# Data Mining
the **Hubble Archives**
to **image Extrasolar Systems**

Elodie Choquet

Direct Imaging of exoplanetary systems

## Planets Dynamics

2009-07-31

20 au
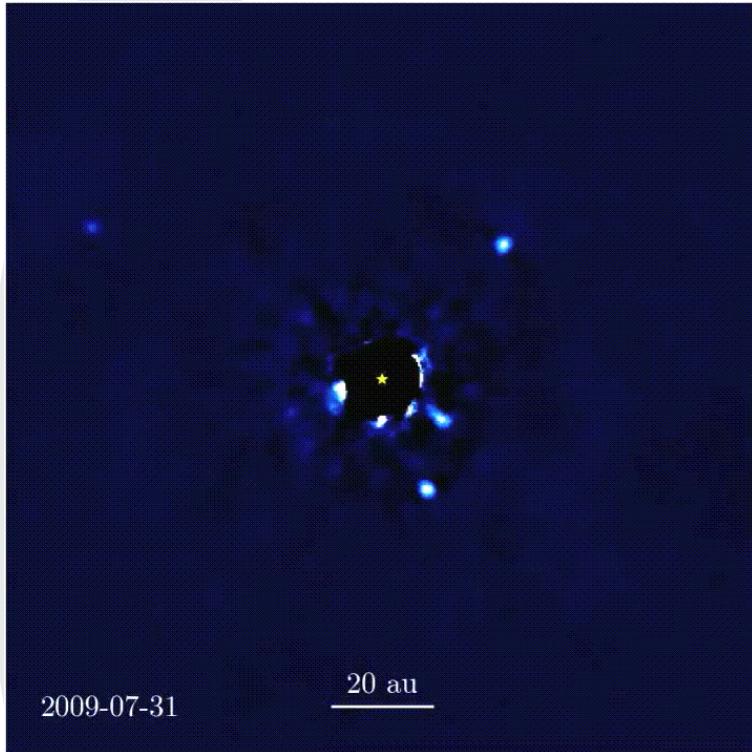
Courtesy J. Wang

Planet Atmospheres
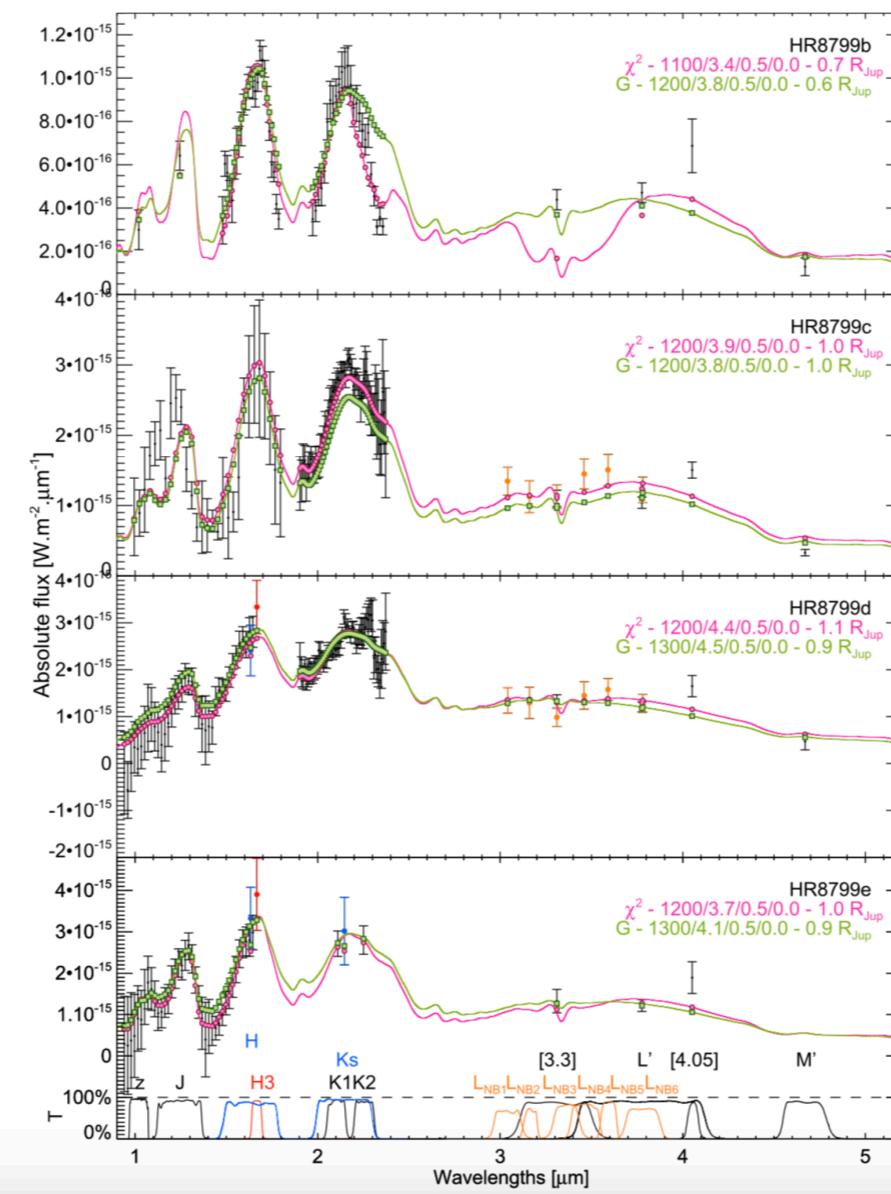
Bonnefoy et al. 2016

Planet Formation
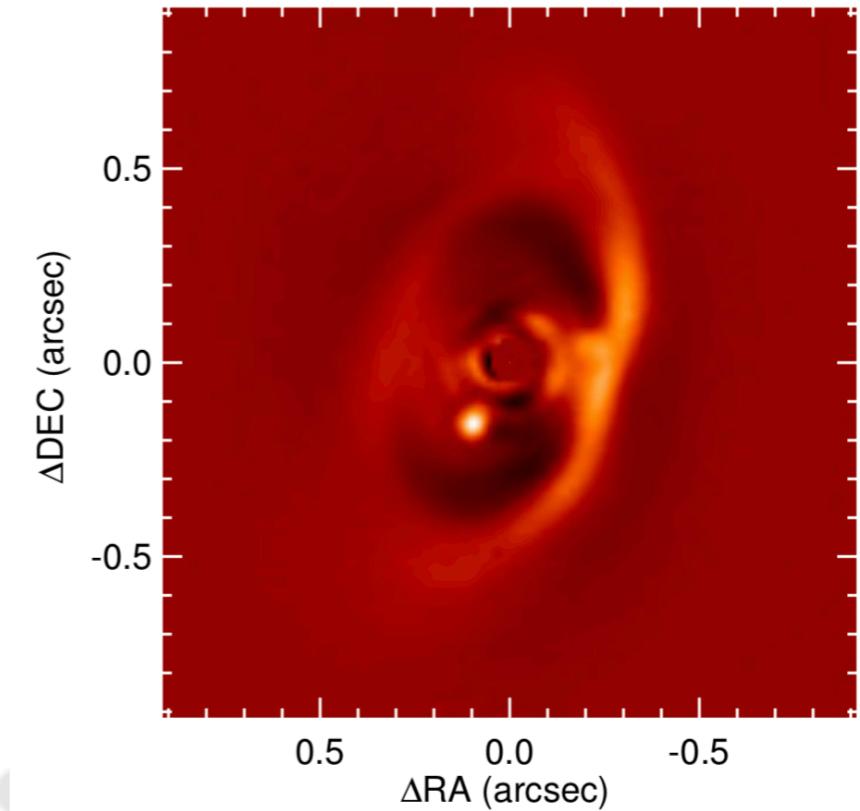
Müller et al. 2018

# Direct Imaging: Challenges

Extreme contrast ratio…

SAO Solar System Model at 10 PC

Star

10^9

Planet

10^6
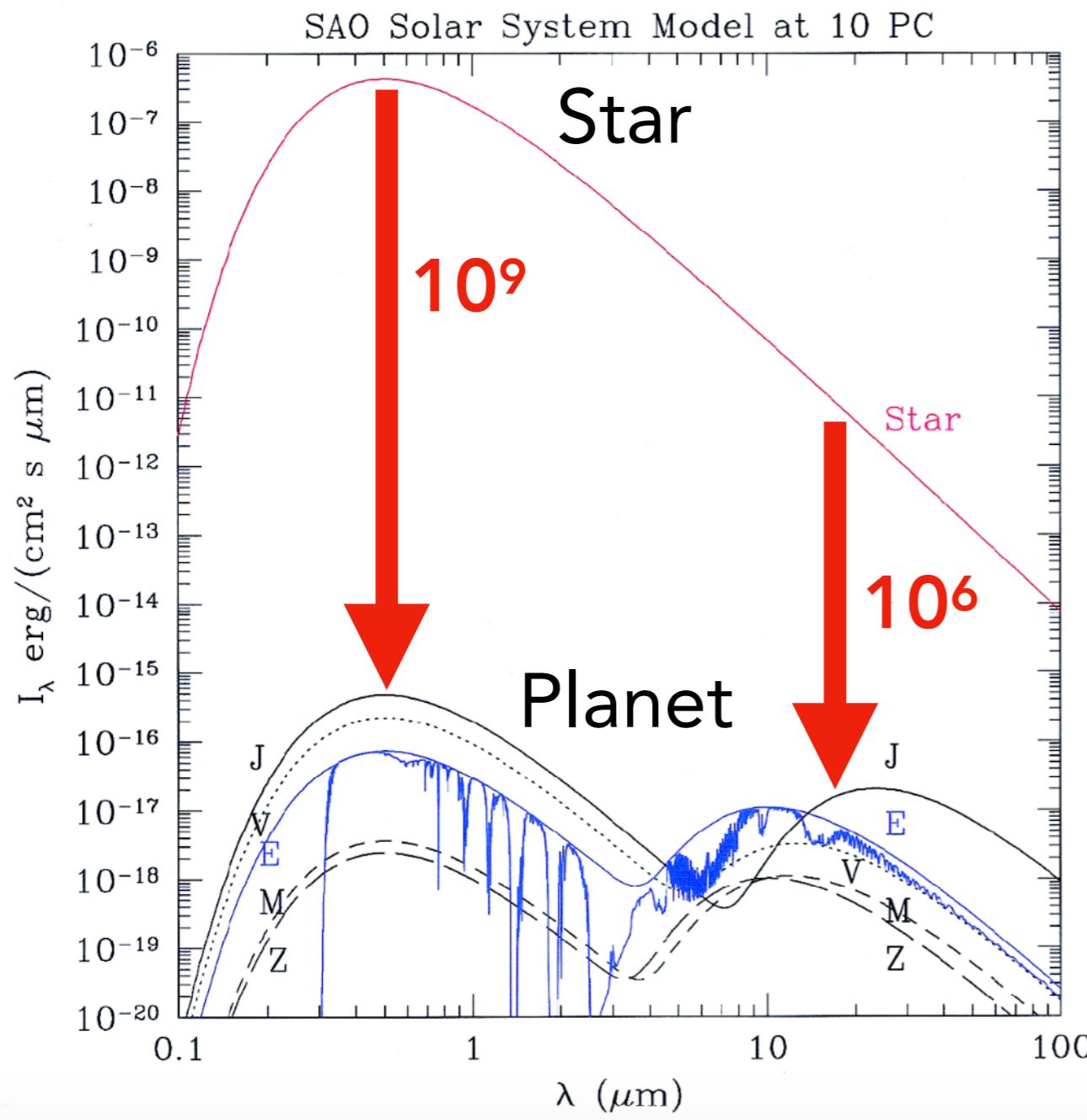
Des Marais et al. 2002

… at Small Separations

10 AU at 50 pc => 0.2″

VLT @2µm => λ/D = 0.05″
HST @1µm => λ/D = 0.09″

2″
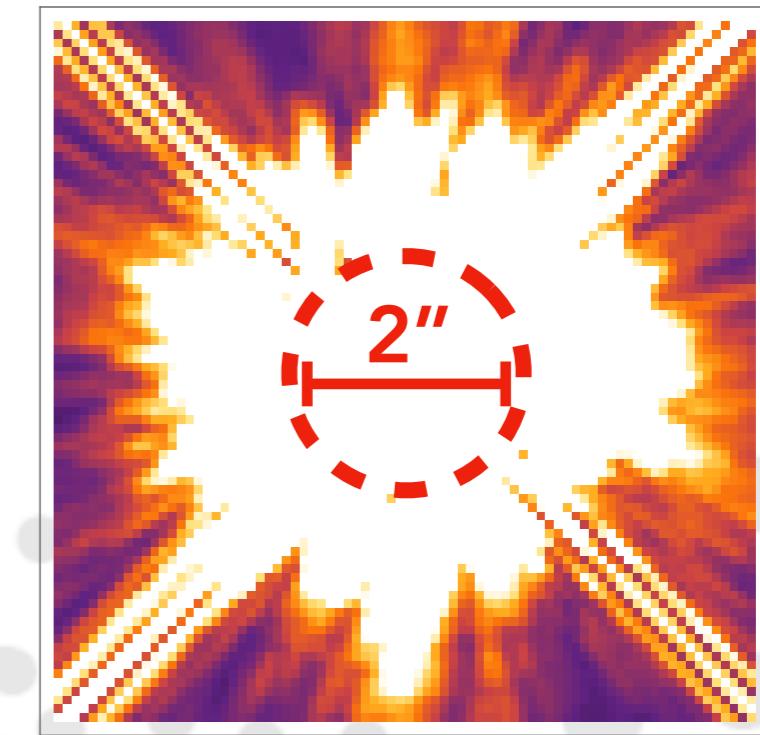
HST, NICMOS

Direct Imaging: Challenges

Extreme contrast ratio…   … at Small Separations

SAO Solar System Model at 10 PC

=> 0.2"

= 0.05"

= 0.09"

Data Processing Critical

HST, NICMOS

Des Marais et al. 2002
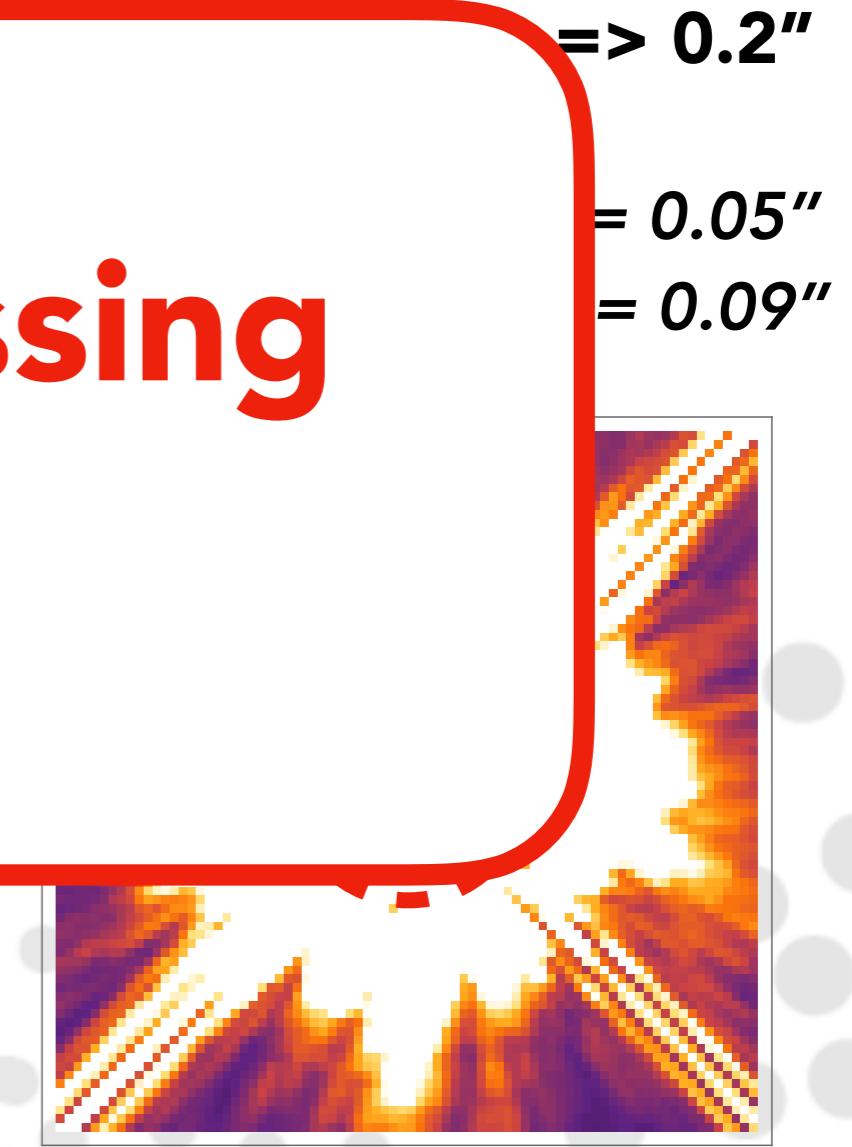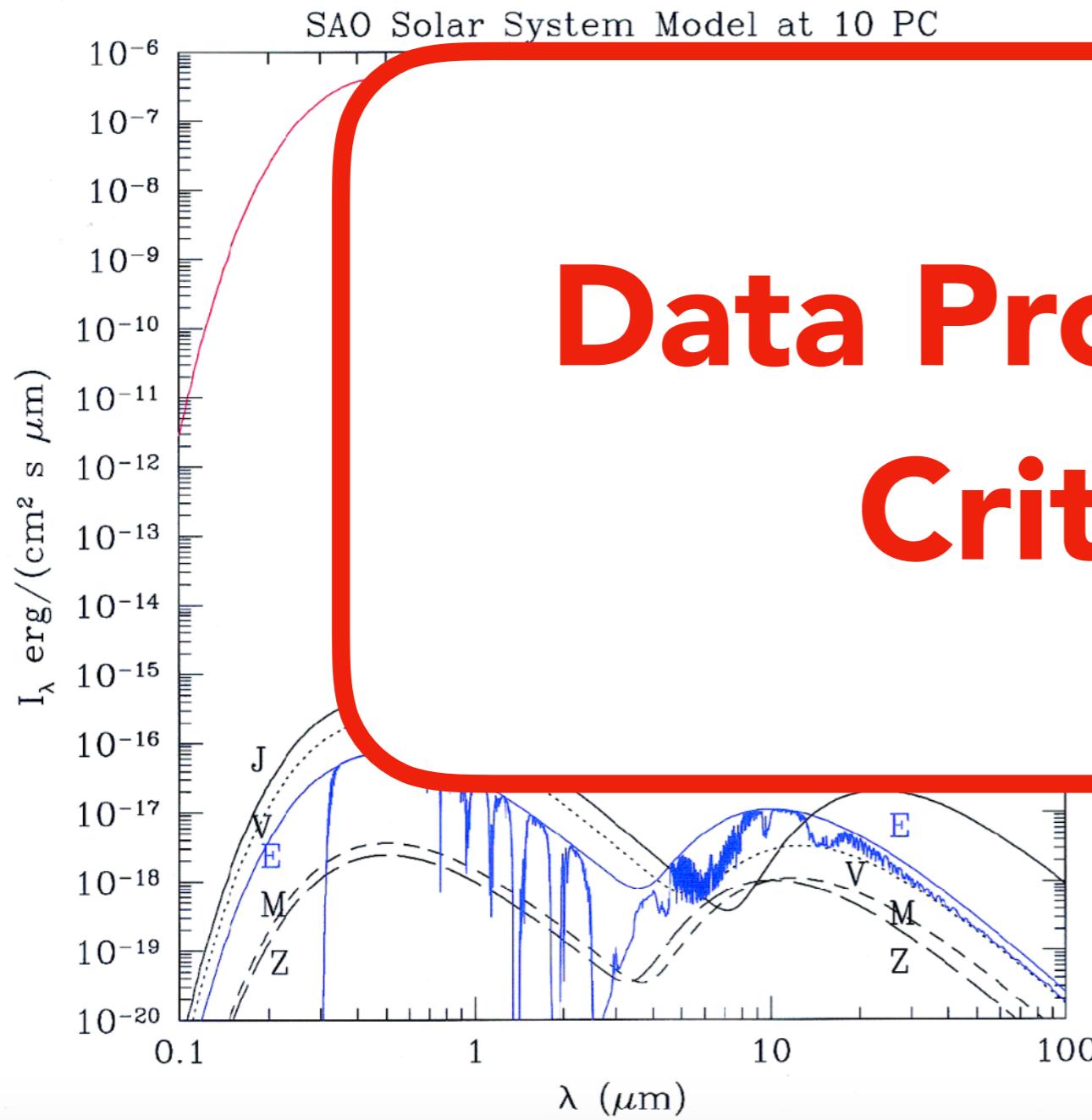
Data Processing Method

Differential Imaging (DI)
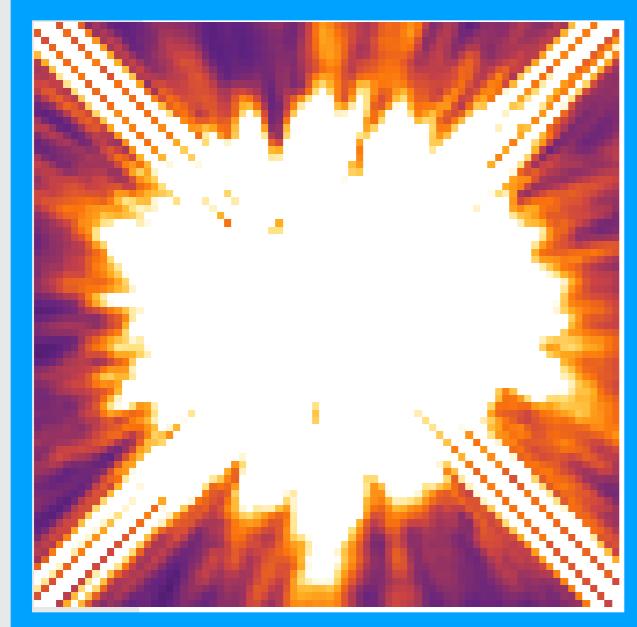
Science Image   **PSF Image**   **Residual Image**
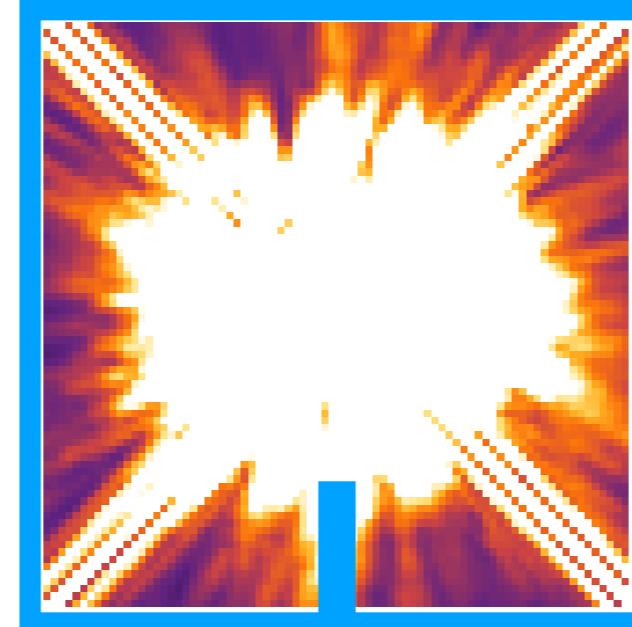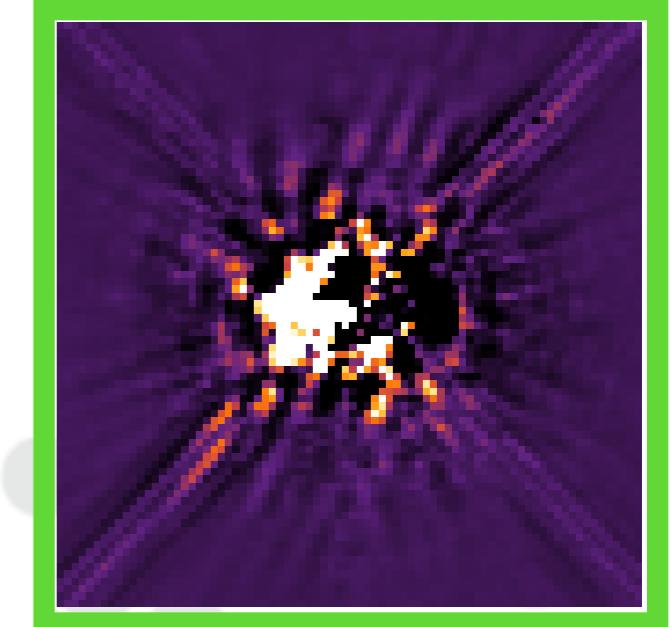
Reference Star

Science Star with Scene Rotated

Data Processing Method

Differential Imaging (DI)
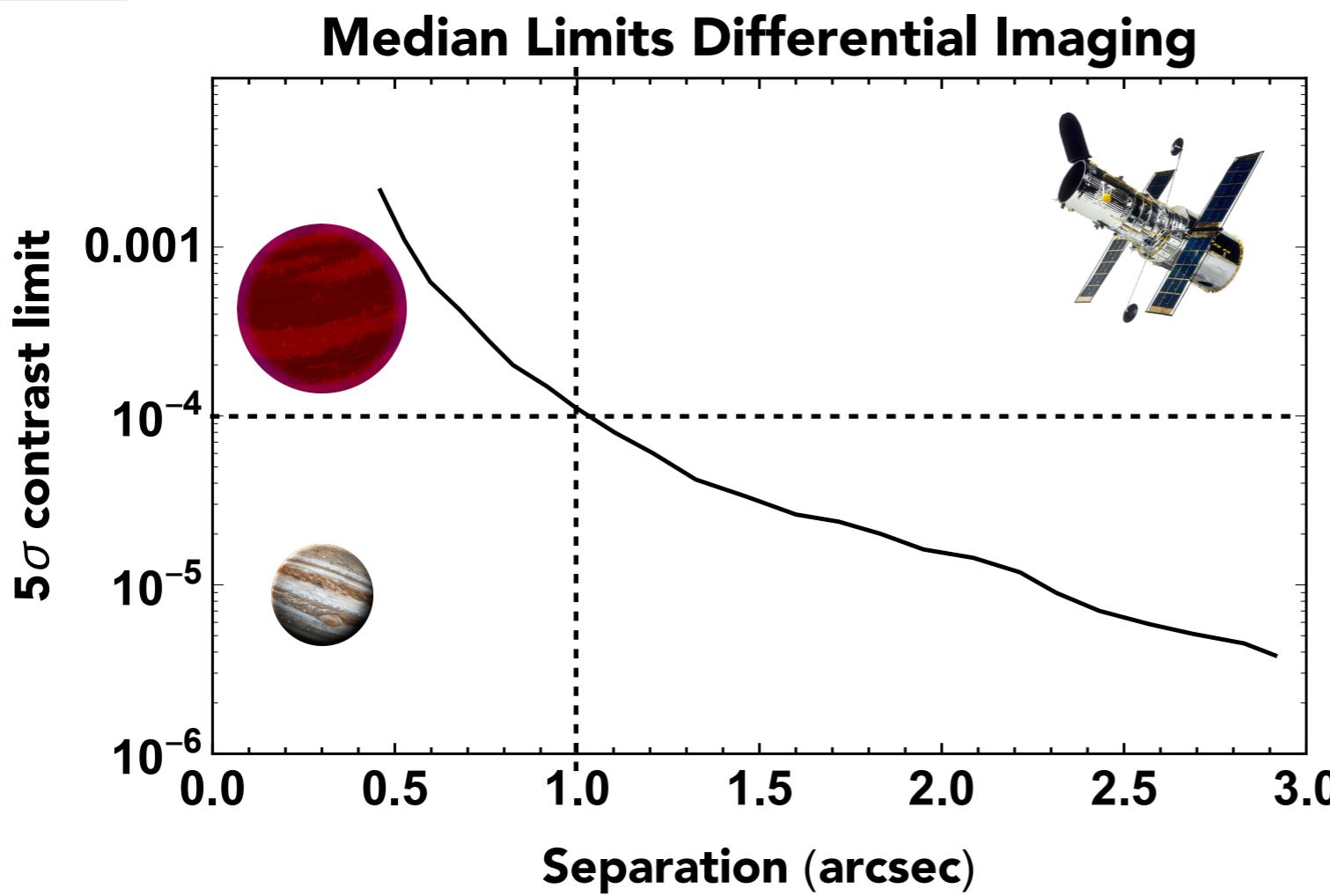
Lowrance et al. 2005
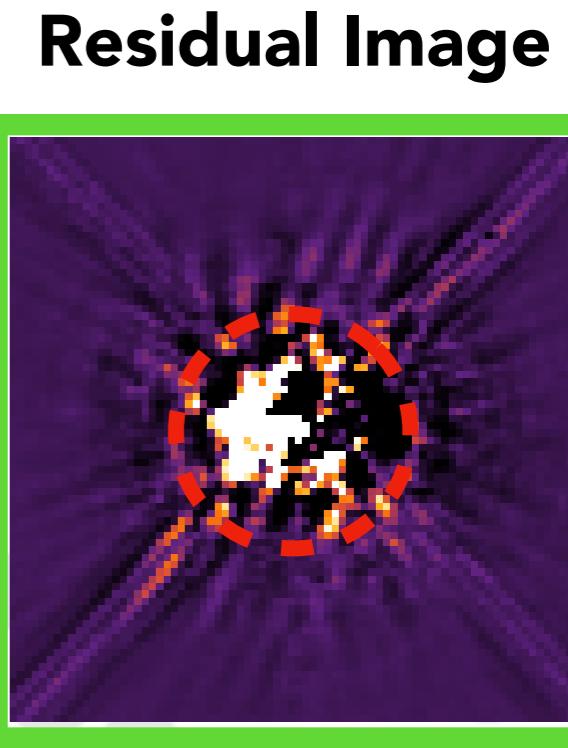
Data Processing Challenges
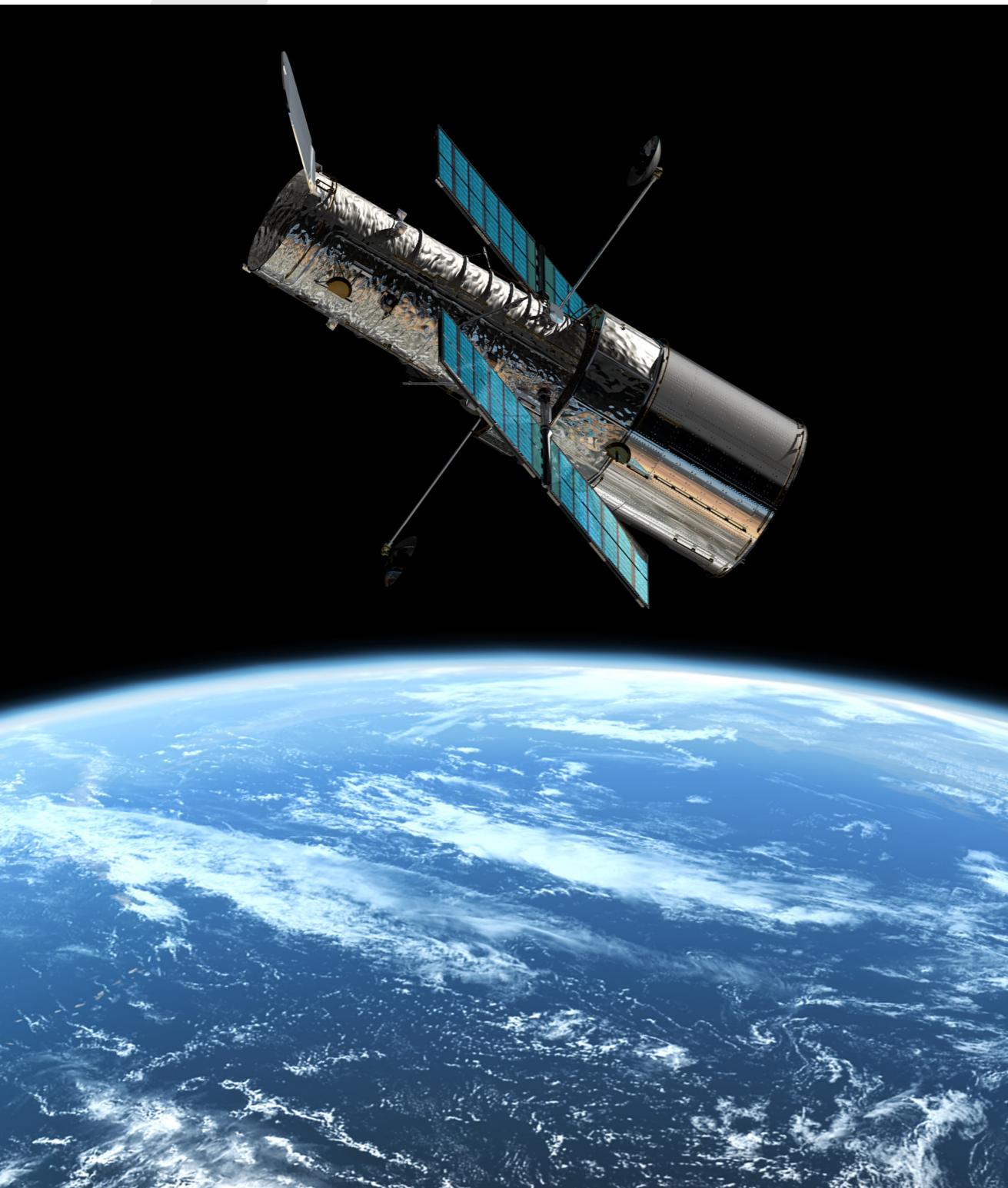
PSF temporal variations

Short term FWHM oscillations

"Telescope Breathing"

90min

10%

Lallo et al. 2006

©ESA
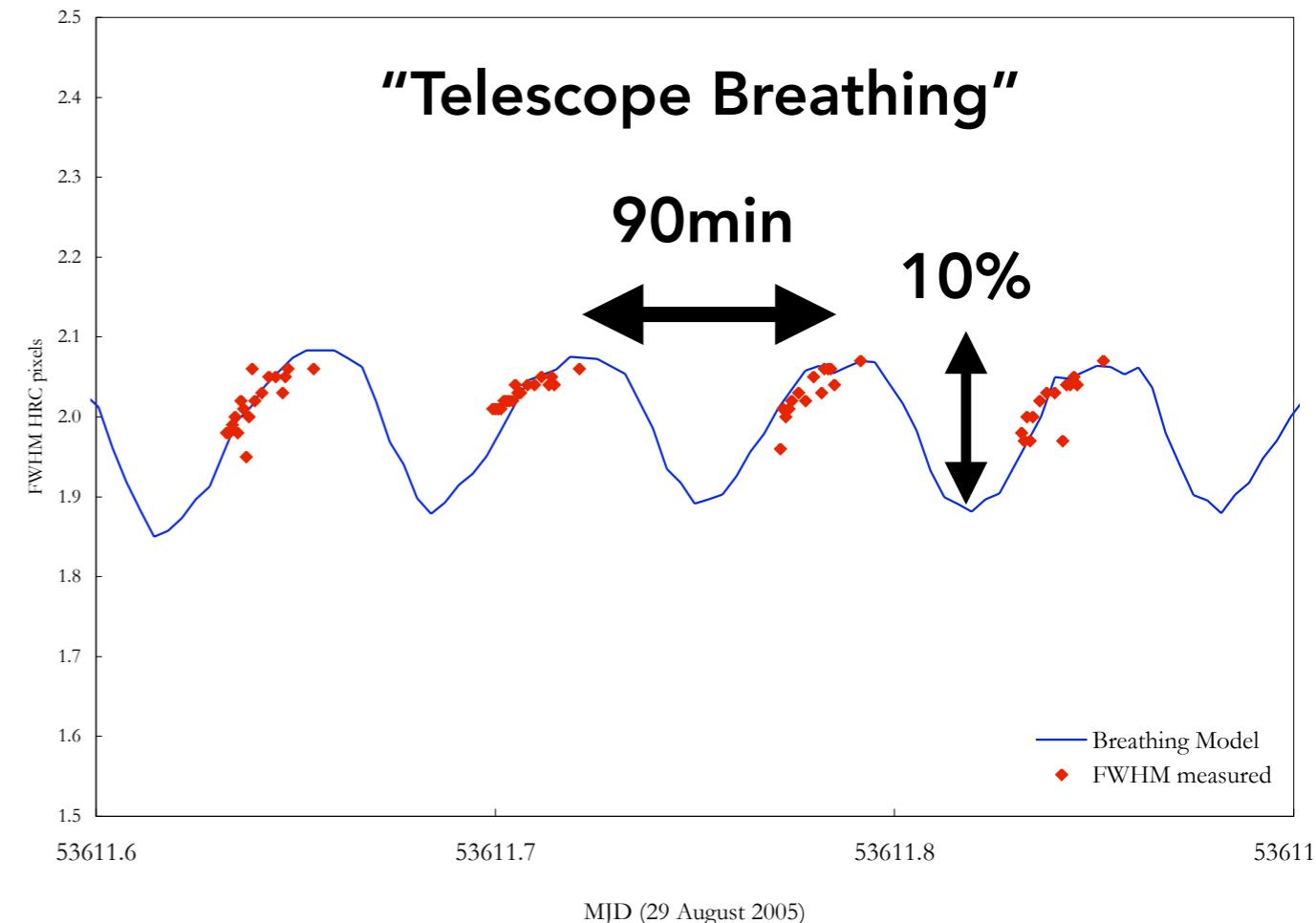
Mining the Hubble Archives

HST Coronagraphs
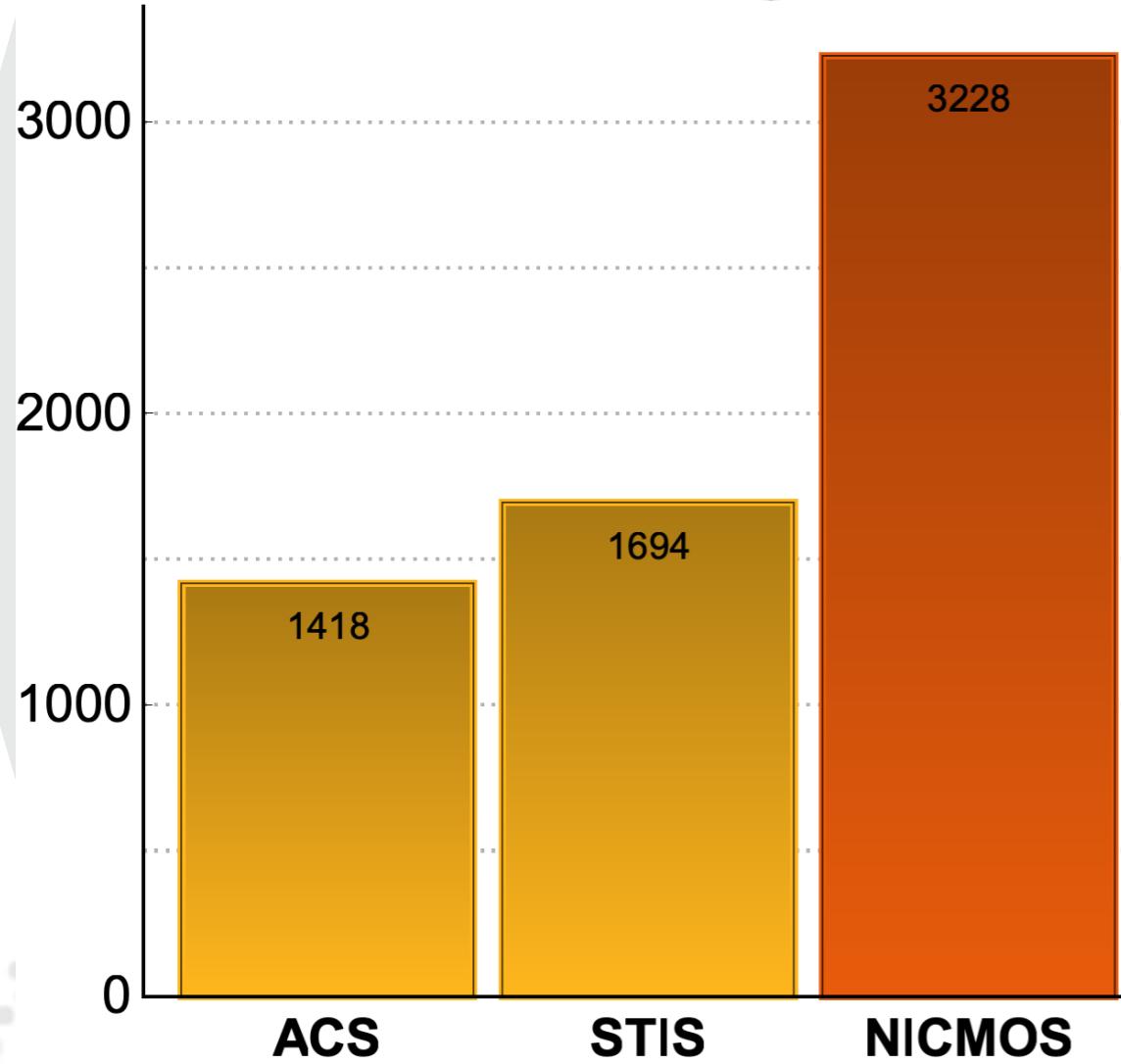
The NICMOS instrument

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

▸ 400 targets observed
▸ Goals: Planets, disks
▸ *5600 images*

Archival PSF libraries
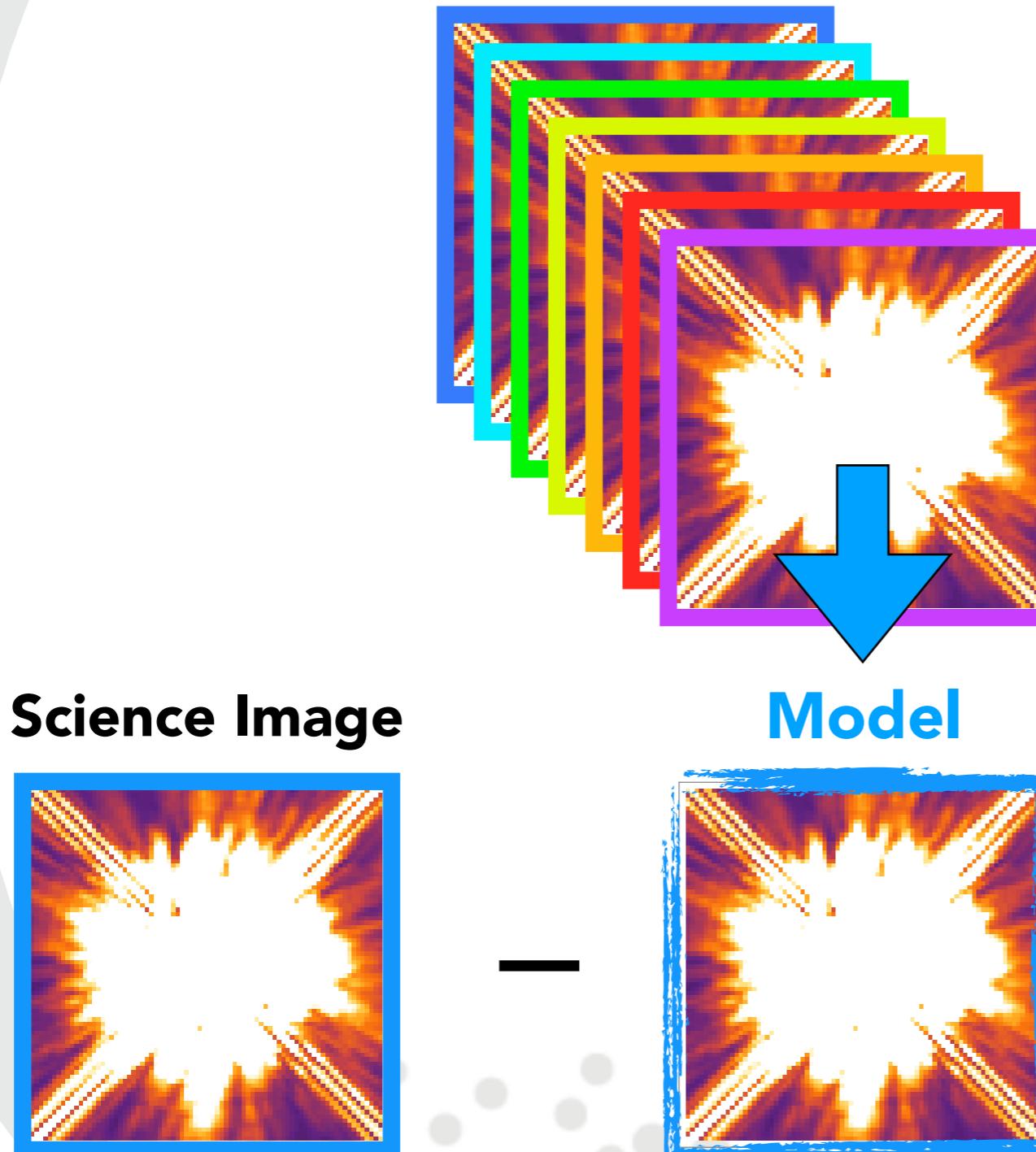
Archival Library

▶ 10^2 Reference stars

▶ 10^3 PSF images

▶ Samples tmp variations

Science Image   **Model**   **Residual Image**
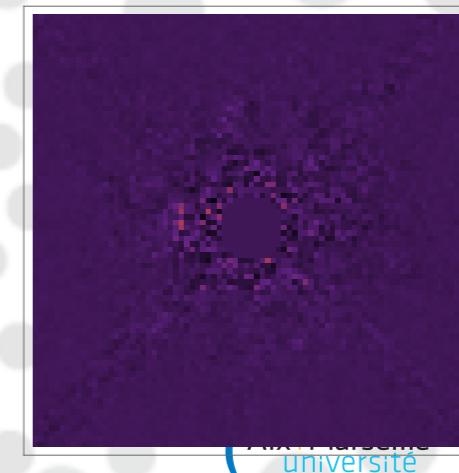
Principal Component Analysis (PCA)

Machine Learning Algorithm to create the PSF Model
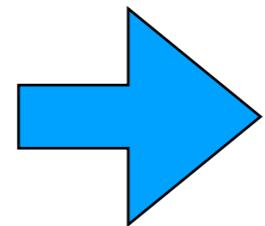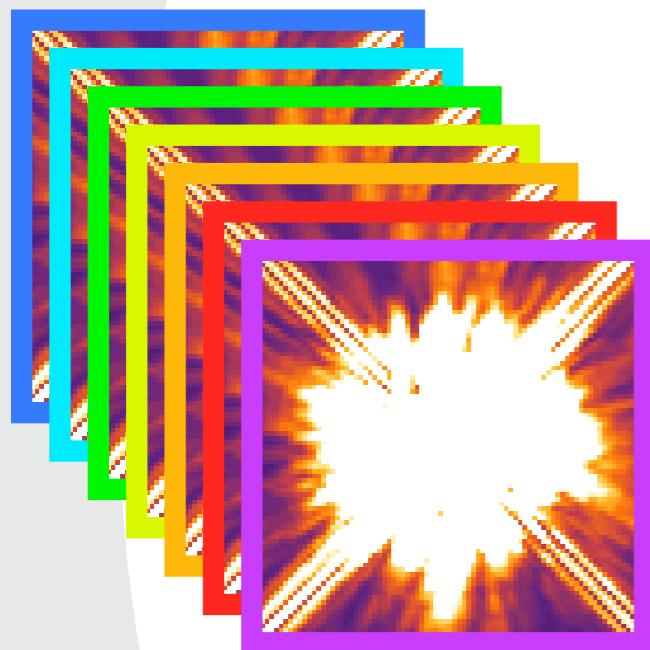
Principal components of the library

Soummer et al. 2012

Principal Component Analysis (PCA)

Machine Learning Algorithm to create the PSF Model
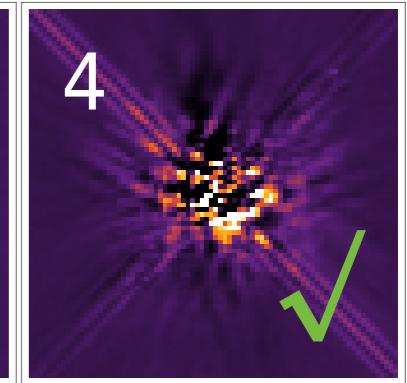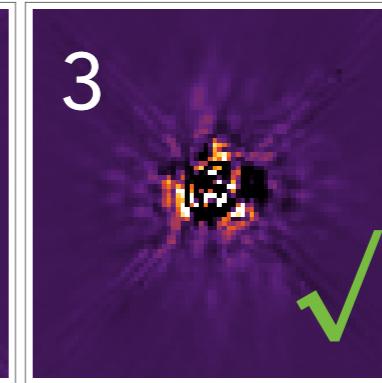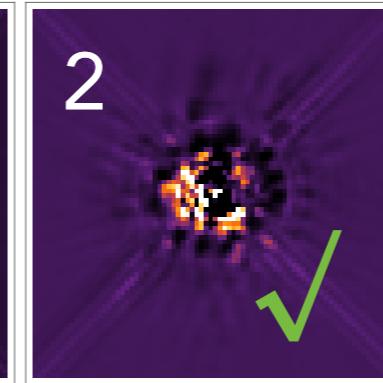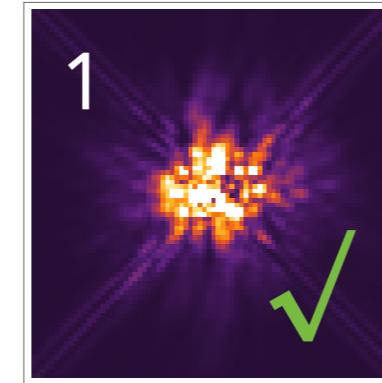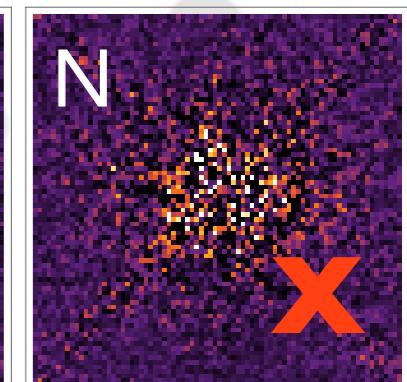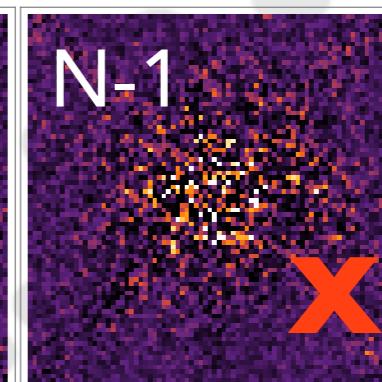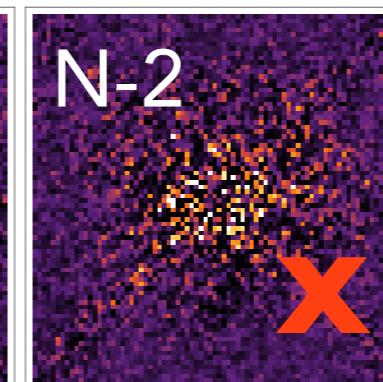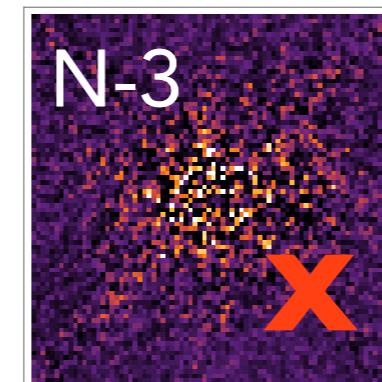
The ALICE Projet

Archival Library Investigations for Circumstellar Environments

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

Detection gallery

New Debris Disks
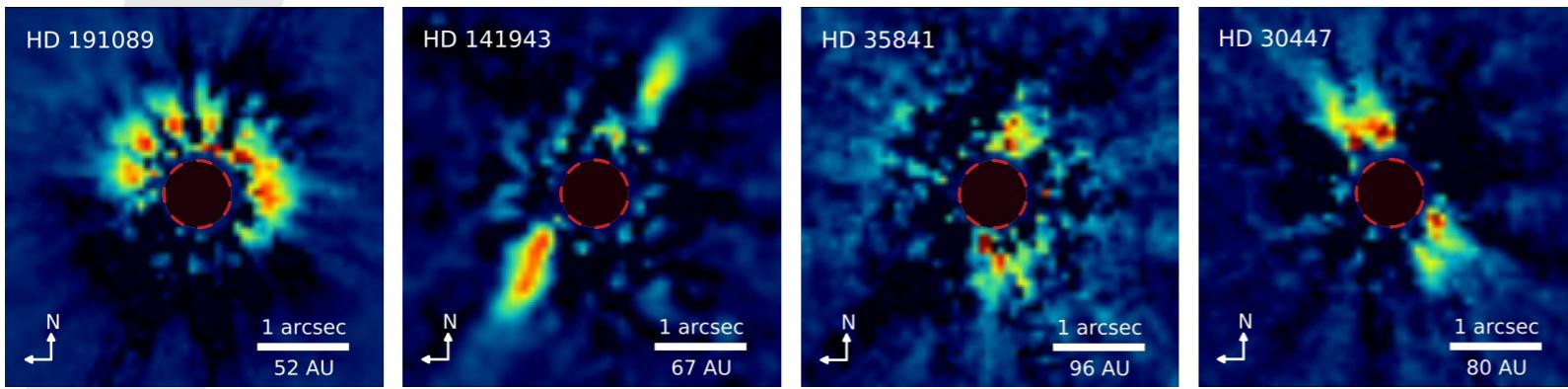
Known Planets (HR 8799)
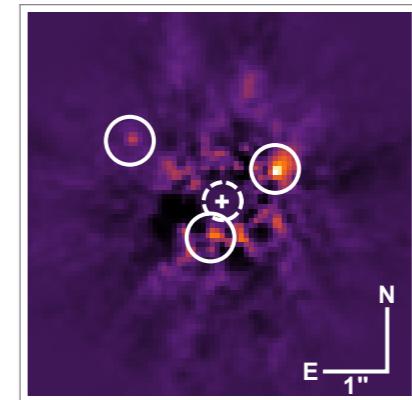
Soummer et al. 2011
Soummer et al. 2014
Choquet et al. 2016
Choquet et al. 2017
*Choquet et al. 2018*
Marshall et al. 2018
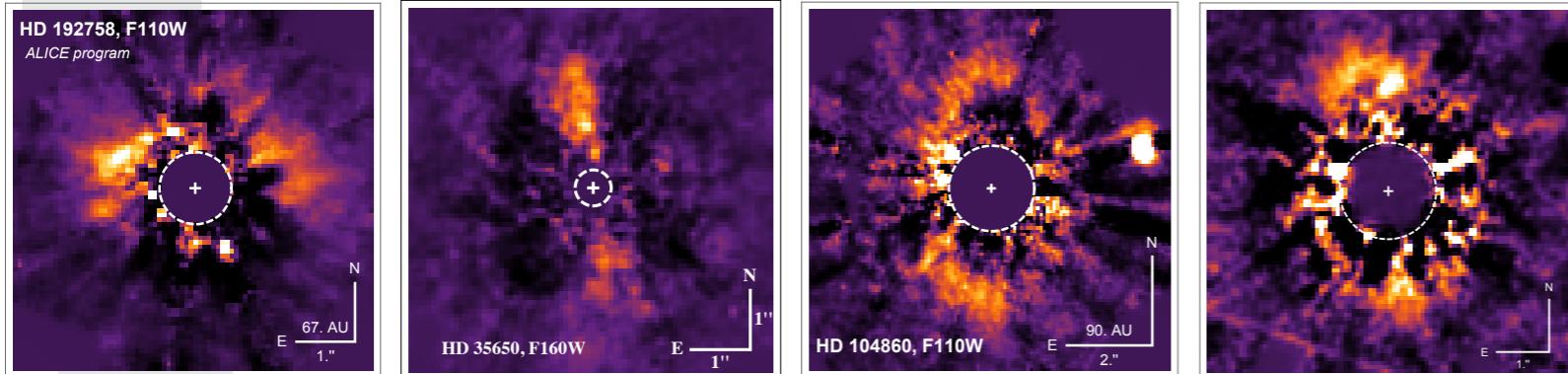
Many new candidates

Improved detection limits

Contrast Limits

Improved detection limits

Contrast Limits

NACO

ALICE

SPHERE

In λ/D units

5σ contrast limit vs Separation (λ/D)
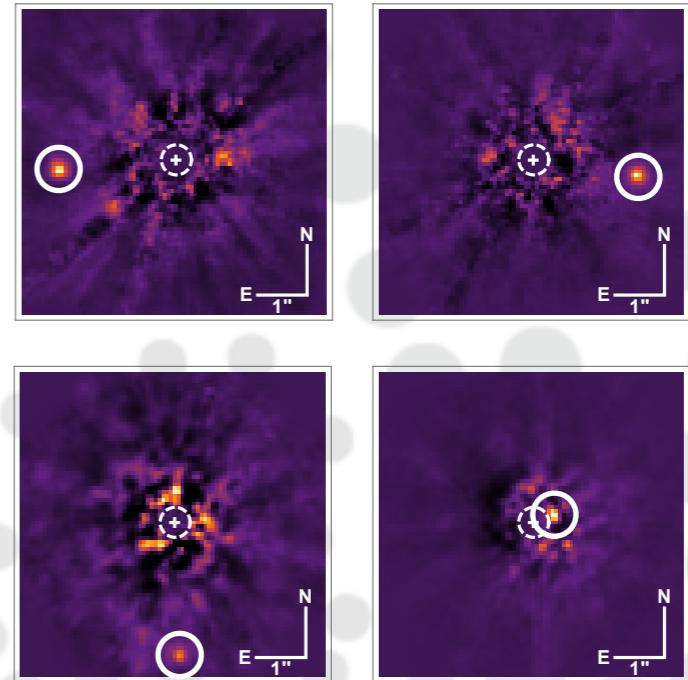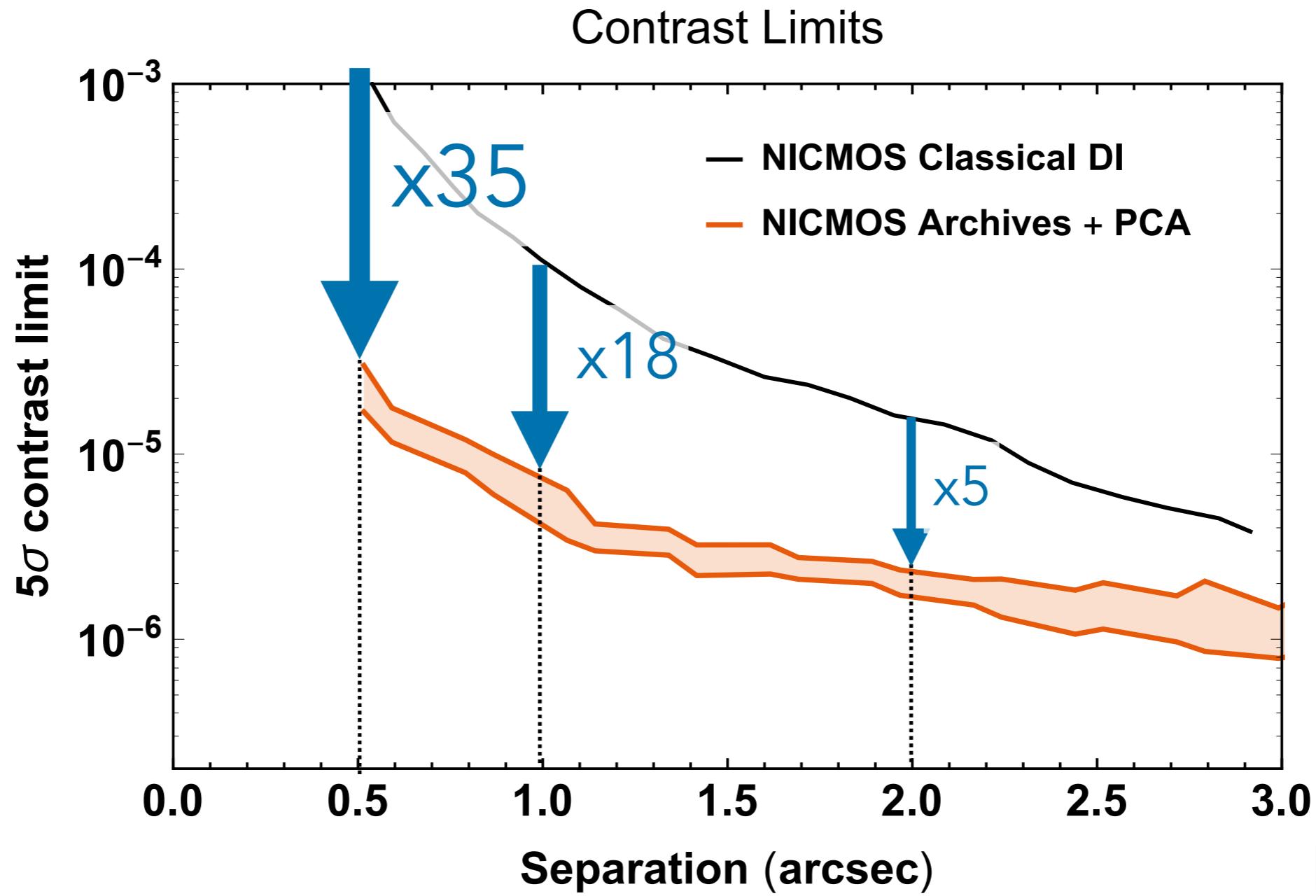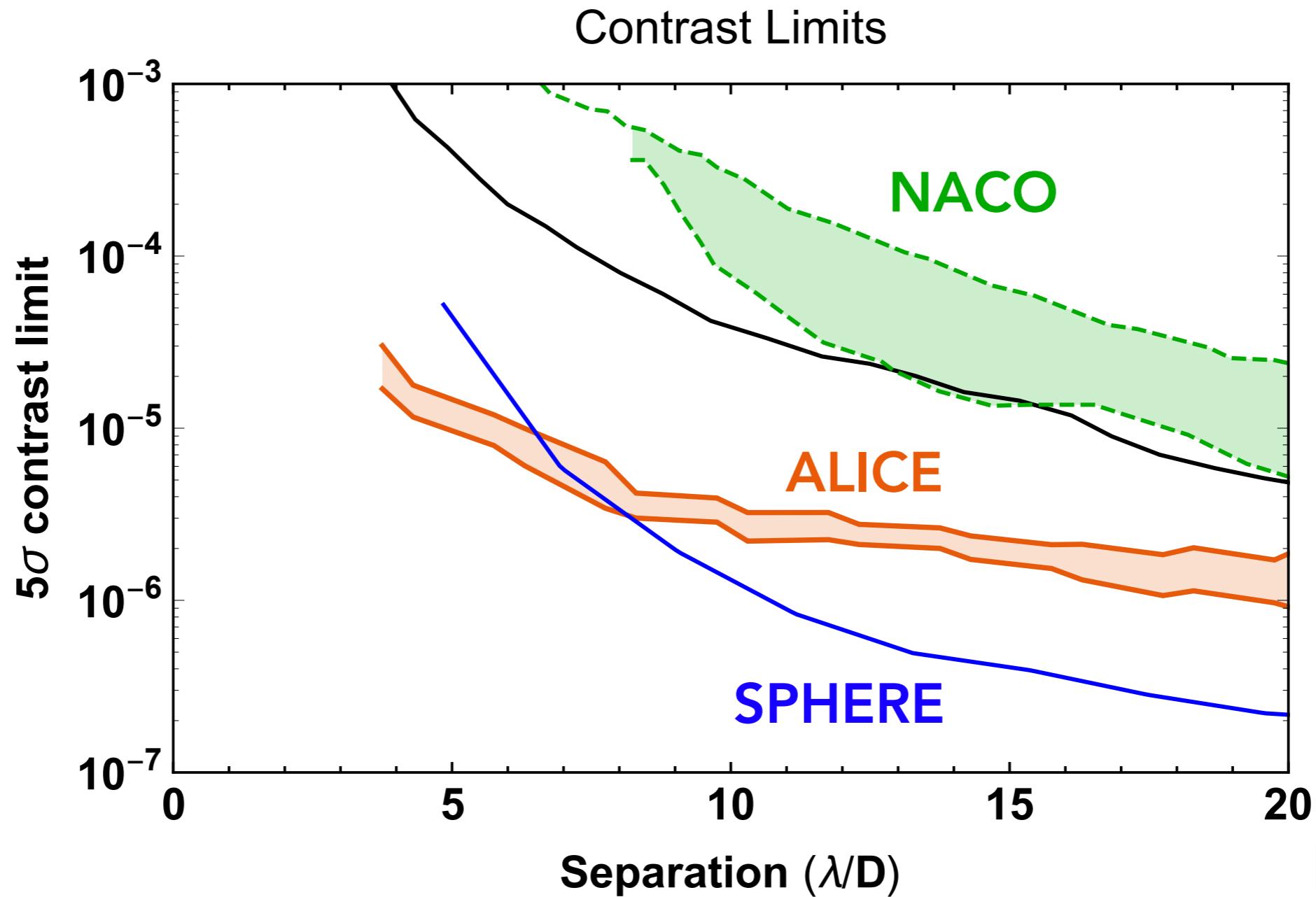
Summary

▸ 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
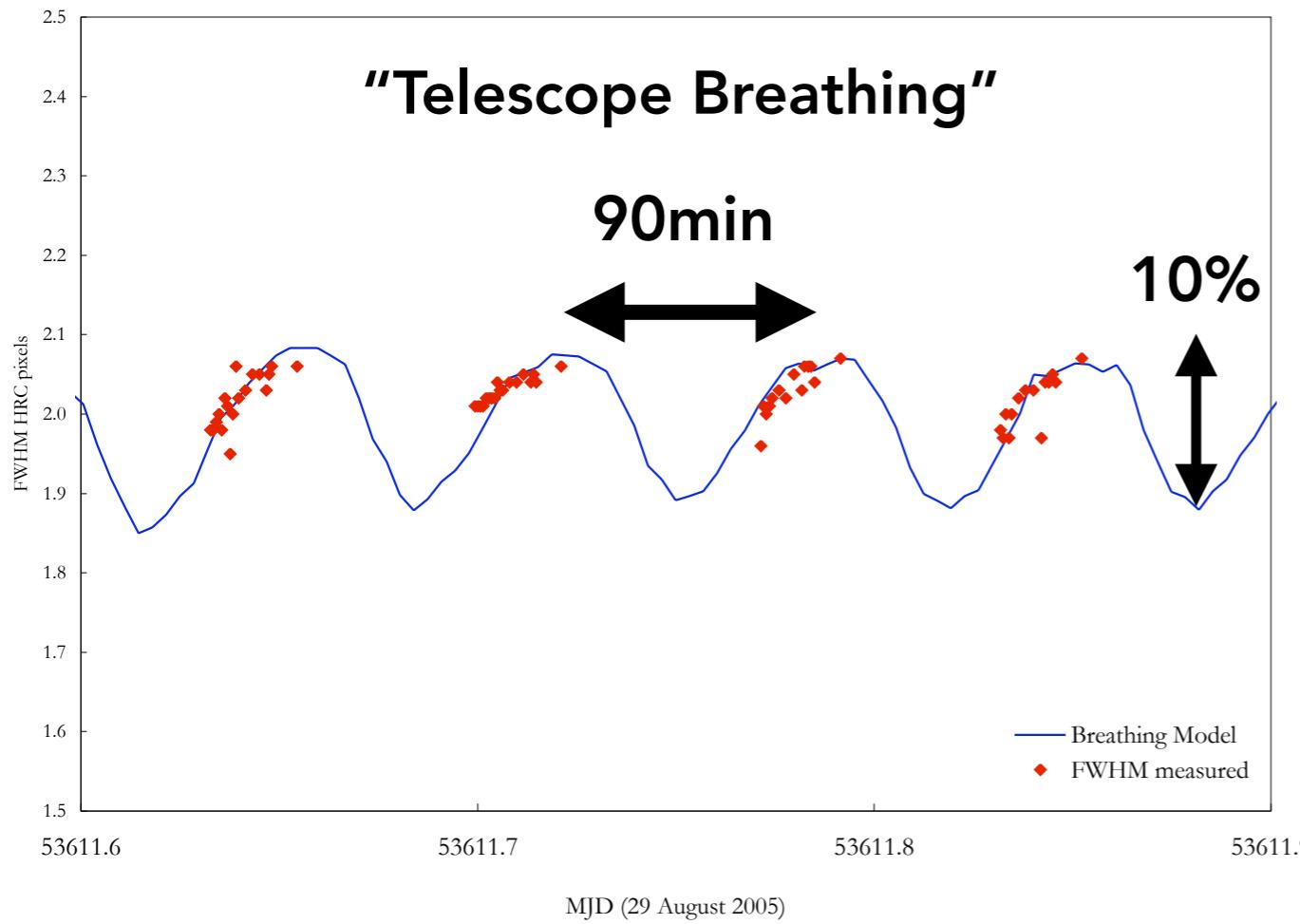
Long term focus drift

Lallo et al. 2006