

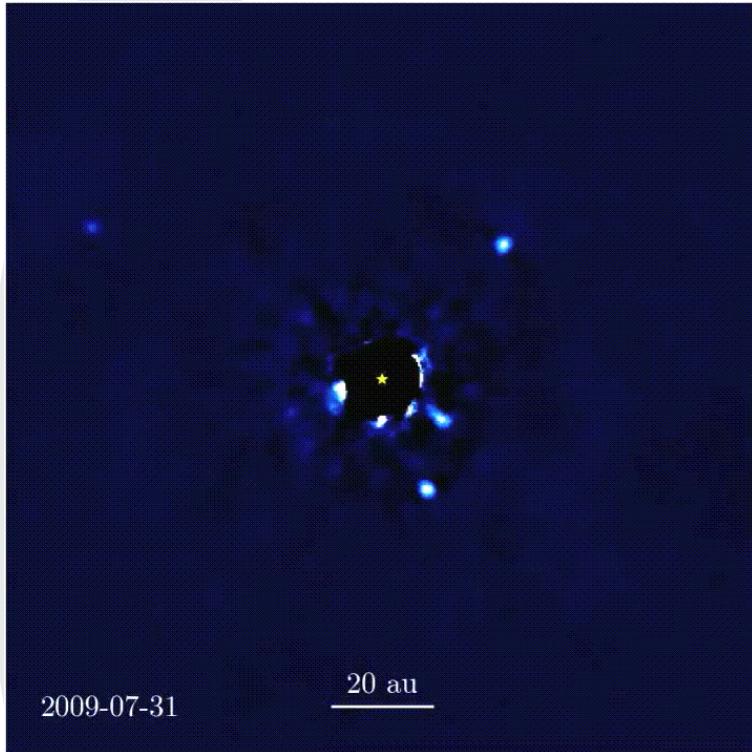


Data Mining the Hubble Archives to image Extrasolar Systems

Elodie Choquet

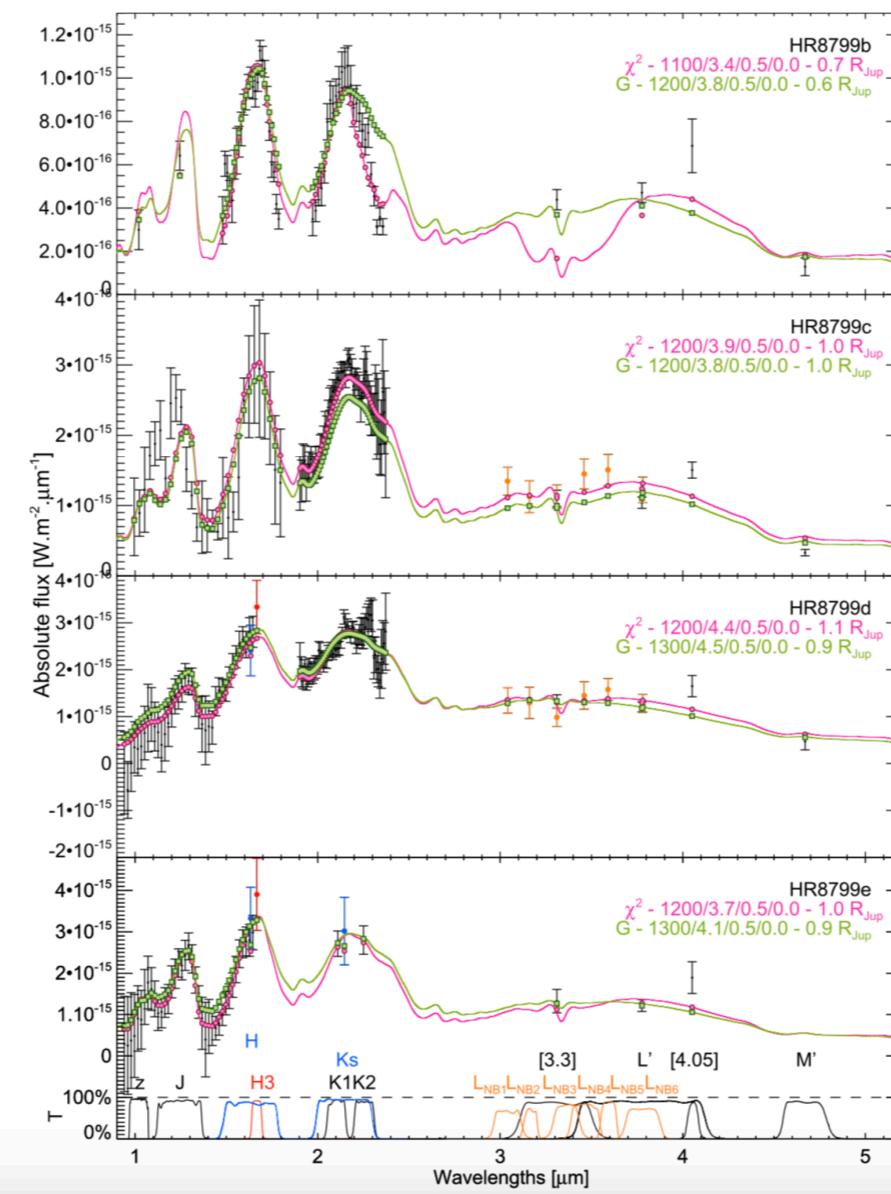
Direct Imaging of exoplanetary systems

Planets Dynamics



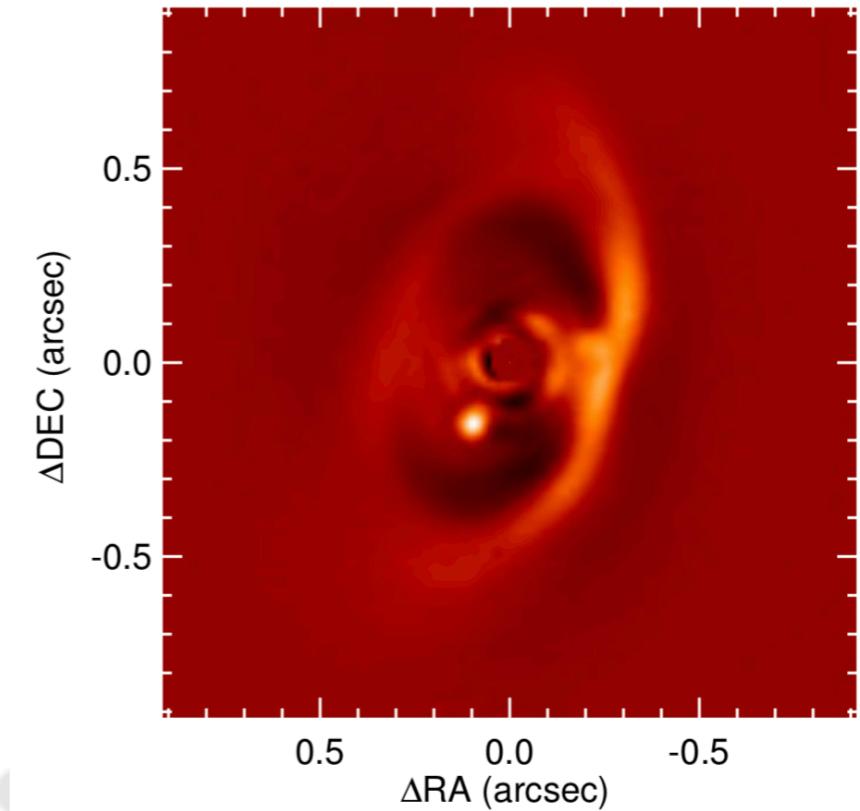
Courtesy J. Wang

Planet Atmospheres



Bonnefoy et al. 2016

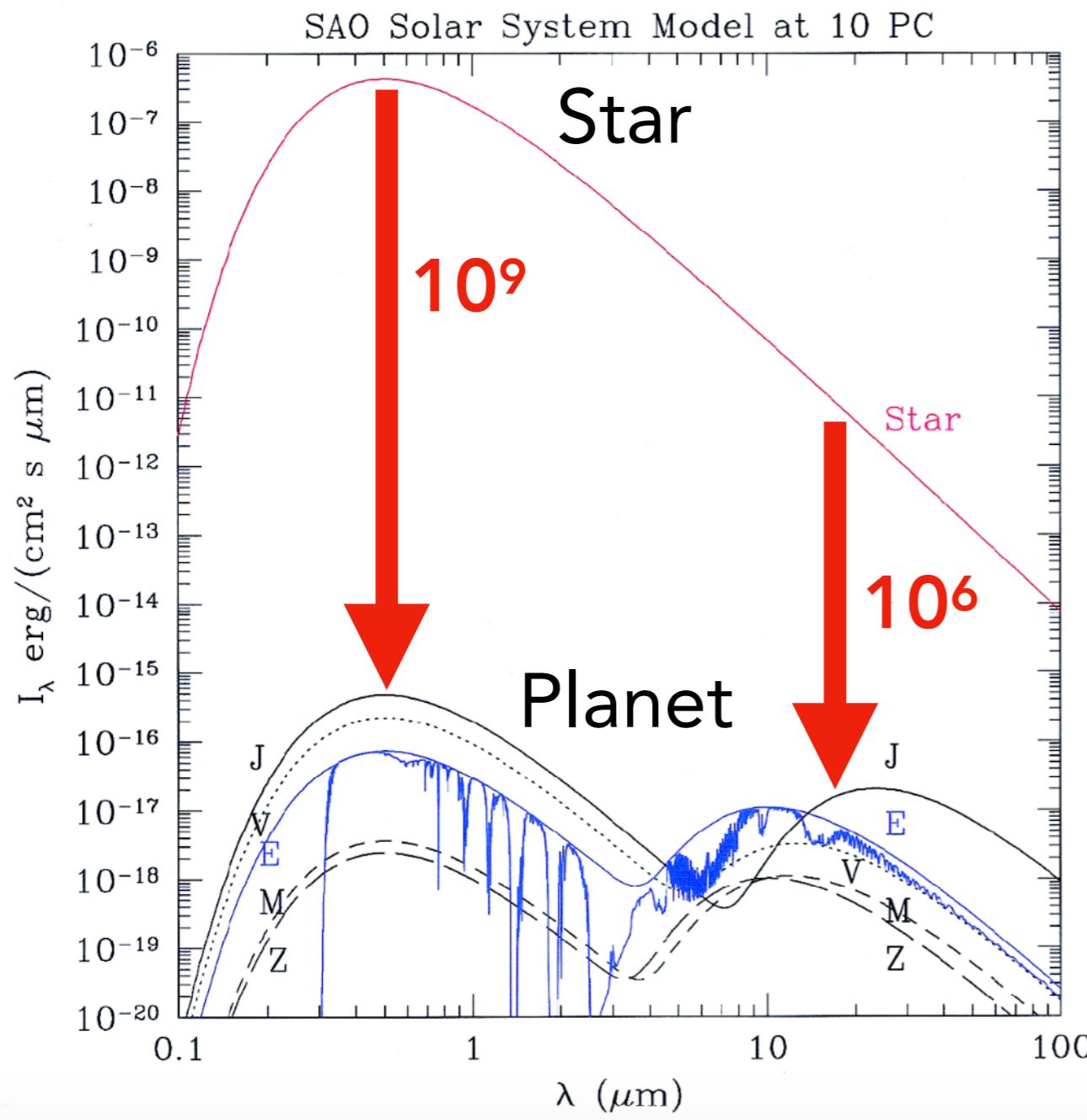
Planet Formation



Müller et al. 2018

Direct Imaging: Challenges

Extreme contrast ratio...



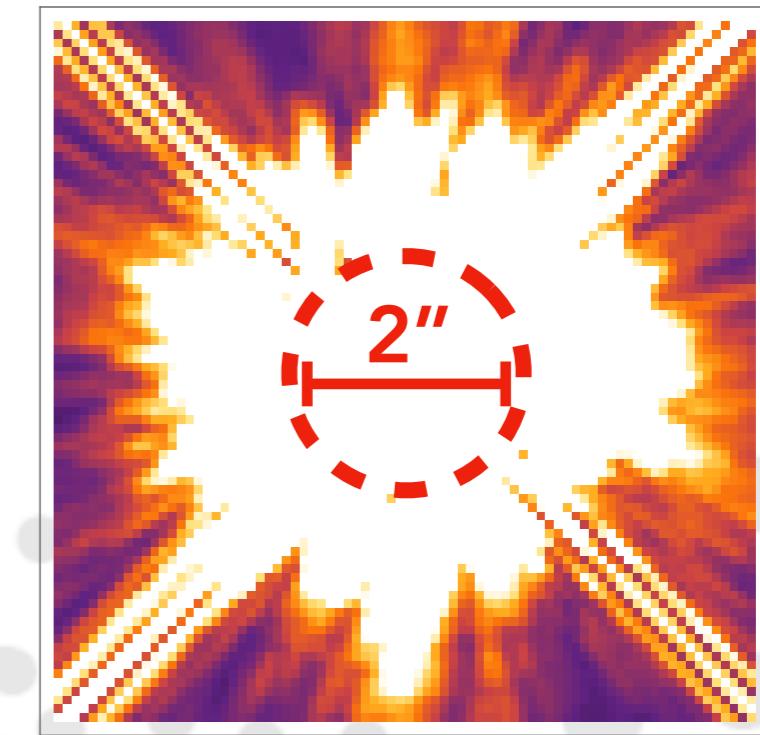
Des Marais et al. 2002

... at Small Separations

10 AU at 50 pc => 0.2"

VLT @2μm => $\lambda/D = 0.05''$

HST @1μm => $\lambda/D = 0.09''$



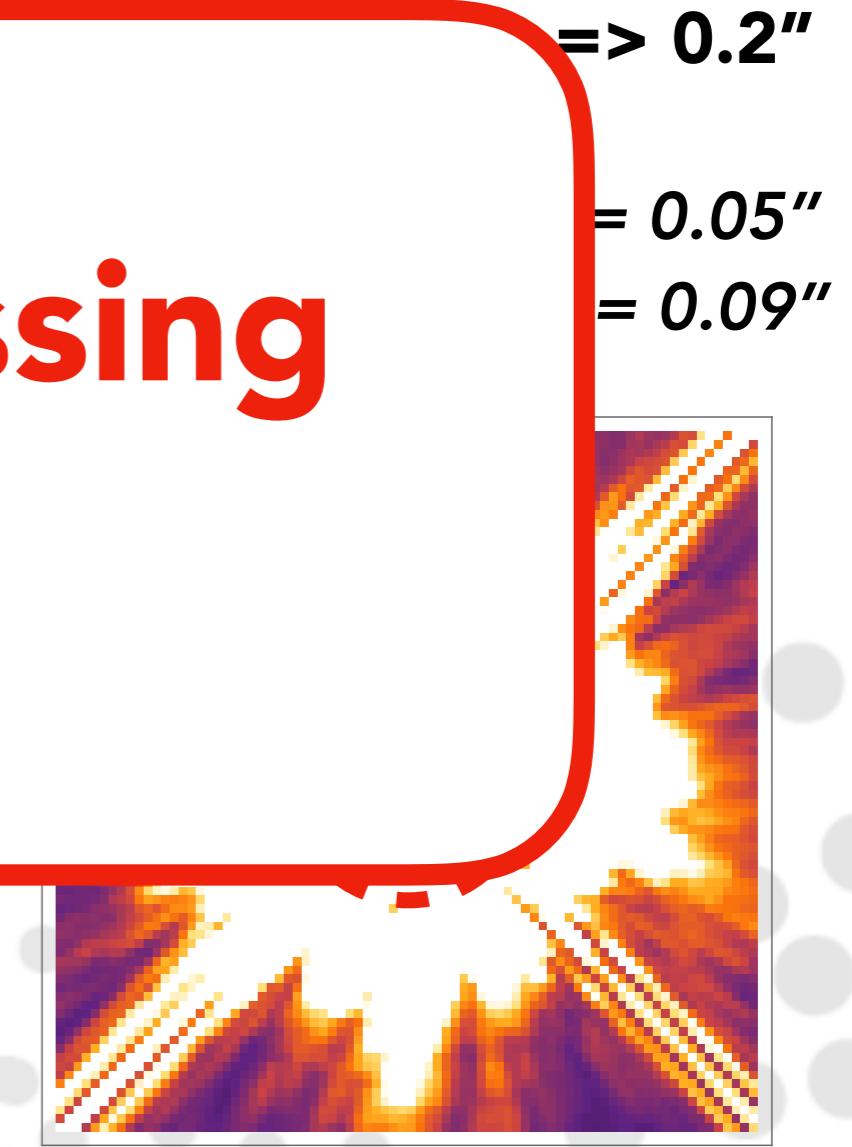
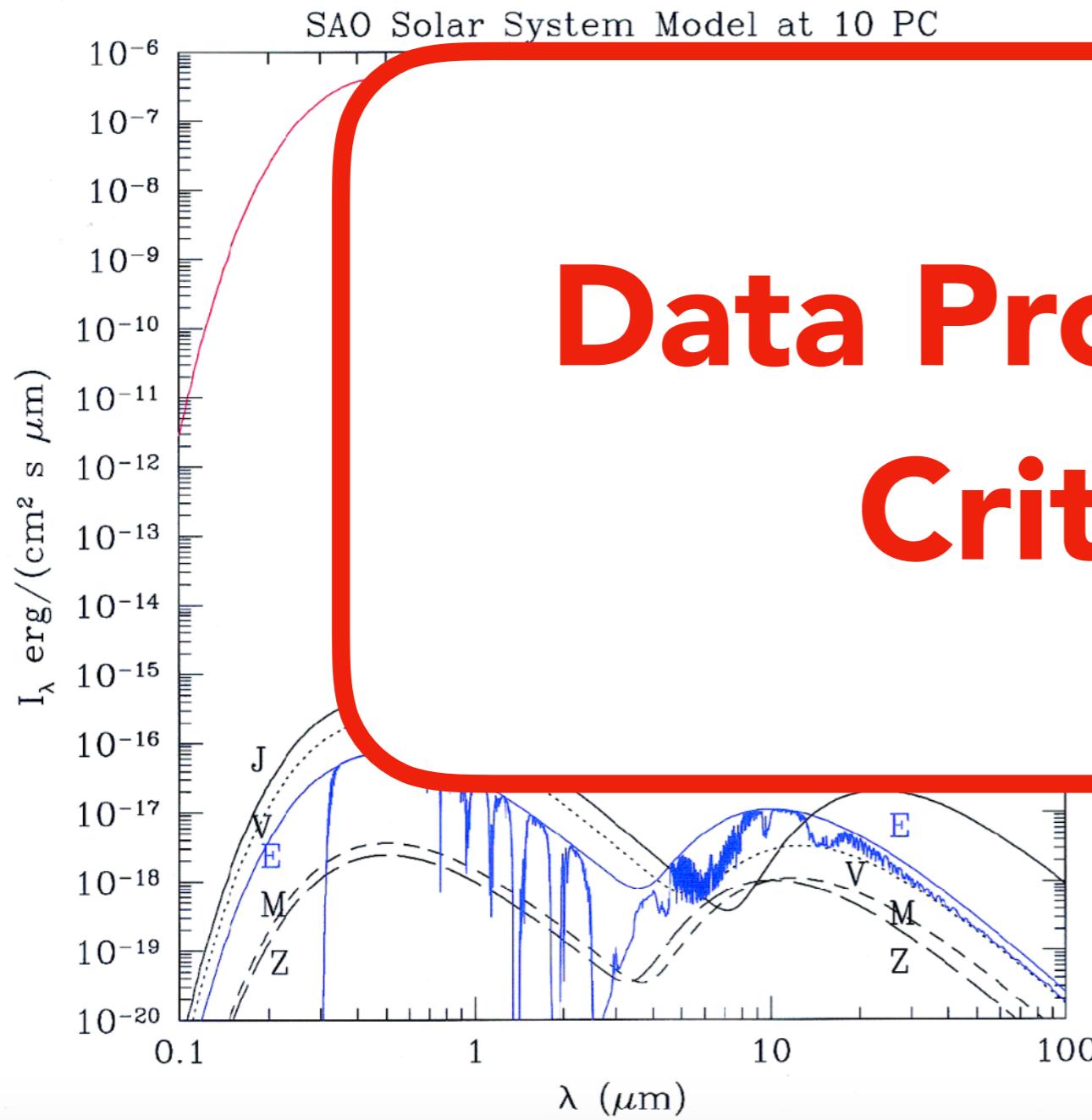
HST, NICMOS

Direct Imaging: Challenges

Extreme contrast ratio...

... at Small Separations

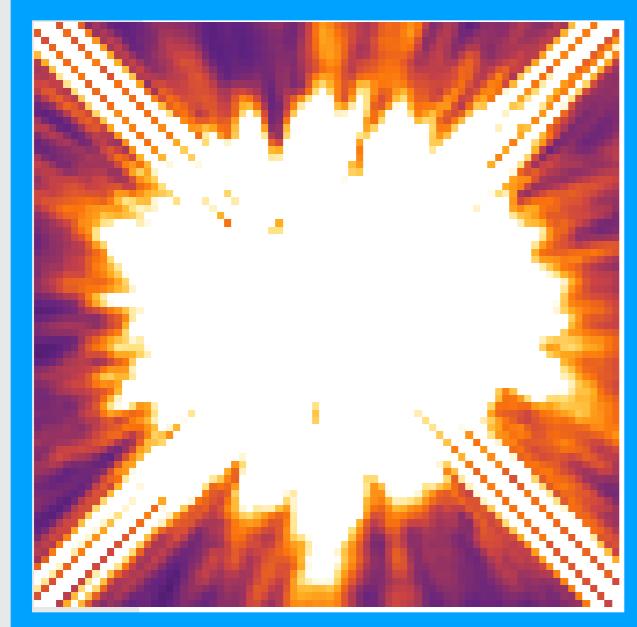
Data Processing
Critical



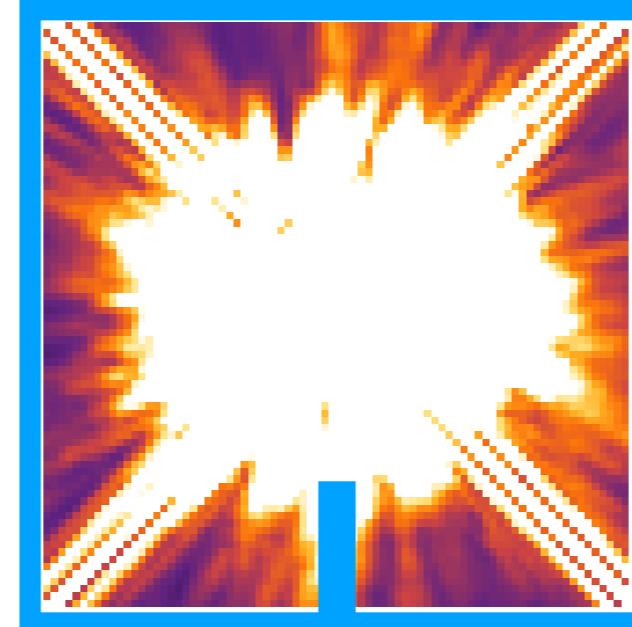
Data Processing Method

Differential Imaging (DI)

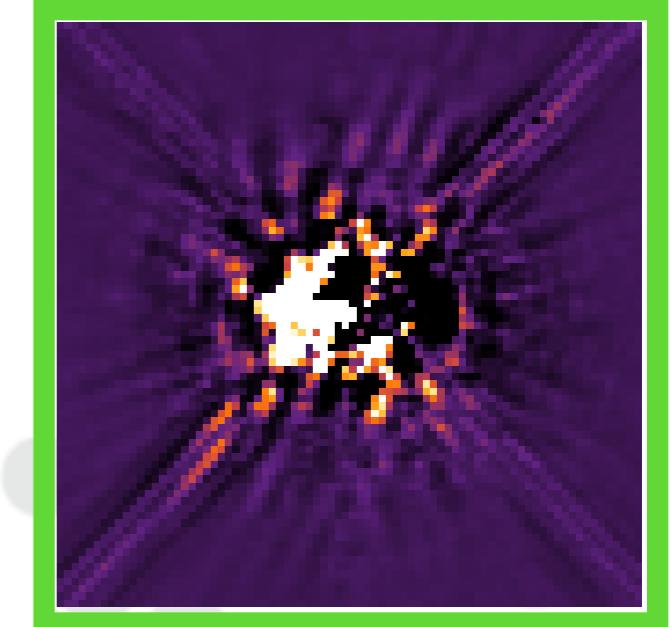
Science Image



PSF Image



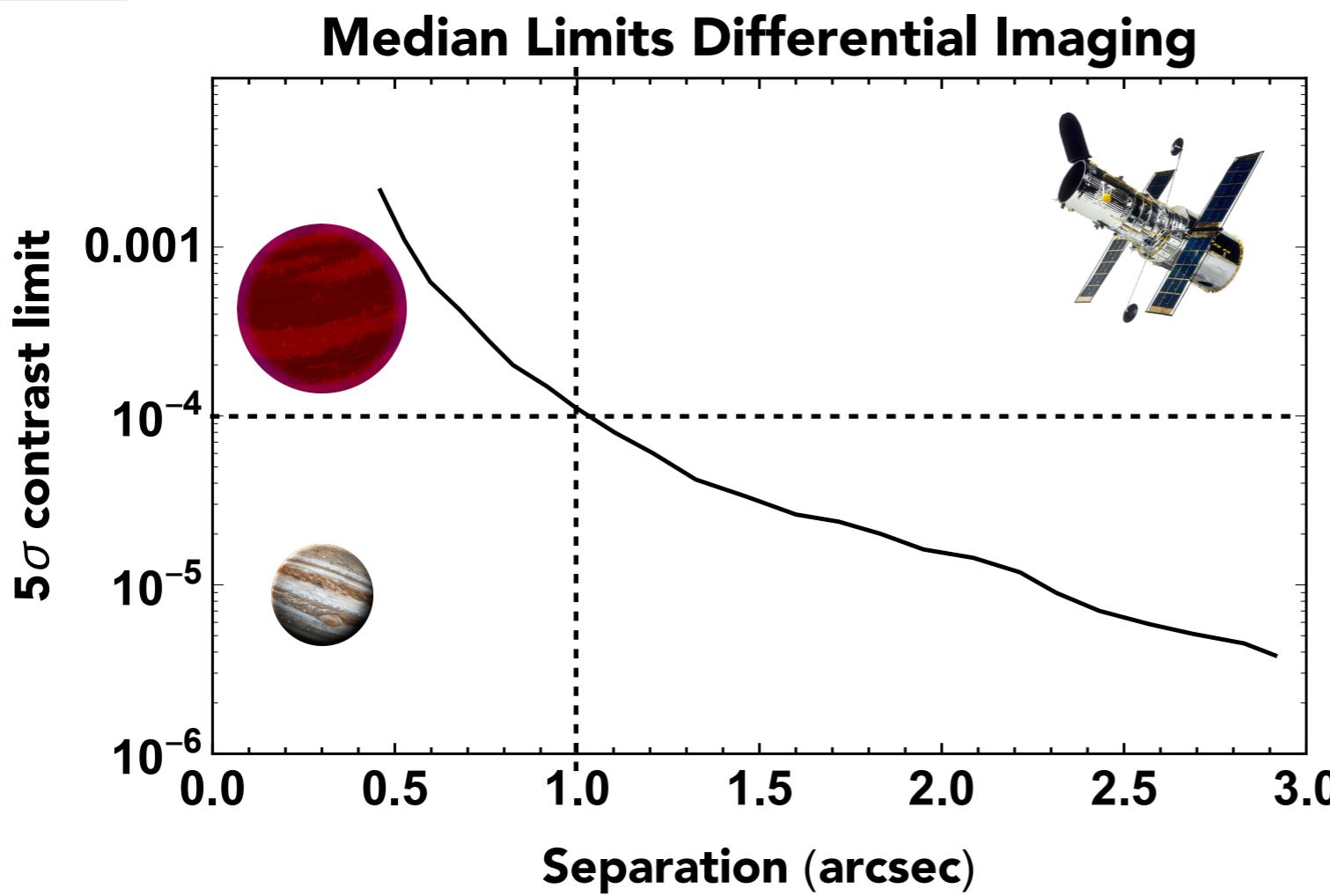
Residual Image



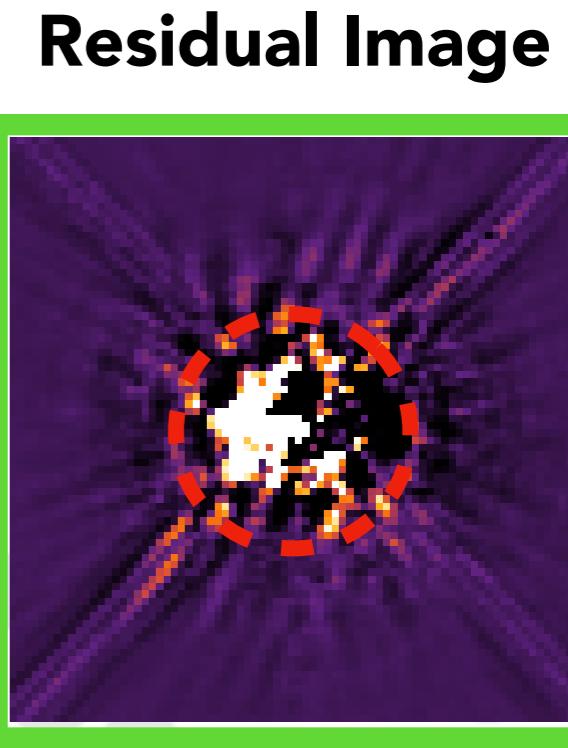
Reference Star
Science Star with Scene Rotated

Data Processing Method

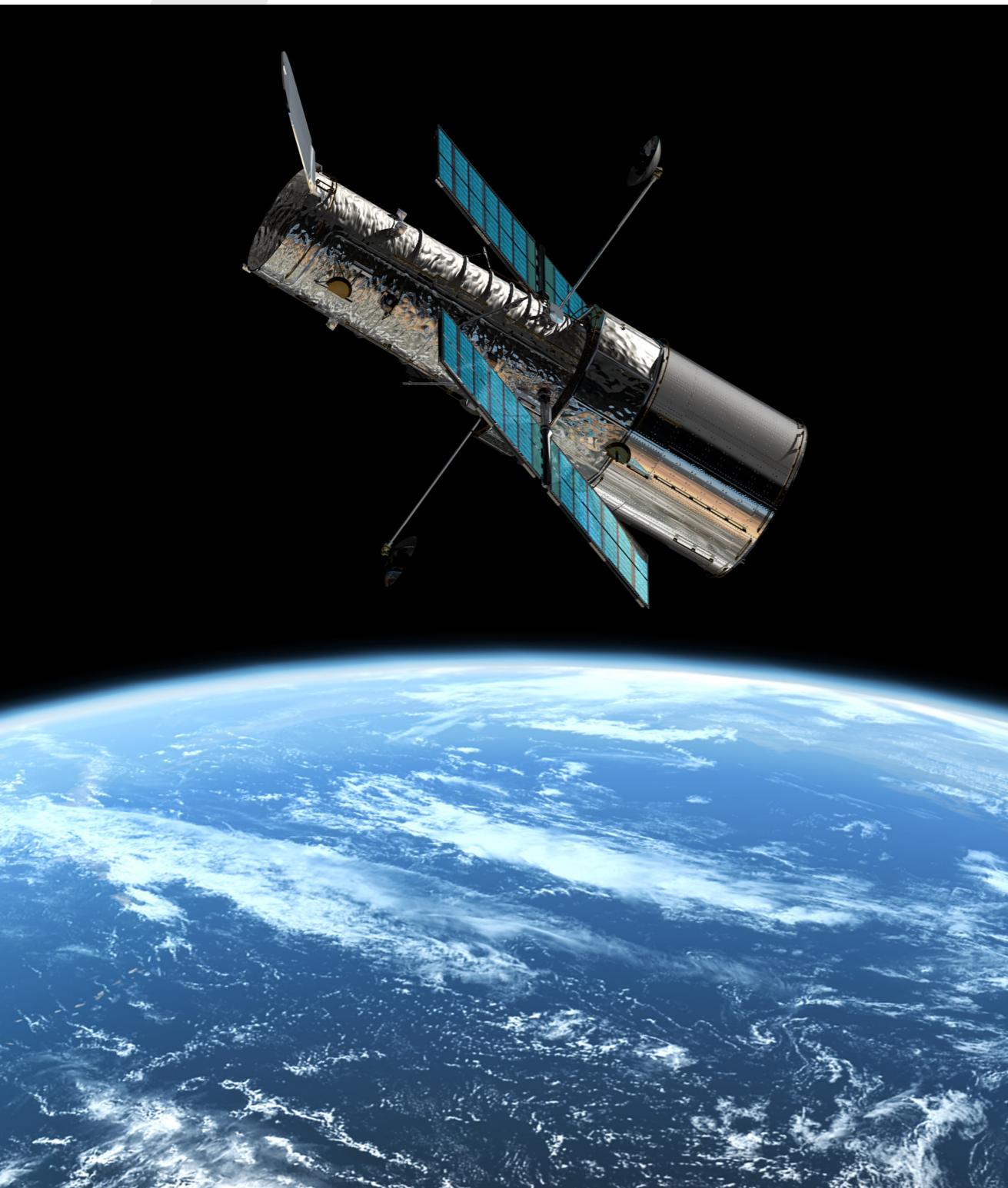
Differential Imaging (DI)



Lowrance et al. 2005

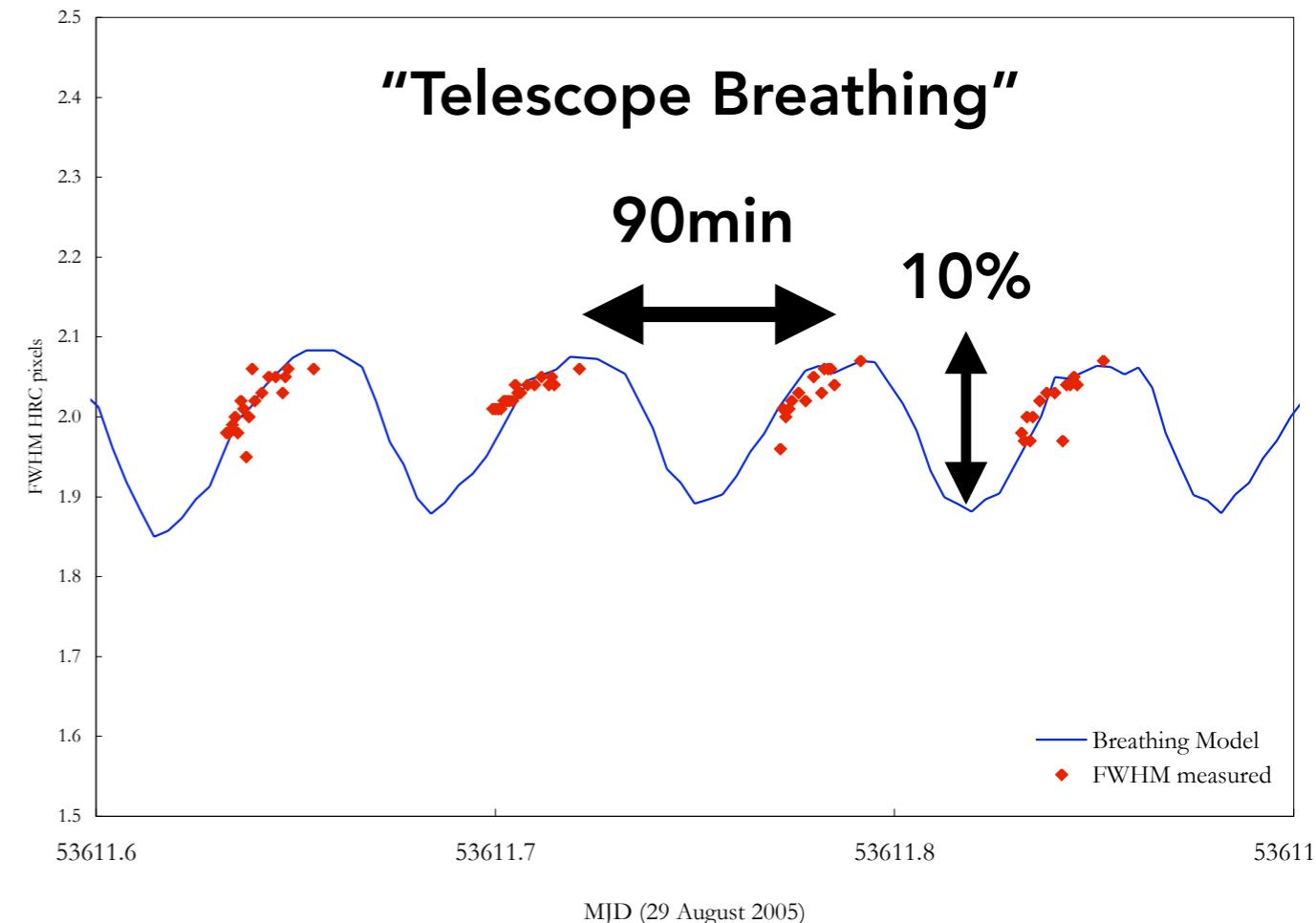


Data Processing Challenges



PSF temporal variations

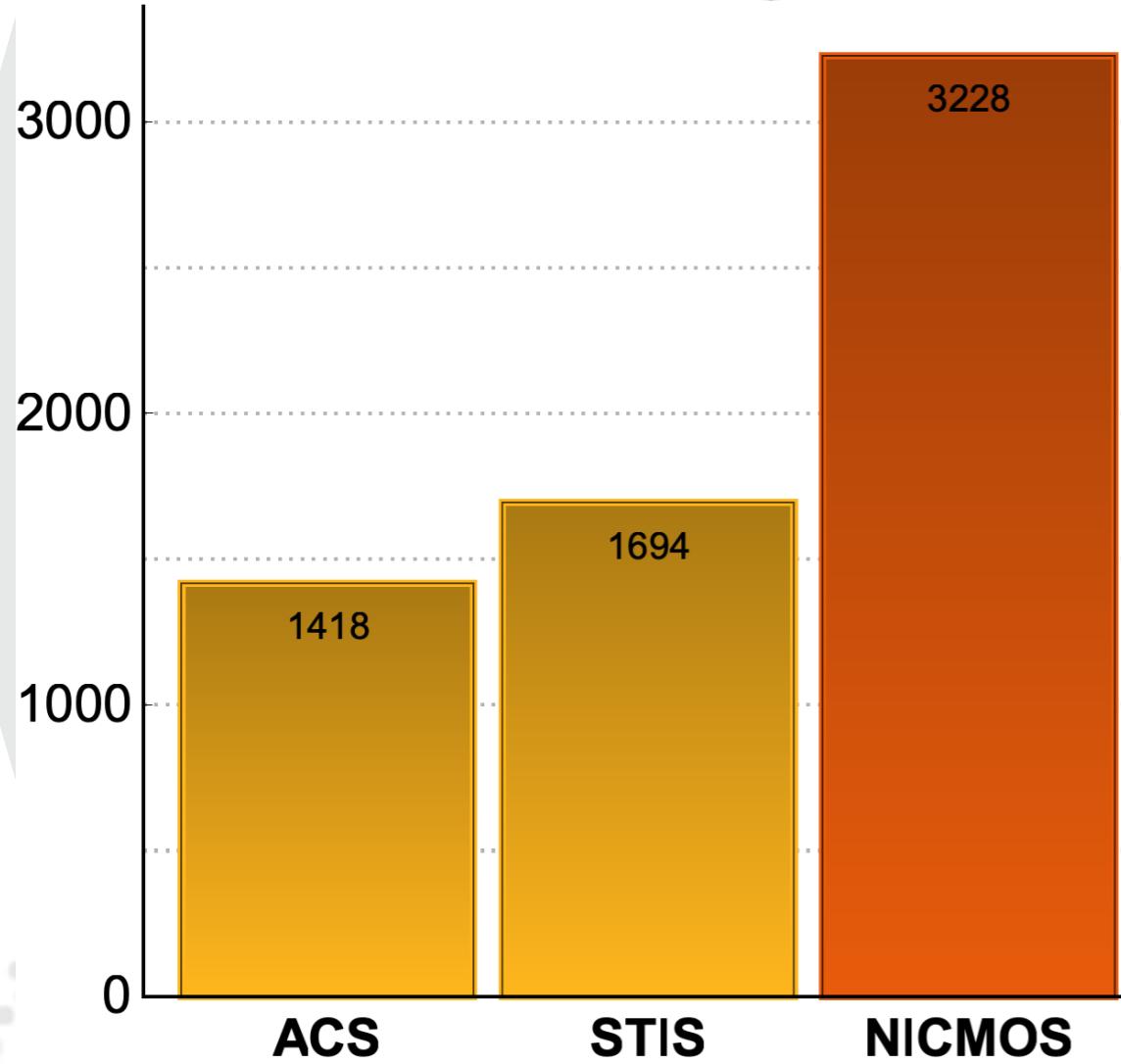
Short term FWHM oscillations



Lallo et al. 2006

Mining the Hubble Archives

HST Coronagraphs

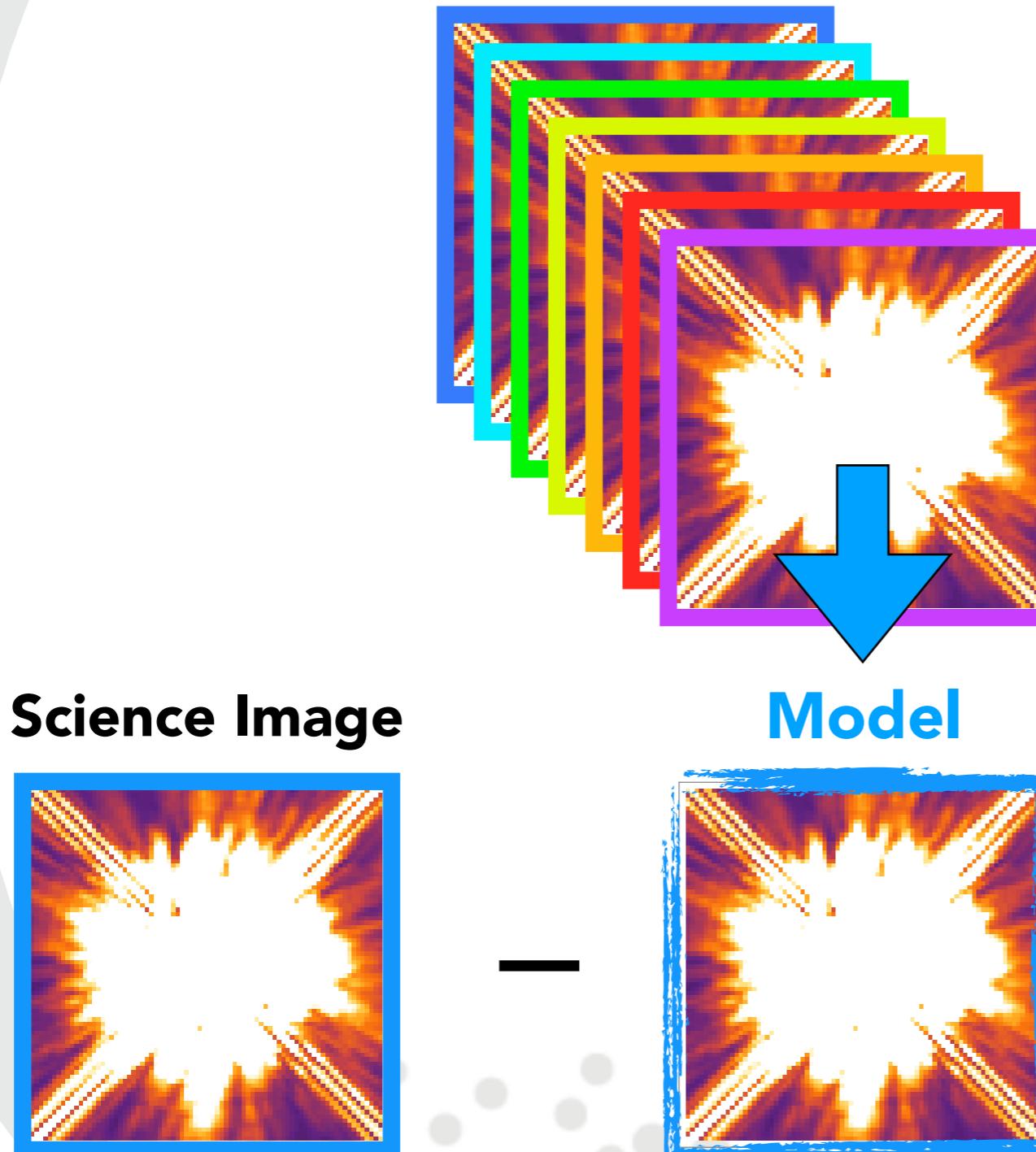


The NICMOS instrument

- ▶ In operation for 8 yr
- ▶ Coronagraph: R=0.3"
- ▶ Near-IR (mainly J & H)

- ▶ 400 targets observed
- ▶ Goals: Planets, disks
- ▶ **5600 images**

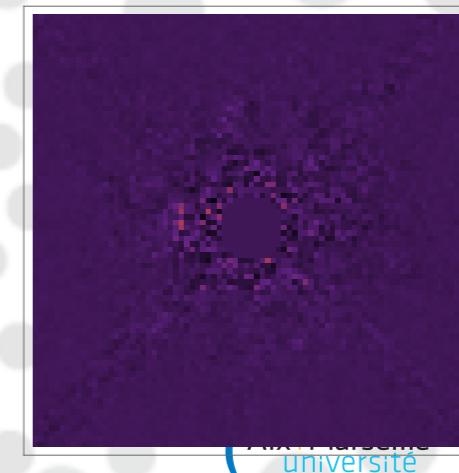
Archival PSF libraries



Archival Library

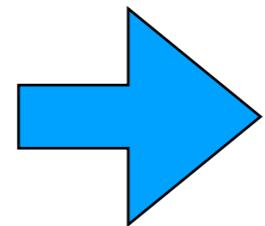
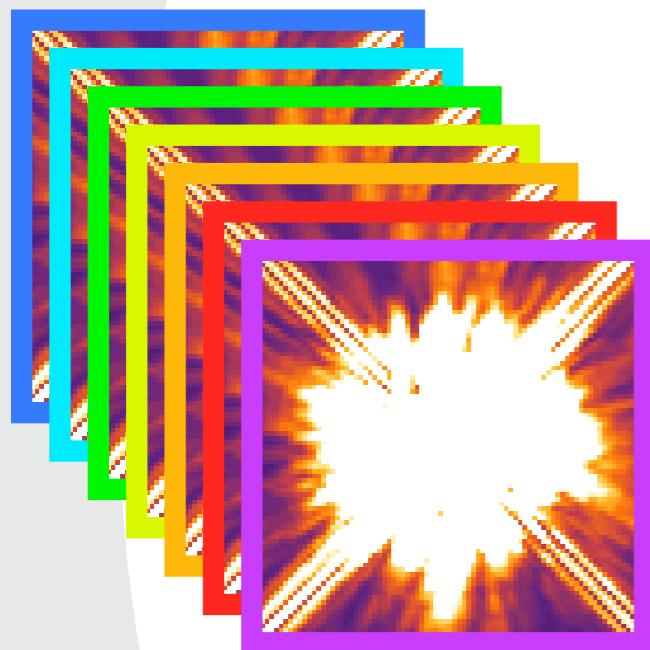
- ▶ 10² Reference stars
- ▶ 10³ PSF images
- ▶ Samples tmp variations

Residual Image

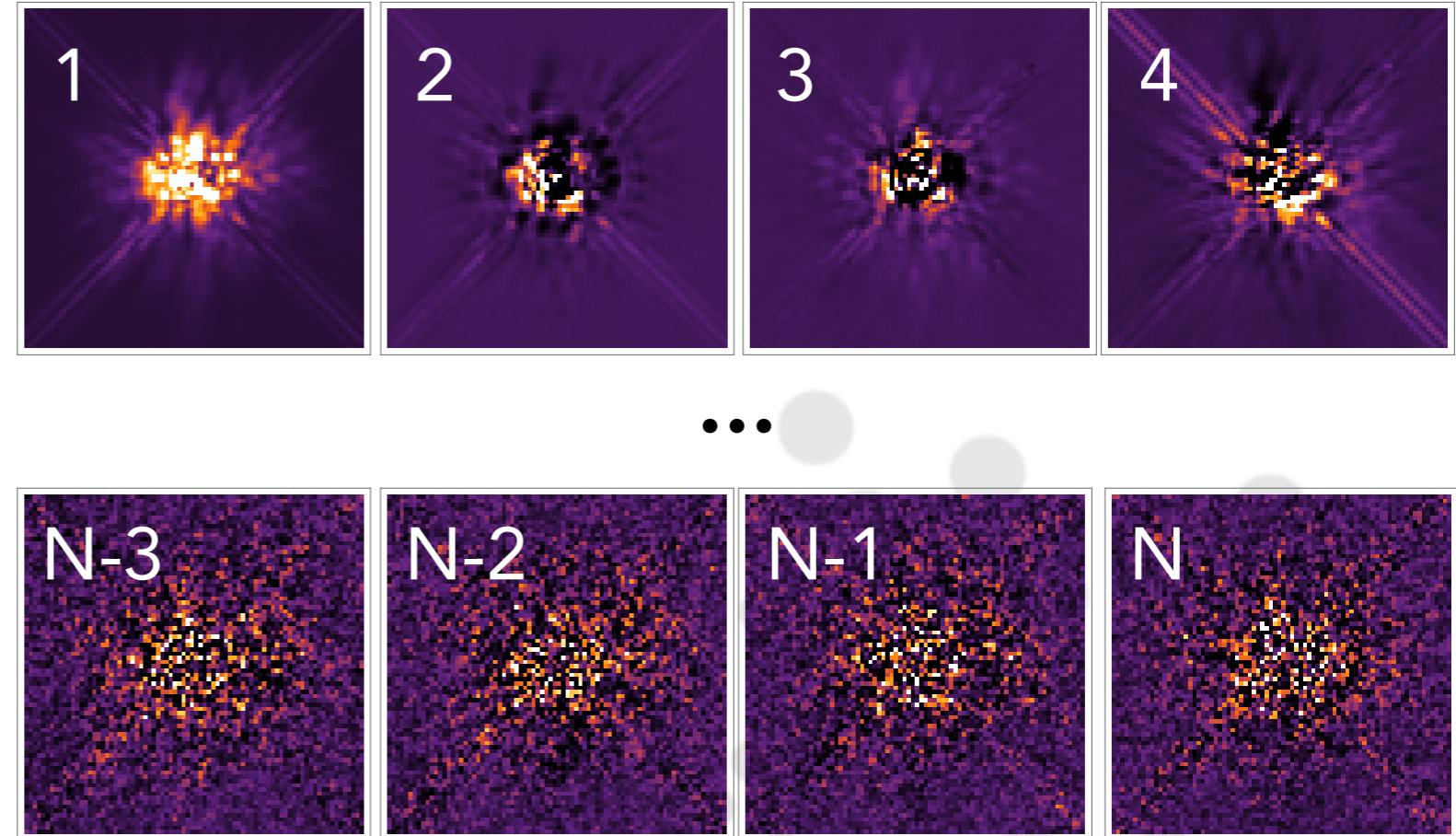


Principal Component Analysis (PCA)

Machine Learning Algorithm to create the PSF Model



Principal components of the library



Soummer et al. 2012

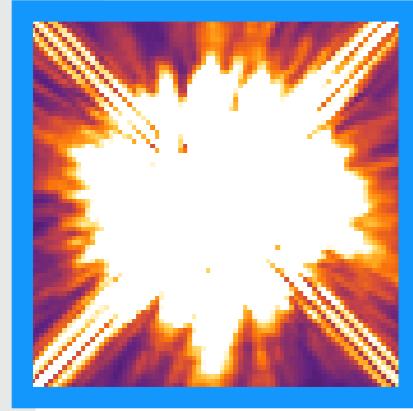
Principal Component Analysis (PCA)

Machine Learning Algorithm to create the PSF Model

Science

Model

Residual

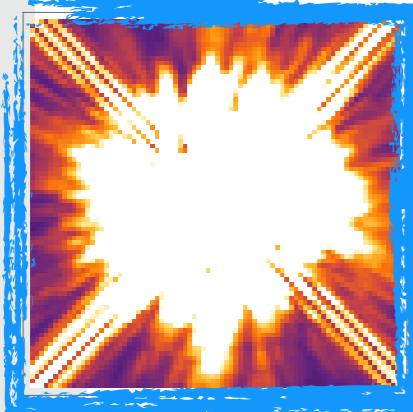


Projection

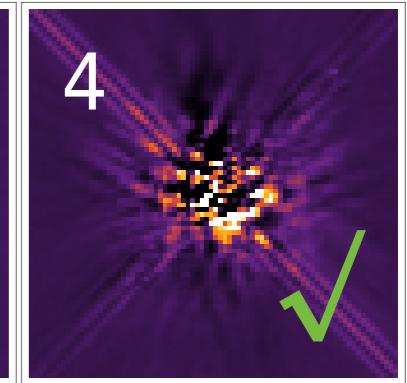
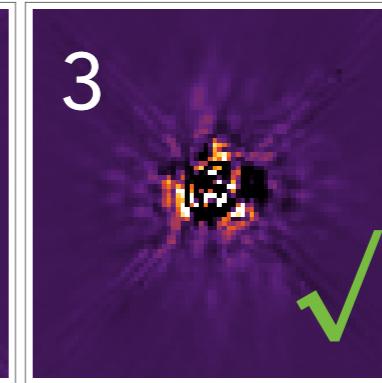
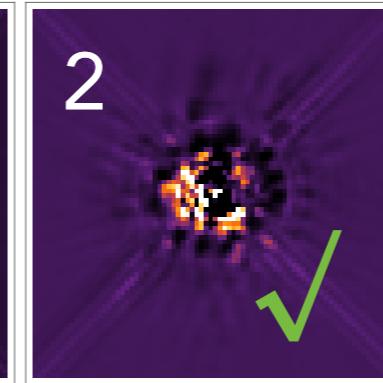
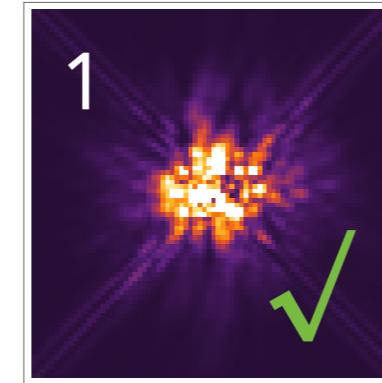
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Projection

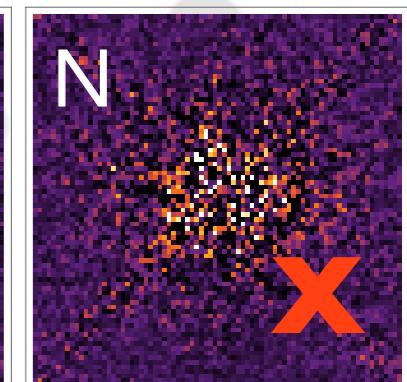
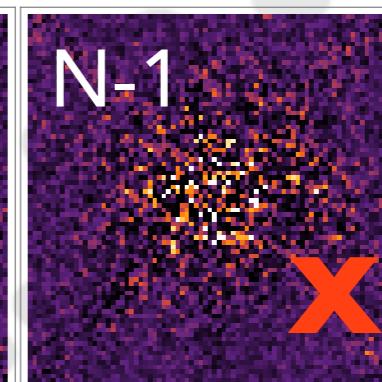
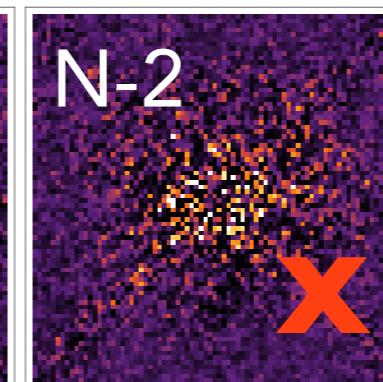
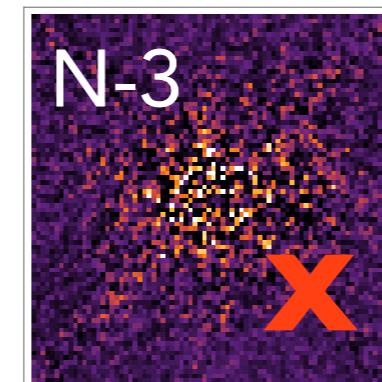
=



Principal components of the library



...



The ALICE Project

Archival **L**ibrary **I**nvestigations for **C**ircumstellar **E**nvironments

PI: Rémi Soummer (STScI)

- ▶ Consistent re-analysis of the whole NICMOS archive
- ▶ Data delivered back to the community
- ▶ <https://archive.stsci.edu/prepds/alice/>

Hagan et al. 2018



The screenshot shows the MAST homepage. At the top, there's a dark header bar with the MAST logo on the left and the text "Barbara A. MIKULSKI ARCHIVE FOR SPACE TELESCOPES" in the center. Below this is a light blue navigation bar with links for "MAST", "STScI", "Tools", "Mission Search", "Search Website", "Follow Us", "Register", and "Forum". Underneath the navigation bar is a tan-colored footer bar with links for "About MAST" and "Getting Started".

Archival Legacy Investigations of Circumstellar Environments (ALICE)

Primary Reference Document

See also (hover for titles):

[Soummer et al. \(2012\), ApJL, 755, 28](#)
[Choquet et al. \(2016\), ApJL, 817, 2](#)
[Debes et al. \(2016\), JATIS, 2a1010D](#)
[Milli et al. \(2017\), A&A, 597, 2](#)

[Soummer et al. \(2014\), ApJL, 786, 23](#)
[Mazoyer et al. \(2016\), ApJ, 818, 150](#)
[Choquet et al. \(2015\), SPIE, 9605, 1](#)

[Choquet et al. \(2014\), SPIE, 9143, 57](#)
[Soummer et al. \(2011\), ApJ, 741, 55](#)
[Milli et al. \(2015\), A&A, 577, 57](#)

[Rajan et al. \(2015\), ApJL, 809, 33](#)
[Choquet et al. \(2017\), ApJL, 834, 12](#)
[Choquet et al. \(2014\), SPIE, 9147, 51](#)

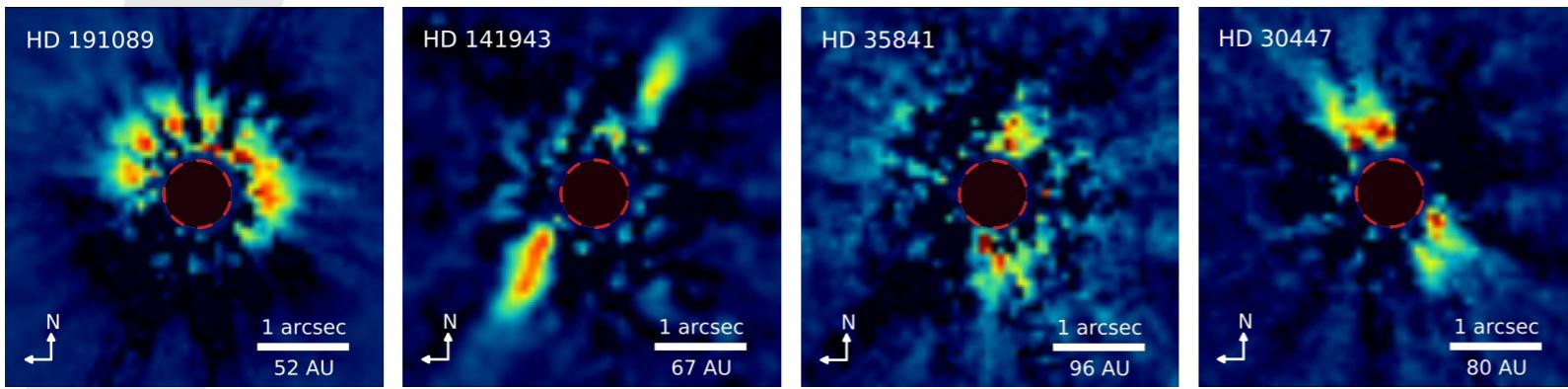
[Introduction](#)

[Data Products](#)

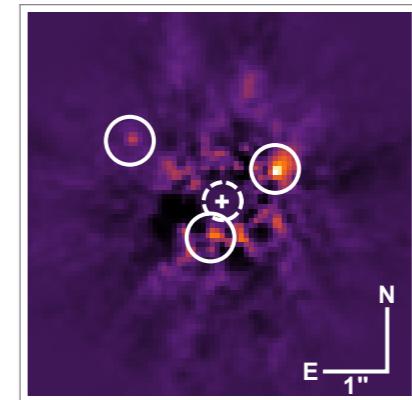
[Data Access](#)

Detection gallery

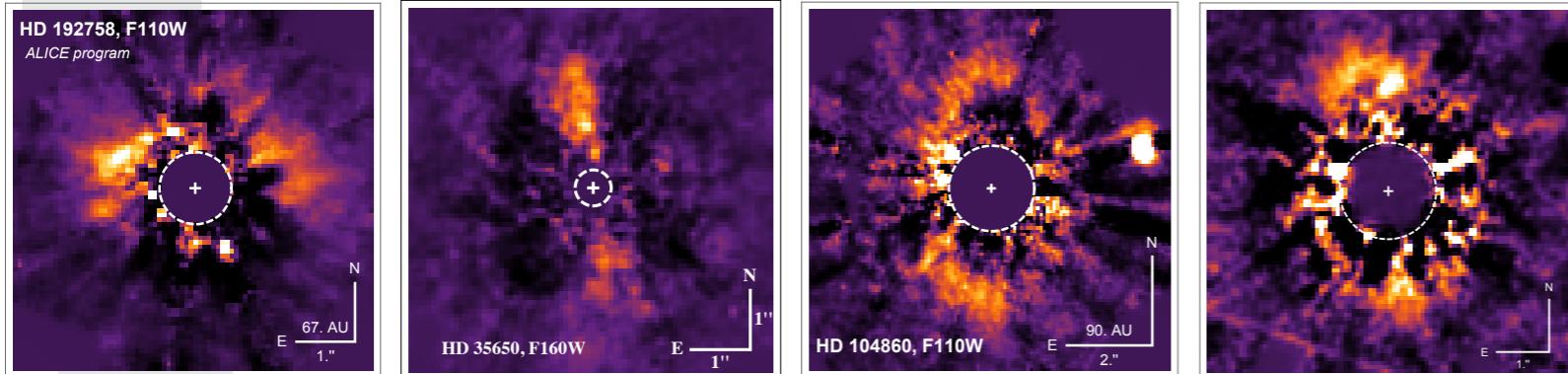
New Debris Disks



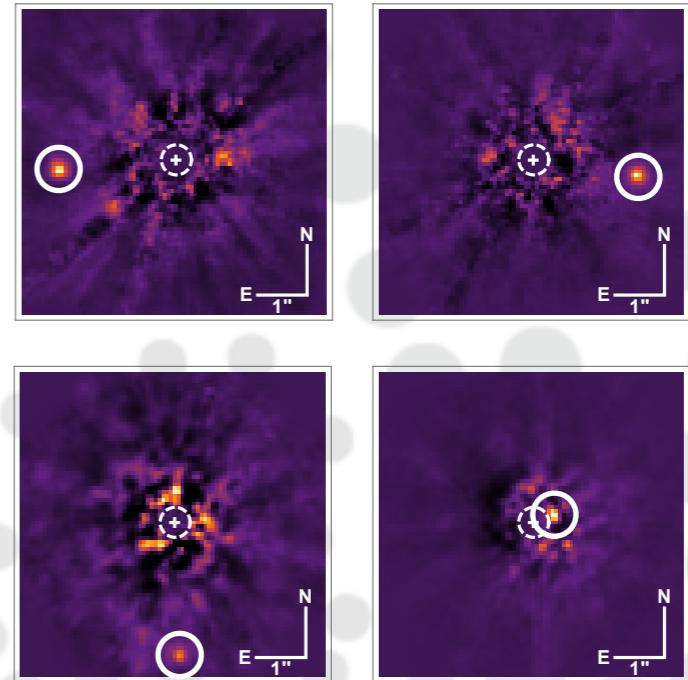
Known Planets (HR 8799)



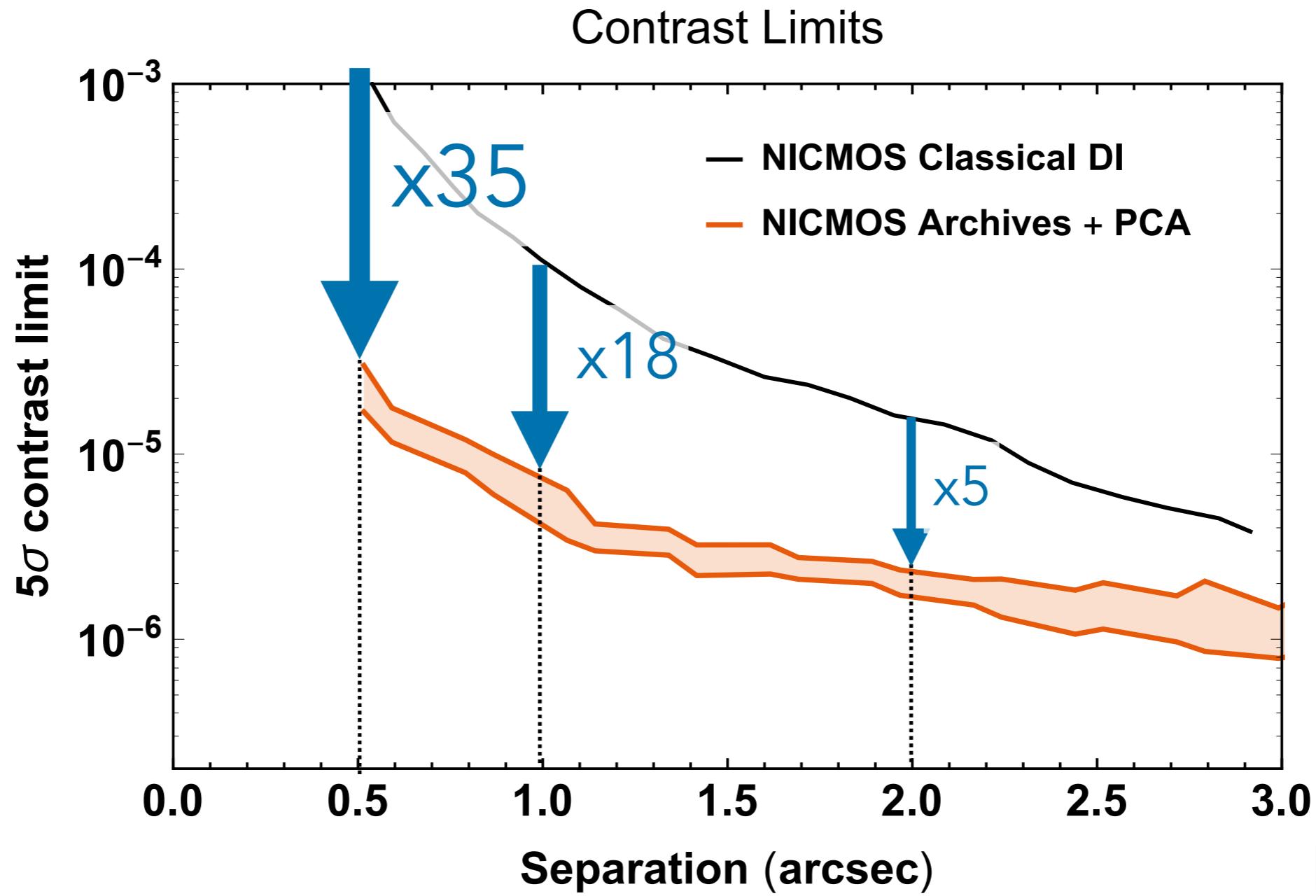
Soummer et al. 2011
Soummer et al. 2014
Choquet et al. 2016
Choquet et al. 2017
Choquet et al. 2018
Marshall et al. 2018



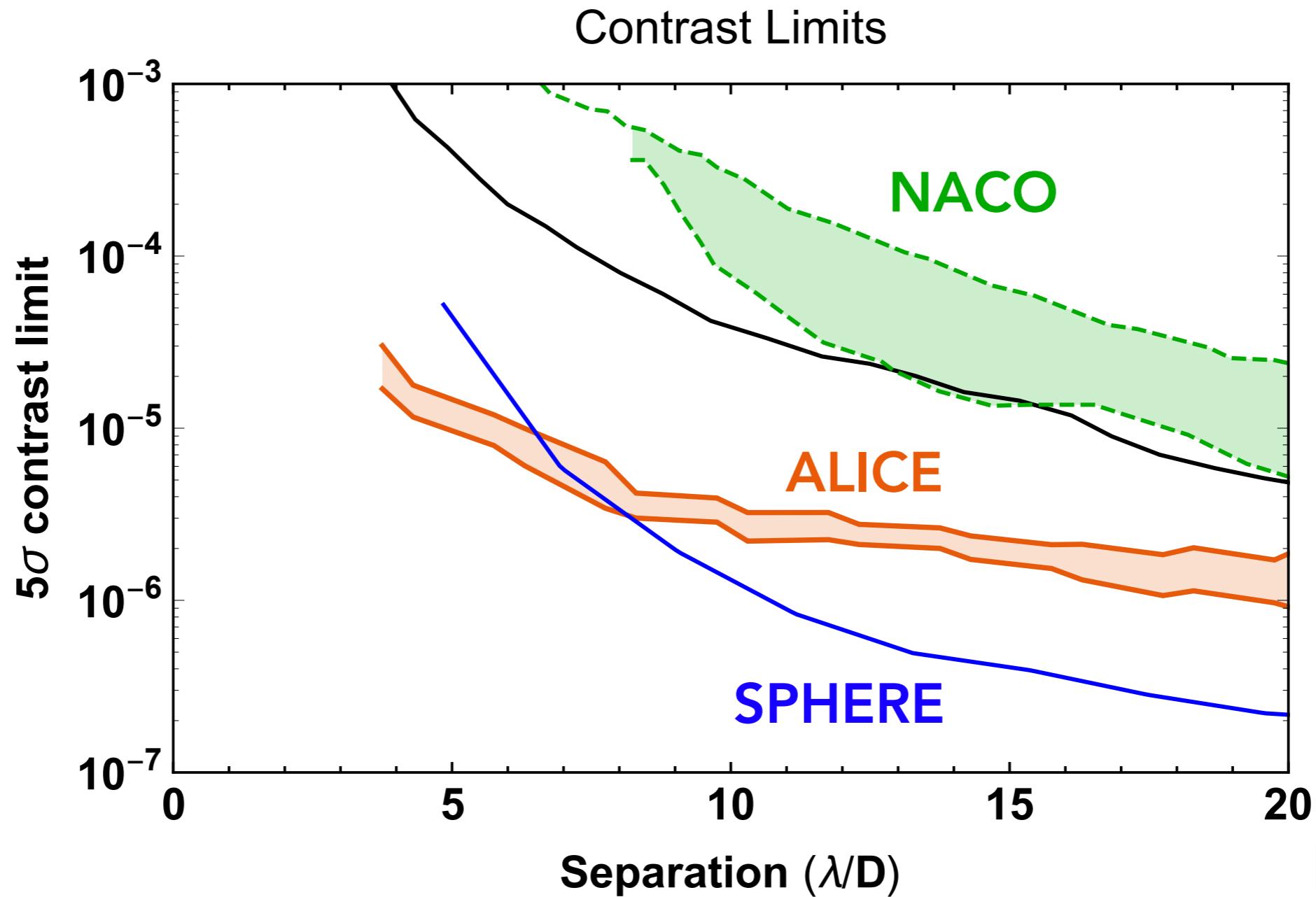
Many new candidates



Improved detection limits



Improved detection limits



Summary

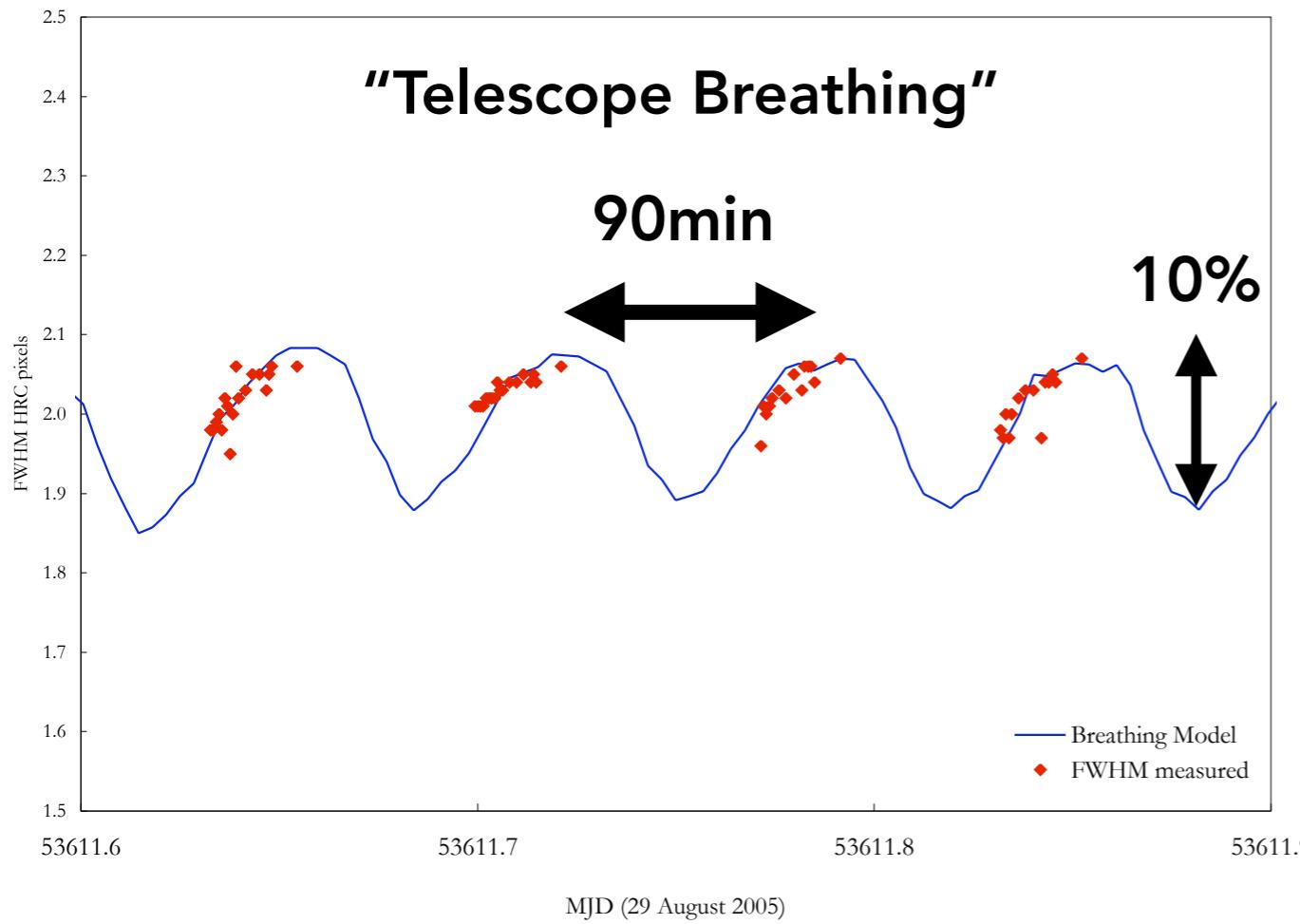
- ▶ Successful mining of the HST archives
- ▶ Project to apply the method to VLT-SPHERE archives
 - ▶ More temporal diversity (atmosphere)
 - ▶ More data in the archives (short exposures)
 - ▶ More contextual data (WFS, DIMM-MASS)

END

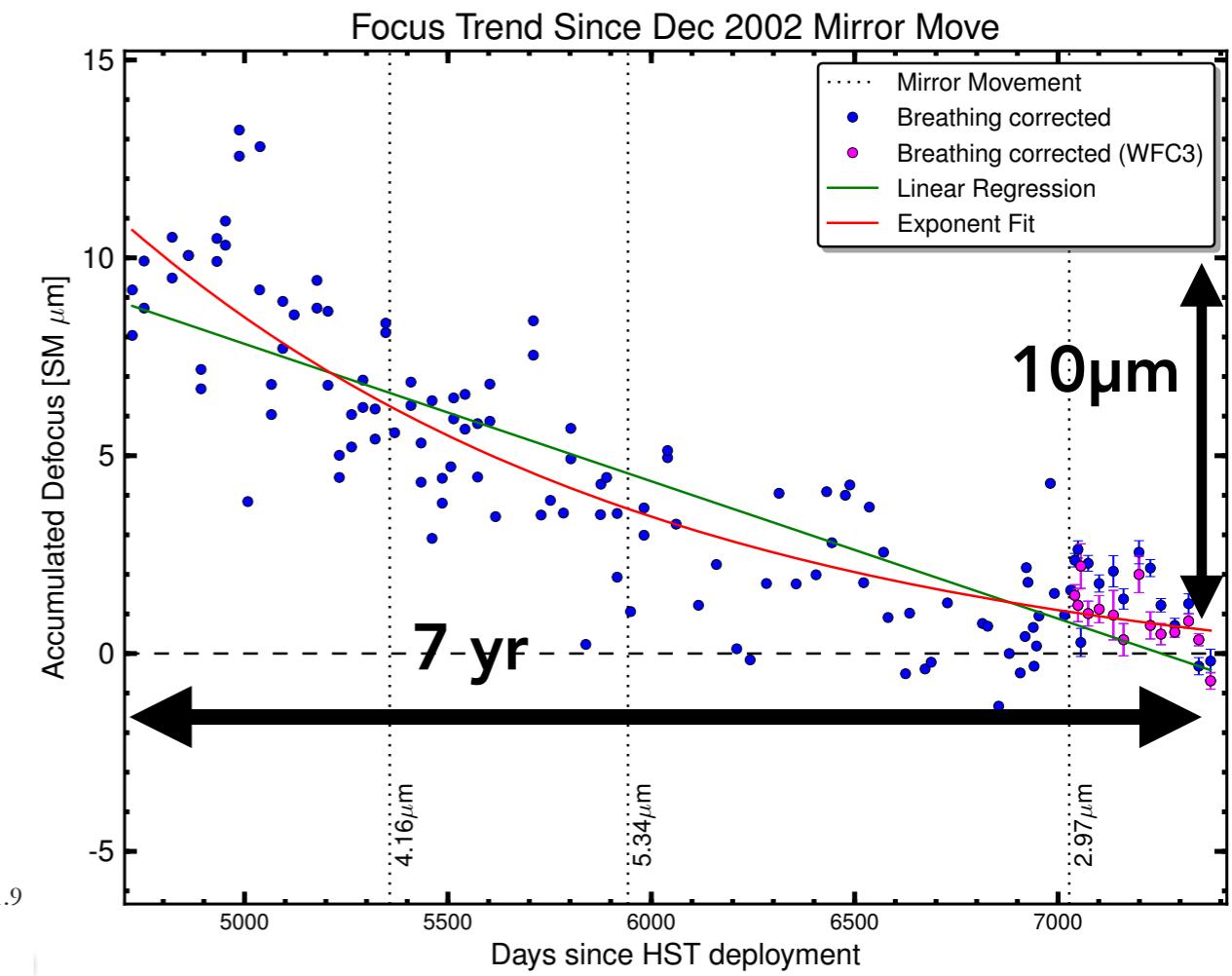
Data Processing Challenges

PSF temporal variations

Short term FWHM oscillations



Long term focus drift



Lallo et al. 2006