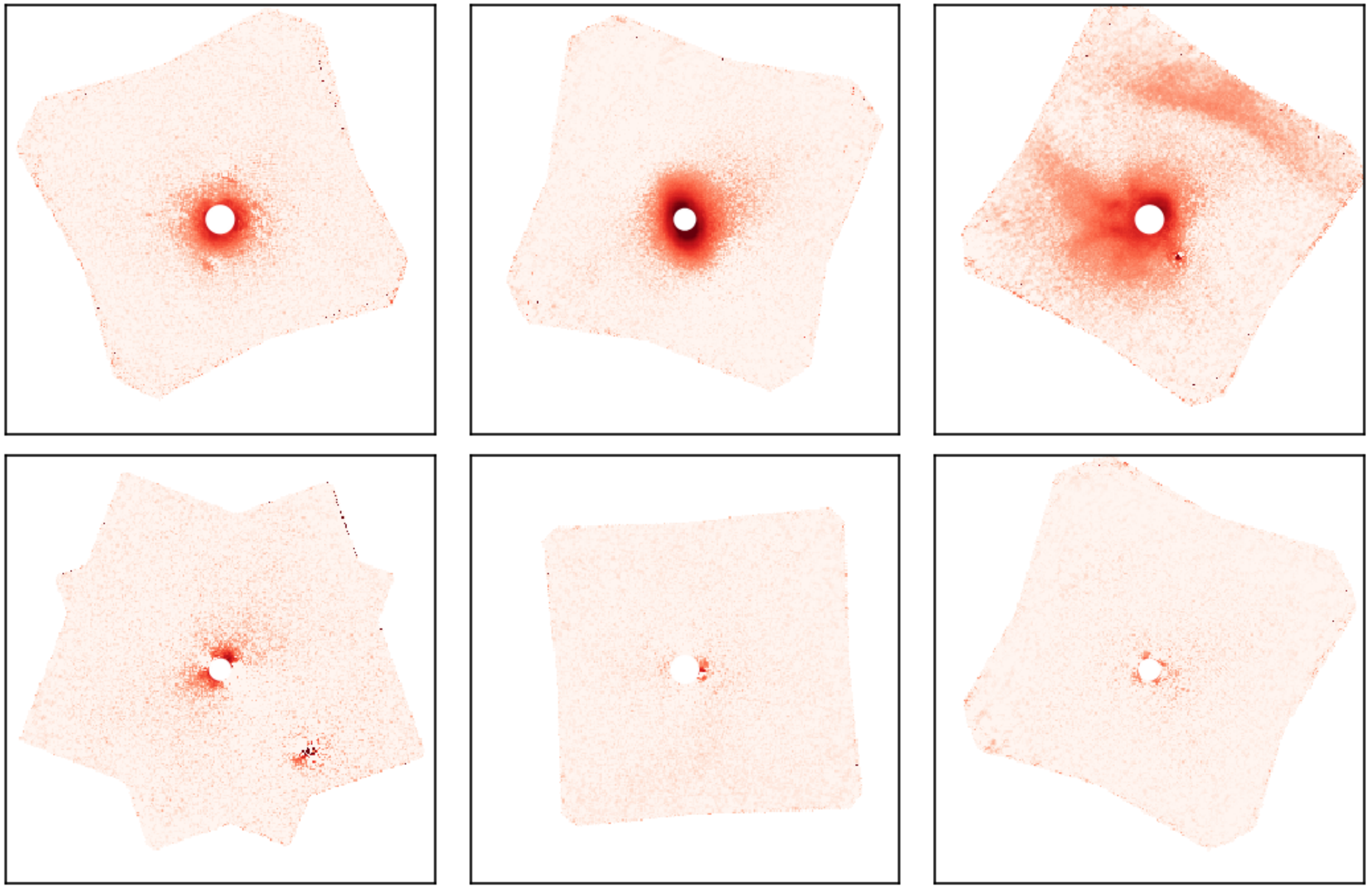


- First AO images of MWC 789
- Newly discovered companions
- Complex U_Φ structure suggesting multiple scatters

Laws et al. 2019

arxiv: 1911.04214

What is a "Detection" of scattered light?



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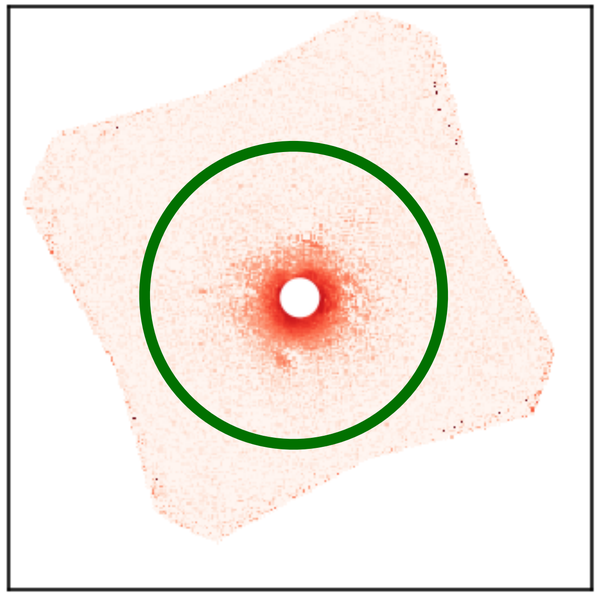

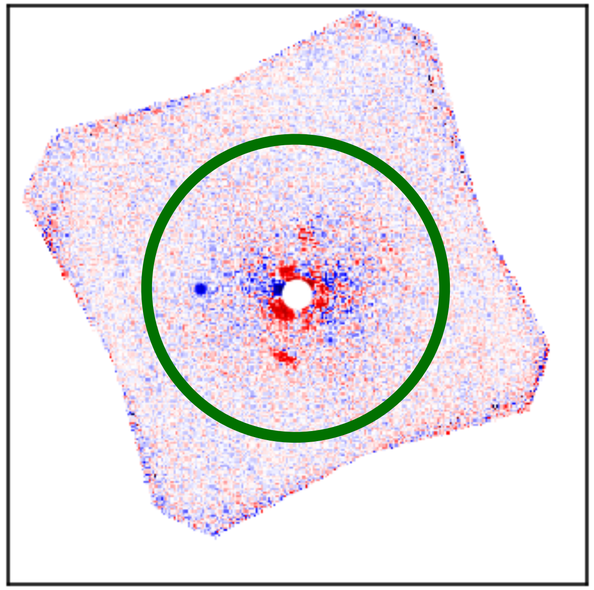

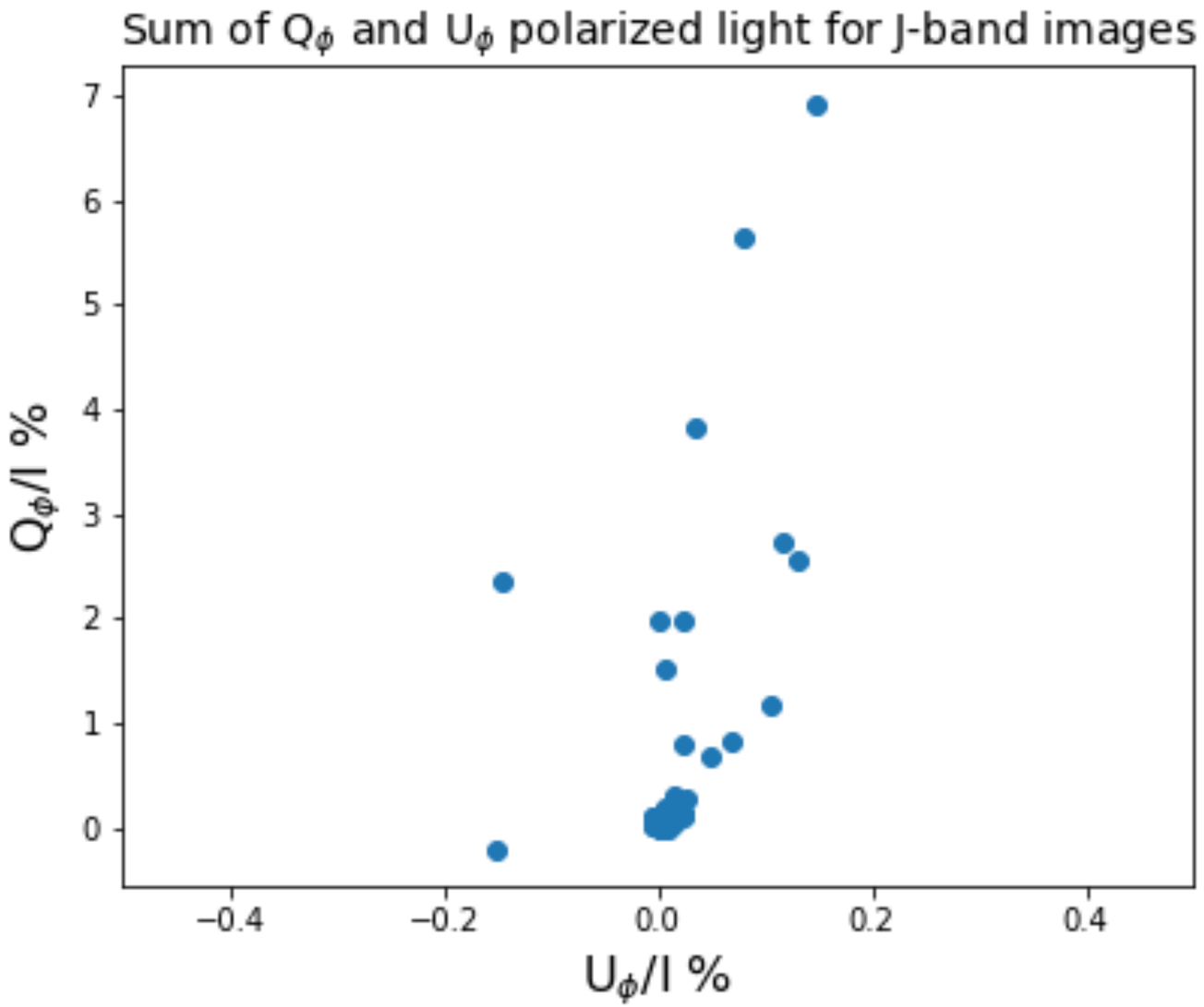

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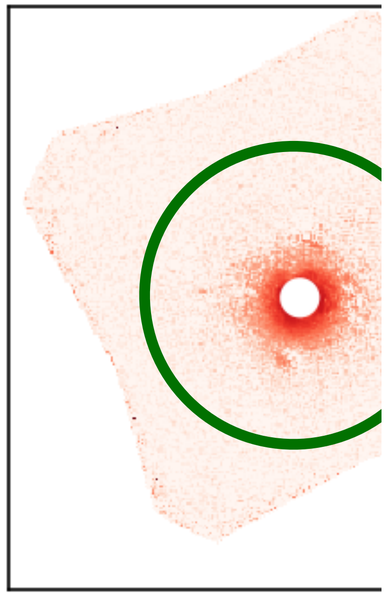

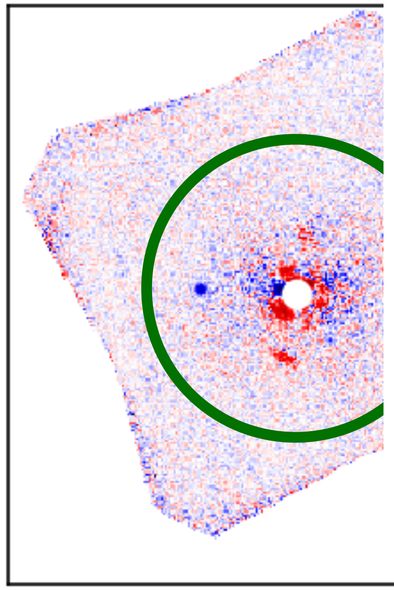

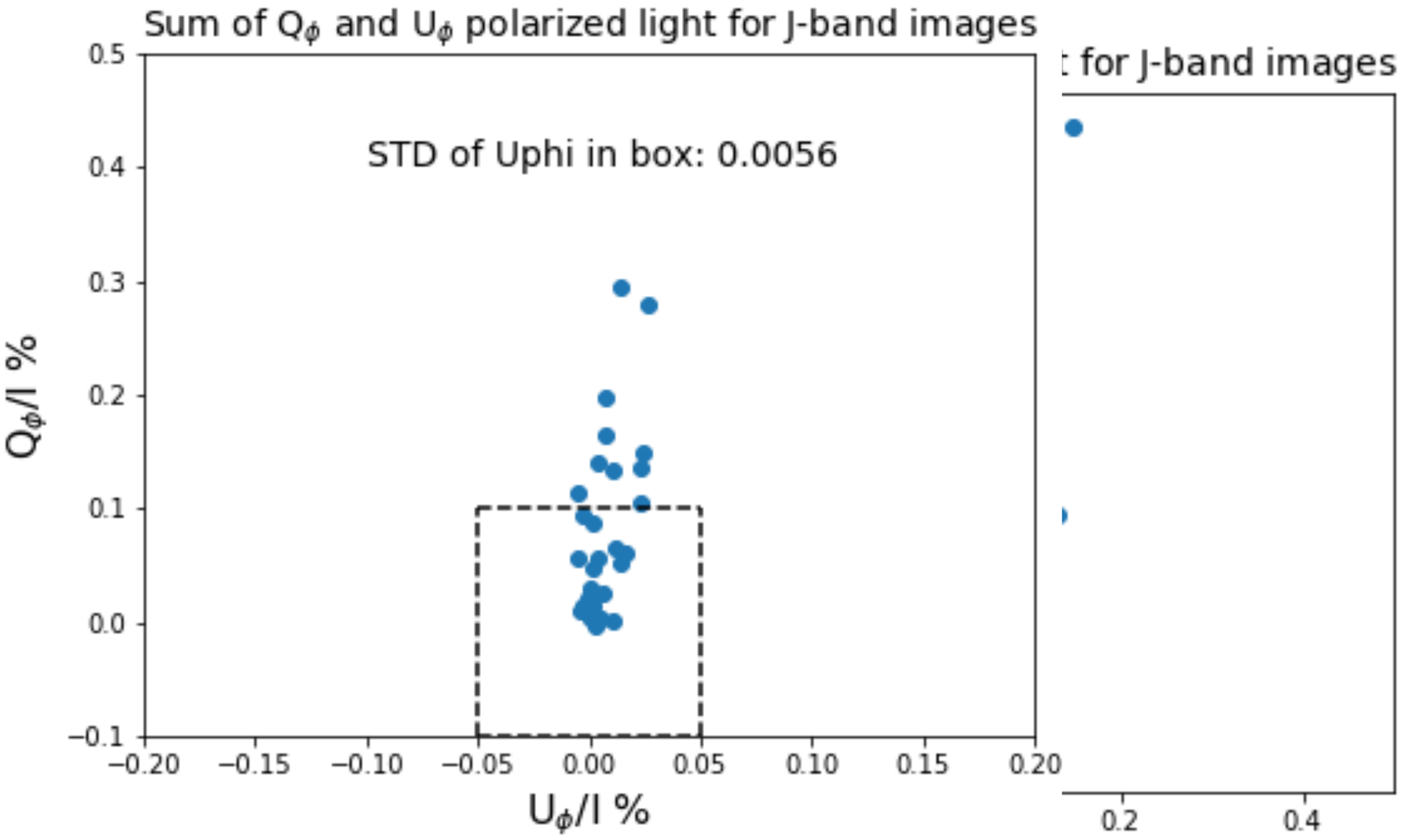

- ~38 of 44 targets detected some scattered light

Summary/Conclusion

- Complete scattered light sample of 44 Herbig and T-Tarui disks at variety of evolutionary states.
- Improvements to reducing polarization data from GPI.
- Discovery of interesting disk features (spiral arms) around HD 34700 A (Monnier et al. 2019).
- Irregular dust features around some of our sample targets along with strong U_ϕ flux (Laws et al. 2019).
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You can learn more by visiting our Website:

https://sites.google.com/umich.edu/gemini-lights/

Gemini-LIGHTS:
Entire Sample