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LAM
LABORATOIRE D'ASTROPHYSIQUE
DE MARSEILLE

Hubble High-contrast image processing & Debris Disk imaging

Elodie Choquet

Aix*Marseille université
Initiative d'excellence
cnrs
cnes

1. Make Hubble as competitive as SPHERE

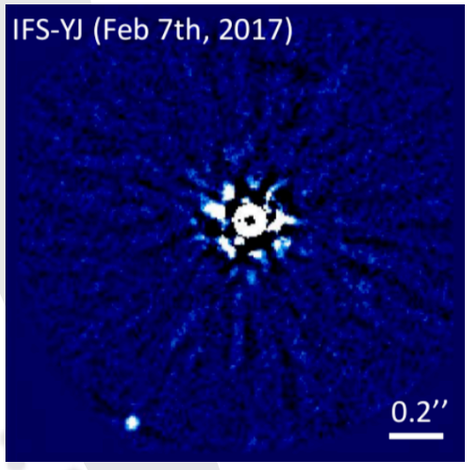
SPHERE: The State-of-the-art in HC imaging

Highly Optimized for planets hunt:

- Extreme AO system
- Stabilized platform
- Optimized coronagraphs

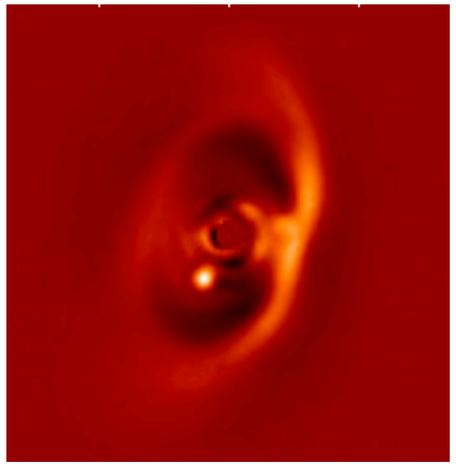
Beuzit et al. 2019

6-12 M_{jup} planet



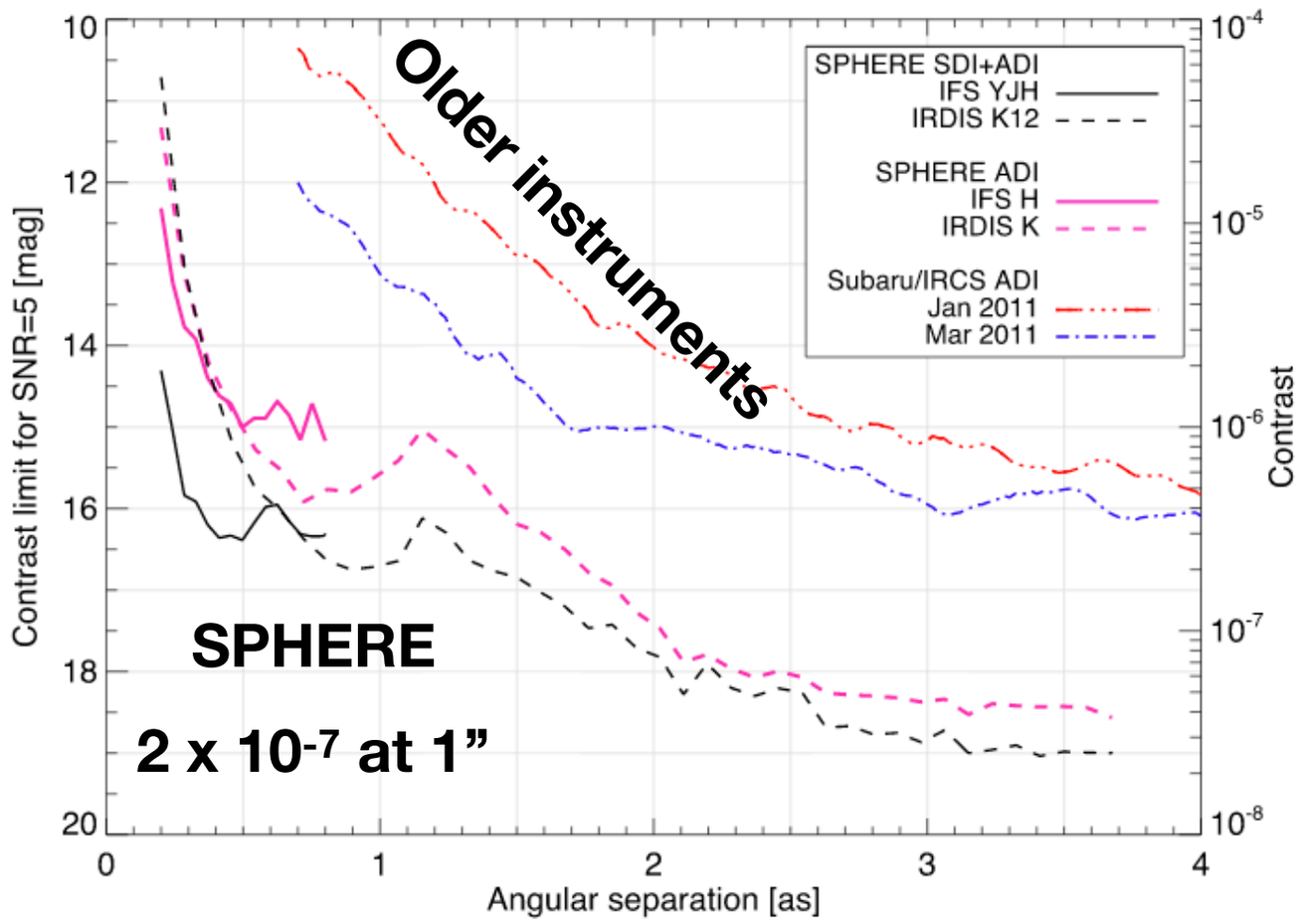
Chauvin et al. 2017

2-17 M_{jup} planet



Müller et al. 2018

Deepest observations ever achieved:



Vigan et al. 2015

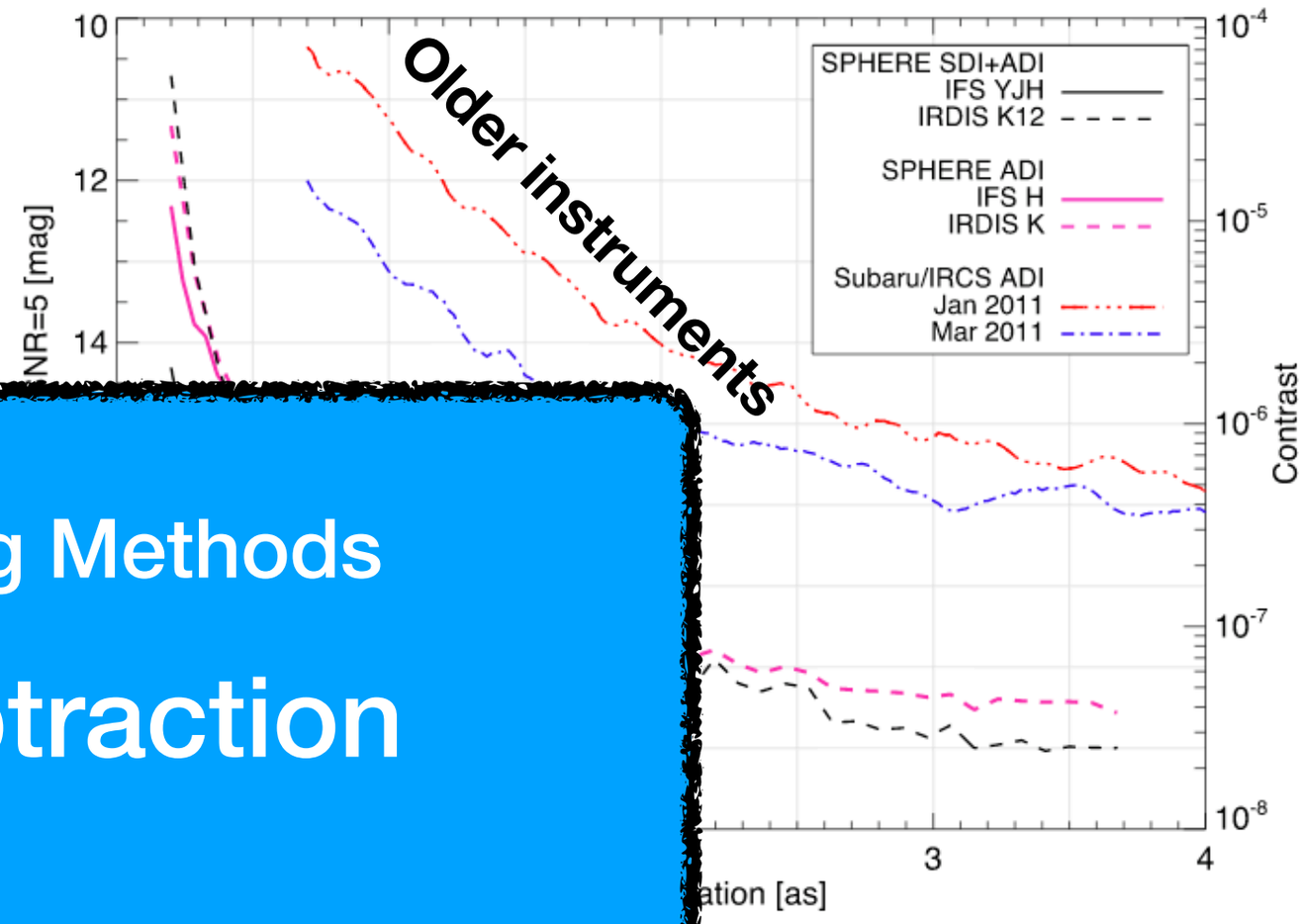
SPHERE: The State-of-the-art in HC imaging

Highly Optimized for planets hunt:

- Extreme AO system
- Low noise detectors
- Optimized coronagraphs
- Stabilized platform
- Optimized data processing Methods

Stellar PSF Subtraction

Deepest observations ever achieved:



Vigan et al. 2015

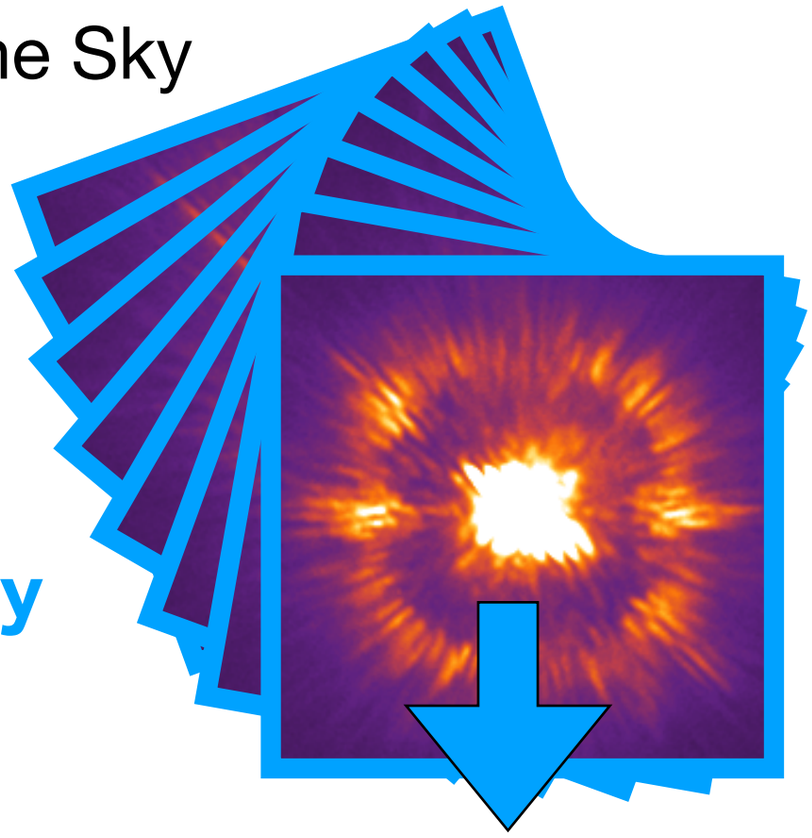
Chauvin et al. 2017

Müller et al. 2018

Well-established method

Marois et al. 2006
Lafreniere et al. 2007
Mugnier et al. 2009
Pueyo et al. 2012
Soummer et al. 2012
Marois et al. 2014
Cantalloube et al. 2015
Gomez-Gonzalez et al. 2016

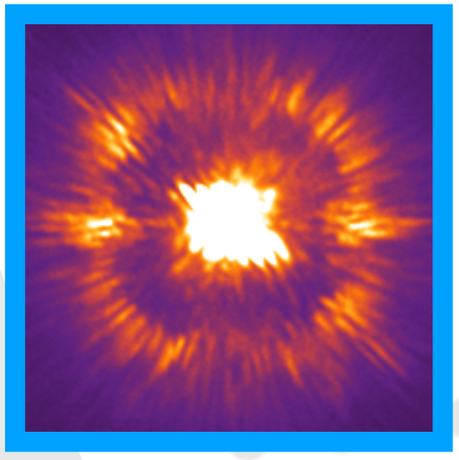
Natural Rotation of the Sky



PSF Library

Linear combination
Median, ...

Science Image



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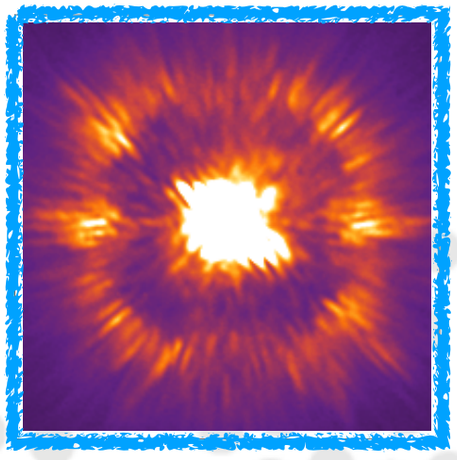
Model



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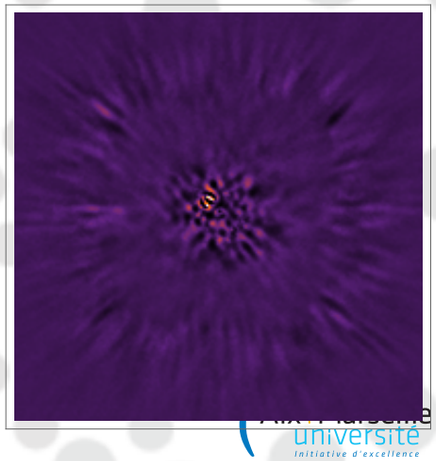
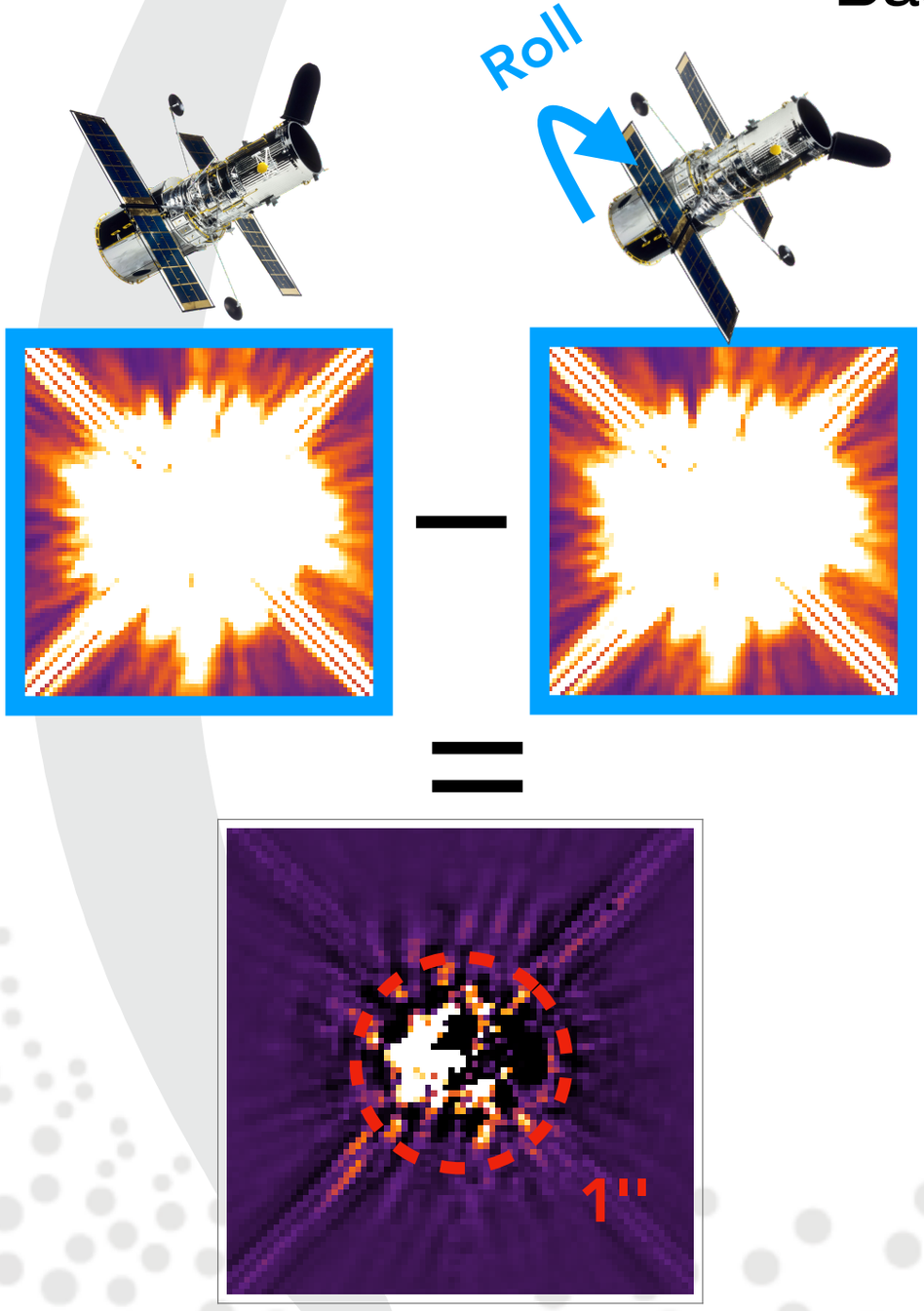
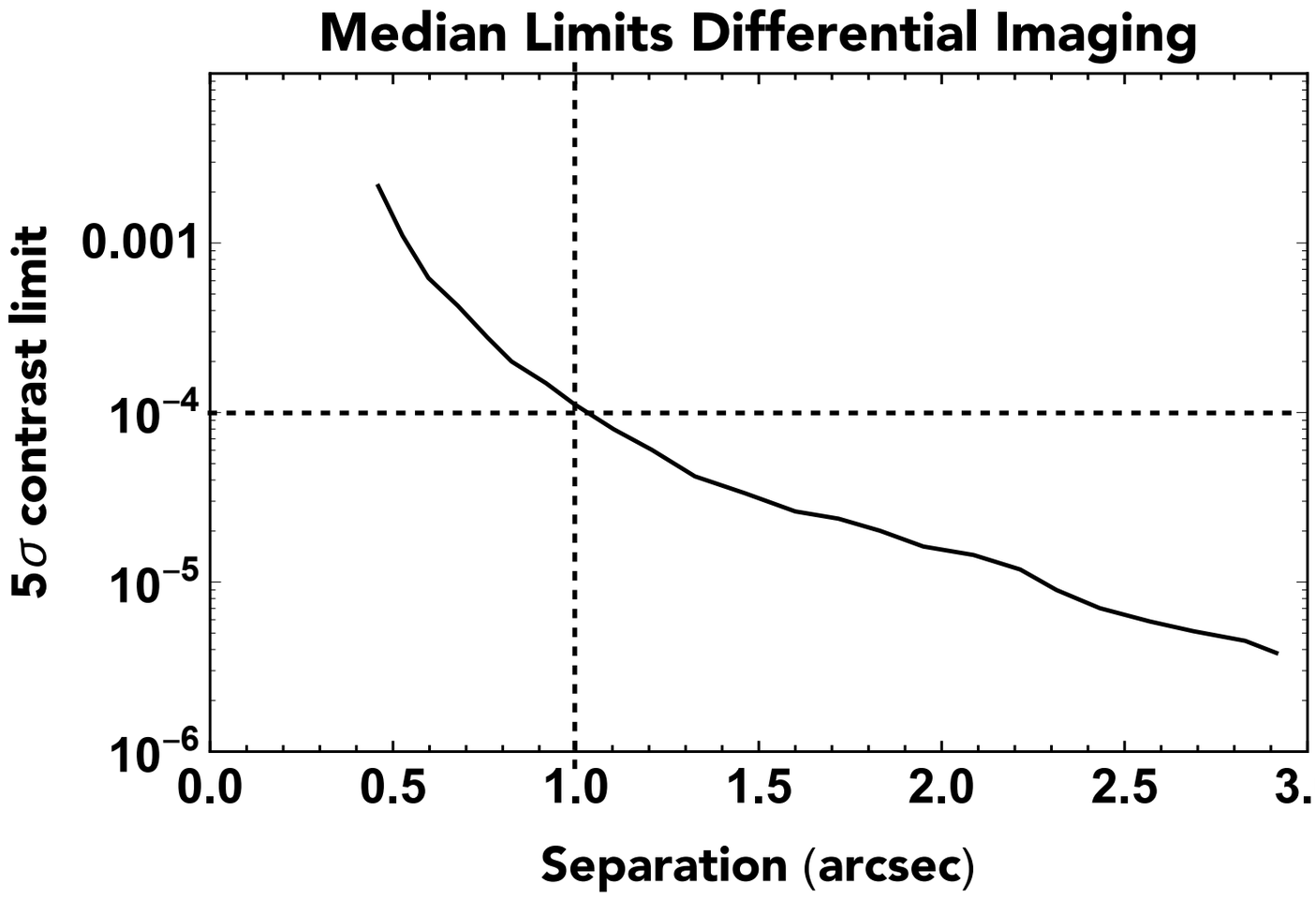
Residuals



High-contrast Imaging with Hubble

Basic differential imaging

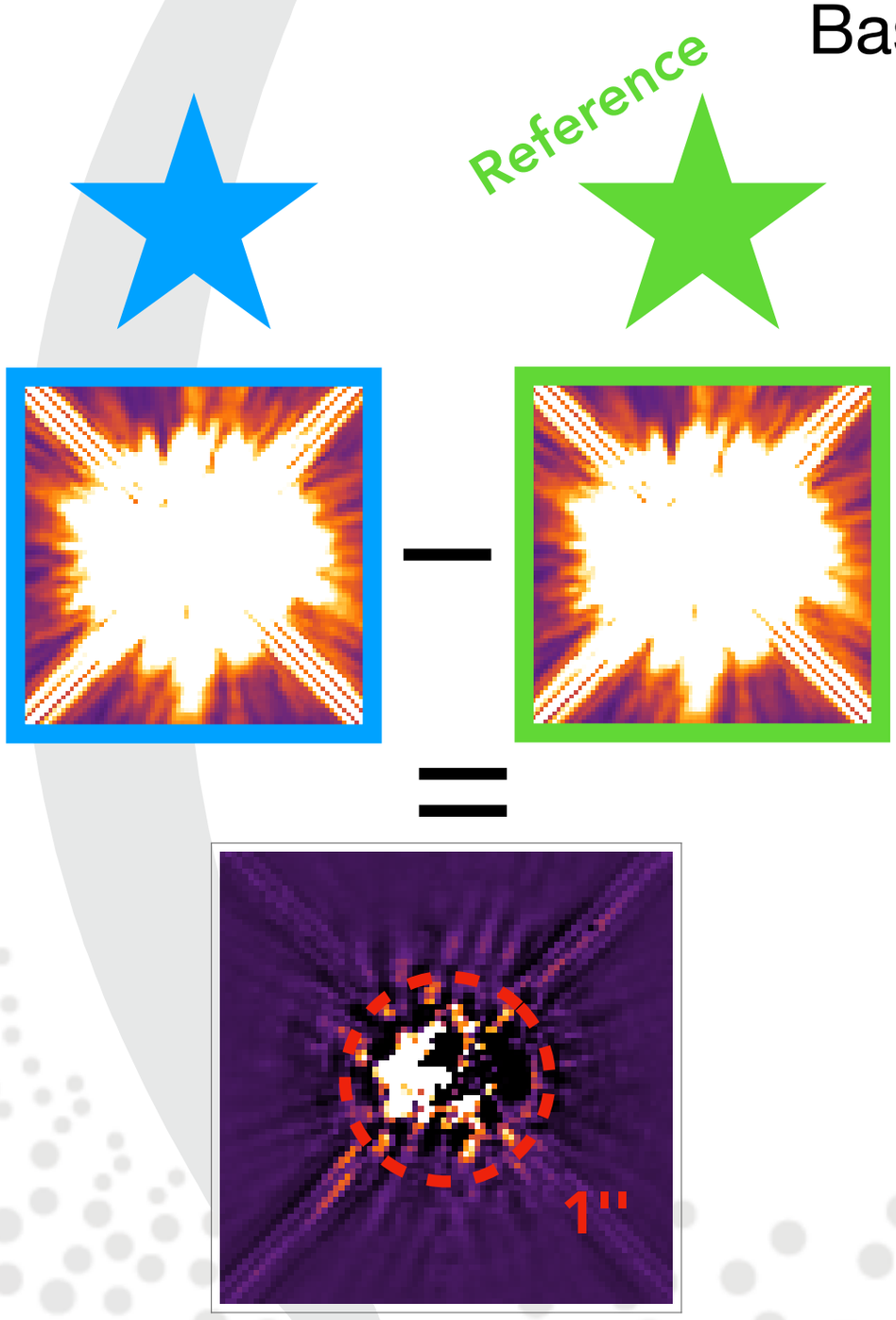


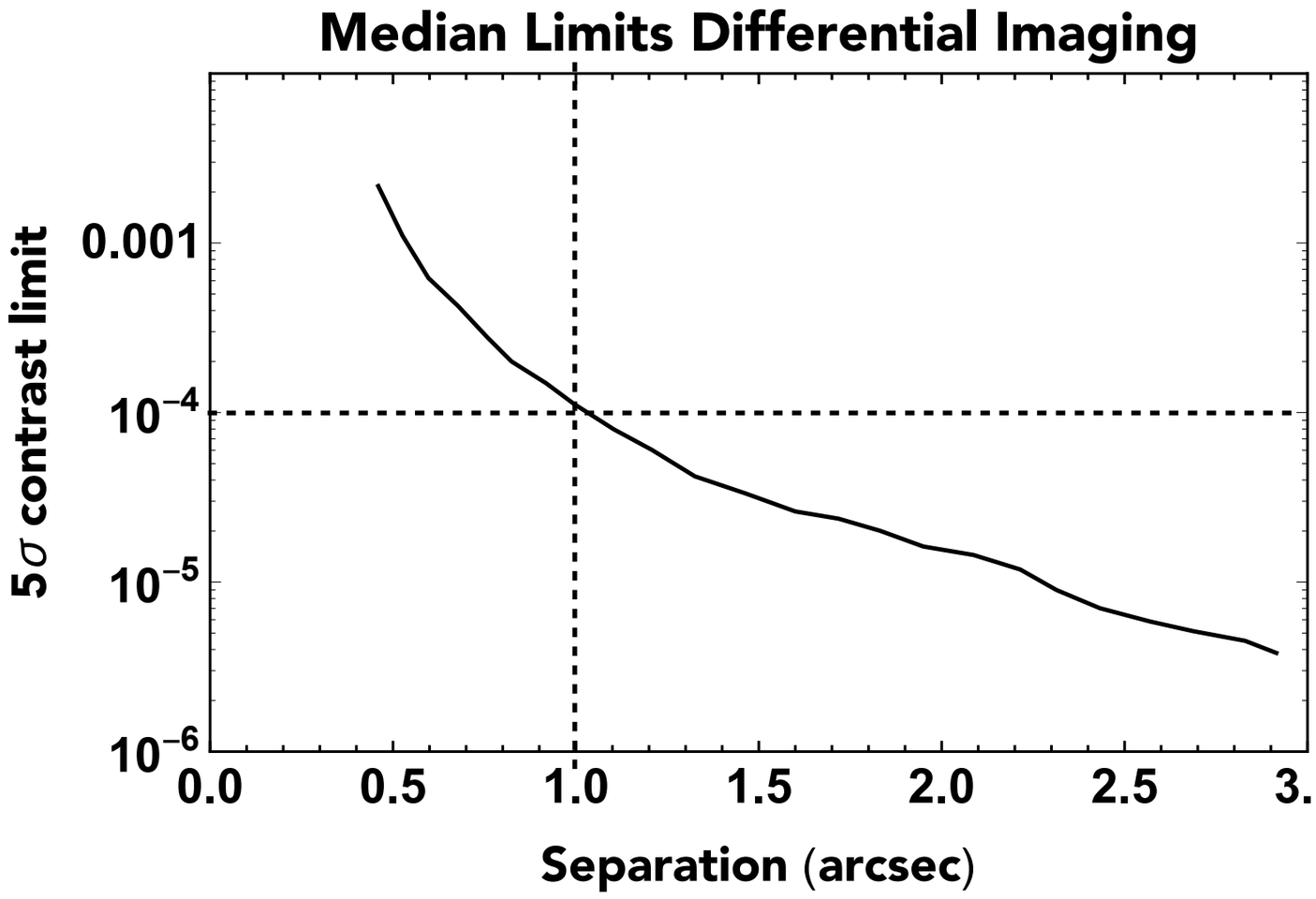


Lowrance et al. 2005

High-contrast Imaging with Hubble

Basic differential imaging

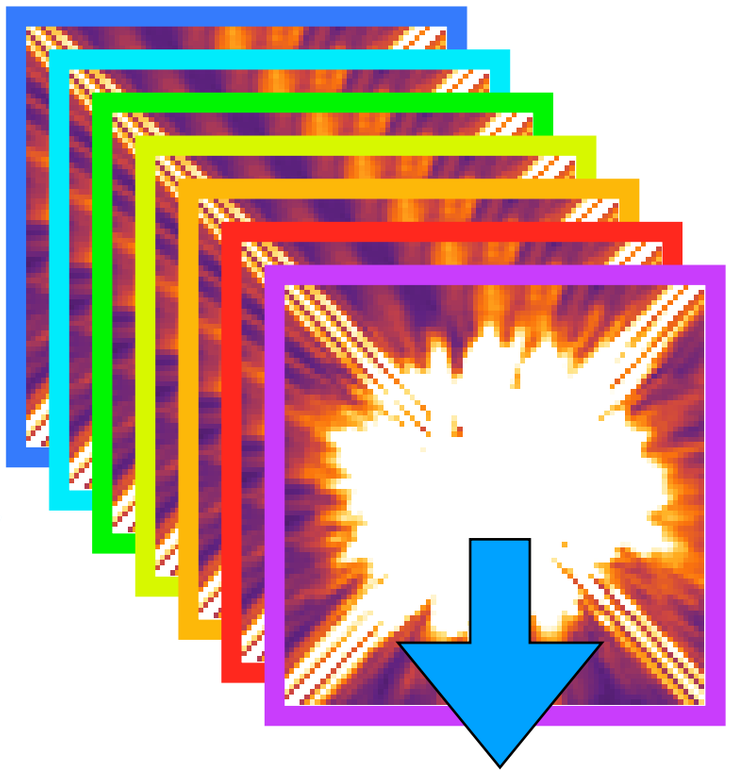




Lowrance et al. 2005

A Novel Method

Multiple Reference Stars

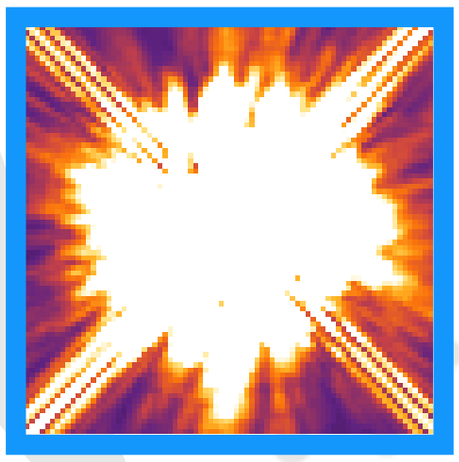


- 10^2 Reference stars
- 10^3 PSF images
- Samples all variations

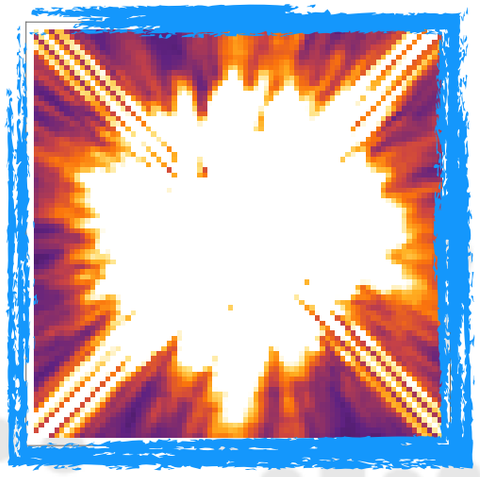
Archival Library

Modern Algorithms

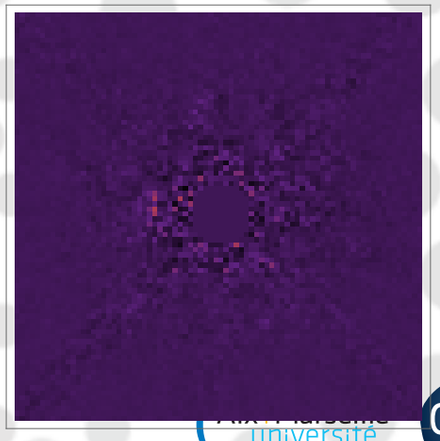
Science Image



Model



Residuals



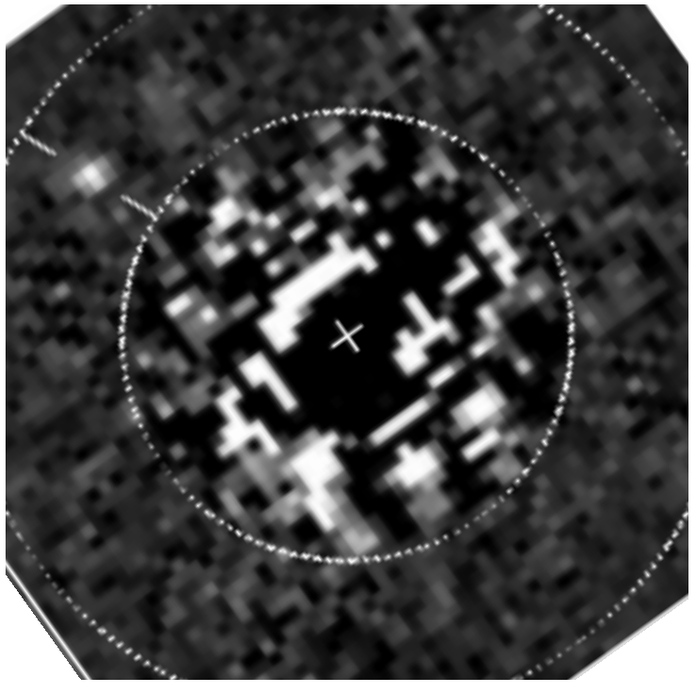
First demonstration: HR 8799 system

Archival library

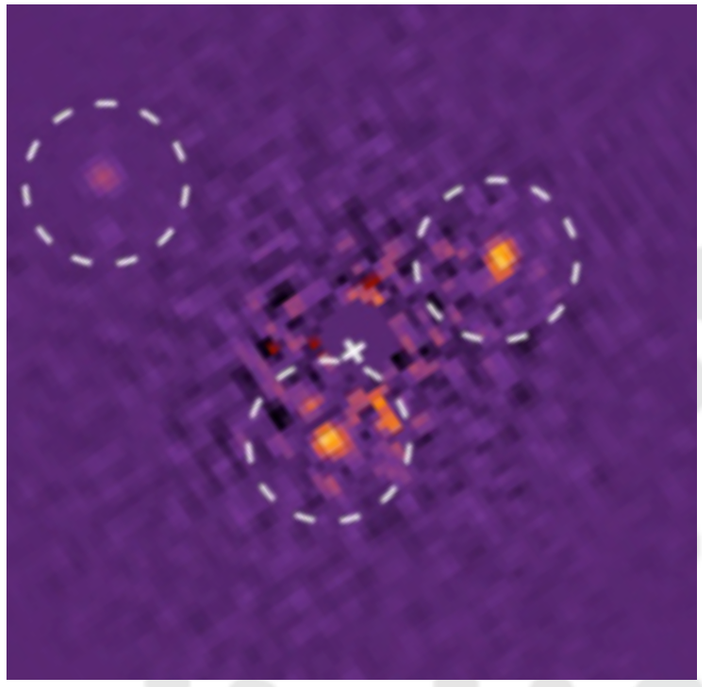
- 23 Reference stars
- 200 PSF images

1998 HST data

Lafrenière et al. 2009



Soummer et al. 2011



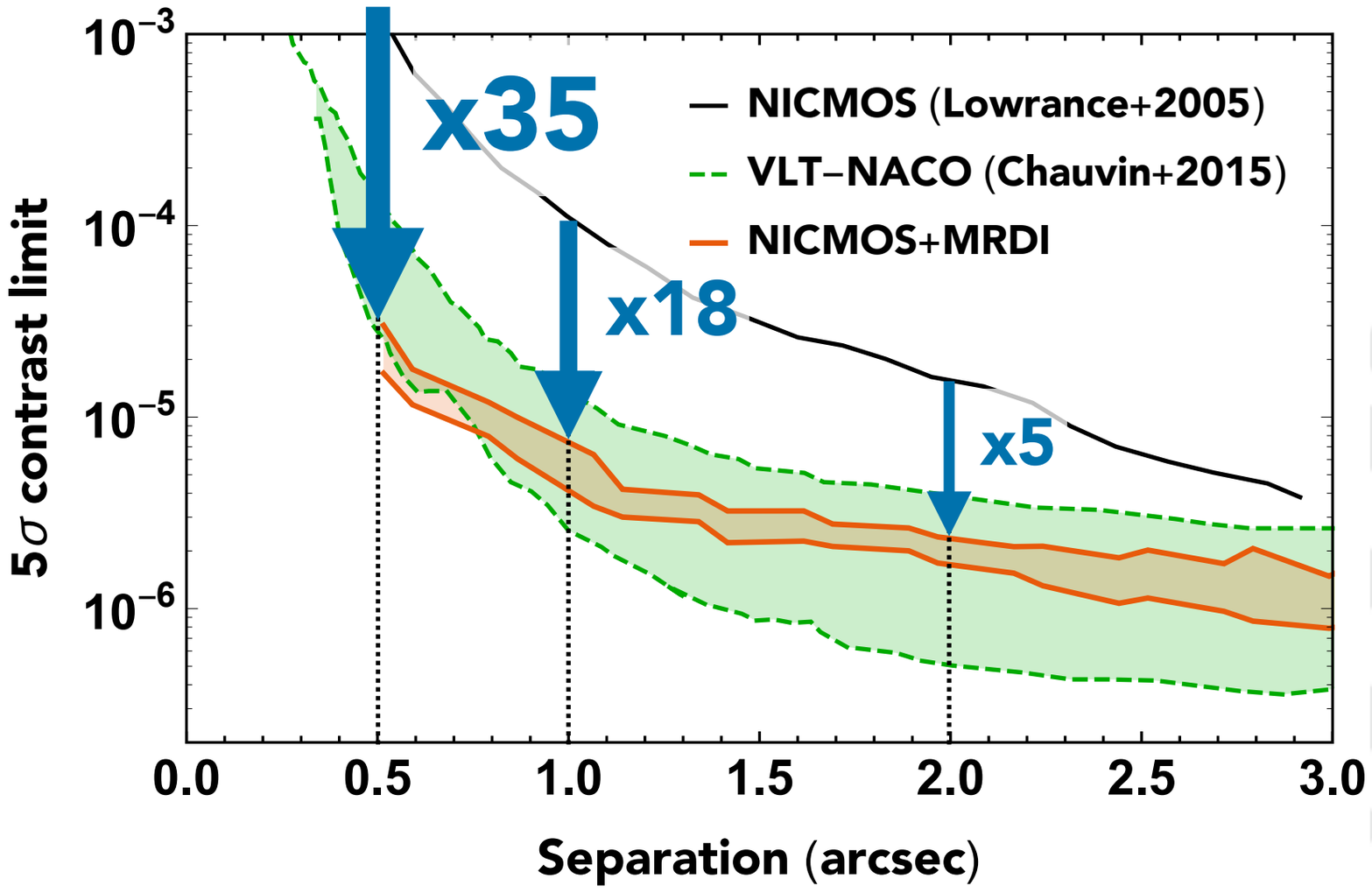
ALICE: Optimization & Generalization

Archival library

- 80 Reference stars
- 850 PSF images

Full NICMOS archive

Median / Best Contrast Limits



Soummer et al. 2012
Choquet et al. 2014
Hagan et al. 2018

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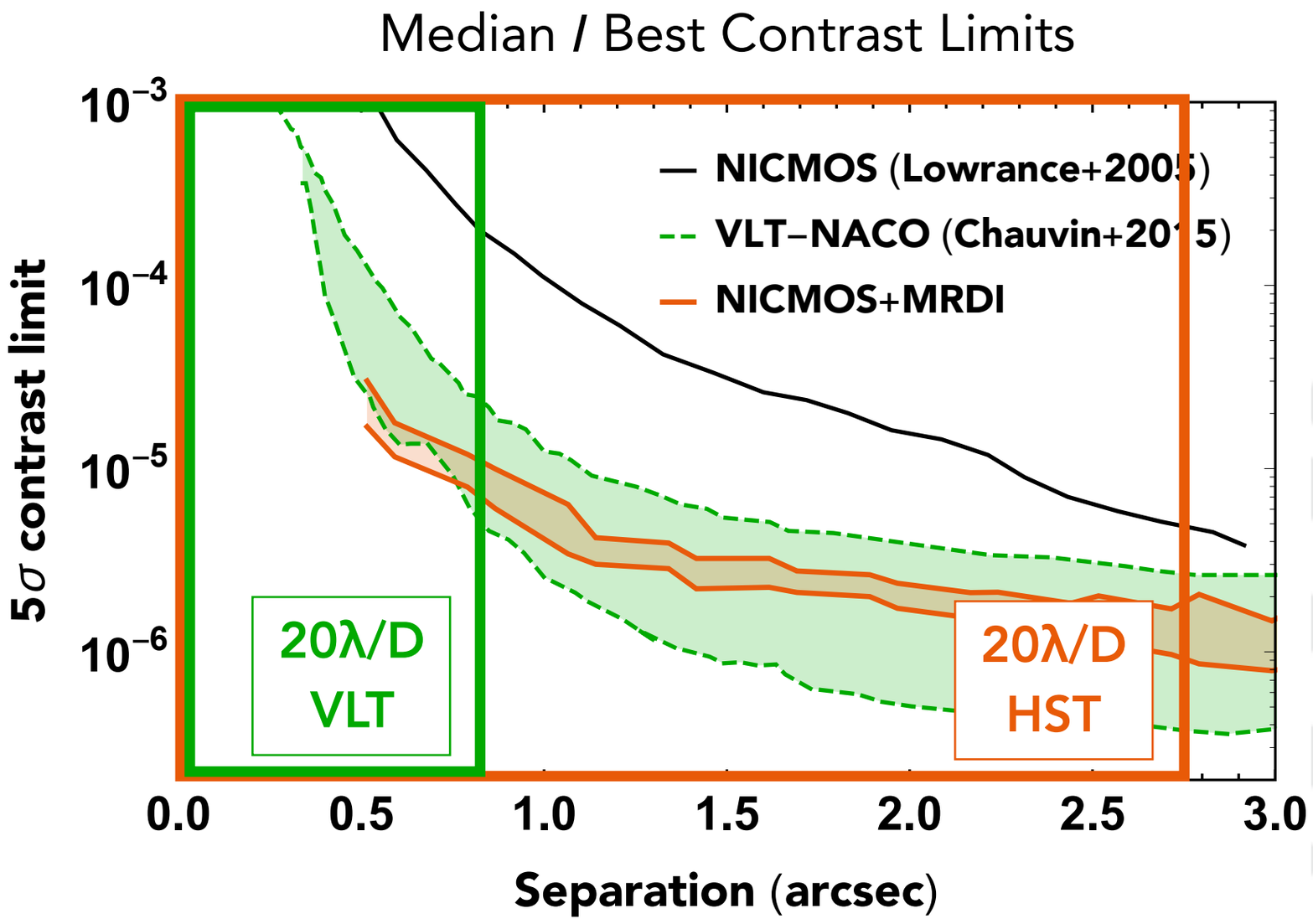

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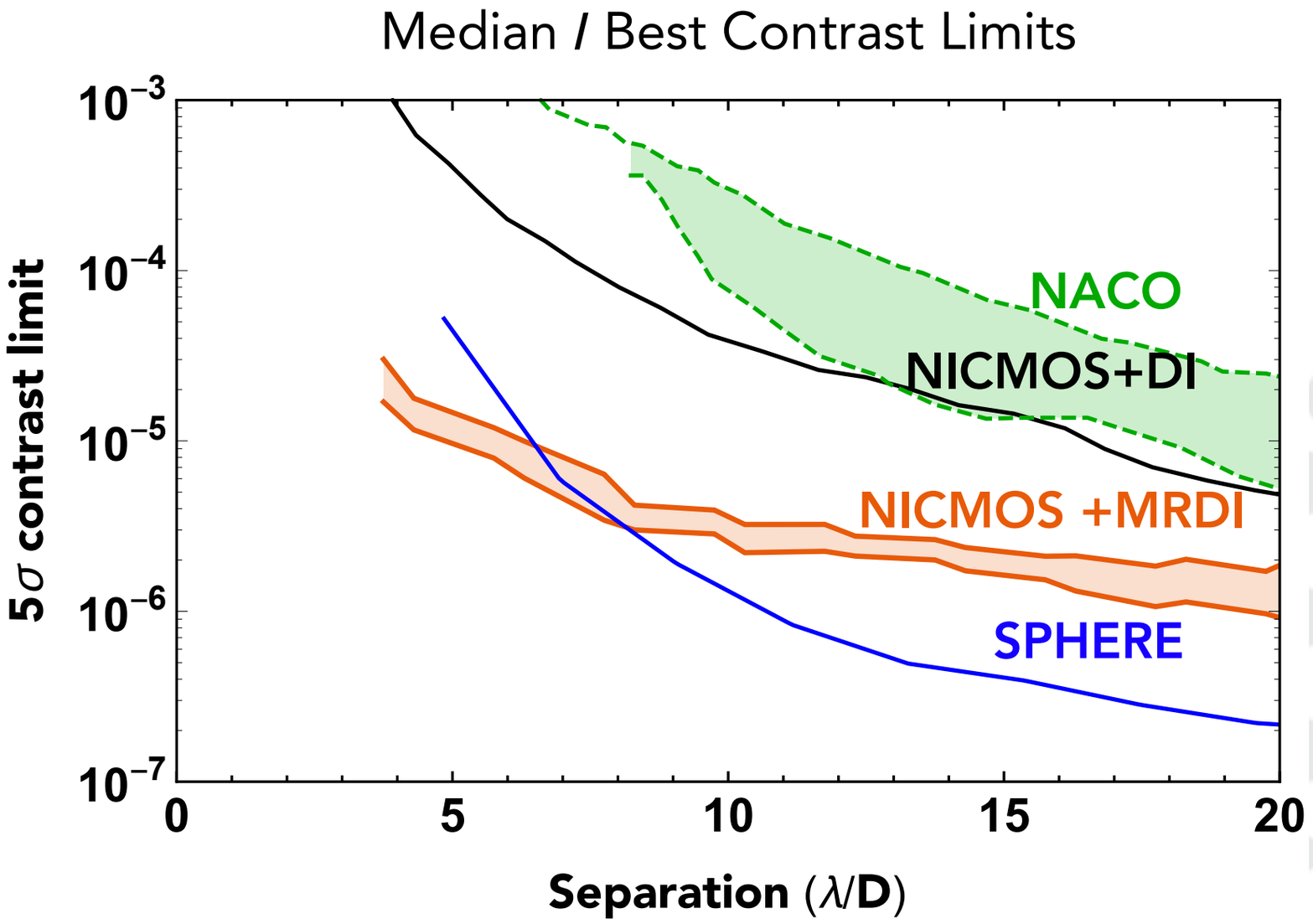
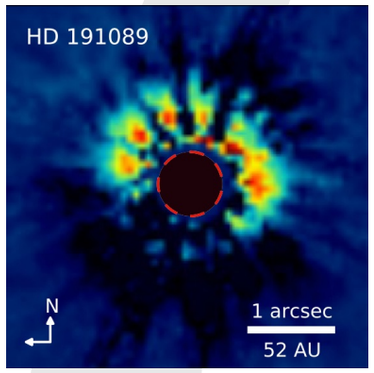
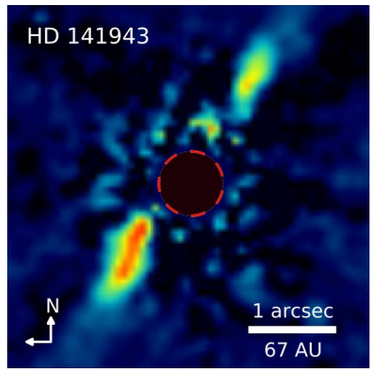


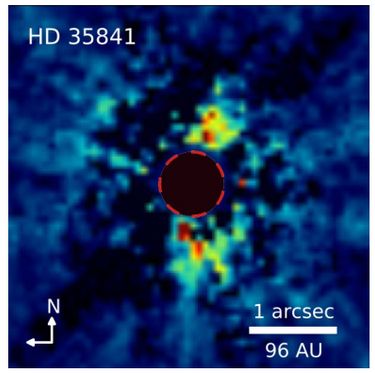
In $\mathcal{N}D$ units

Soummer et al. 2012
Choquet et al. 2014
Hagan et al. 2018

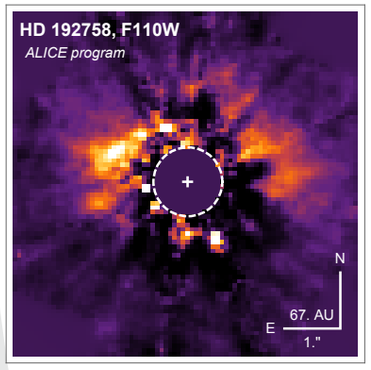
ALICE: Debris disk gallery

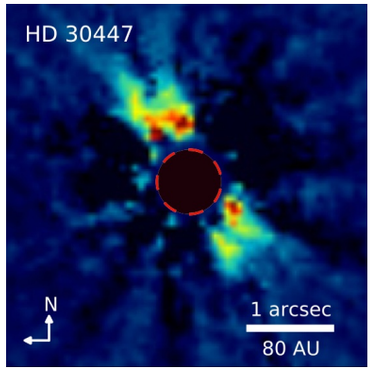


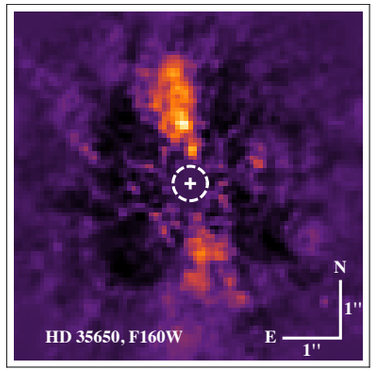


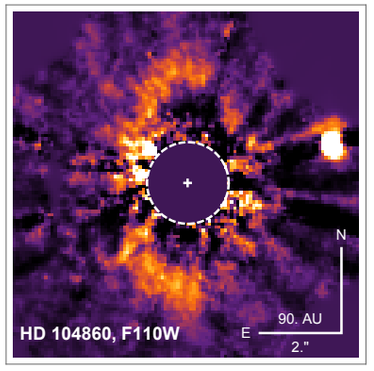


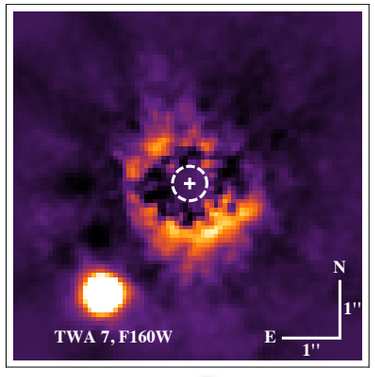
Soummer et al. 2014
Choquet et al. 2016
Choquet et al. 2017
Choquet et al. 2018
Marshall et al. 2018

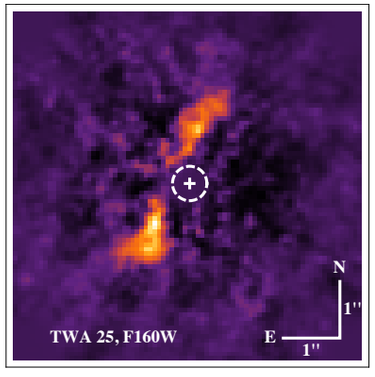


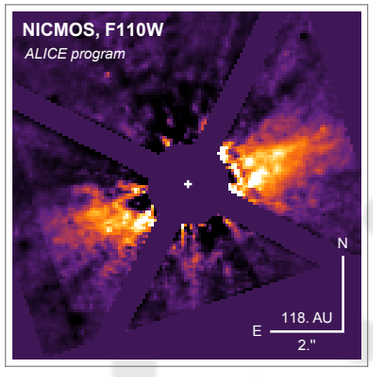


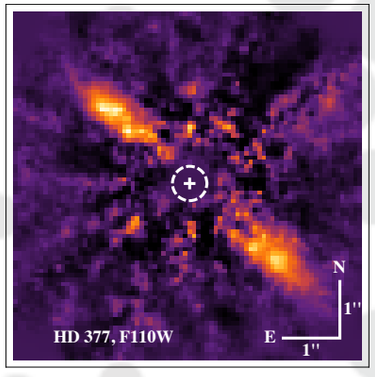


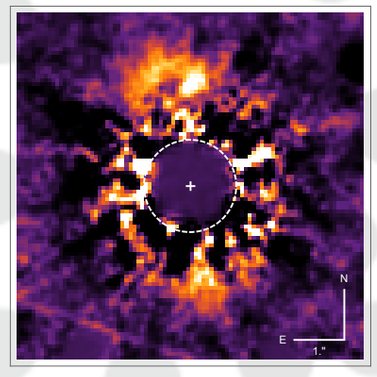




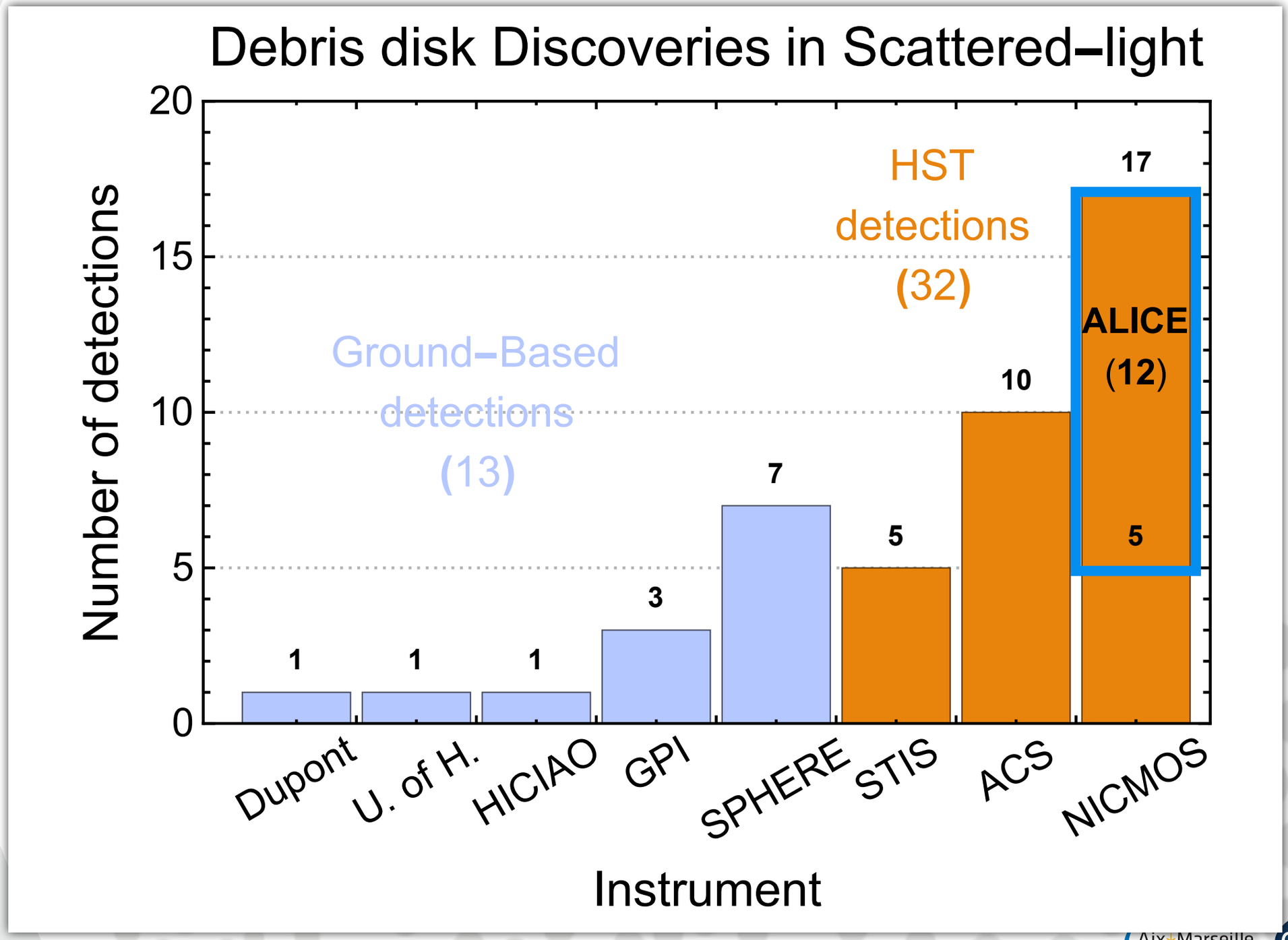








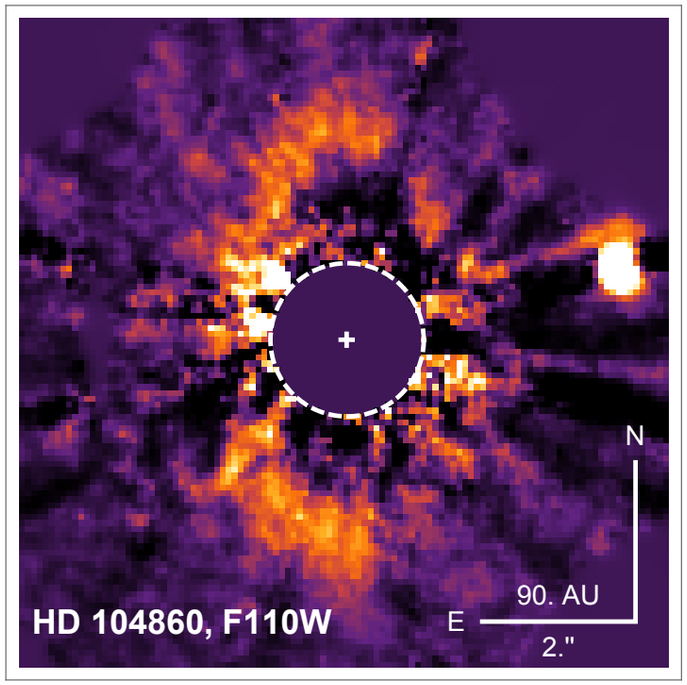
ALICE: Debris disk gallery



2. Understand the properties of Debris Disks

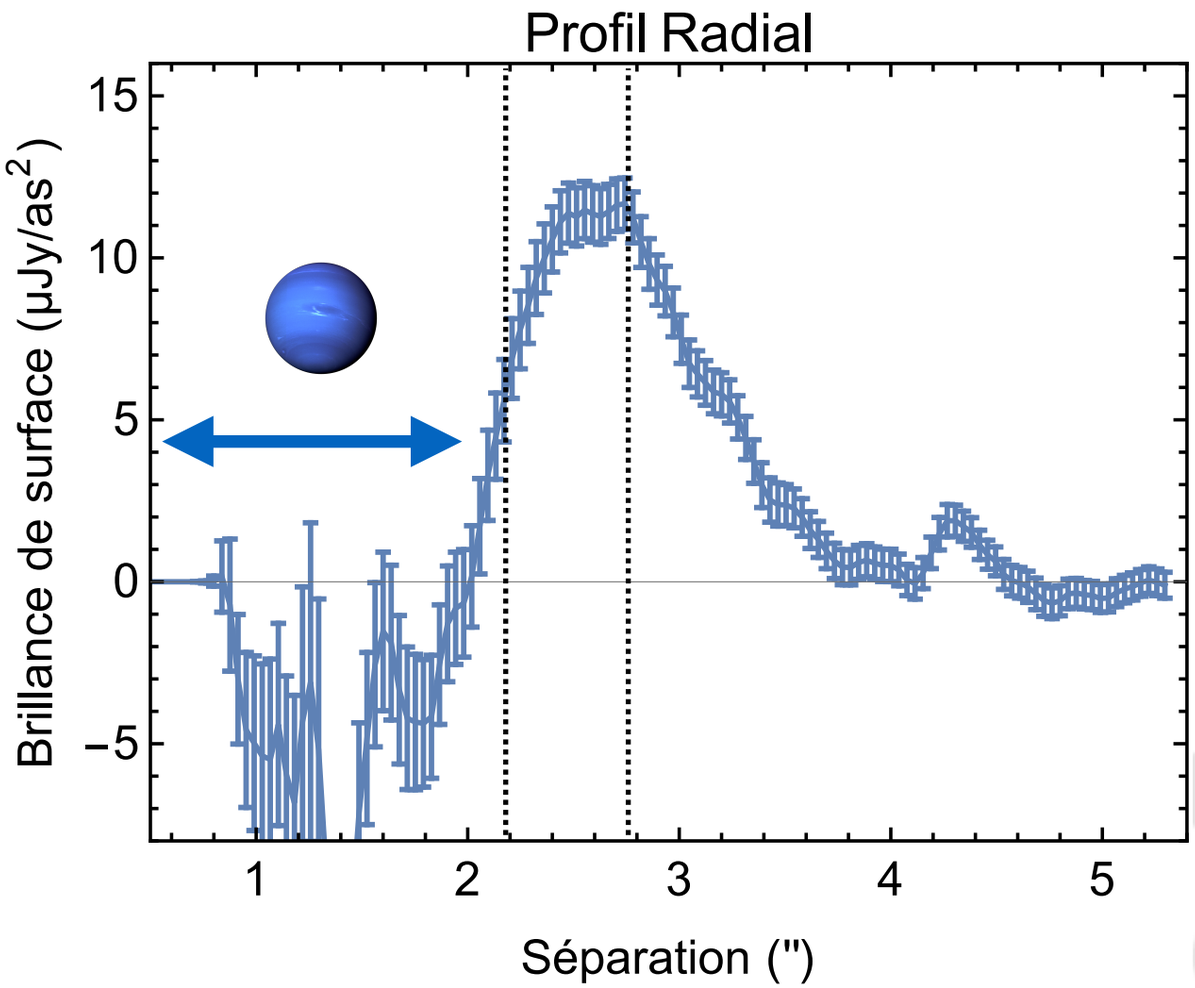
Disk morphologies to probe dynamics

Inner Clearings



Choquet et al. 2018

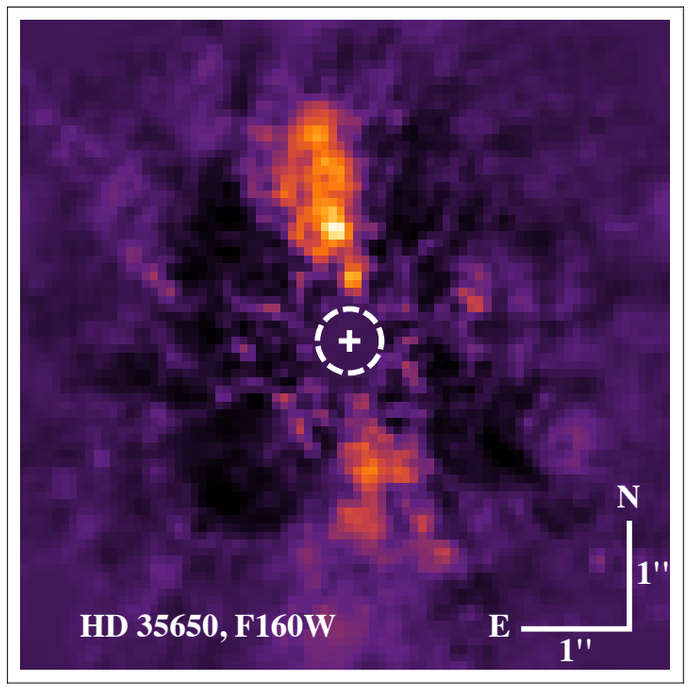
Evidence of planets



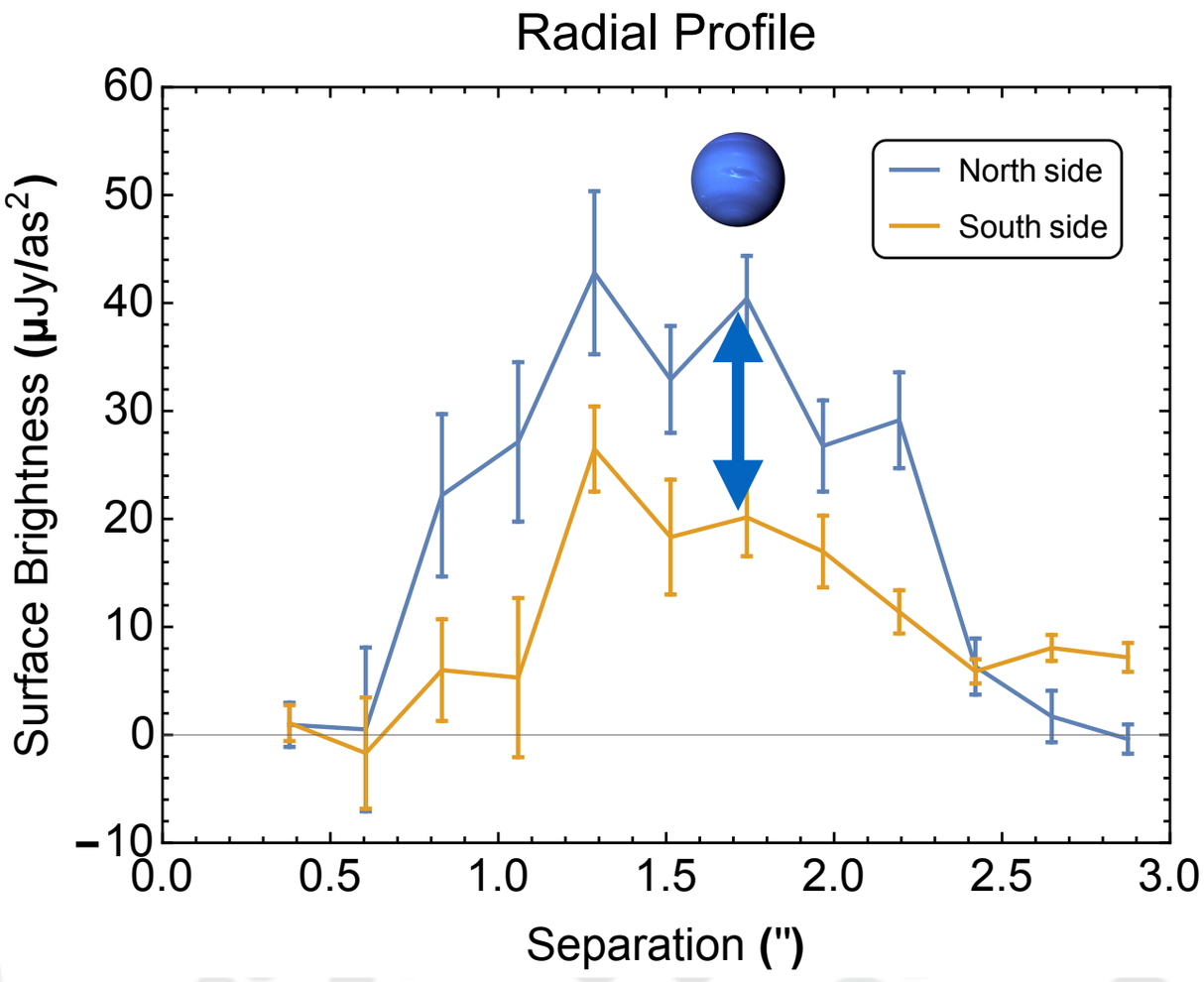
Disk morphologies to probe dynamics

Brightness asymmetries
Offsets from the star

Evidence of planets

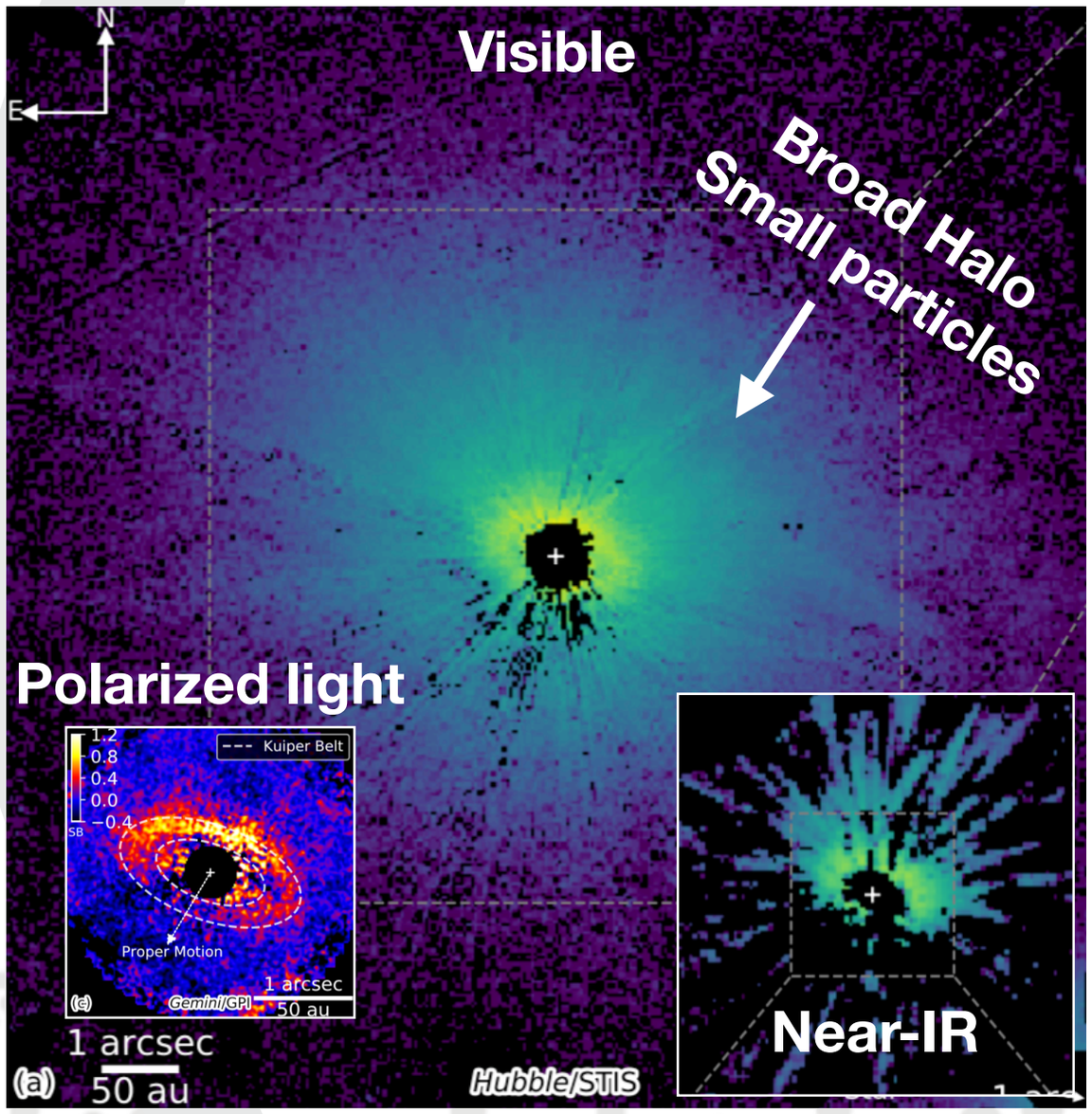


Choquet et al. 2016



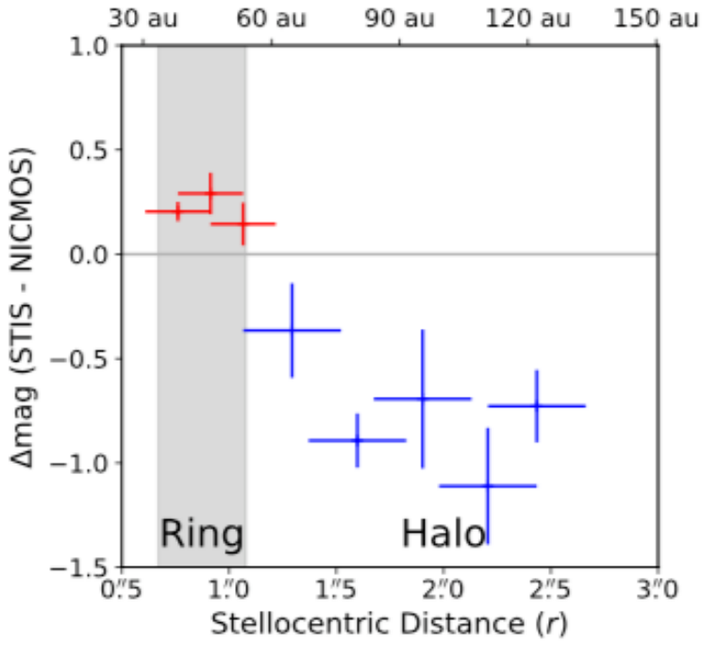
Disks brightness to probe their composition

Color & Scattering phase function

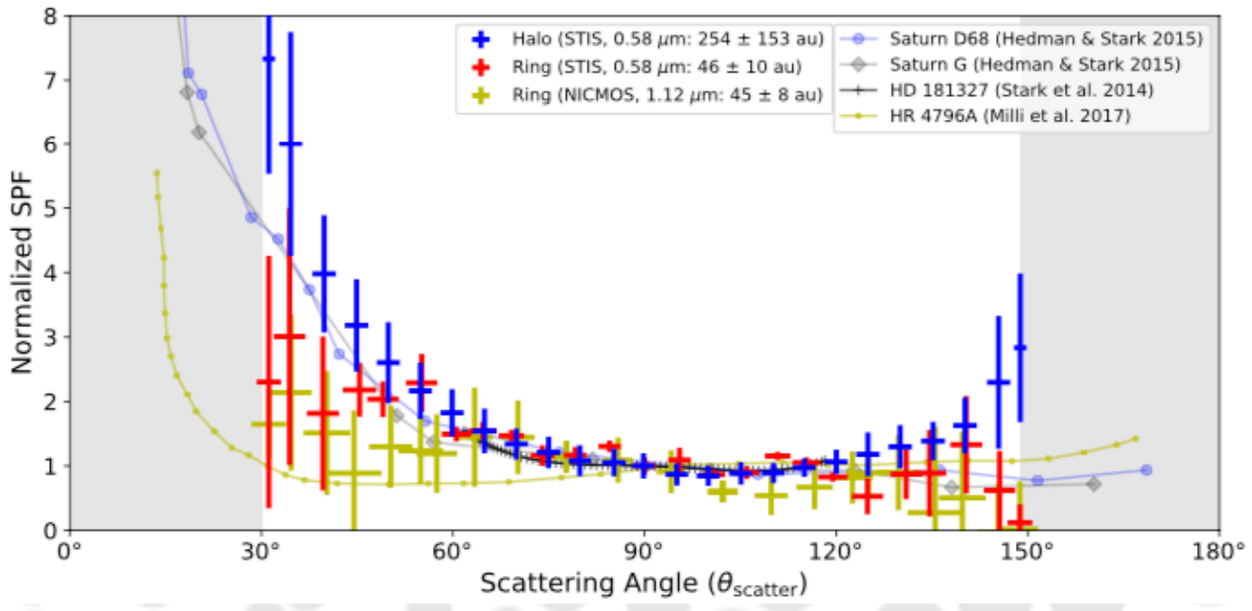


Ren, Choquet et al. 2019, sub.

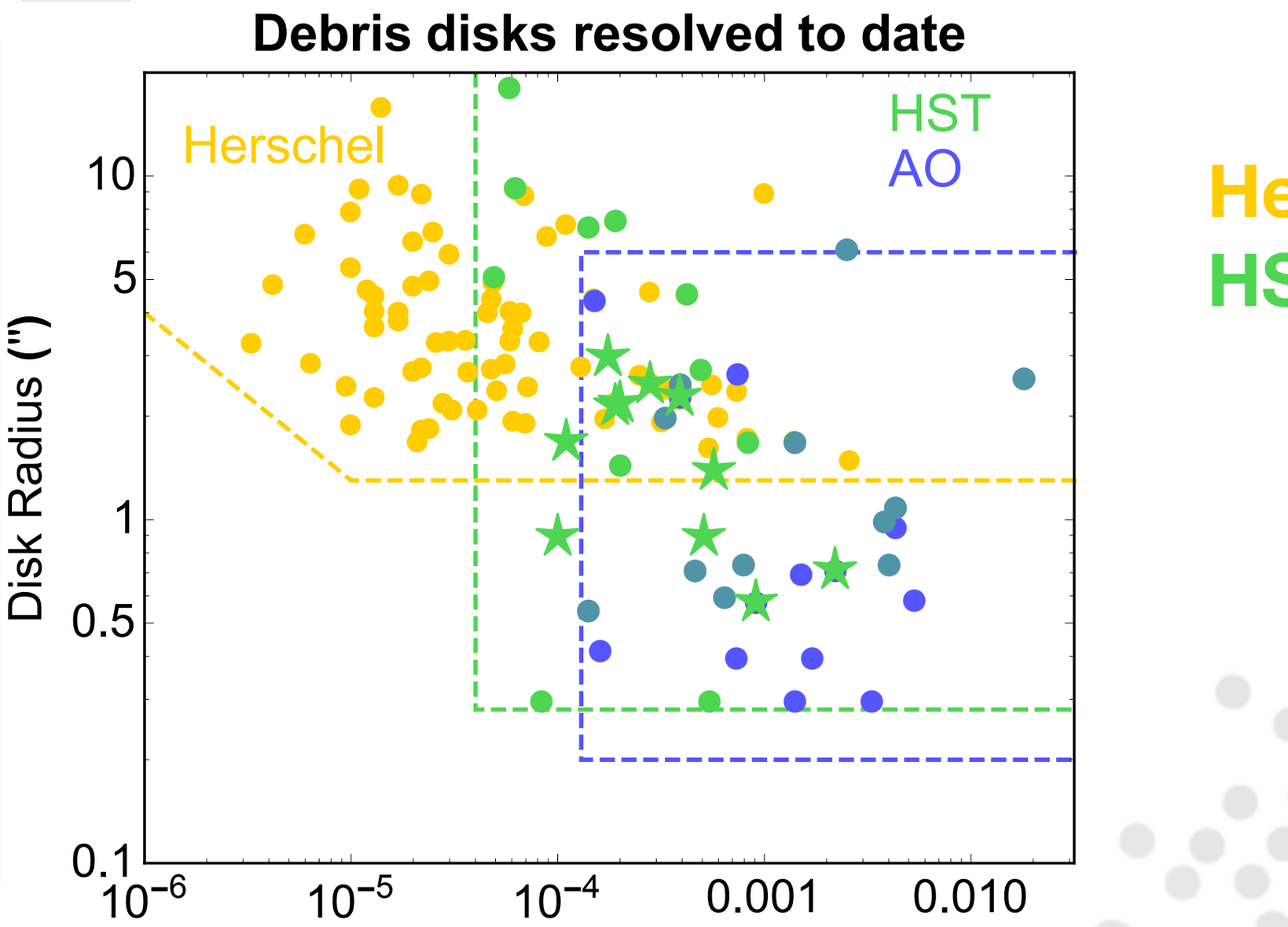
Vis-nIR Color



Scattering phase function



Resolved disk population study



Herschel: 82

HST & AO: 45

Resolved disk population study

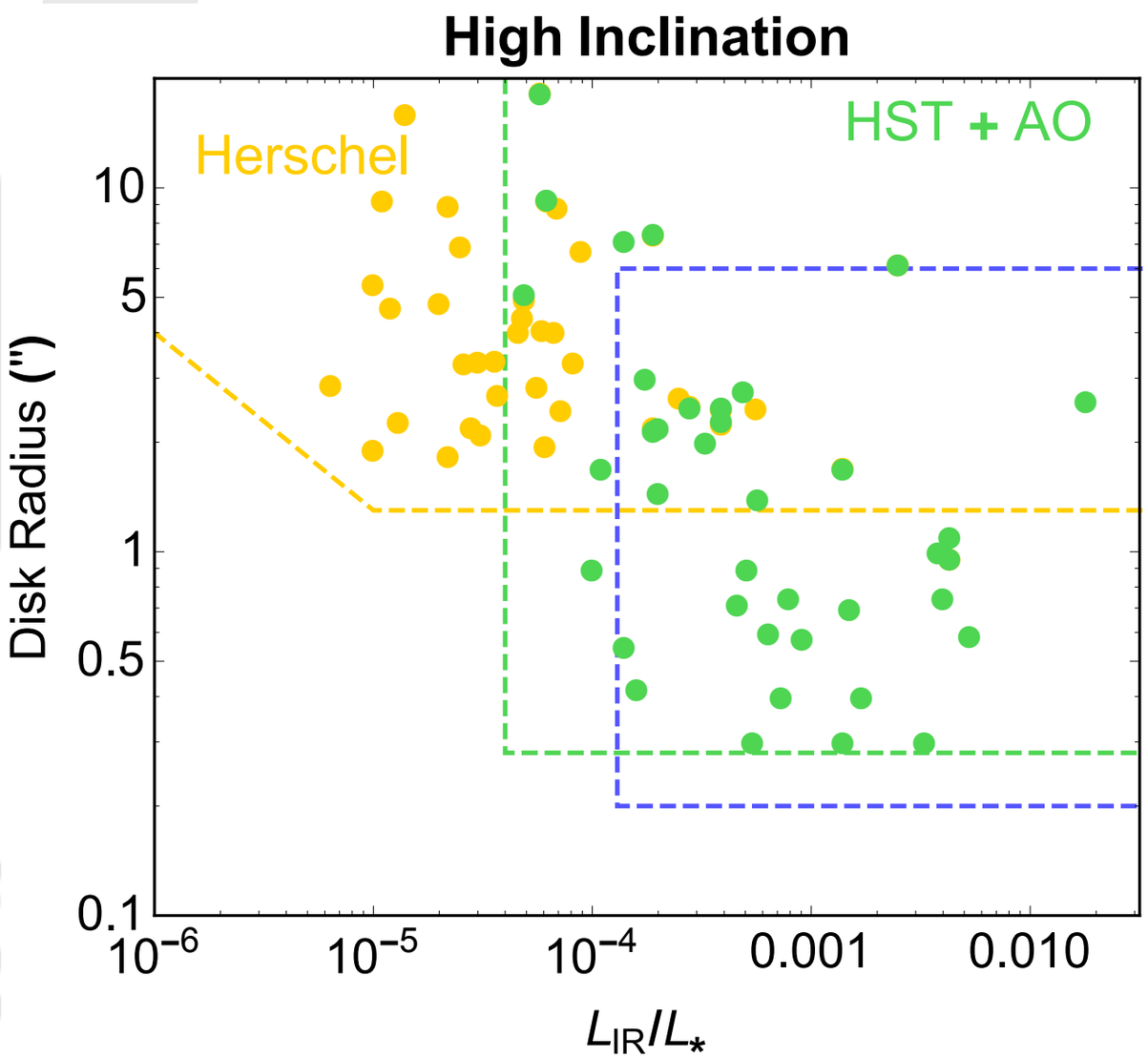
Herschel: 50%
HST + AO: 87%

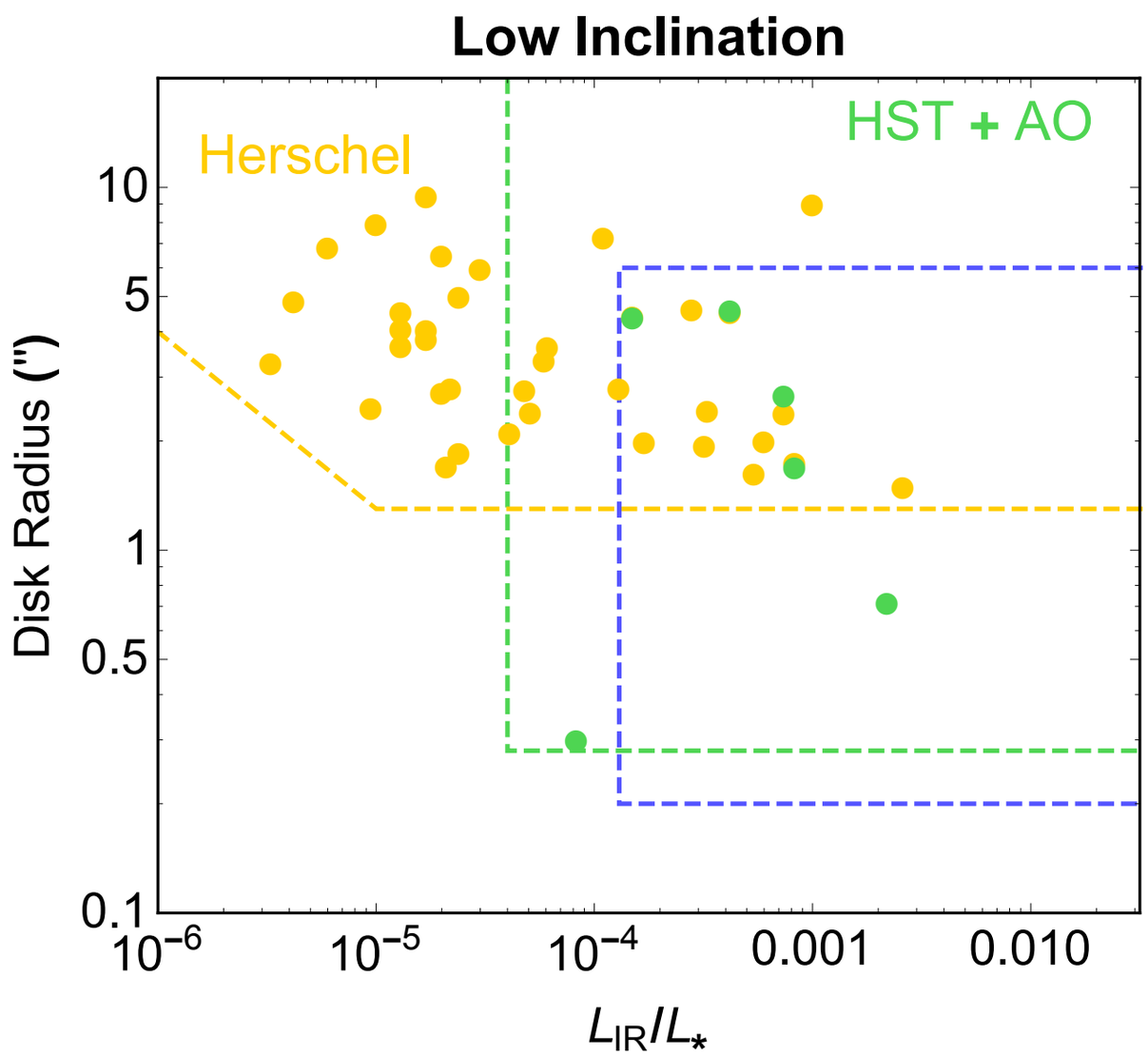
>

45° inc.

>

Herschel: 50%
HST + AO: 13%





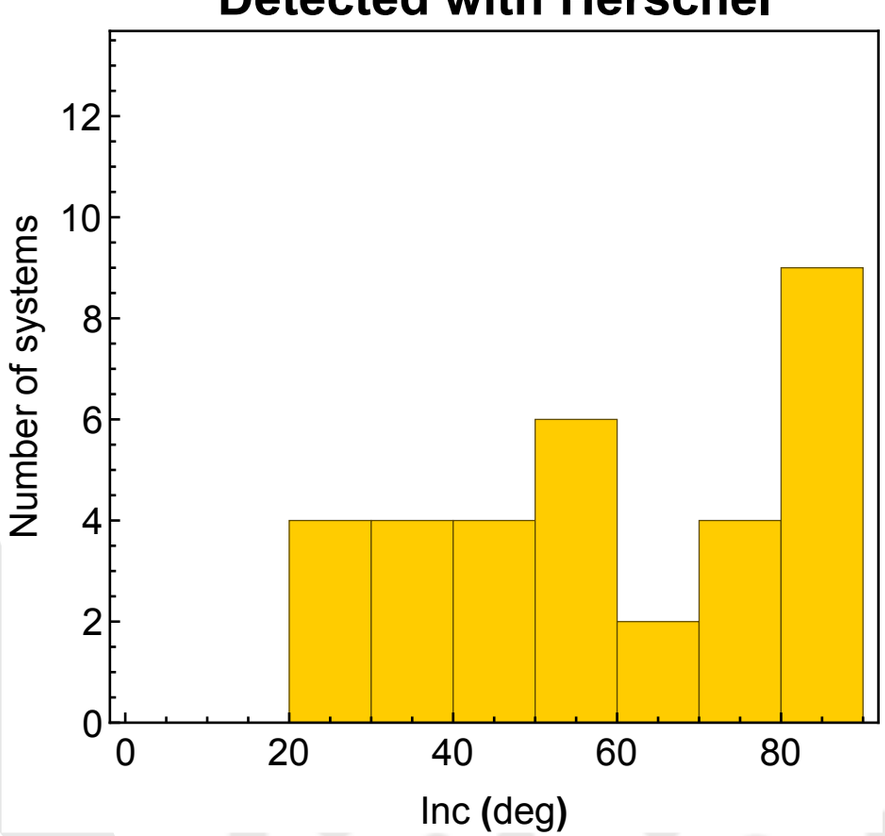
Resolved disk population study

On-going work!

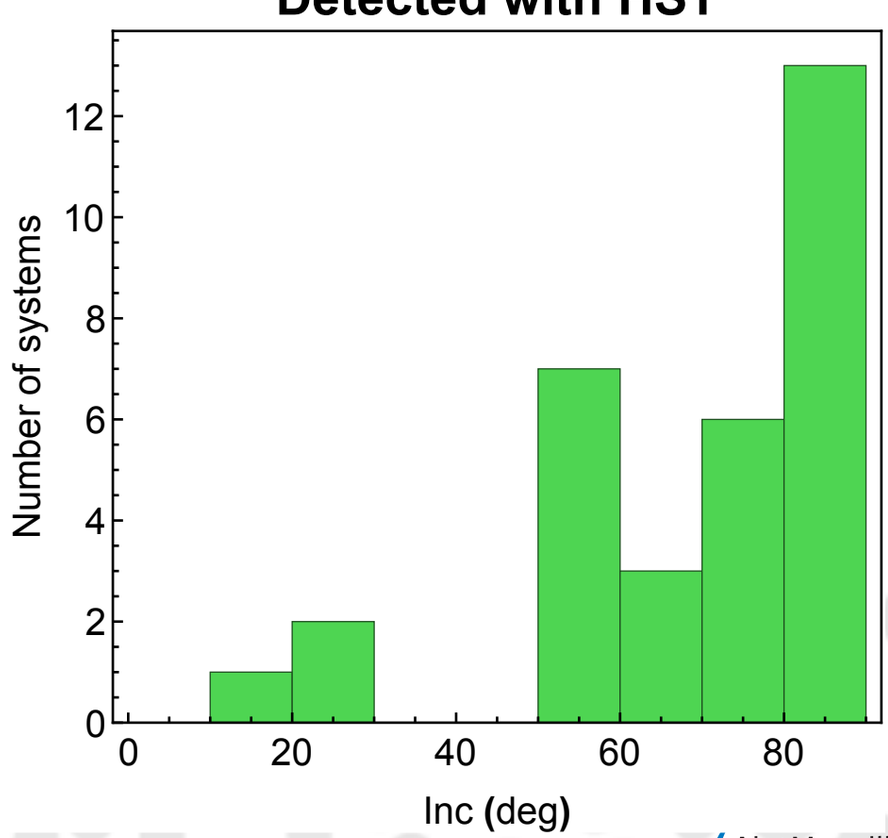
- MCMC population synthesis
- Effect of dust scattering properties

Sub-sample: systems observed with HST + RDI

Detected with Herschel



Detected with HST



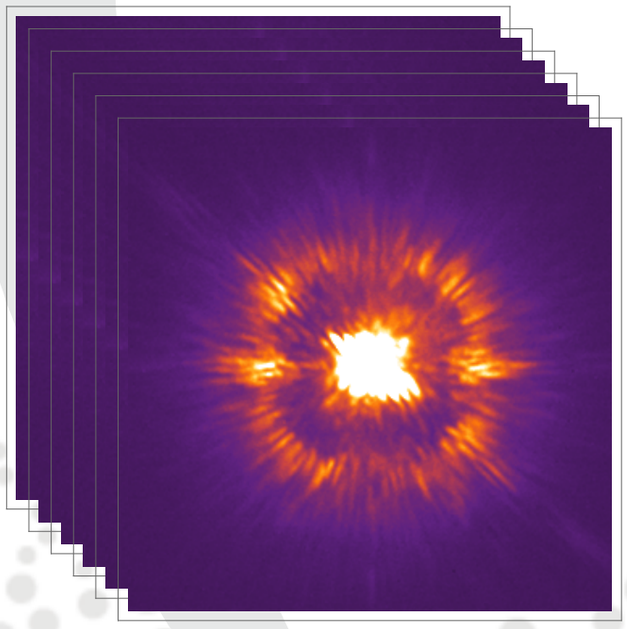
Choquet & Millar-Blanchaer in prep.

Conclusion and Prospects

Image Processing

Reprocess the SPHERE archive

- Using the AO telemetry
- Using Machine Learning approaches



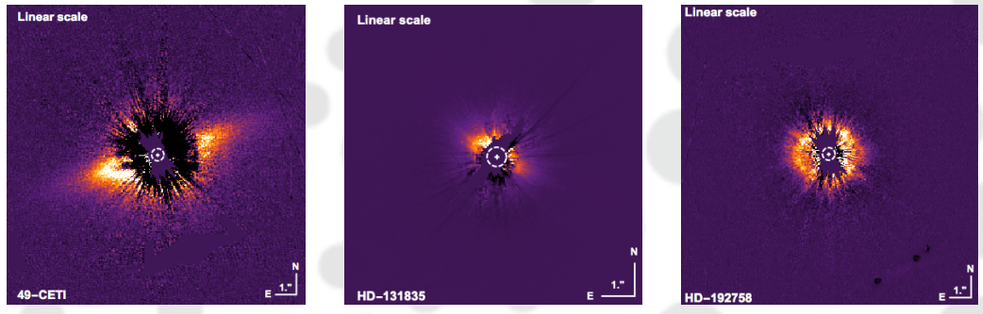
Debris Disk Studies

Characterization of known disks

- On-going HST program
- Visible-nIR characterization

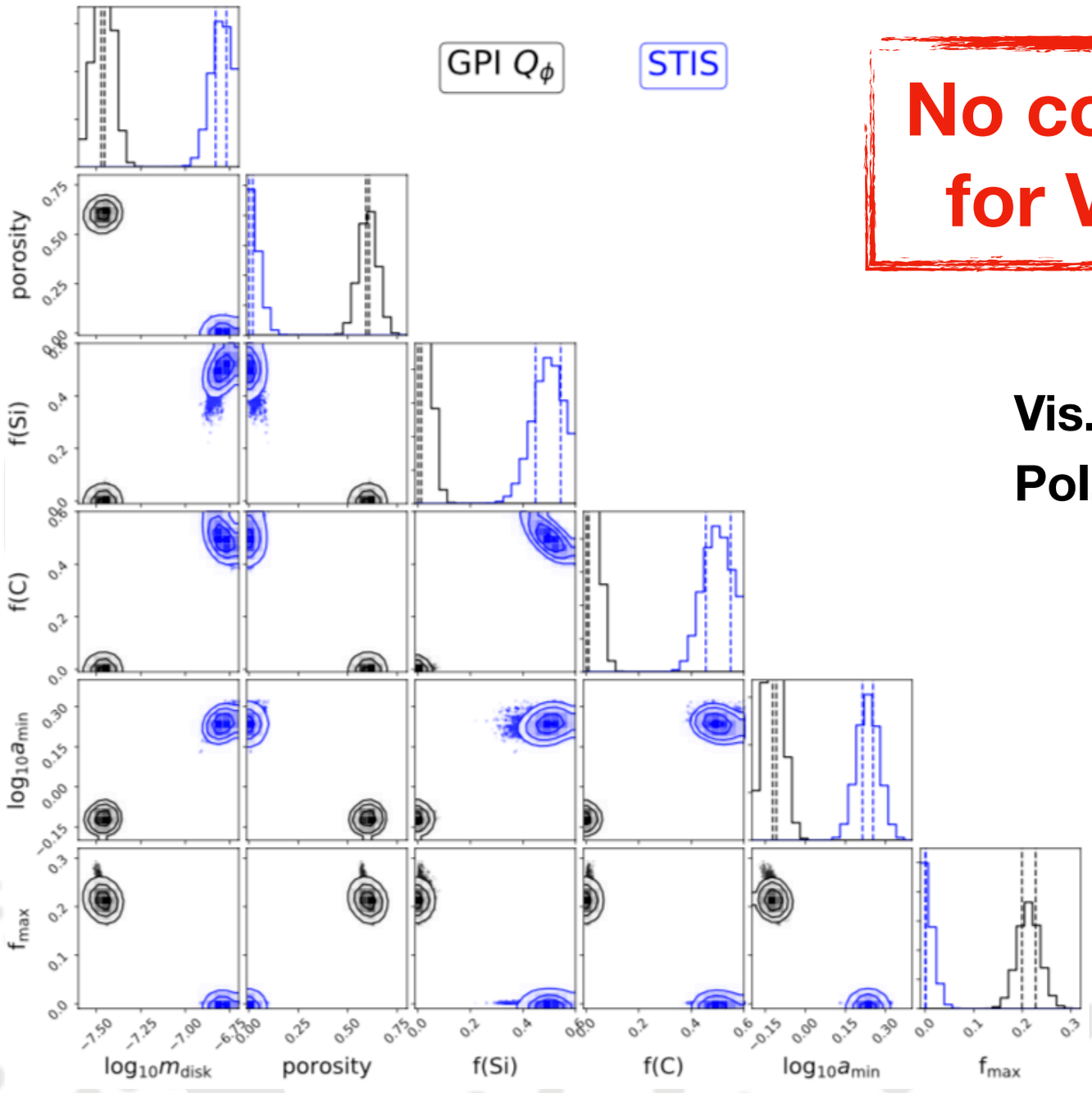
HST Survey of Herschel-resolved disks

- Improve statistical significance
- Statistical study of other properties



END

Limitations of the dust models



Ren, Choquet et al. 2019, sub.

No consistent model for Vis. & Pol. data

Vis. image: homogeneous sphere

Pol. image: Hollow sphere distribution

Complex shapes, aggregates ?