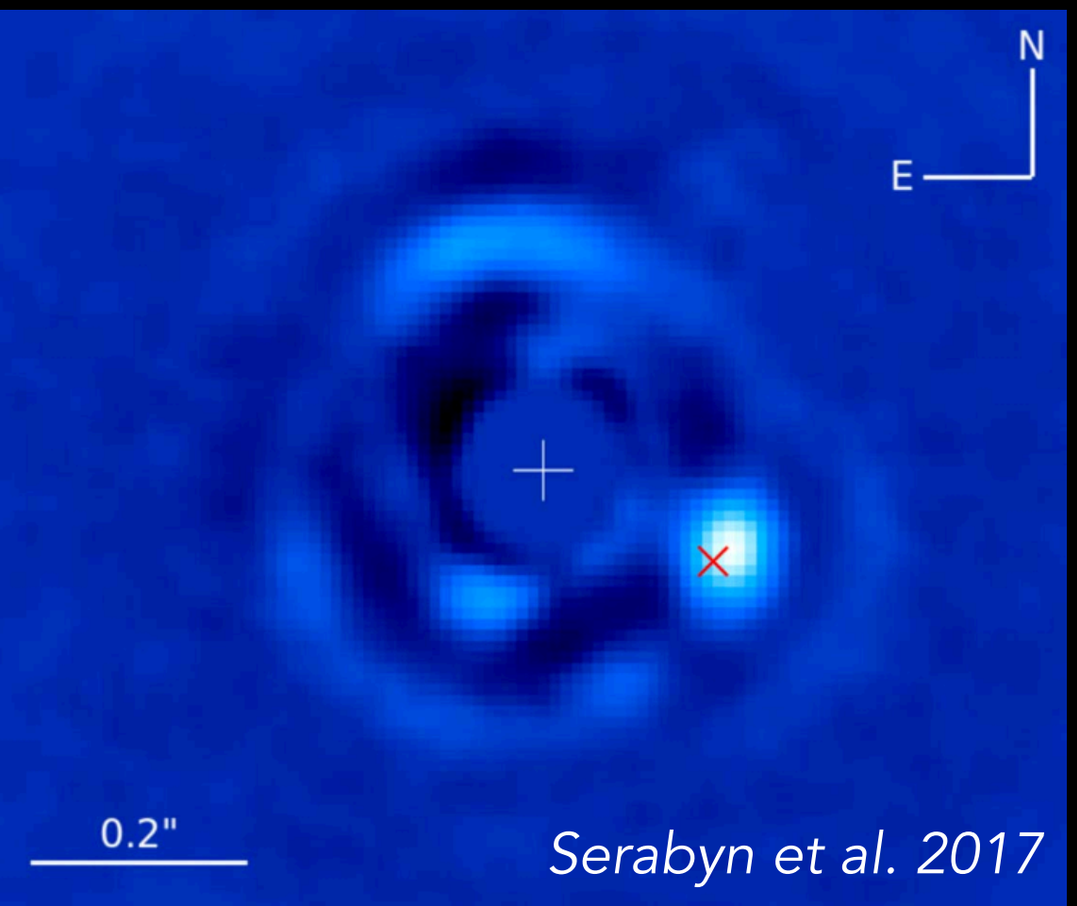
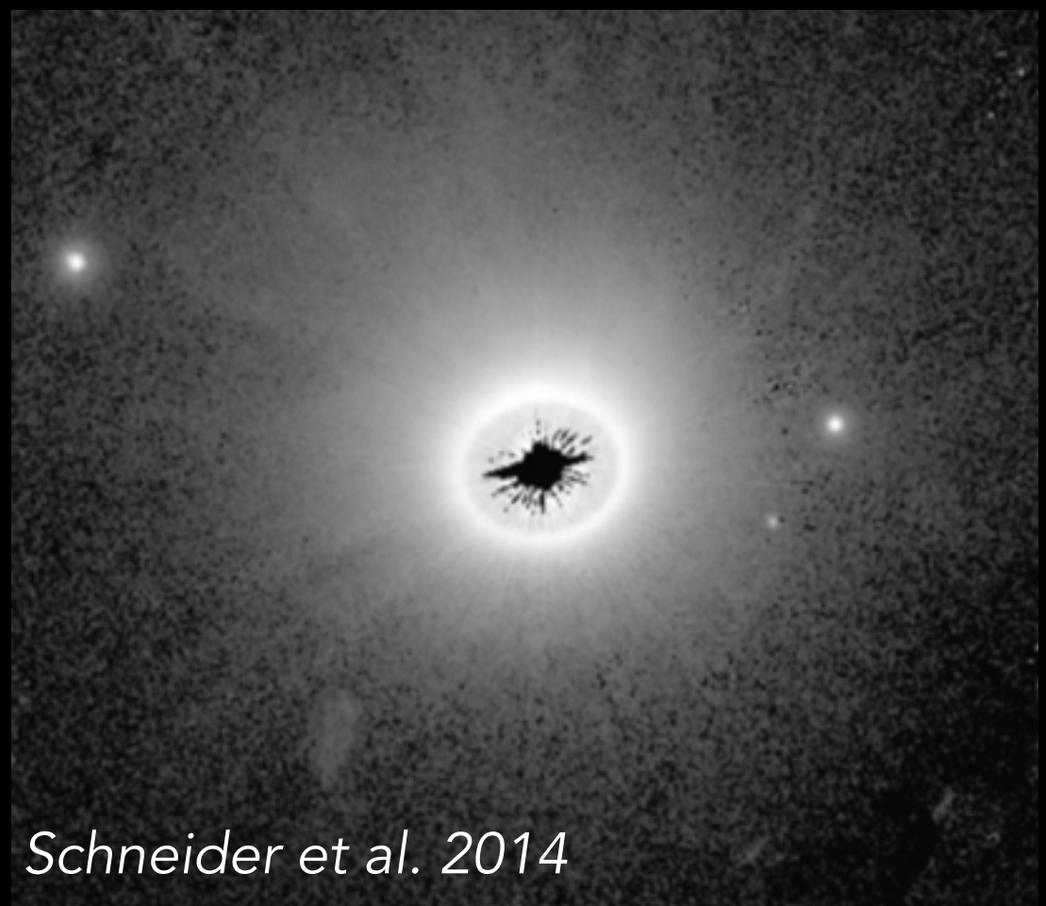
# RDI-importance of PSF libraries

Elodie Choquet
(Hubble Fellow, Caltech)




*Serabyn et al. 2017*



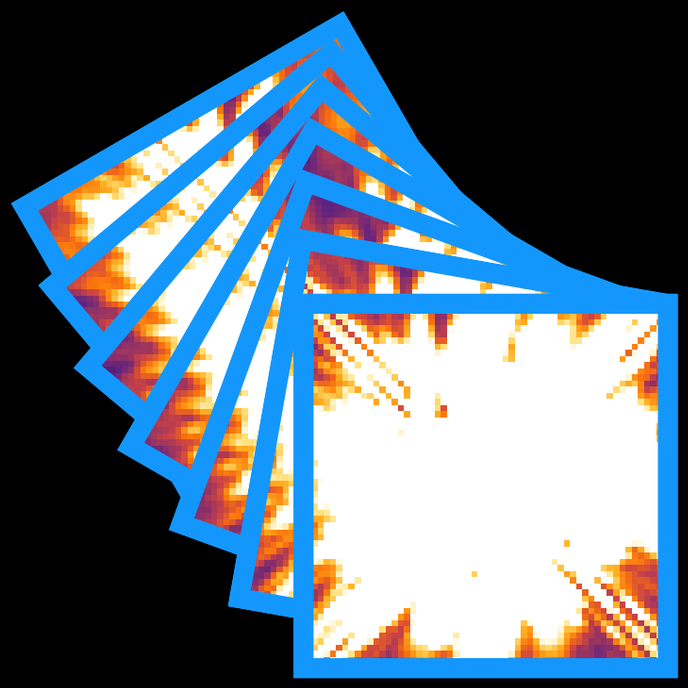
*Schneider et al. 2014*

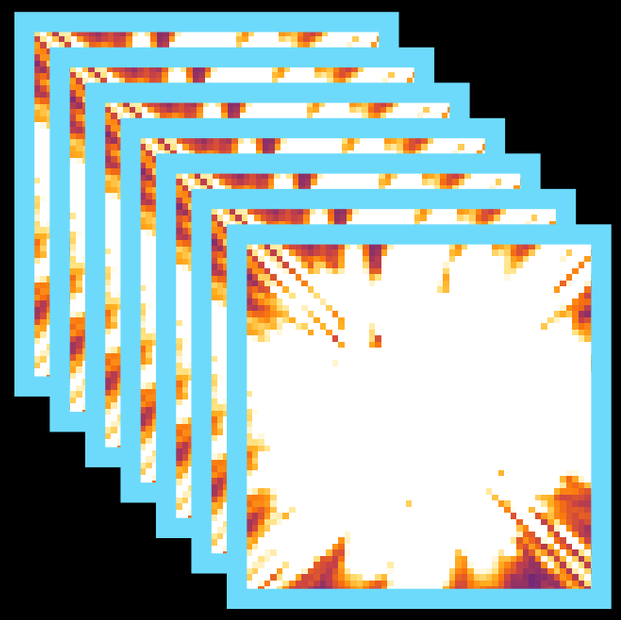
# Outline

- RDI vs. Others (Ground-based case)
- RDI for Space Telescopes
- MRDI for Space Telescopes

# Target vs. Reference

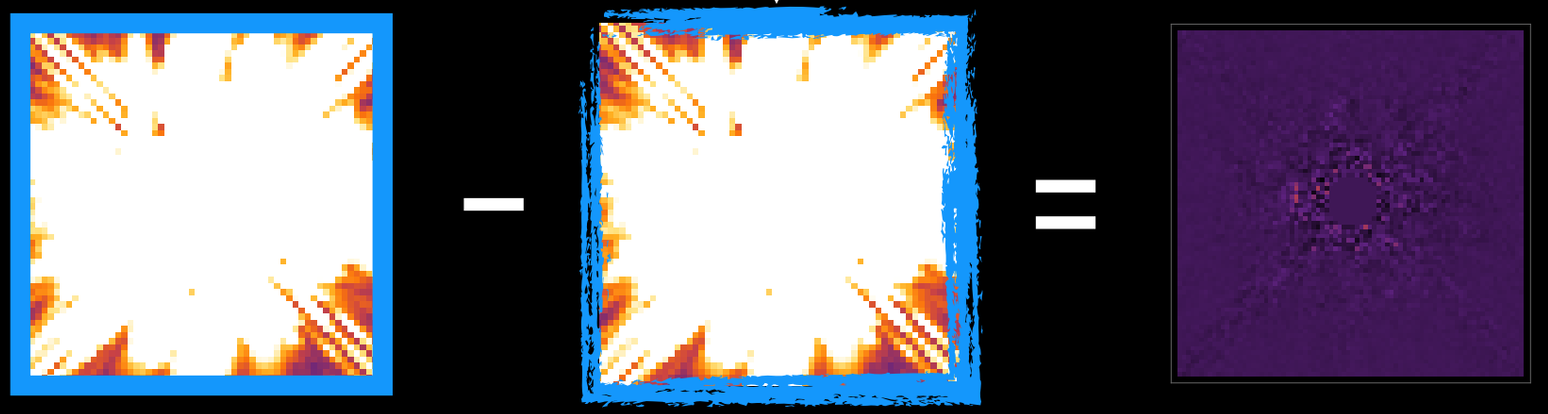
**ADI**
SDI
PDI





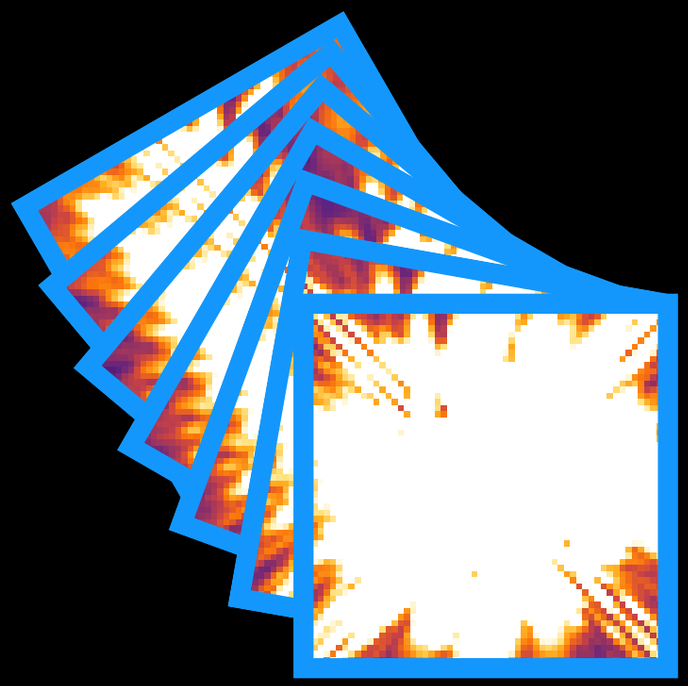
**RDI**

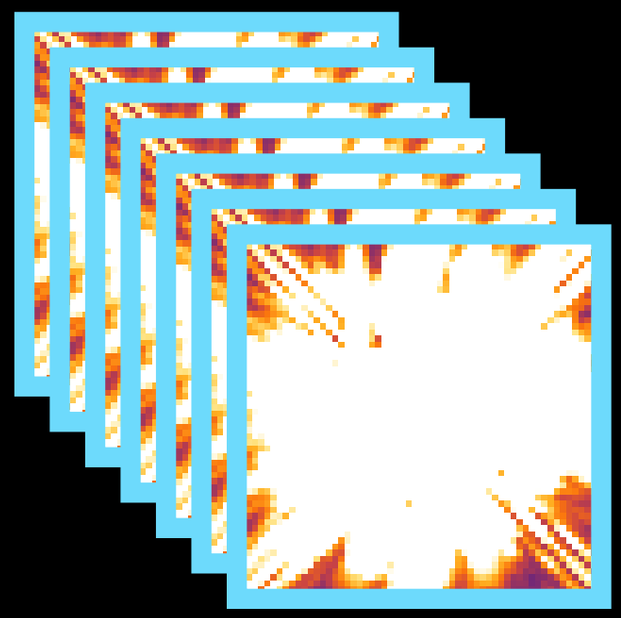
Median, LOCI, PCA...



# Target vs. Reference

**ADI**
SDI
PDI



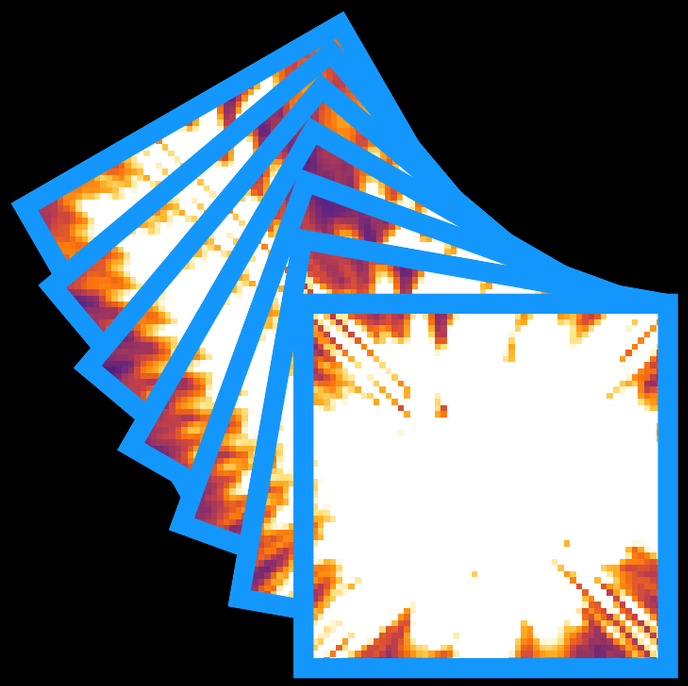


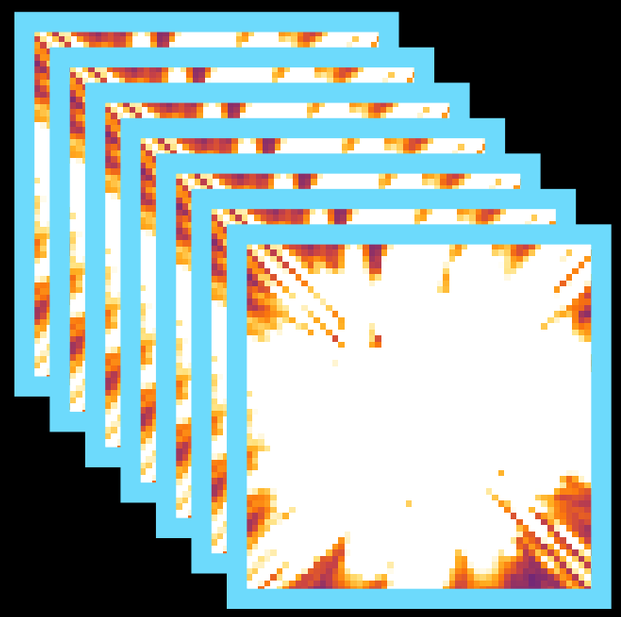
**RDI**

| | Target-based | Reference-based |
|---|---|---|
| WFE-matching | √ | X |
| λ-matching | √ | X |
| Self-subtraction | X | √ |

# Target vs. Reference

**ADI**
SDI
PDI





**RDI**

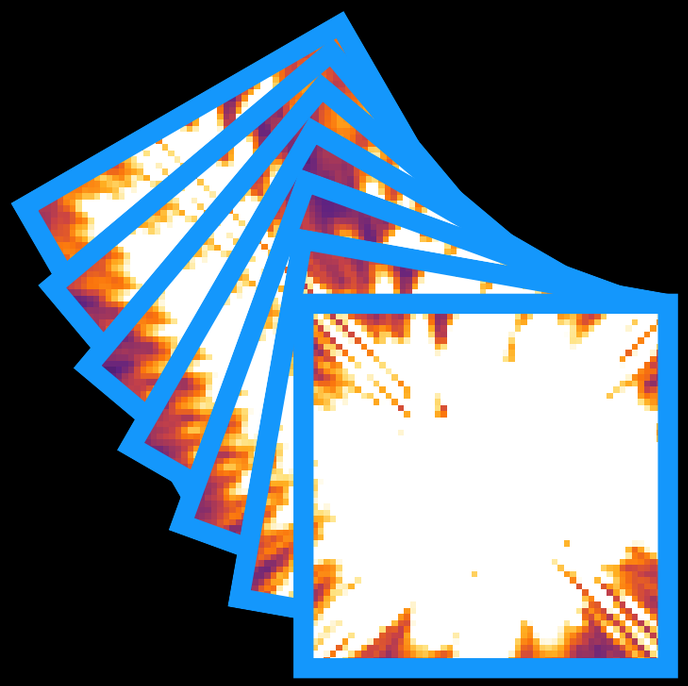
| | Target-based | Reference-based |
|---|---|---|
| WFE-matching | √ | X |
| λ-matching | √ | X |
| Self-subtraction | X | √ |

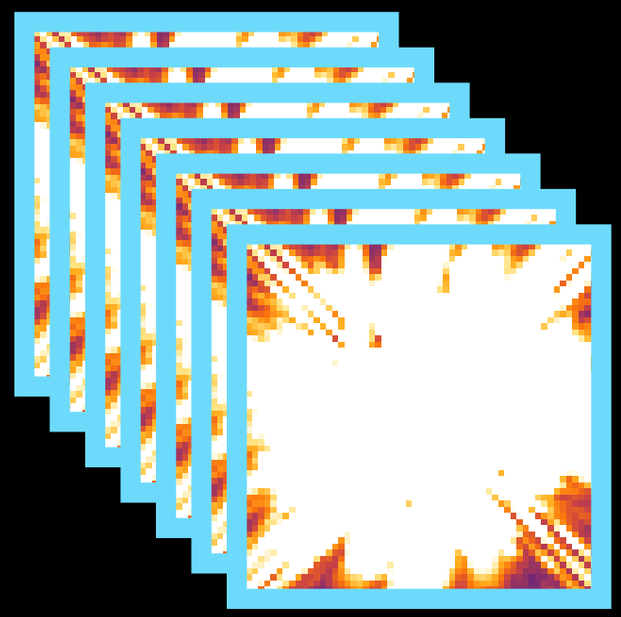
# Target vs. Reference

**ADI**

SDI

PDI





**RDI**

| | Target-based | Reference-based |
|---|---|---|
| WFE-matching | √ | X |
| λ-matching | √ | X |
| Self-subtraction | X | √ |

**d < 1-5°**

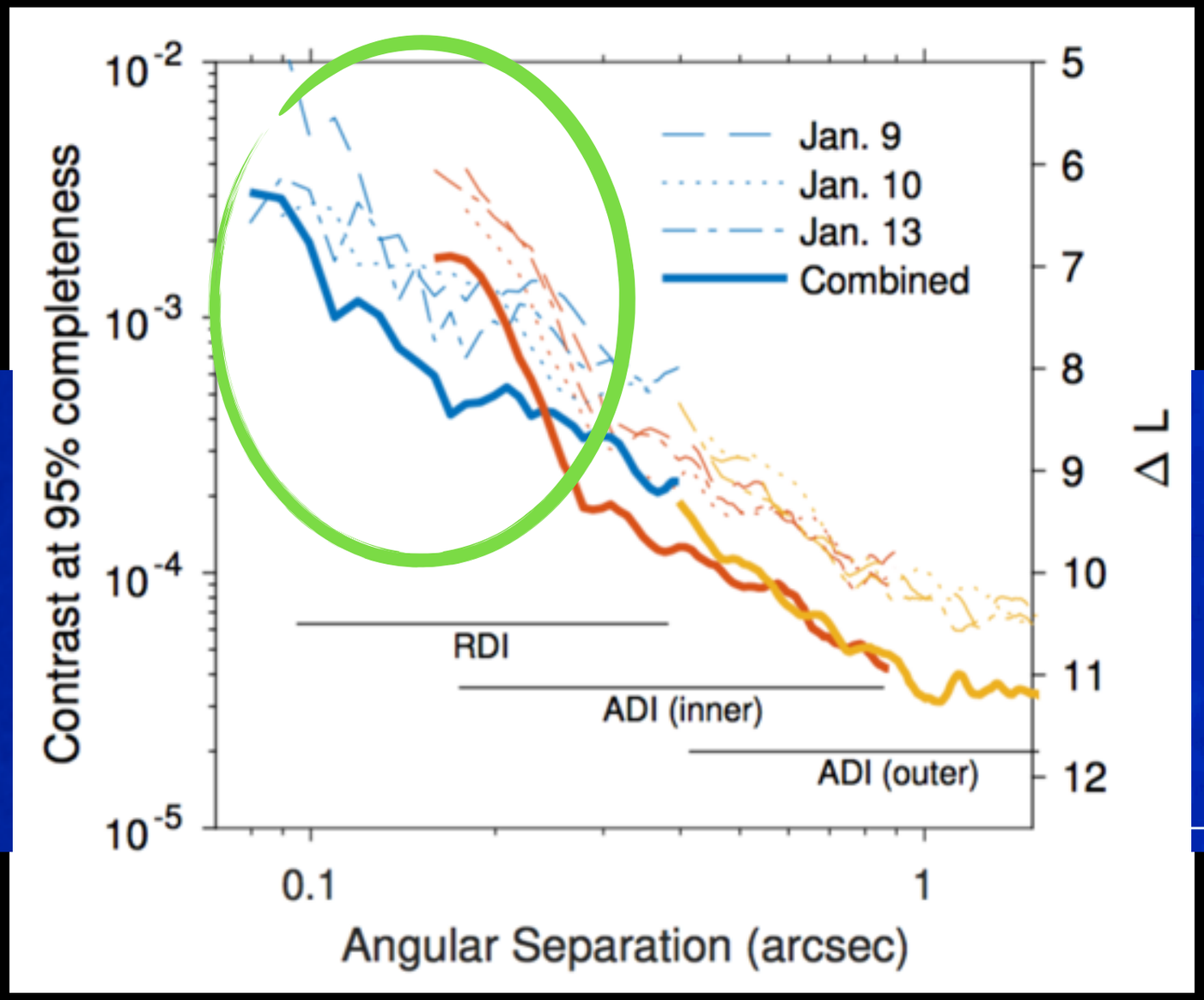
**Color match**

# For Planet searches

**Access to small separations**

ADI

*Zurlo et al. 2016*




*Ruane et al. 2017*

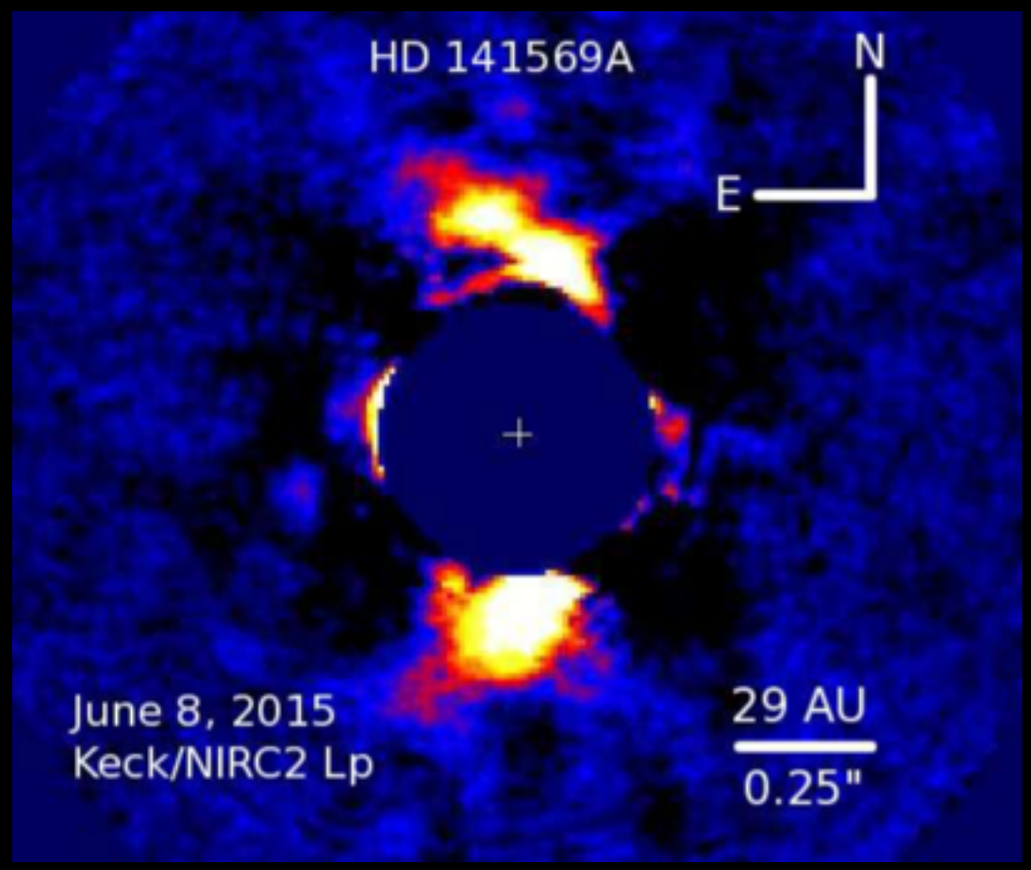
RDI


*Serabyn et al. 2017*

# For Disk science

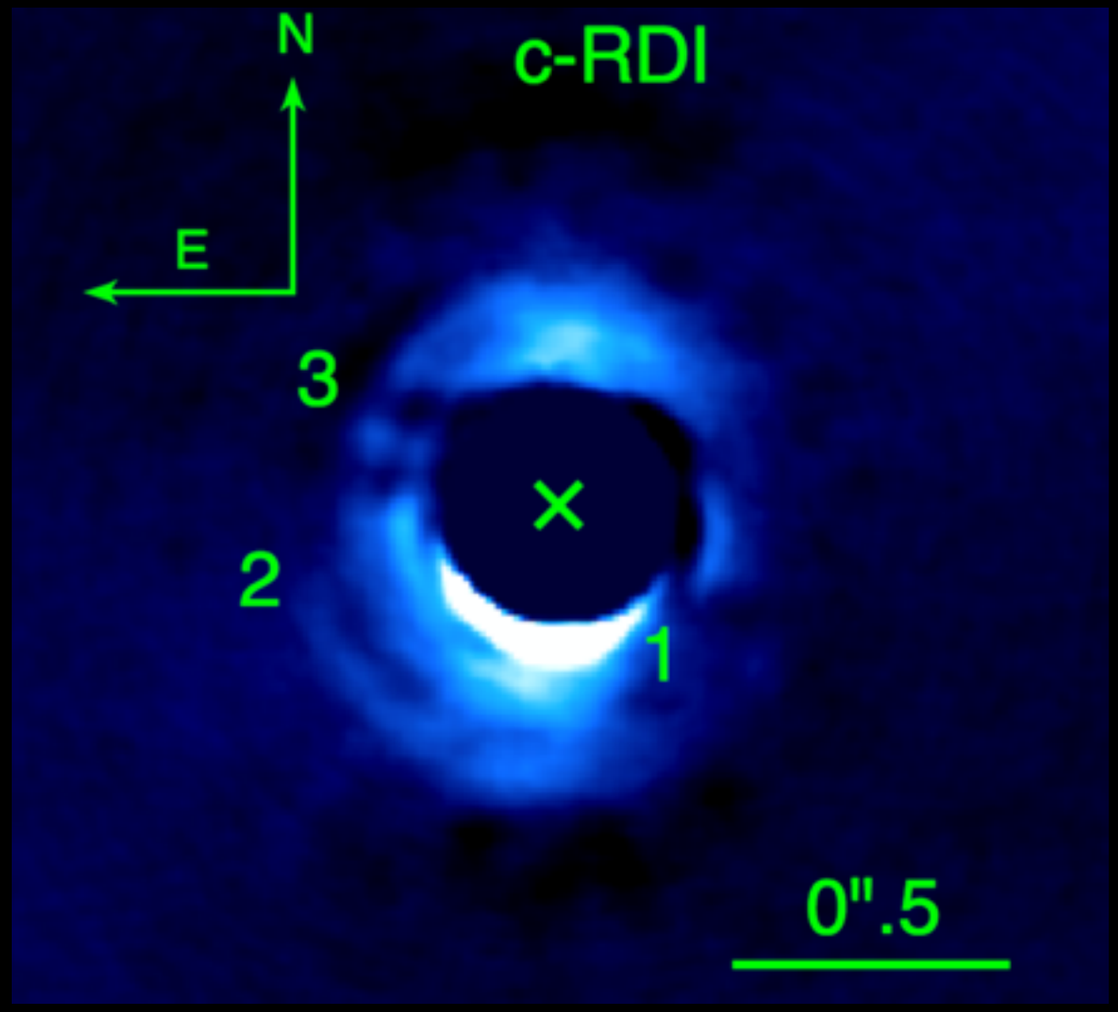
## Unbiased morphology

**ADI**




*Currie et al. 2016*

**RDI**



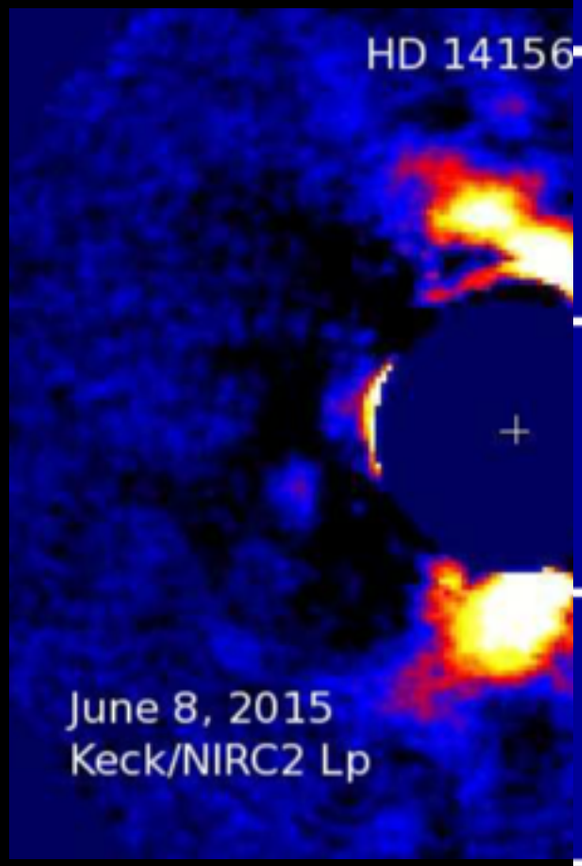

*Mawet et al. 2017*

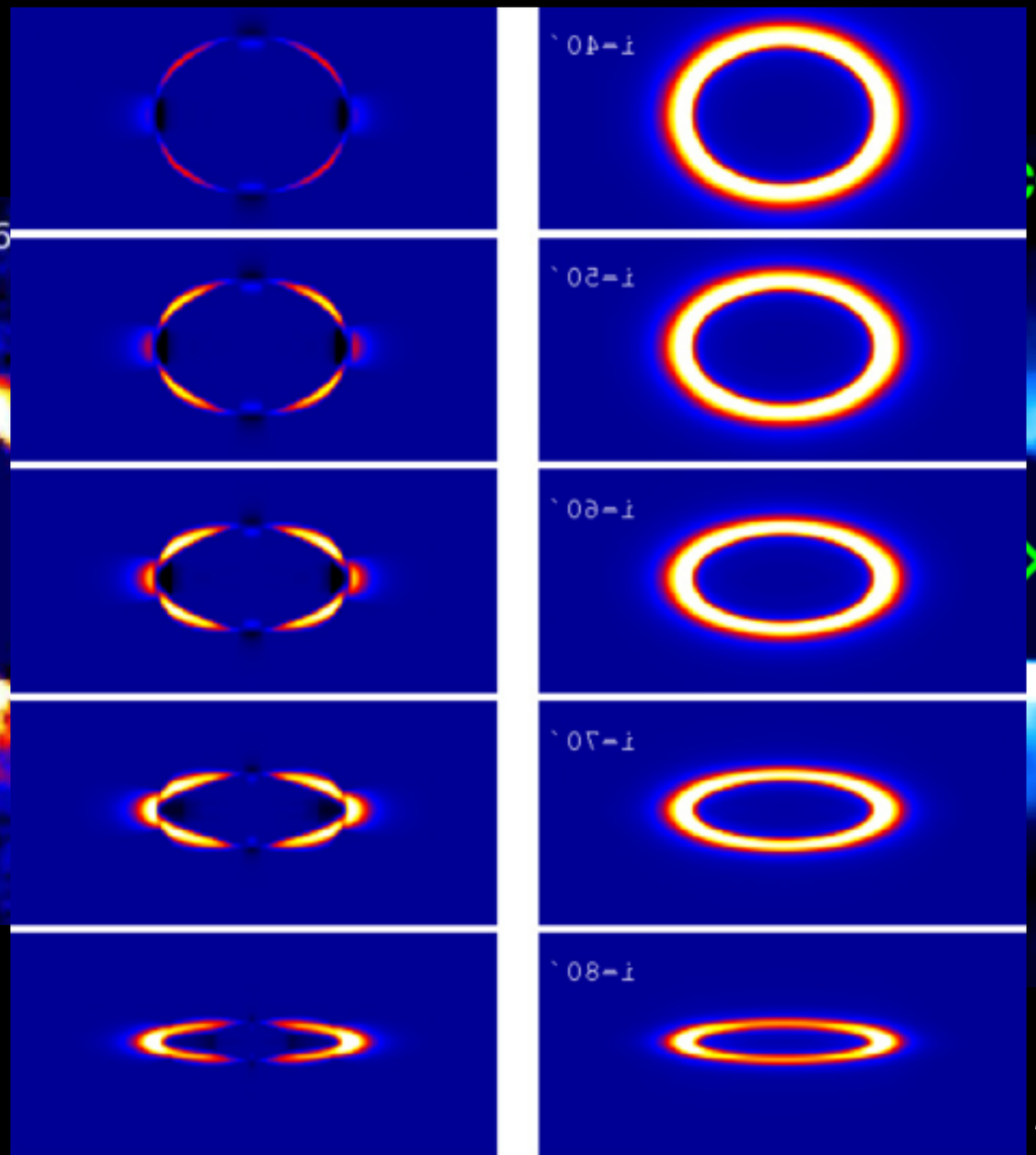
# For Disk science

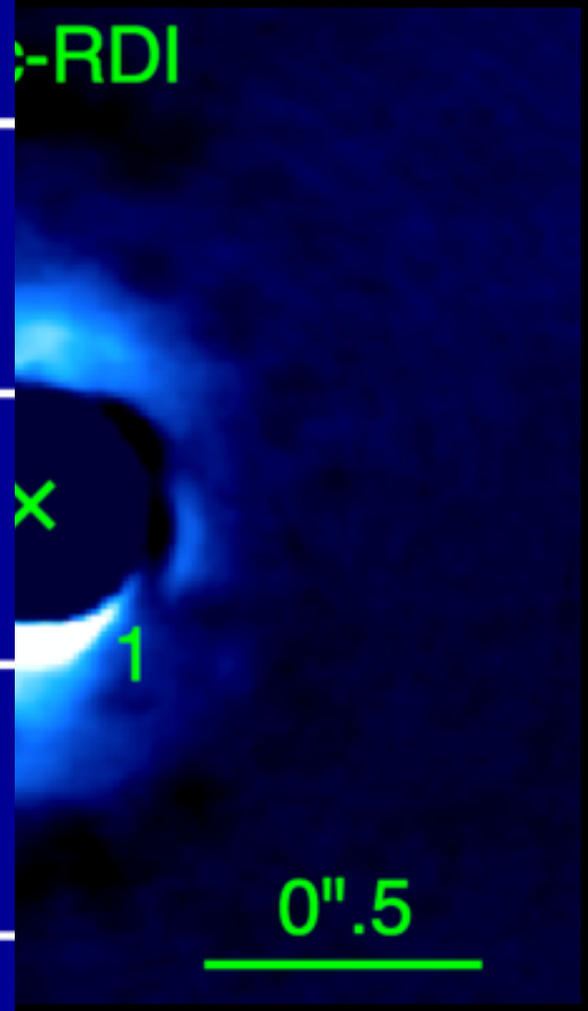
## Unbiased morphology

ADI

RDI



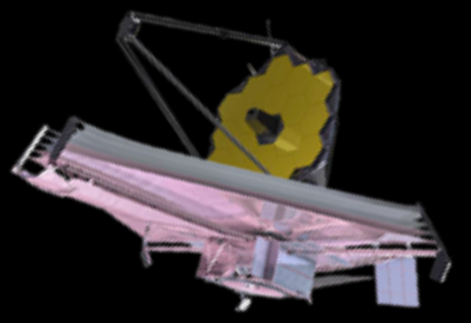



*Currie et al. 2016*

*Mawet et al. 2017*

*Milli et al. 2012*

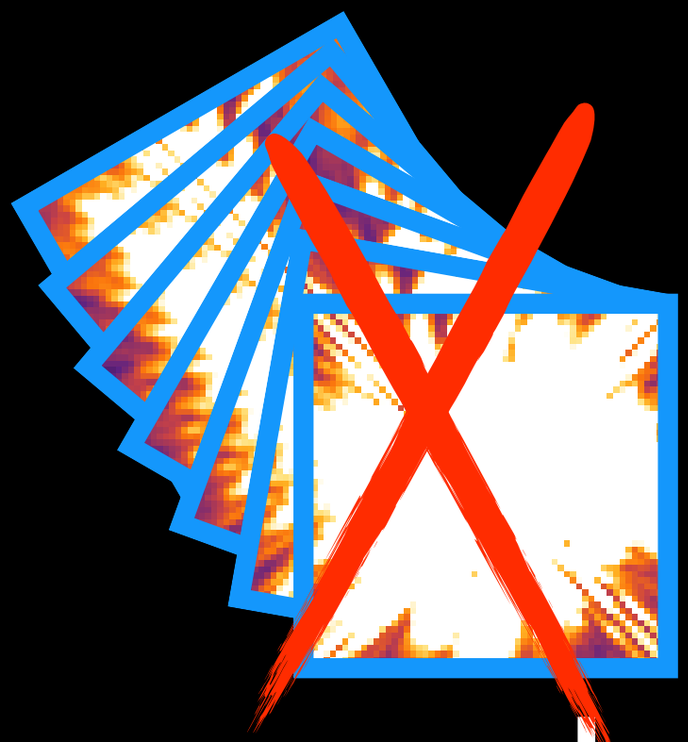
# Space Telescopes

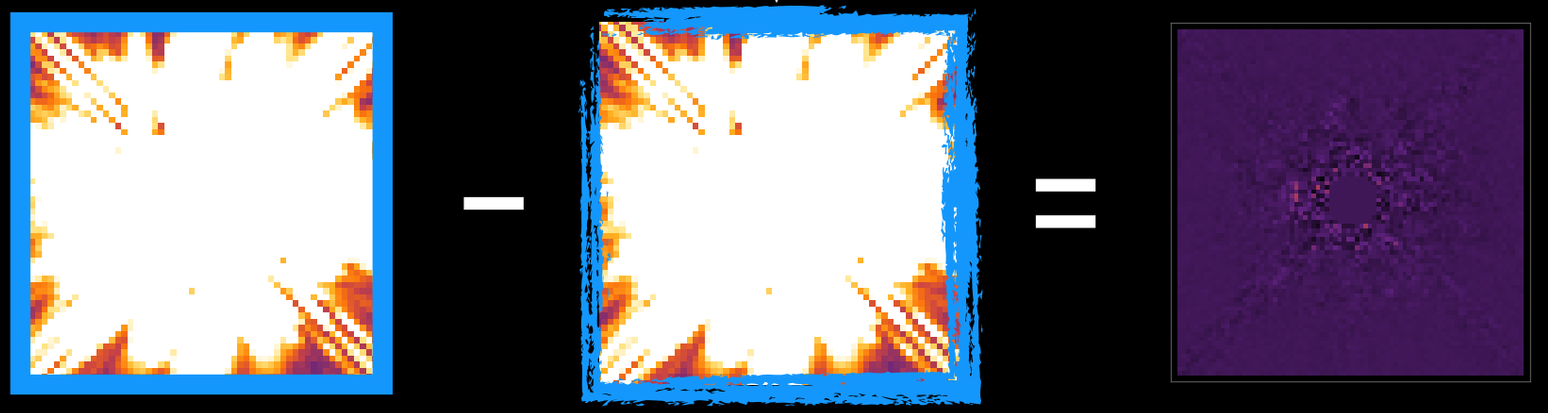


**ADI**

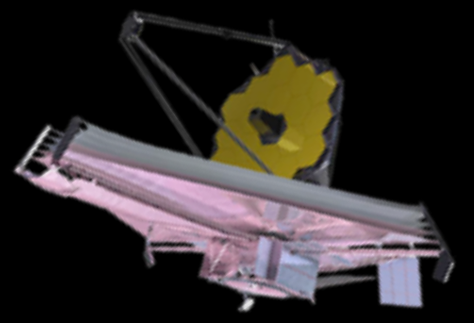
SDI

PDI

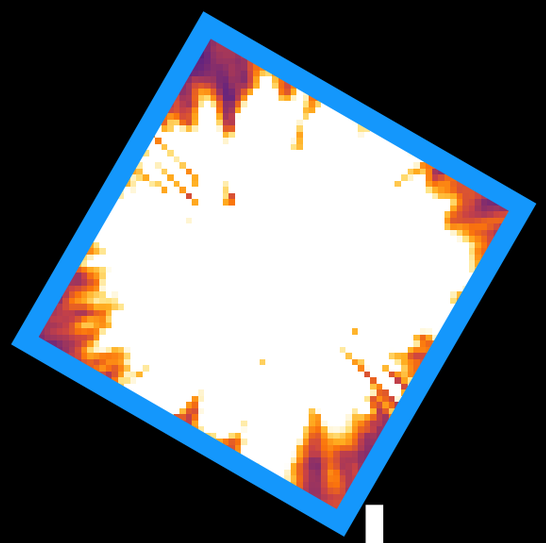




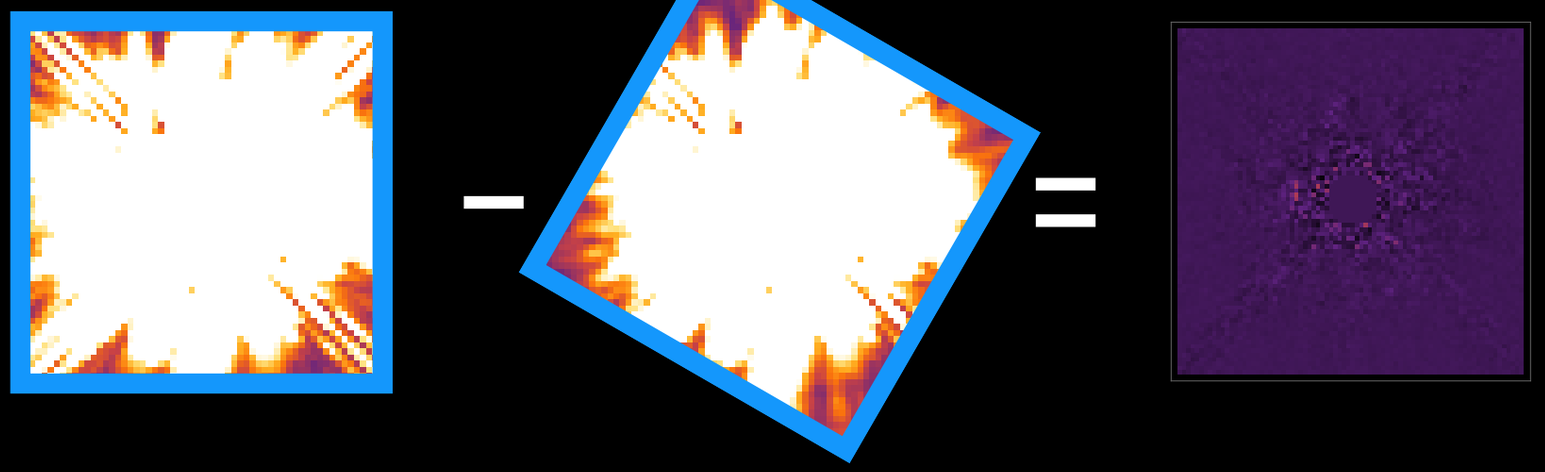
# Space Telescopes



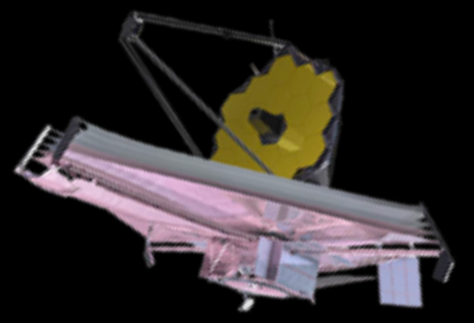
**Rolls**



DI



# Space Telescopes



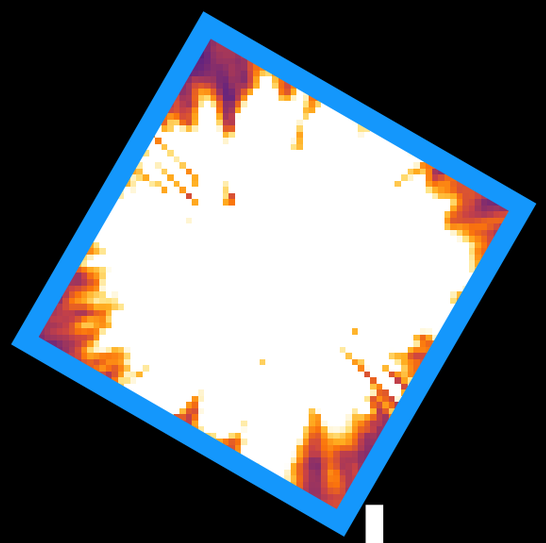
Discontinuous (new acq)

Limited range:

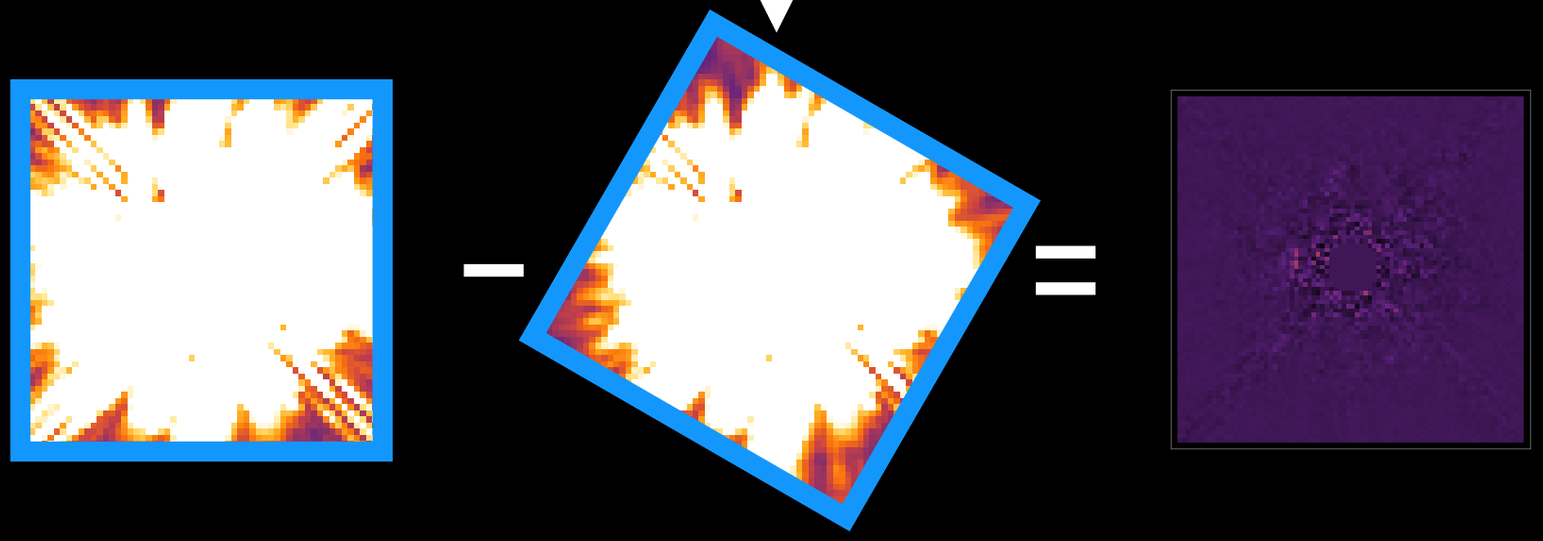
- HST: 30°
- JWST: 10°

But great PSF stability
(no atmosphere, no AO)

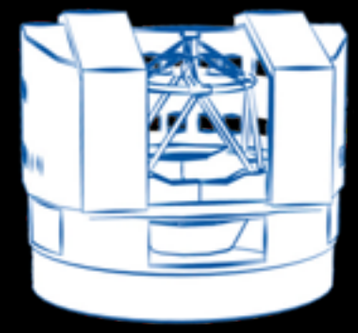
**Rolls**

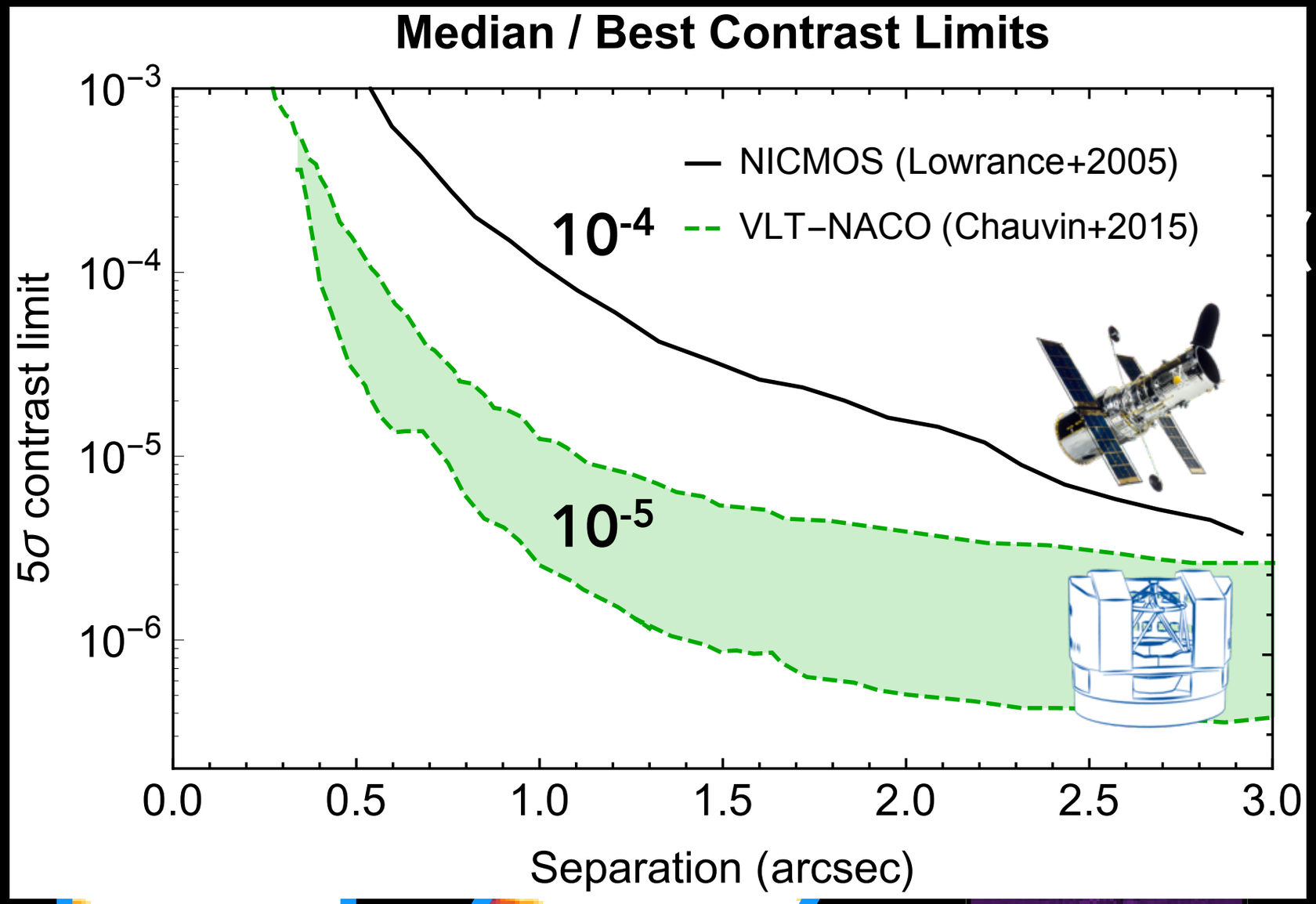


DI



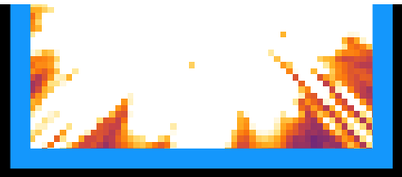
# HST vs Ground

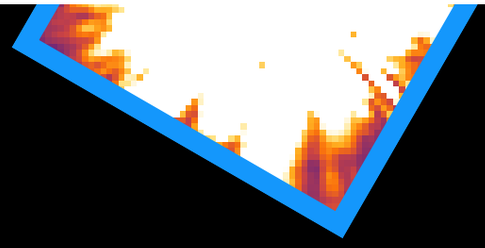


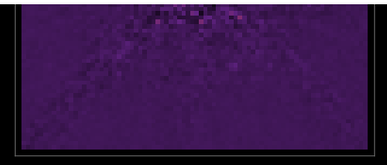


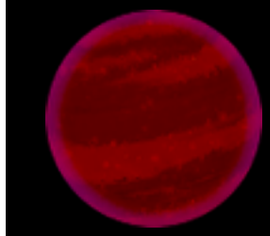

Rolls

(new acq)

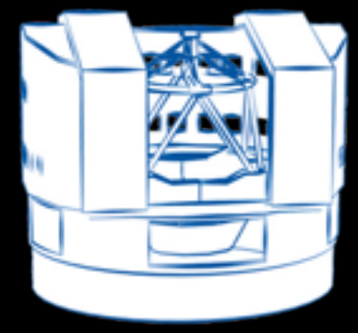


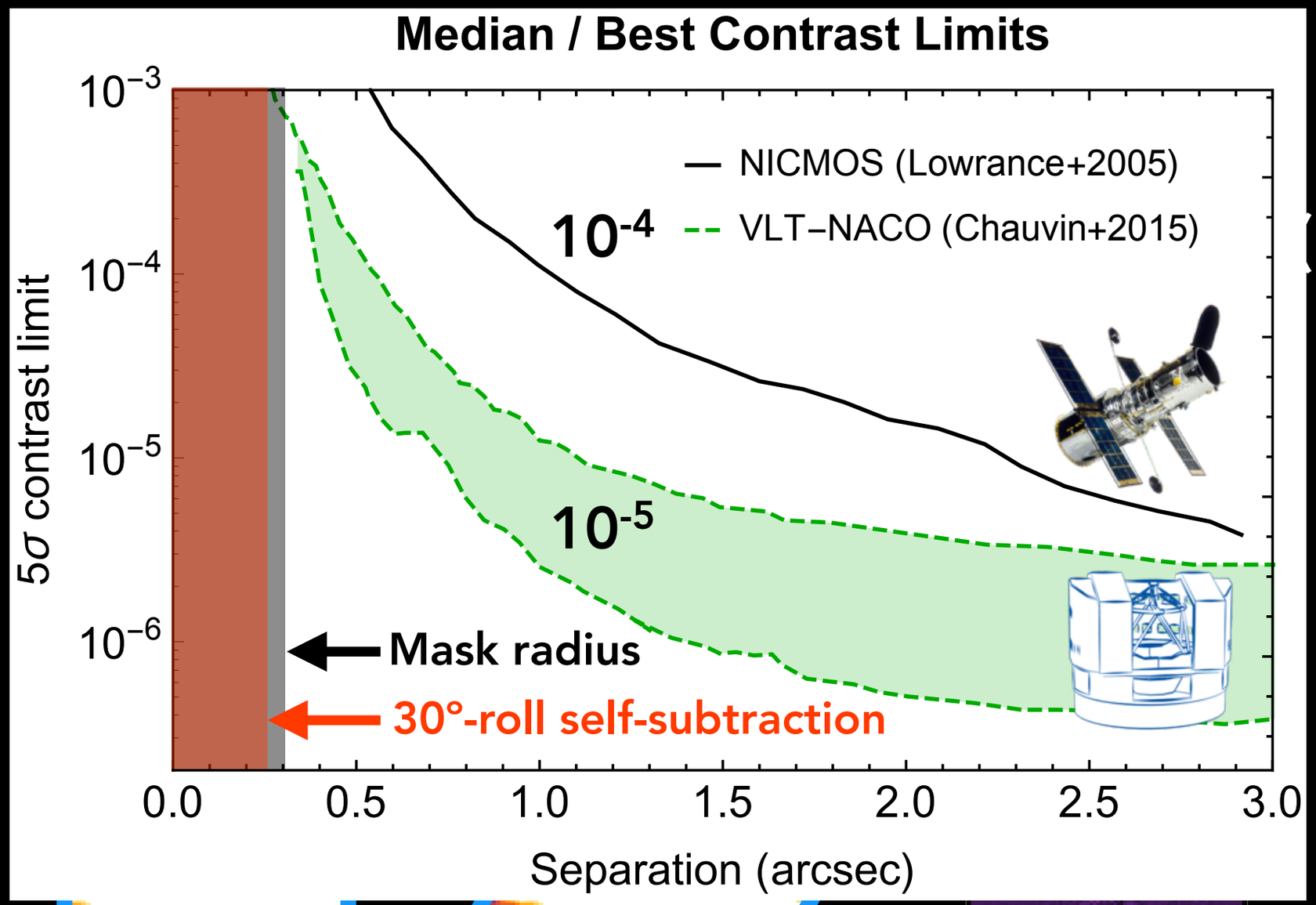






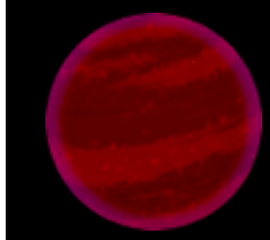
# HST vs Ground



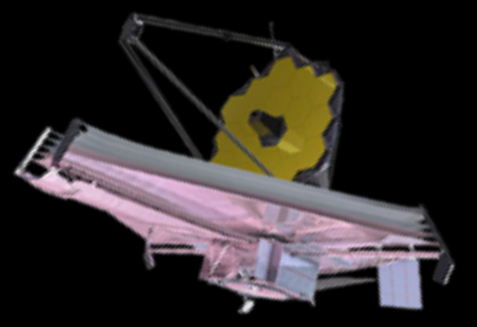



Rolls

(new acq)

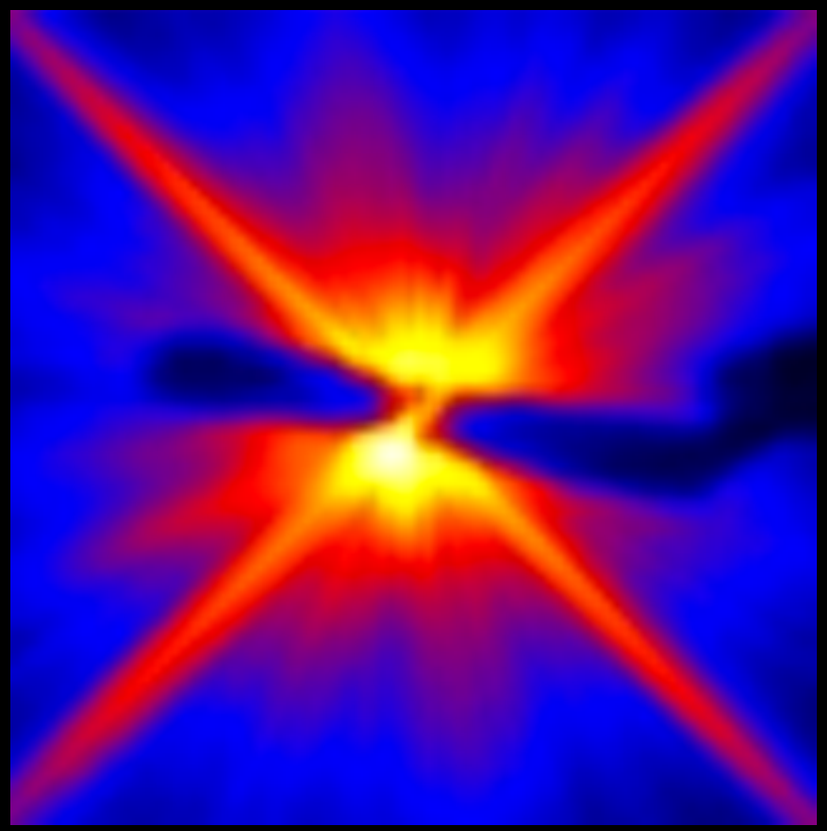


# Space Telescopes



**Small IWA coronagraphs**
(or telescopes with limited roll-angle)

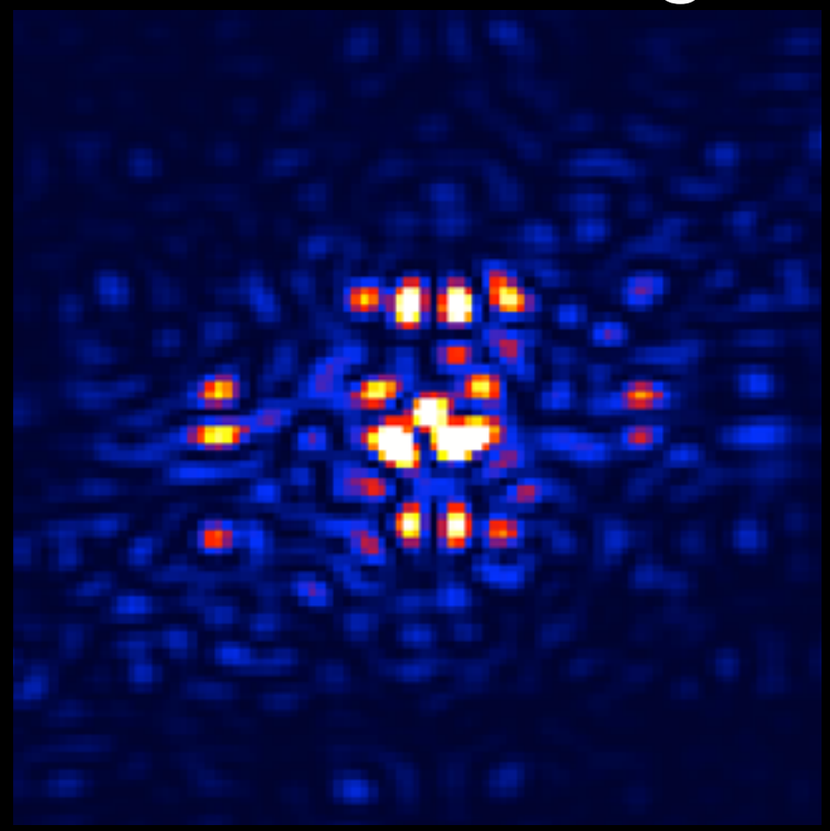
STIS : BAR5



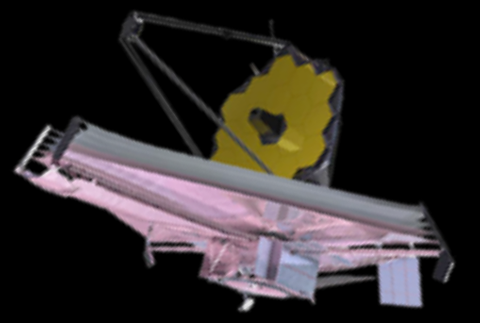
RDI needed

... but limited by pointing errors

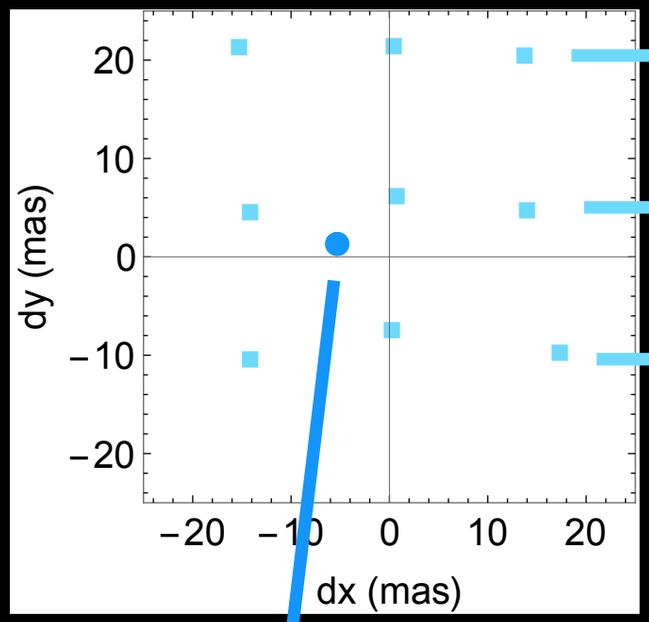
MIRI : 4QPMs
NIRCam : wedge

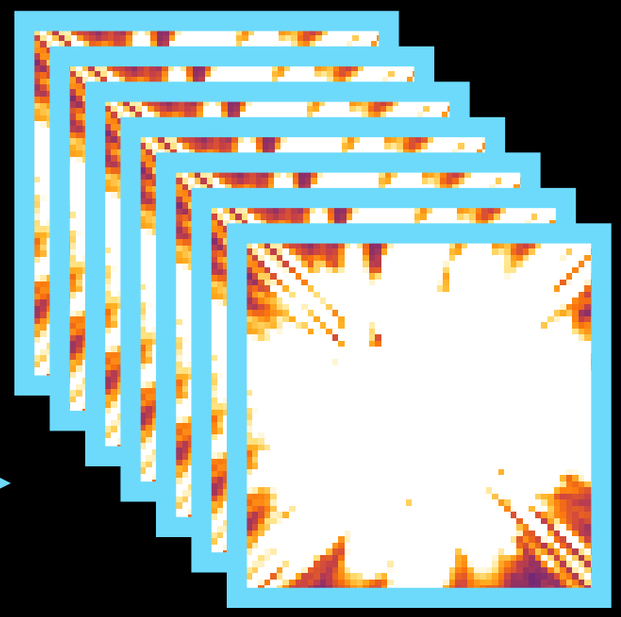


# RDI with dithers



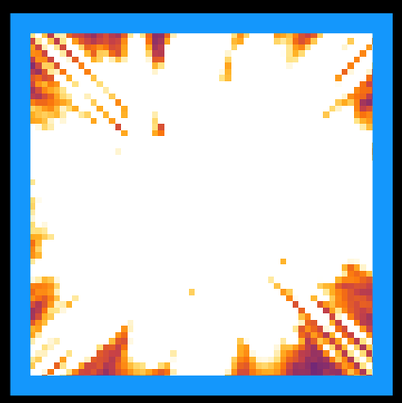
***Small-grid dither***



RDI

PCA



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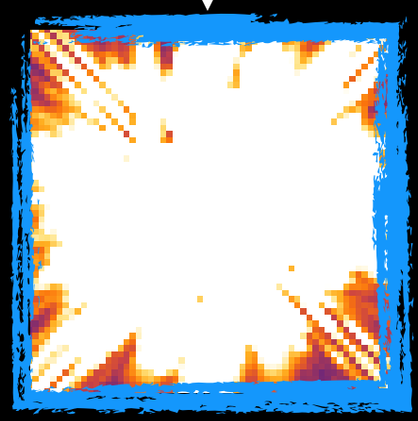

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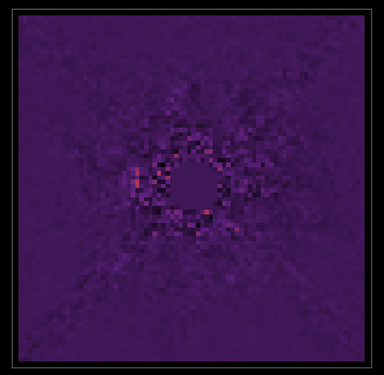
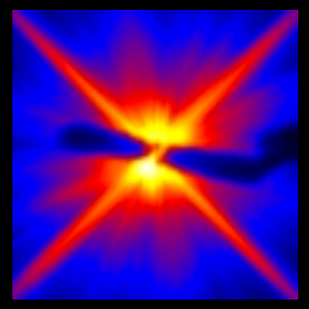
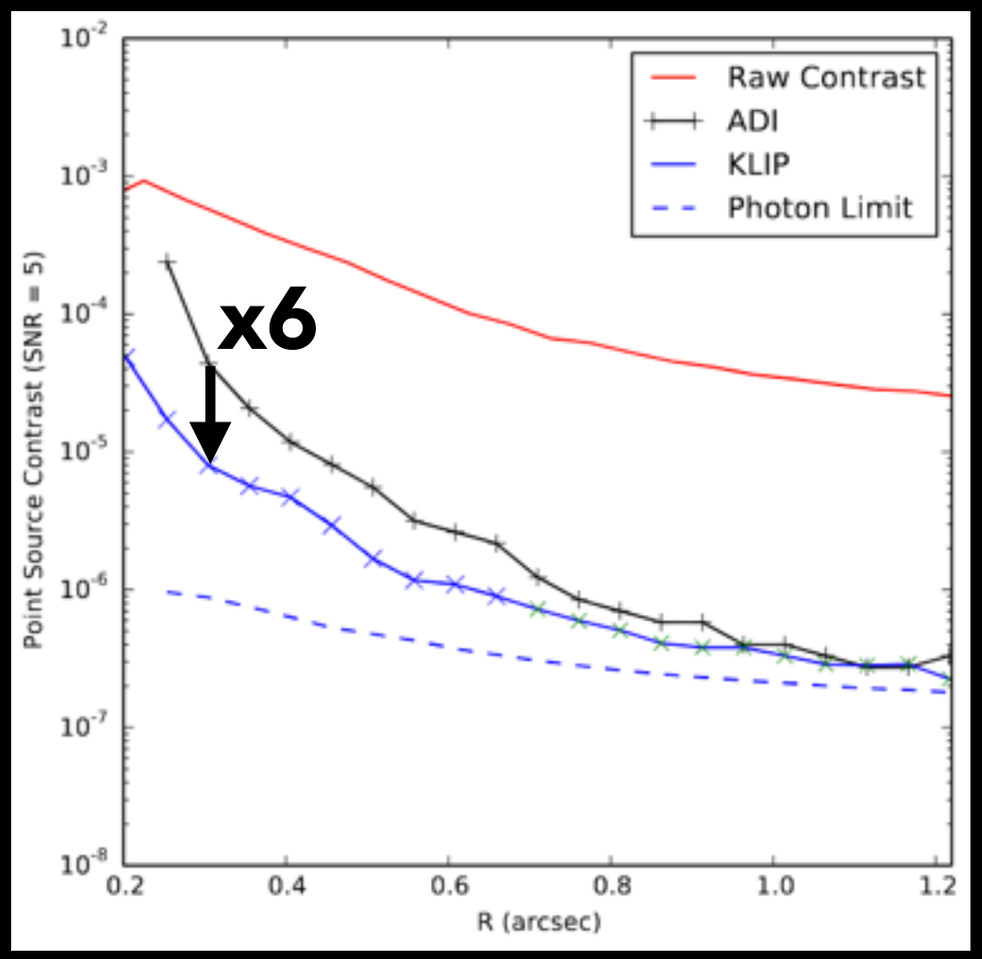


*Soummer et al. 2016*

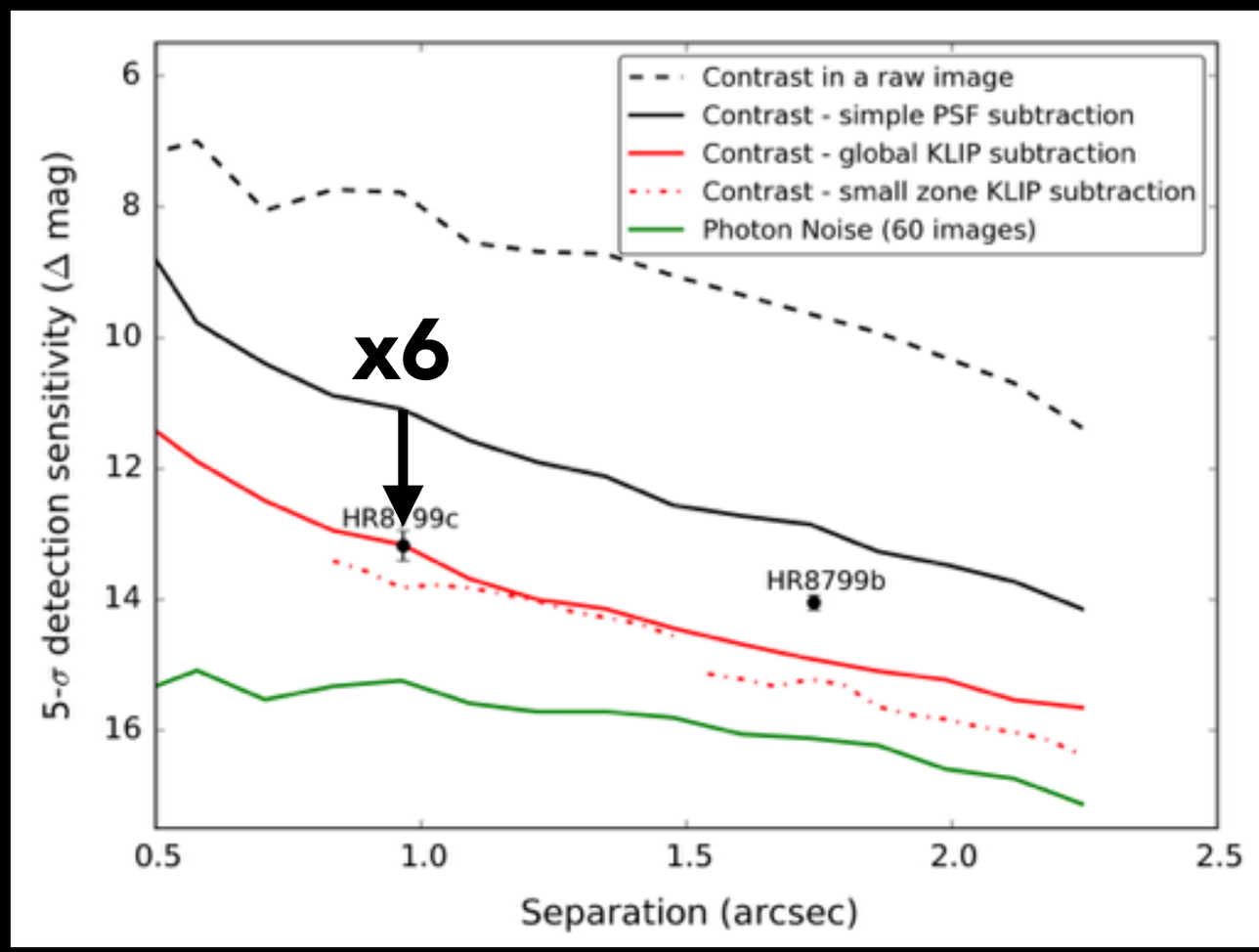
# RDI with dithers

STIS : BAR5





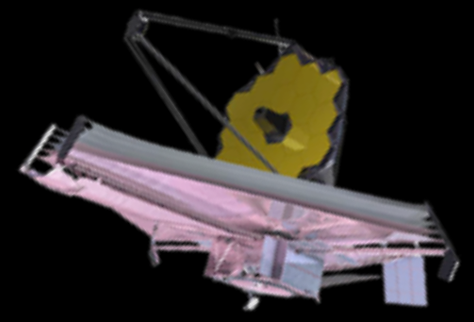

WFC3 : No coronagraph



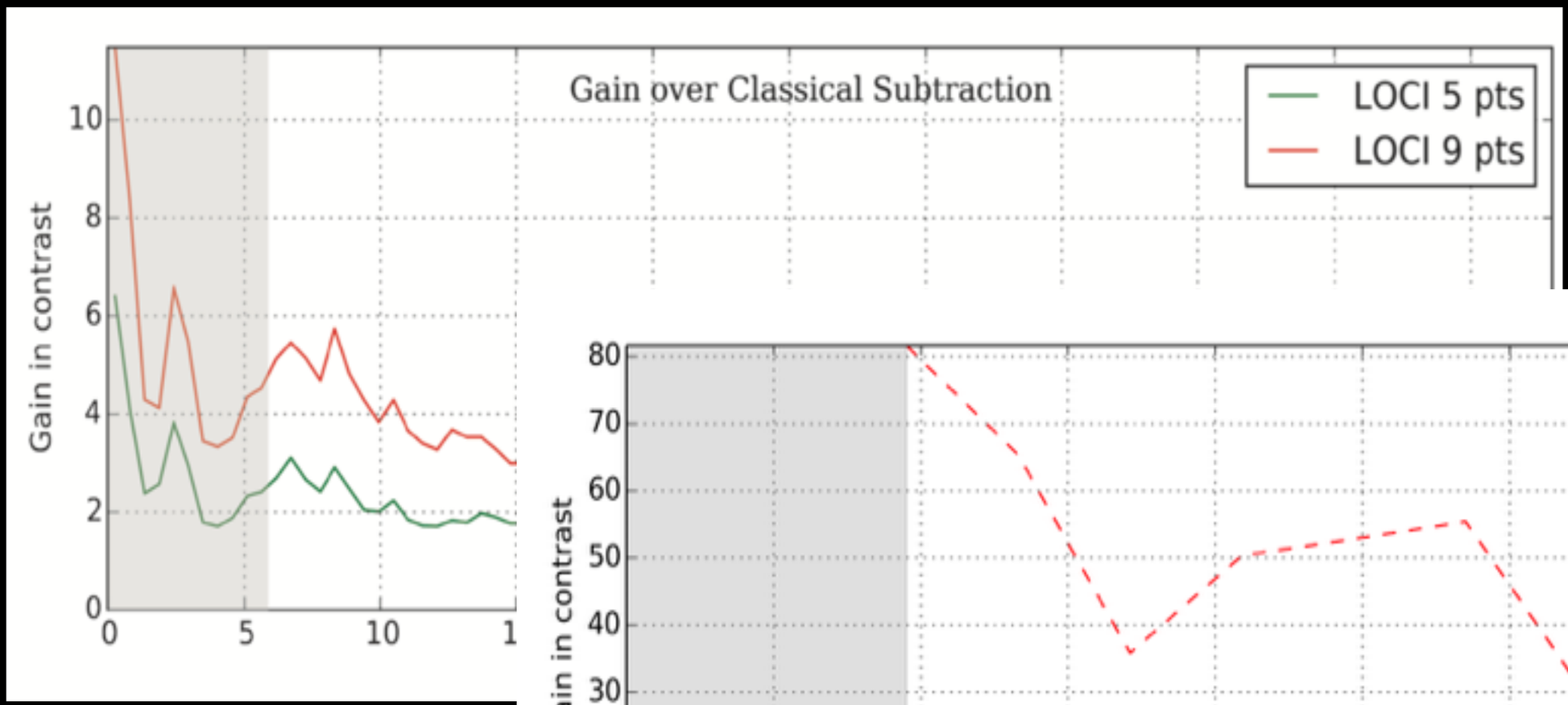

*Ren et al. 2017*

*Rajan et al. 2015*

# RDI with dithers

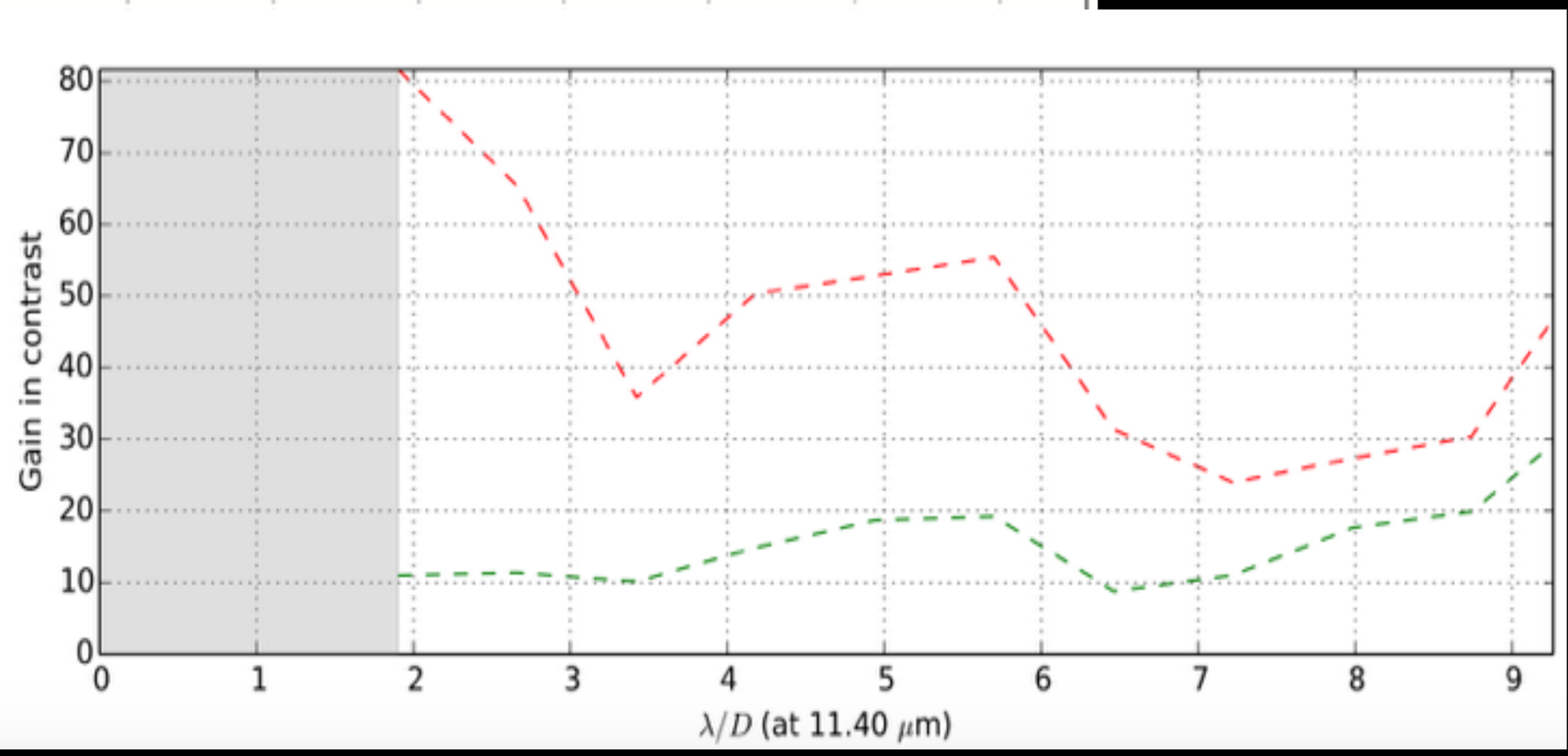


NIRCam



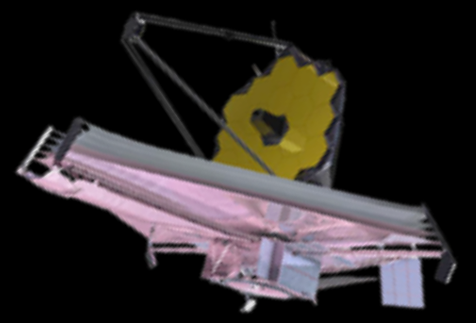

*Lajoie et al. 2016*

MIRI



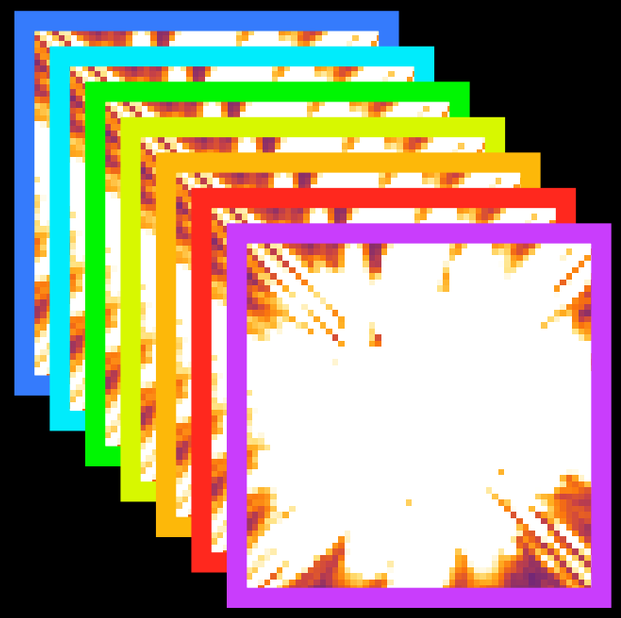

*Soummer et al. 2016*

# MRDI

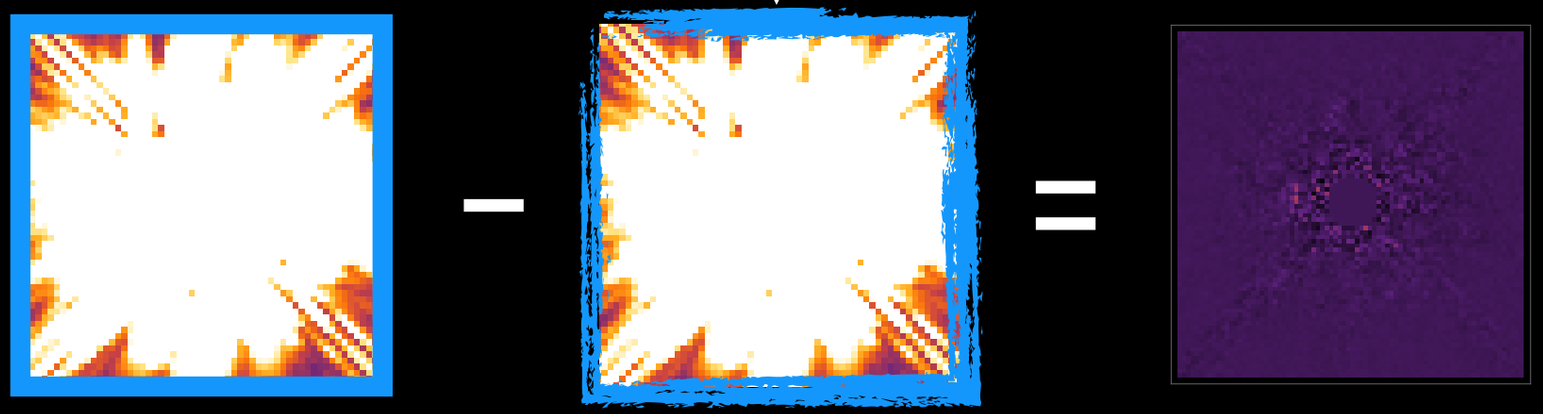


## Multiple Reference stars

- *Self-referencing surveys*
- *Rich archives*



LOCI, PCA...



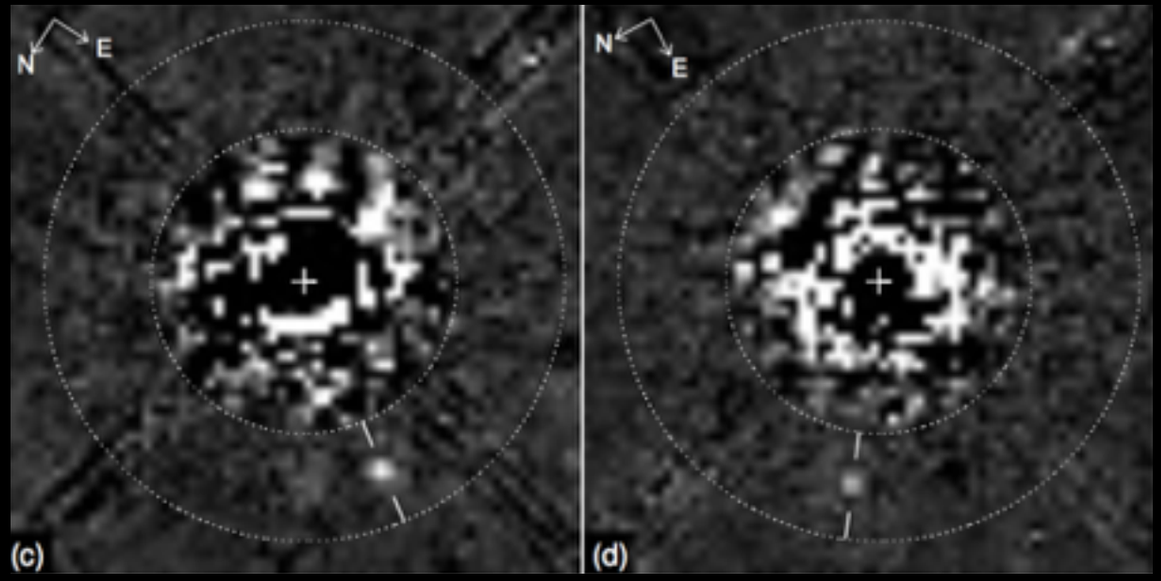
# MRDI

**Self-referencing surveys:**

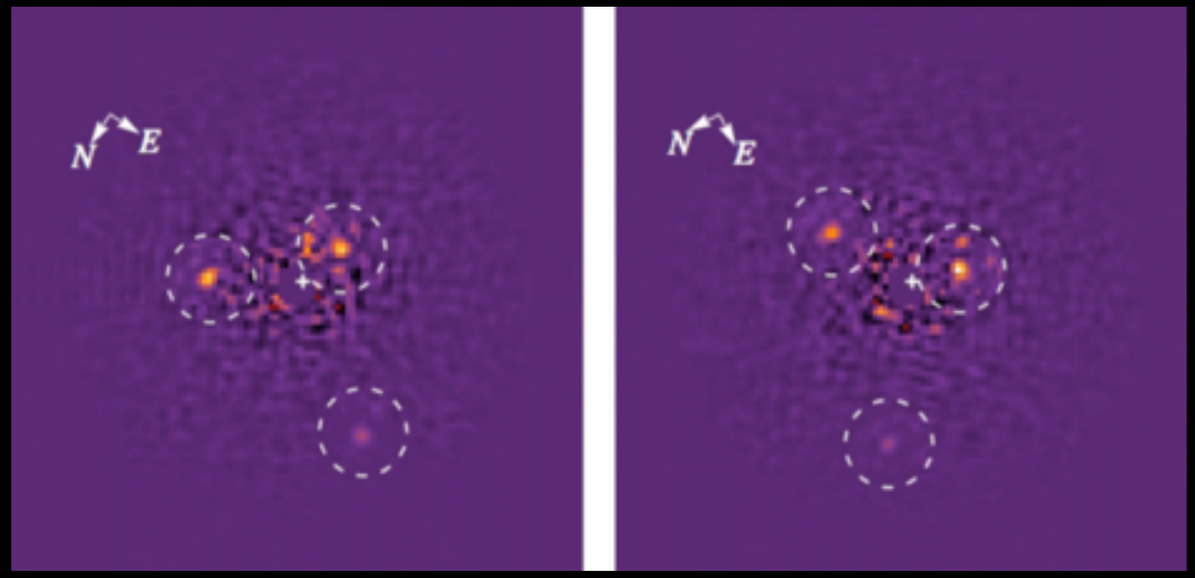
- *Consistent data sets*
- *Same noise levels*

**HR 8799:**

*1998 NICMOS survey*




*Lafrenière et al. 2009*




*Soummer et al. 2011*

| Images | Ref Stars |
|---|---|
| 203 | 23 |

# MRDI

## NICMOS archives

- *Reference stars only*
- *Frame selection (50-90%)*

F110W (~ J band)

| | Images | Ref Stars |
|---|---|---|
| **N2 Cooling** | 54 | 7 |
| **Cryo-cooling** | 655 | 74 |

F160W (H band)

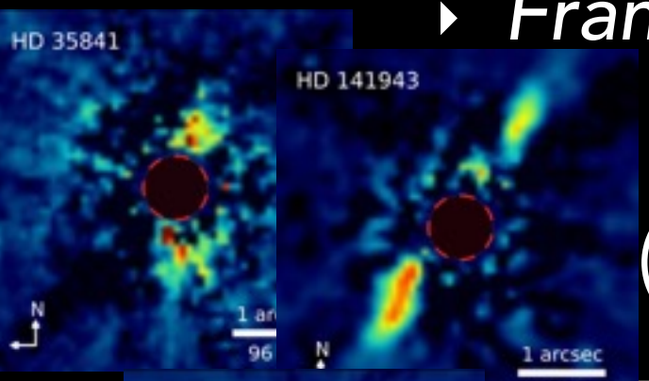
| | Images | Ref Stars |
|---|---|---|
| **N2 Cooling** | 360 | 55 |
| **Cryo-cooling** | 809 | 66 |

# MRDI

## NICMOS archives

- *Reference stars only*
- *Frame selection (50-90%)*

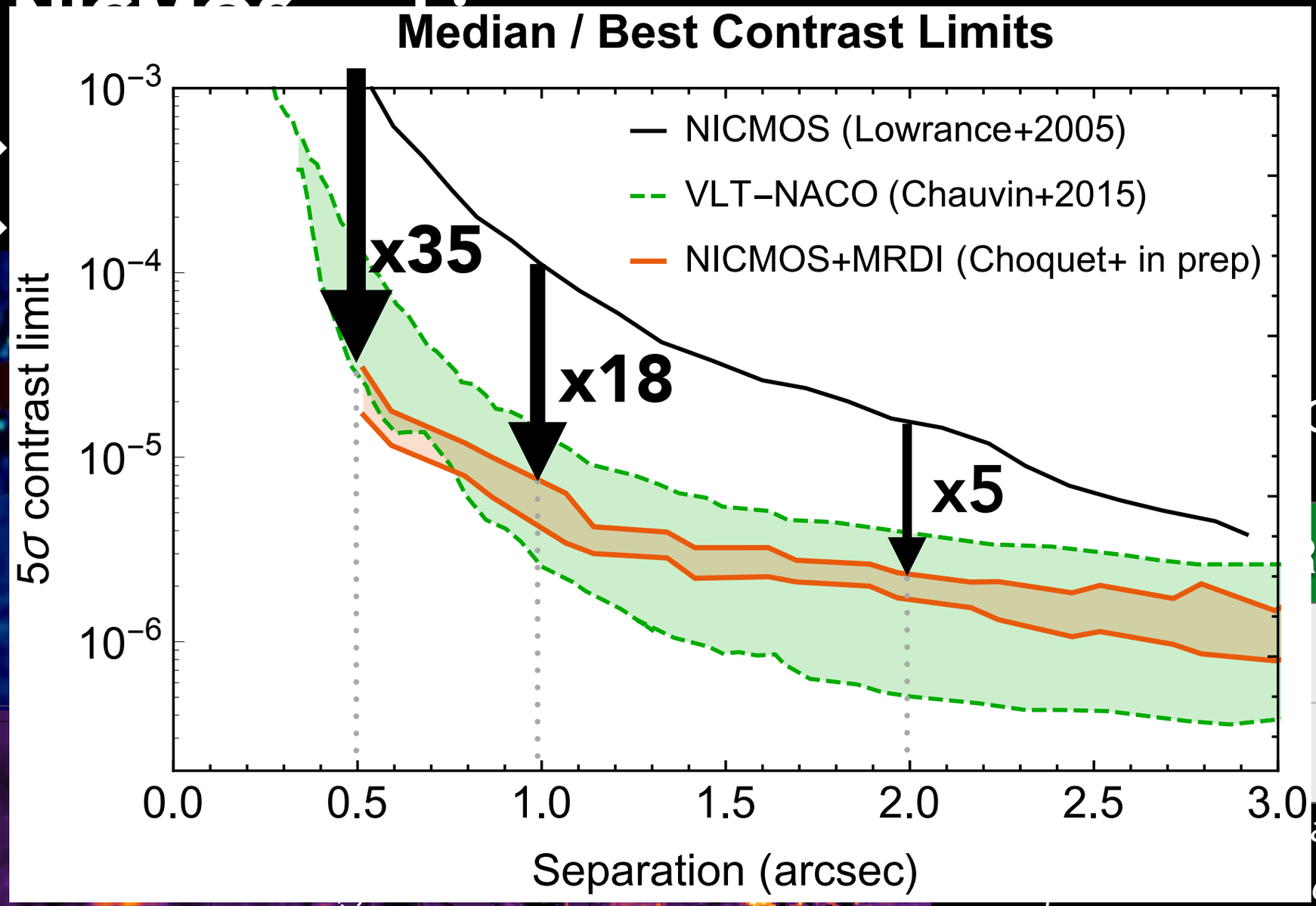
(~ J band) F160W (H band)

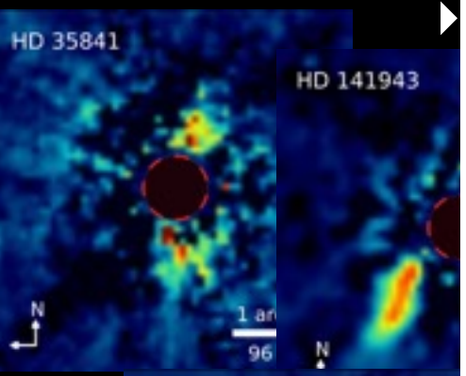


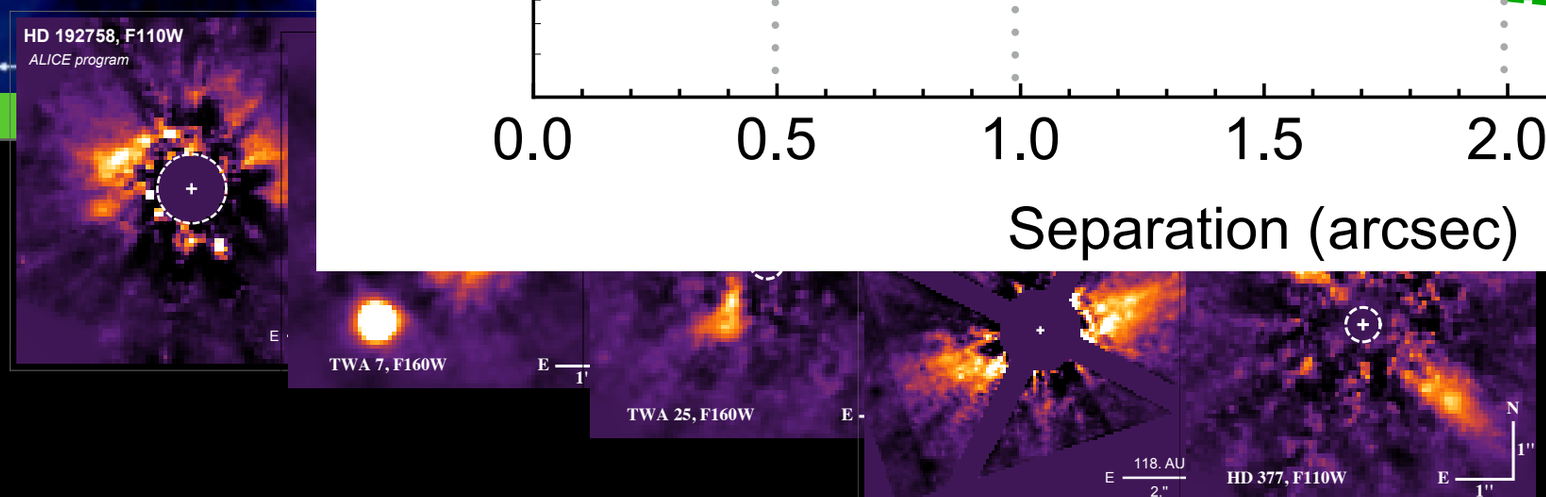

| Ref Stars |
|---|
| 55 |
| 66 |

*Soummer et al. 2014*
*Choquet et al. 2016, 2017, 2018*
*Mazoyer et al. 2016*
*Milli et al. 2015*
*Ren et al. 2018*

# MRDI



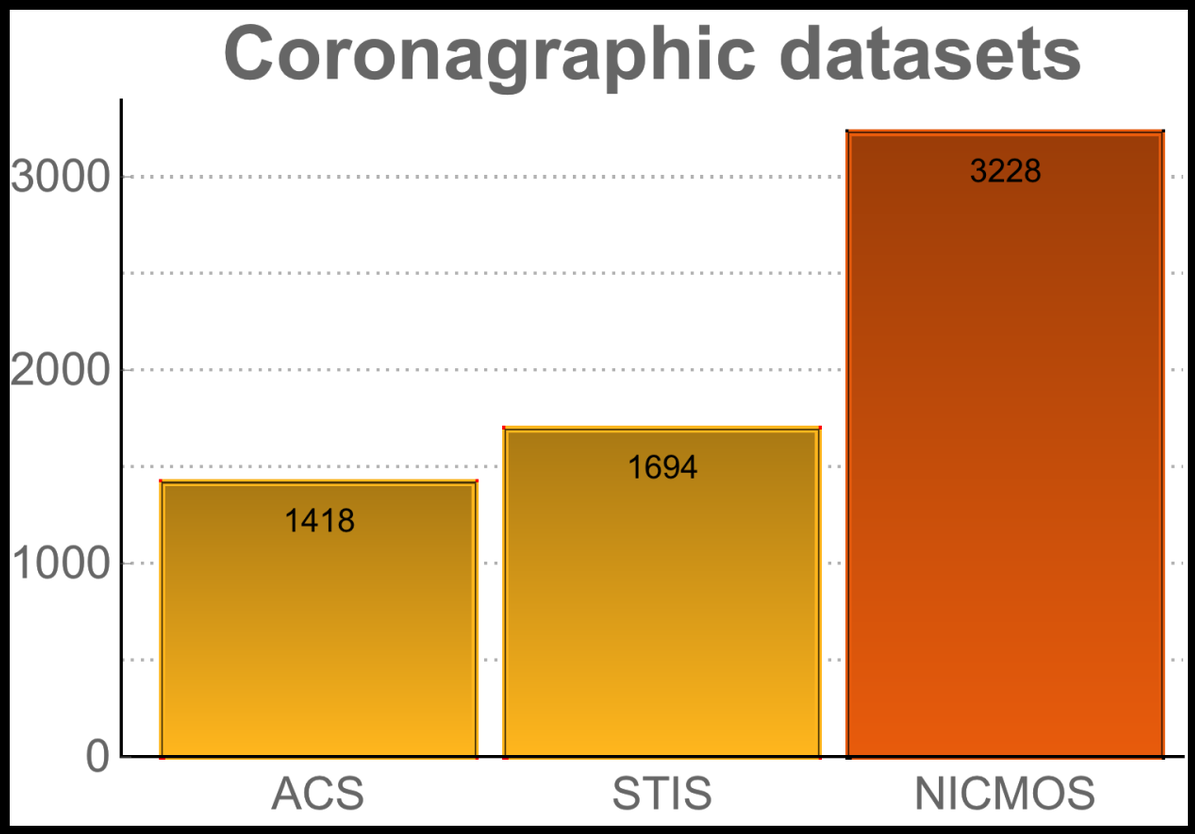

d)

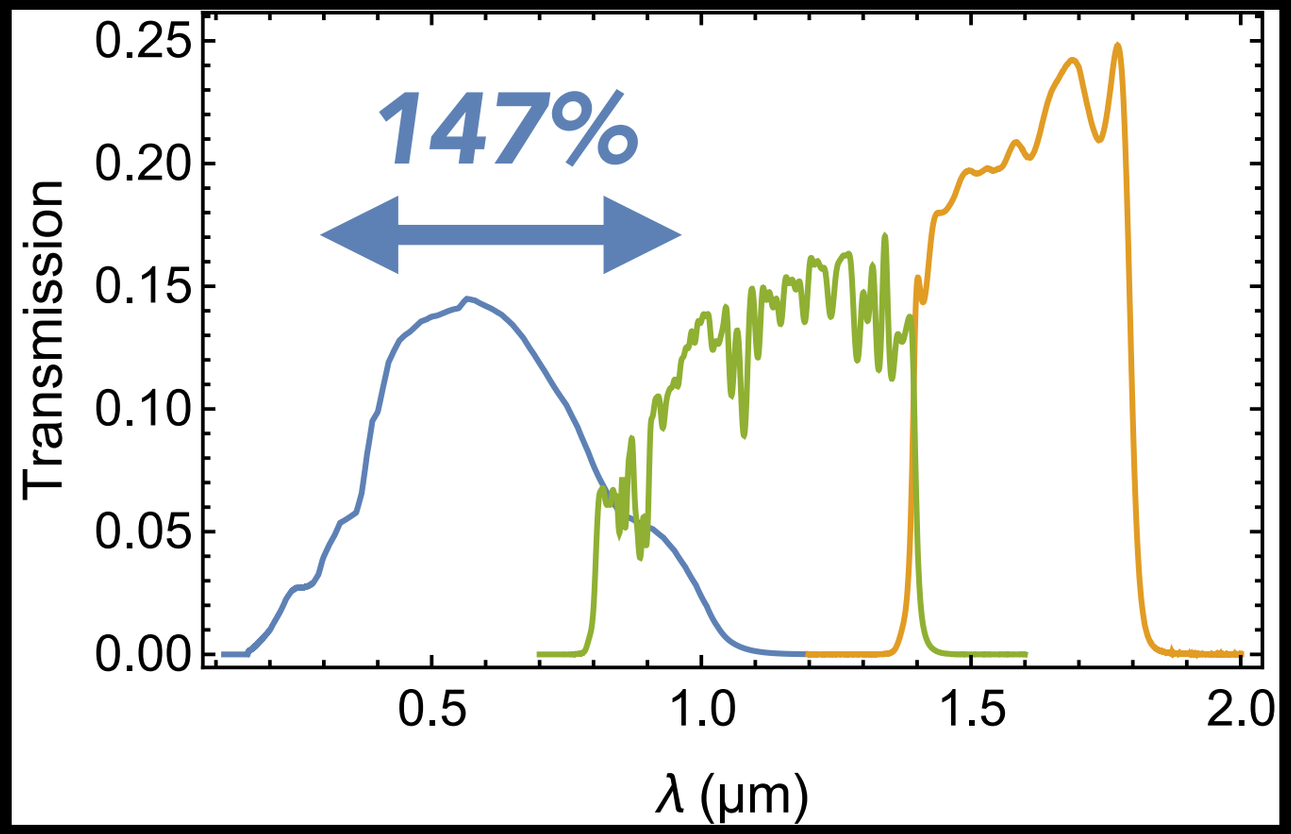
| ef Stars |
|---|
| 55 |
| 66 |

*al. 2014*
*6, 2017, 2018*
*Mazoyer et al. 2016*
*Milli et al. 2015*
*Ren et al. 2018*

# MRDI

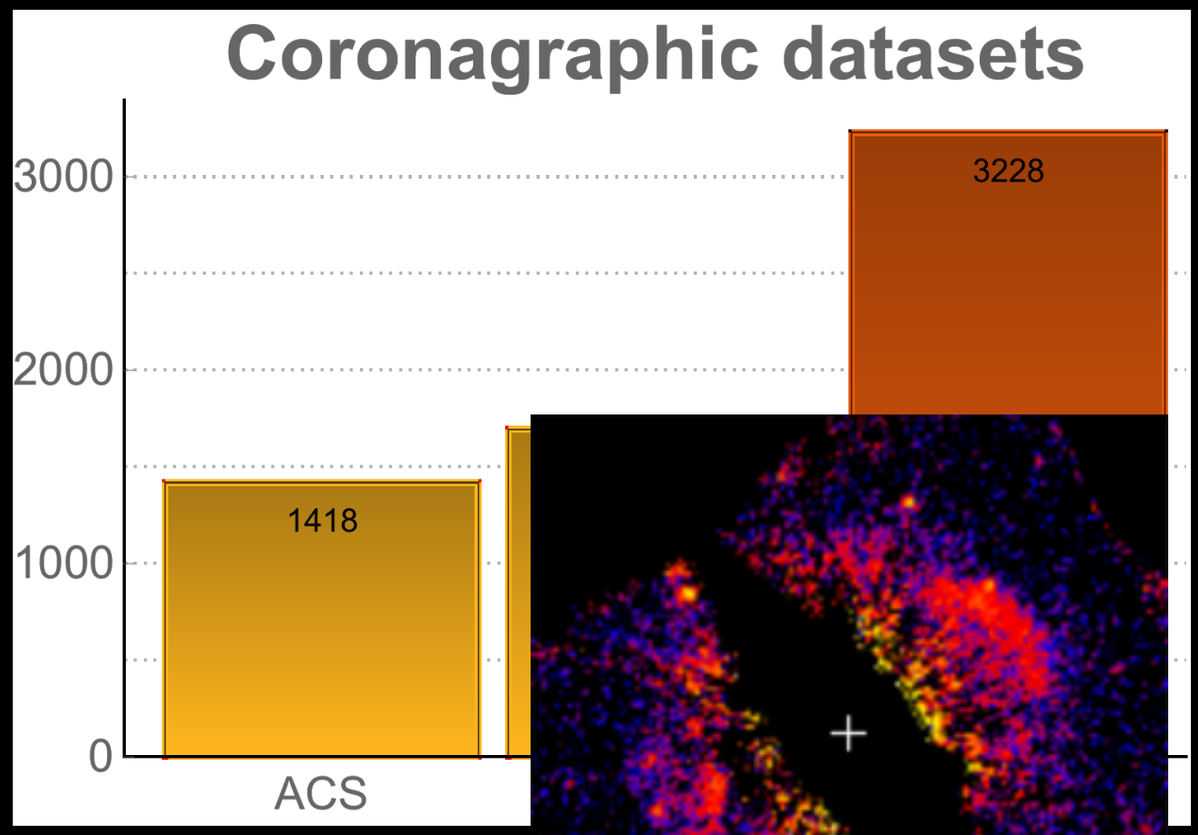
## STIS archives

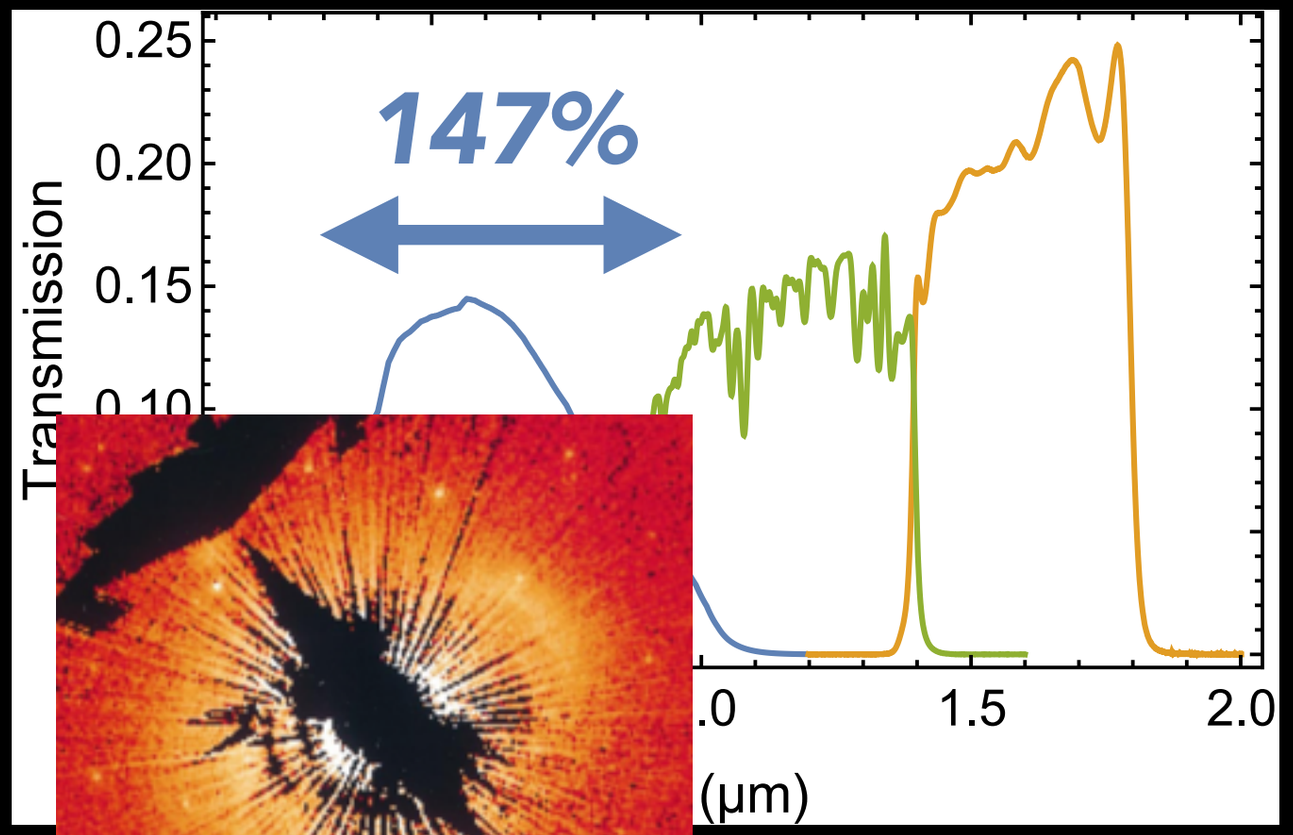


# MRDI

## STIS archives



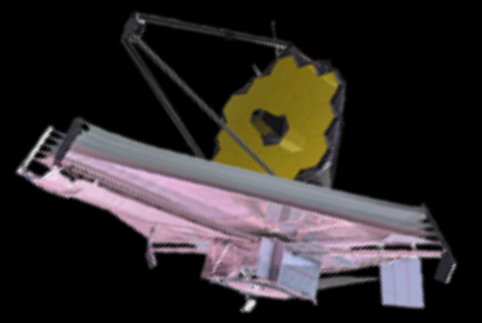

**MRDI**

*Ren et al. 2017*

**RDI**

*Ren et al. 2017*

# Summary



**Importance of (M)RDI :**

- ✓ Access to small separations
- ✓ Un-biased morphologies & photometries
- ➡ Better sensitivity limits

**MRDI + Space Tel.**

**Needs :**

- ✓ Good matching reference stars
- ✓ Diversity (dithering, archives)