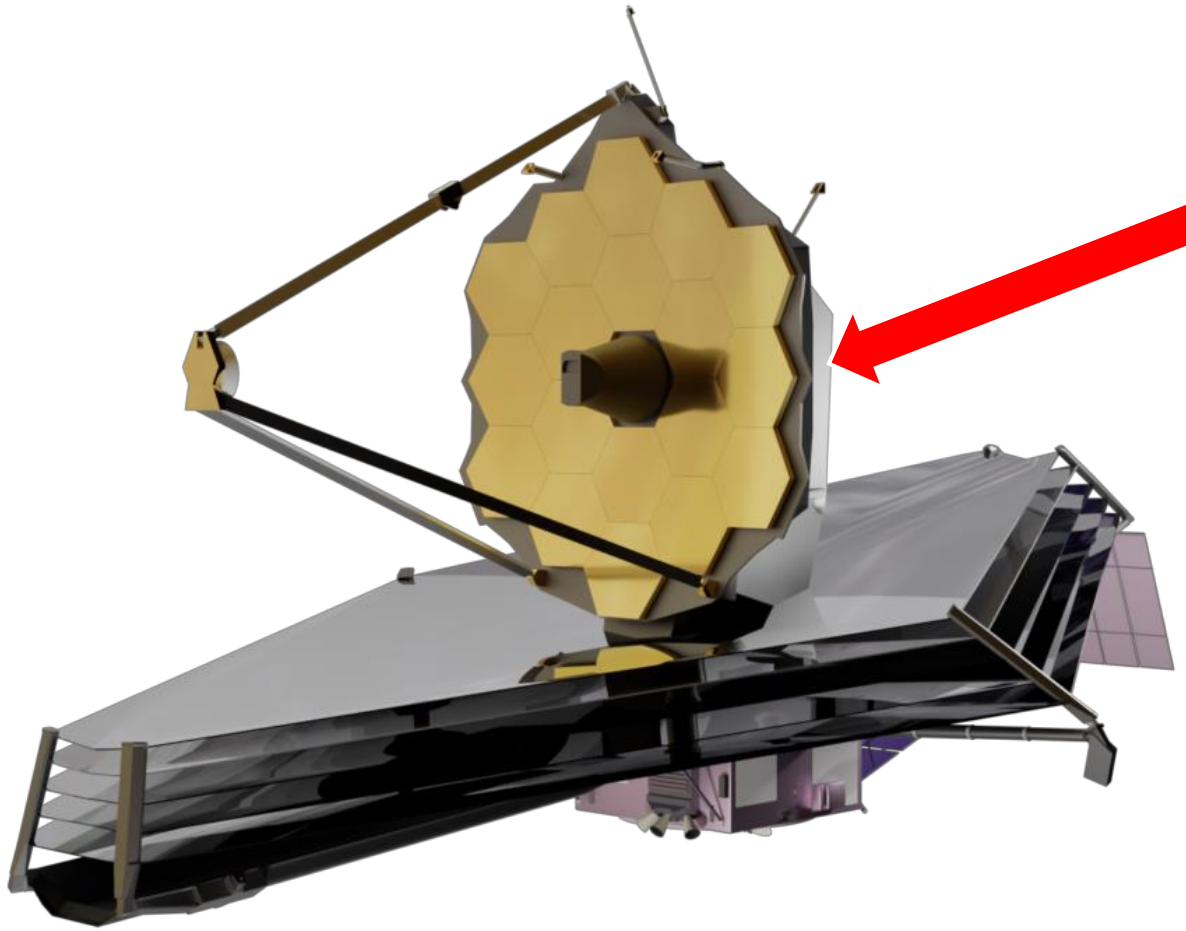

# and the James Webb Interferometer

Max Charles
THE UNIVERSITY OF SYDNEY

# JWST / AMI

James Webb Space Telescope / Aperture Masking Interferometer



NIRISS Filter Wheels

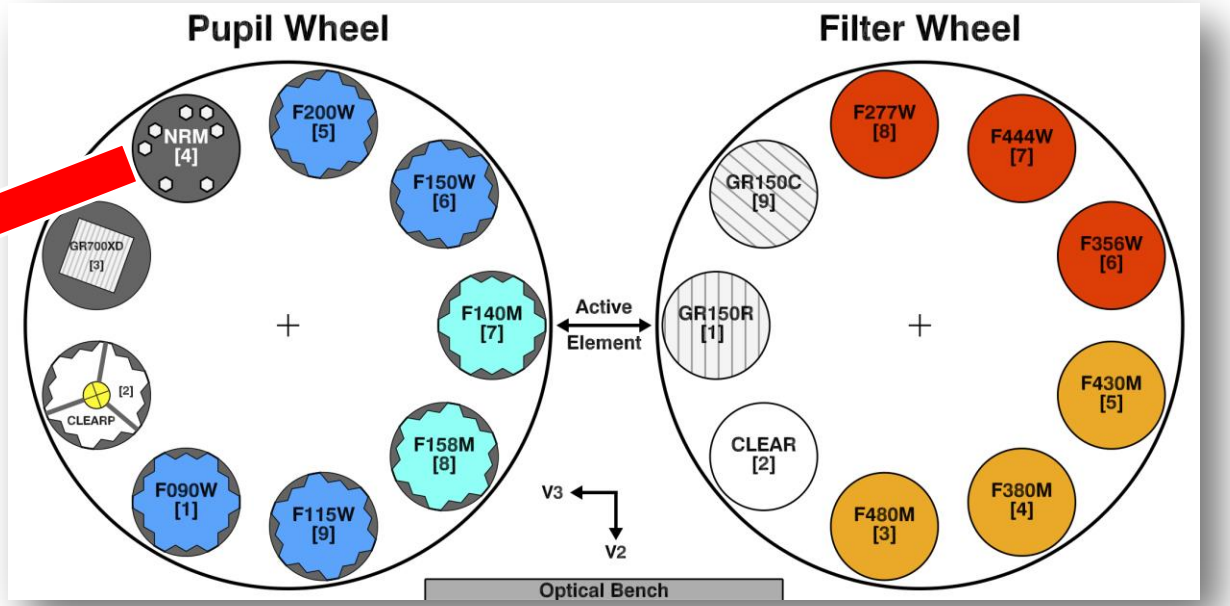


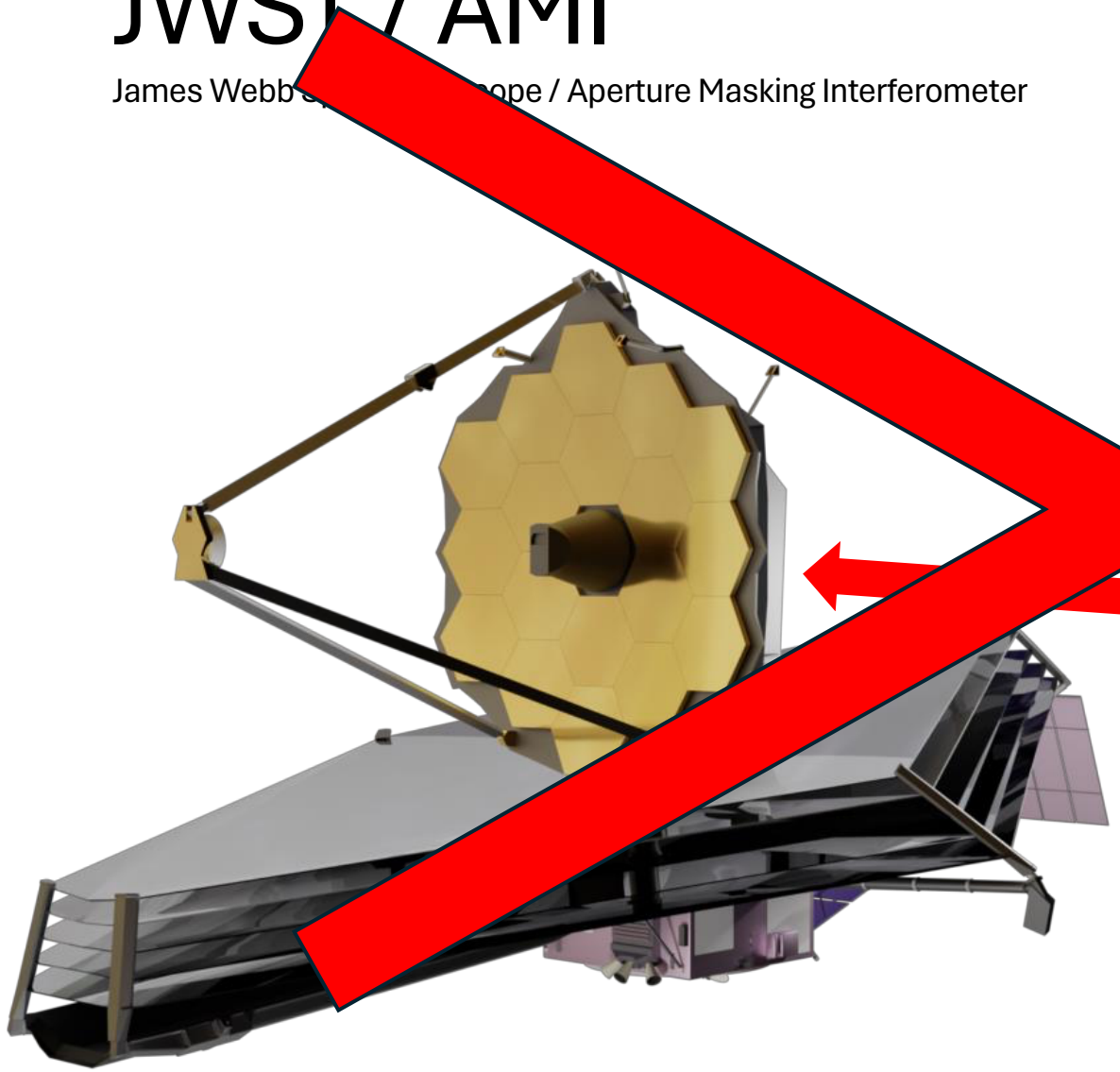

Image Credit: STScI

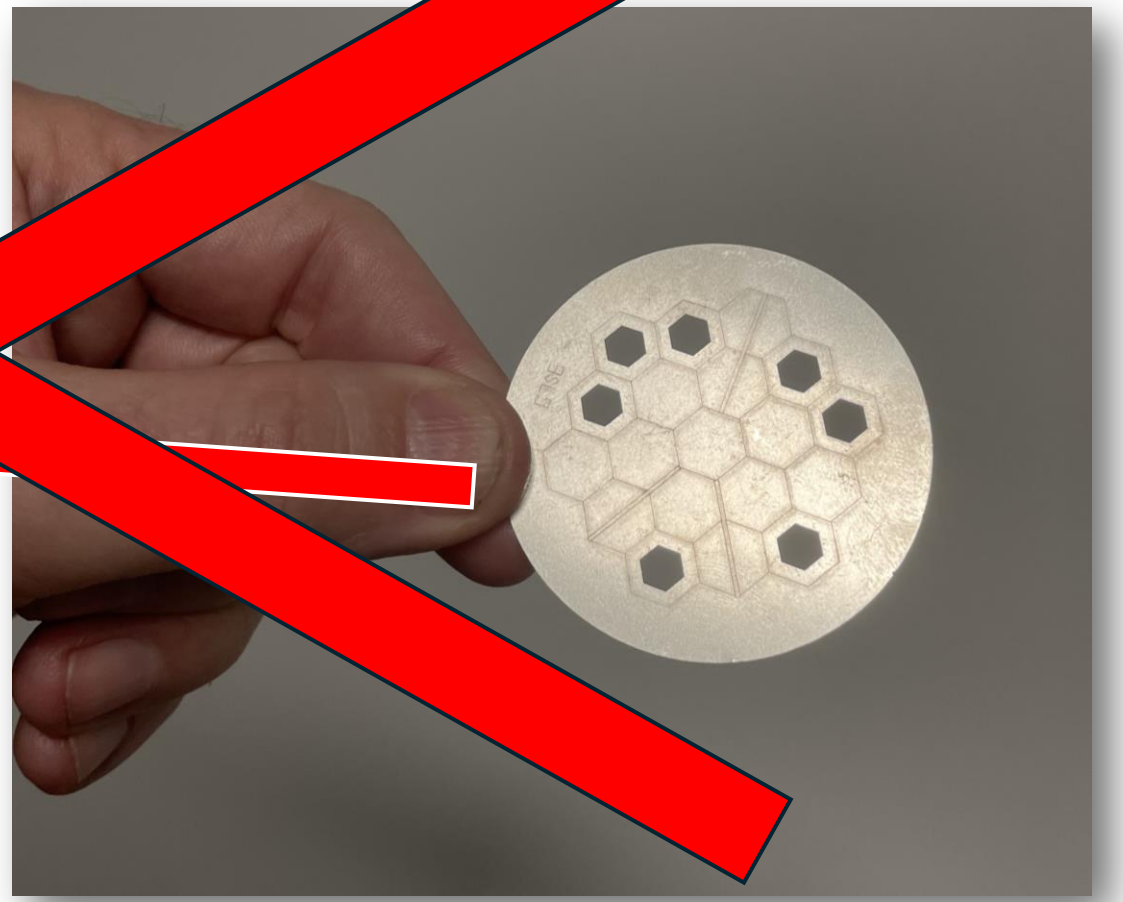
# JWST / AMI

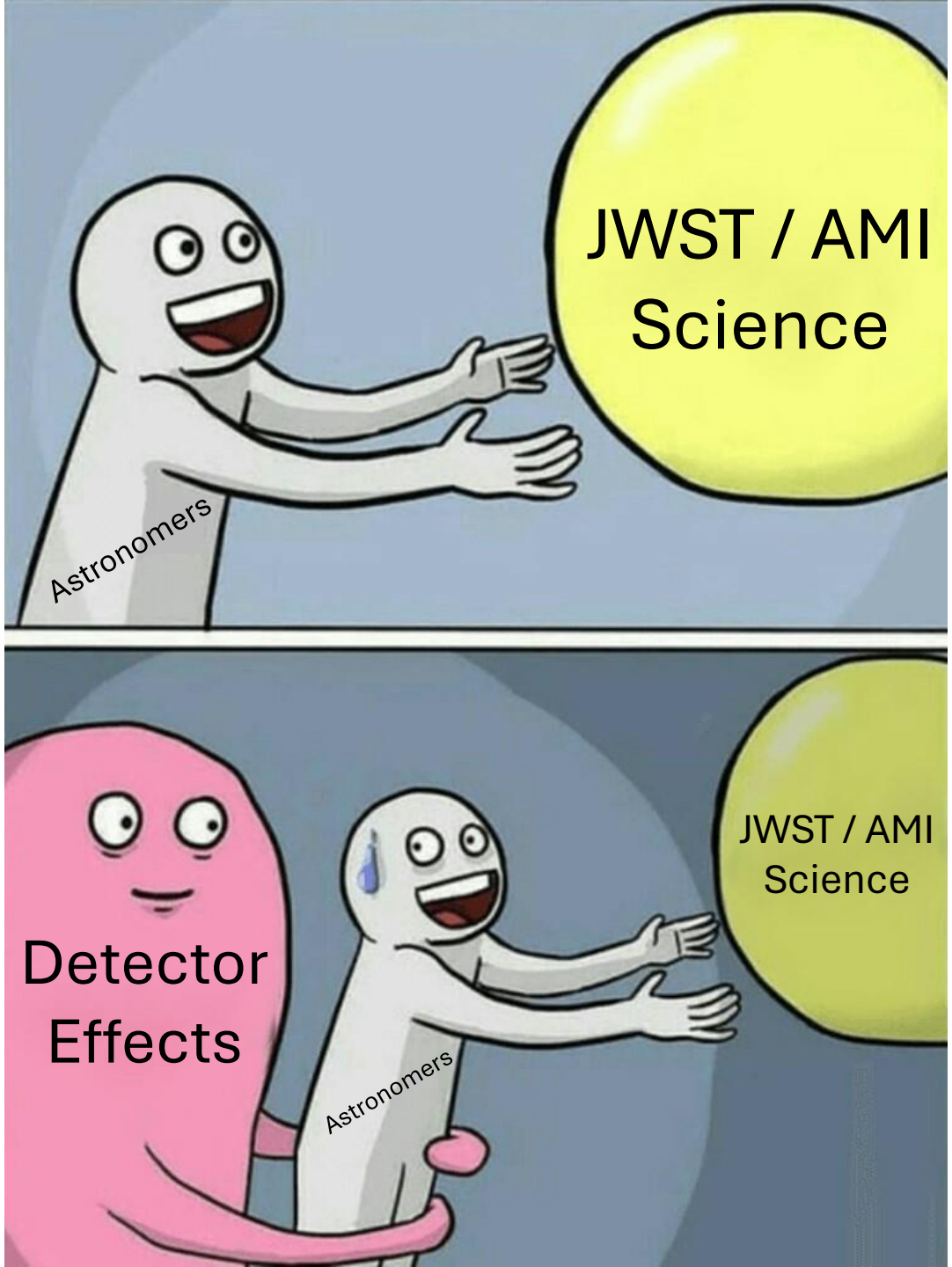
James Webb [illegible] ope / Aperture Masking Interferometer

Direct imaging of:

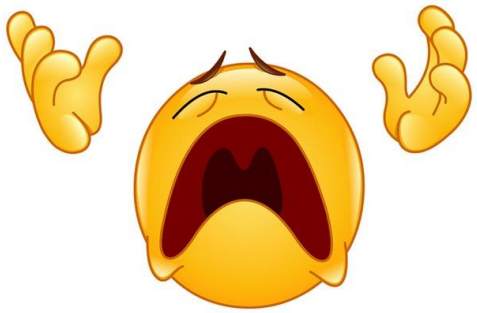
- *Protoplanetary disks!*
- *Exoplanets!*
- *Moons of [illegible]!*
- *AGN [illegible]*



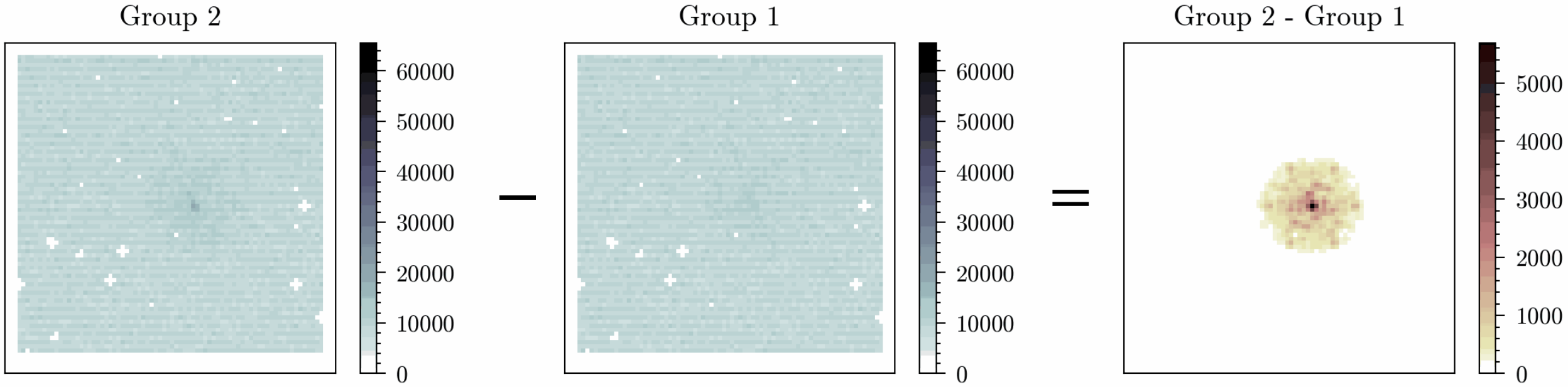



JWST / AMI Science
Astronomers
Detector Effects
Astronomers
JWST / AMI Science

# JWST / AMI … doesn't work!

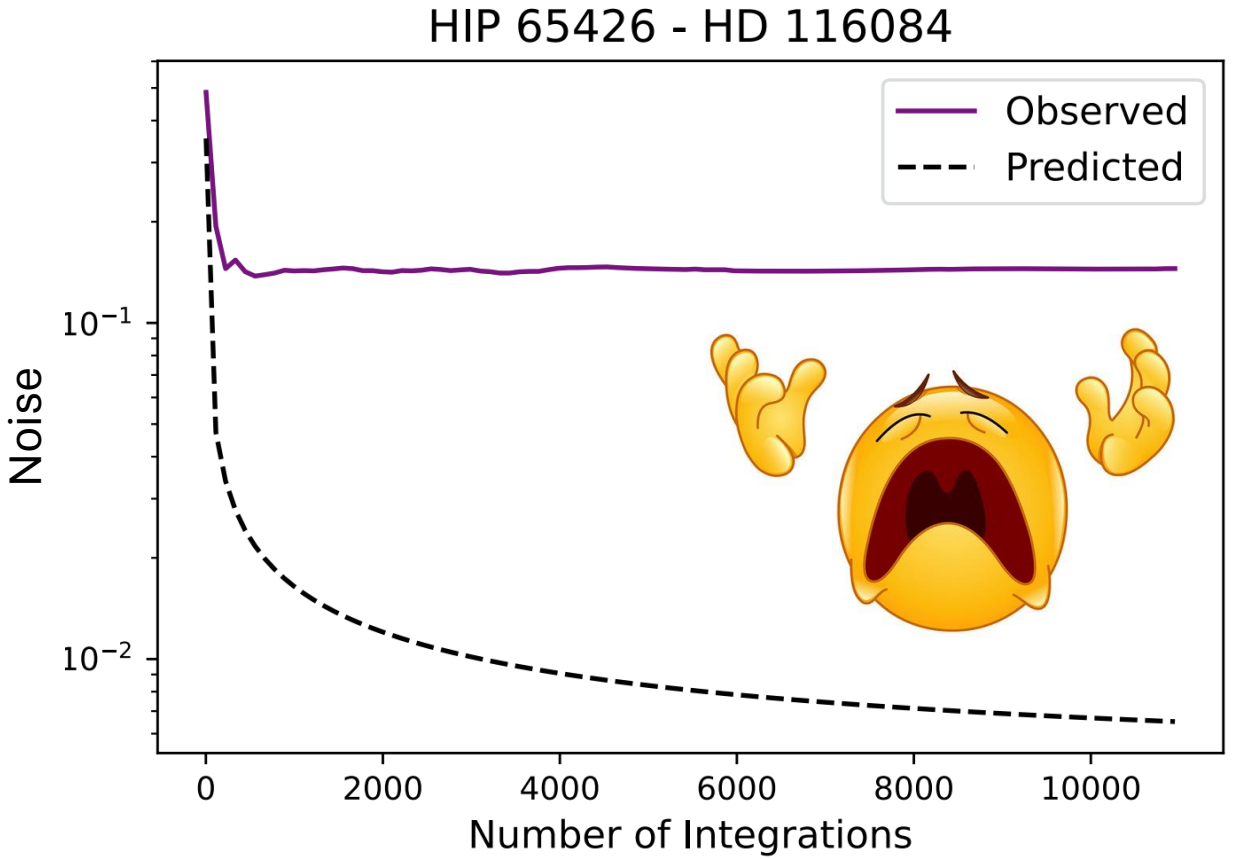


- Non-linear charge migration: *The Brighter-Fatter Effect*



# JWST / AMI … doesn't work!

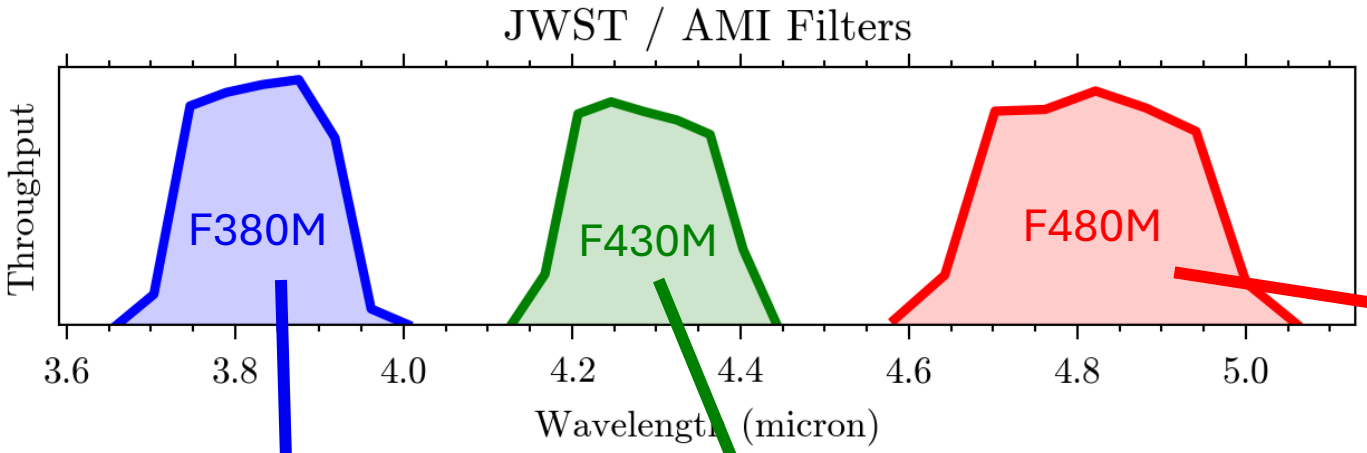
- No better than the ground!

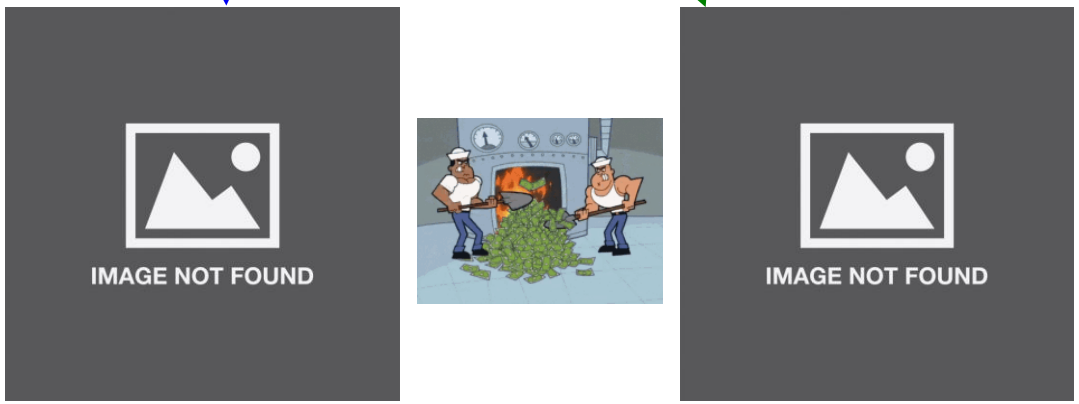


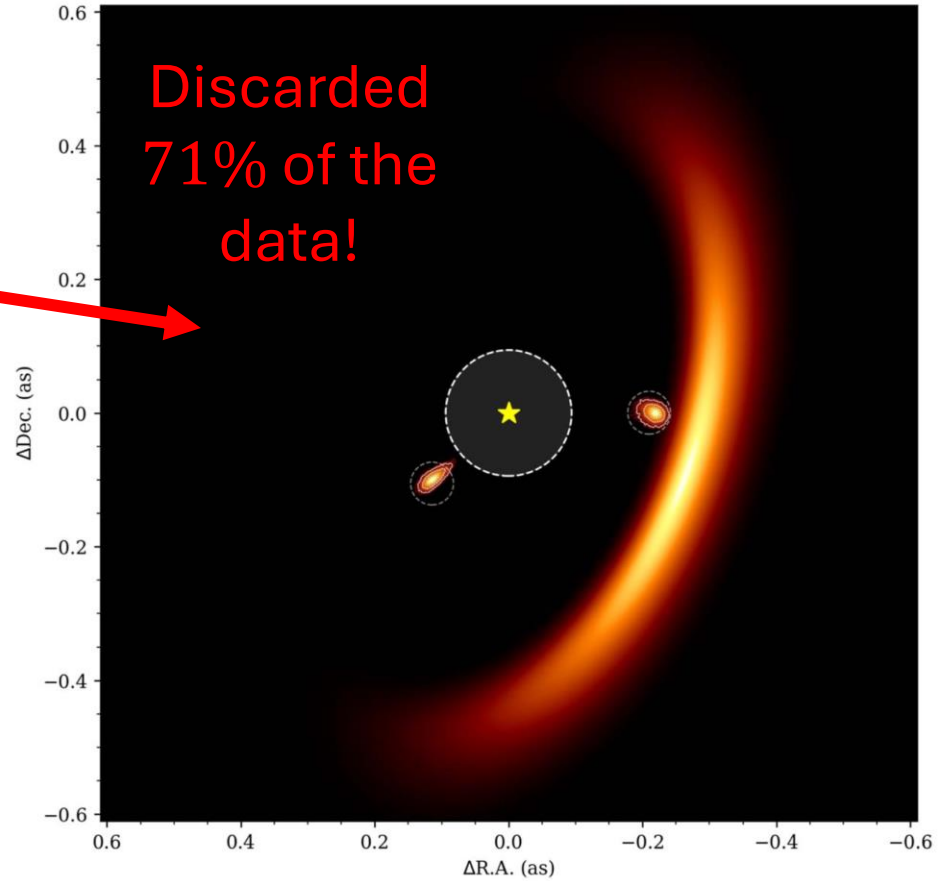

*Sallum+ 2024*

# PDS 70 Pre-AMIGO Results

Dori Blakely



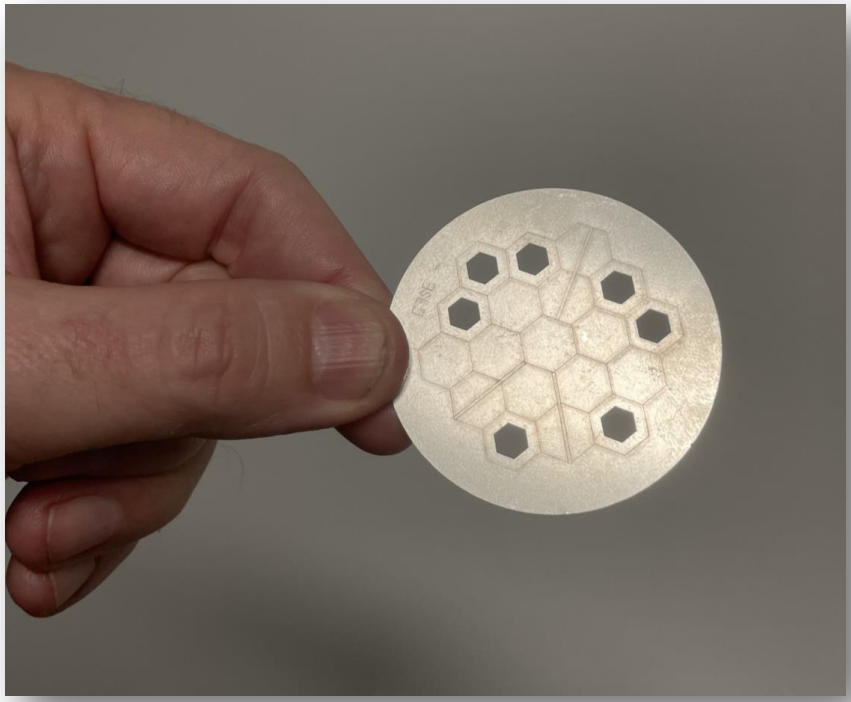



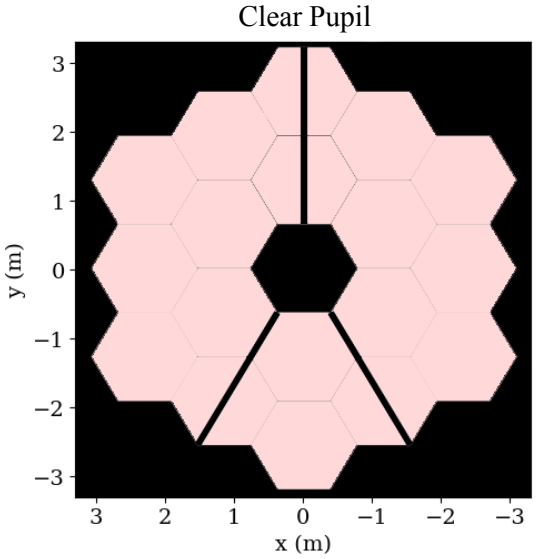



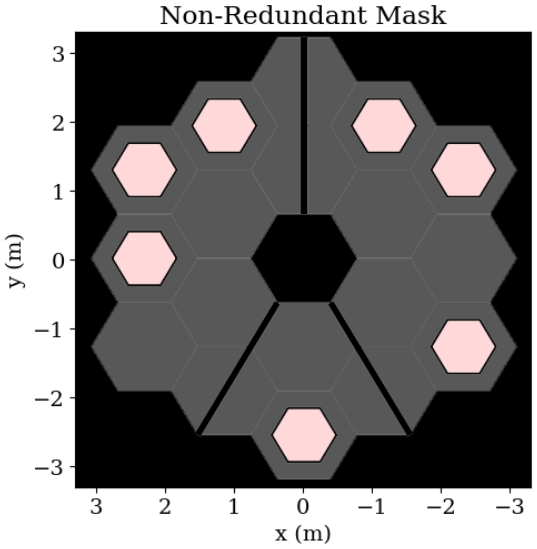

*from Blakely+ 2025*

Part 1

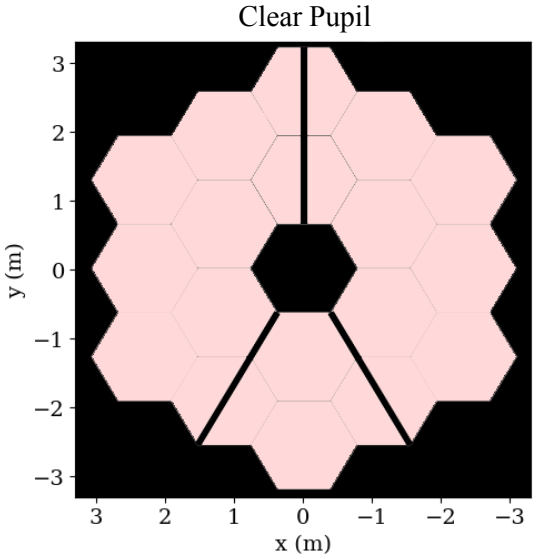
# Aperture Masking Interferometry

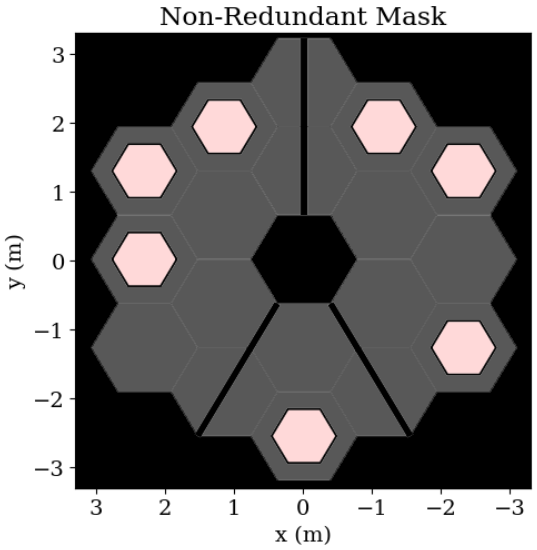


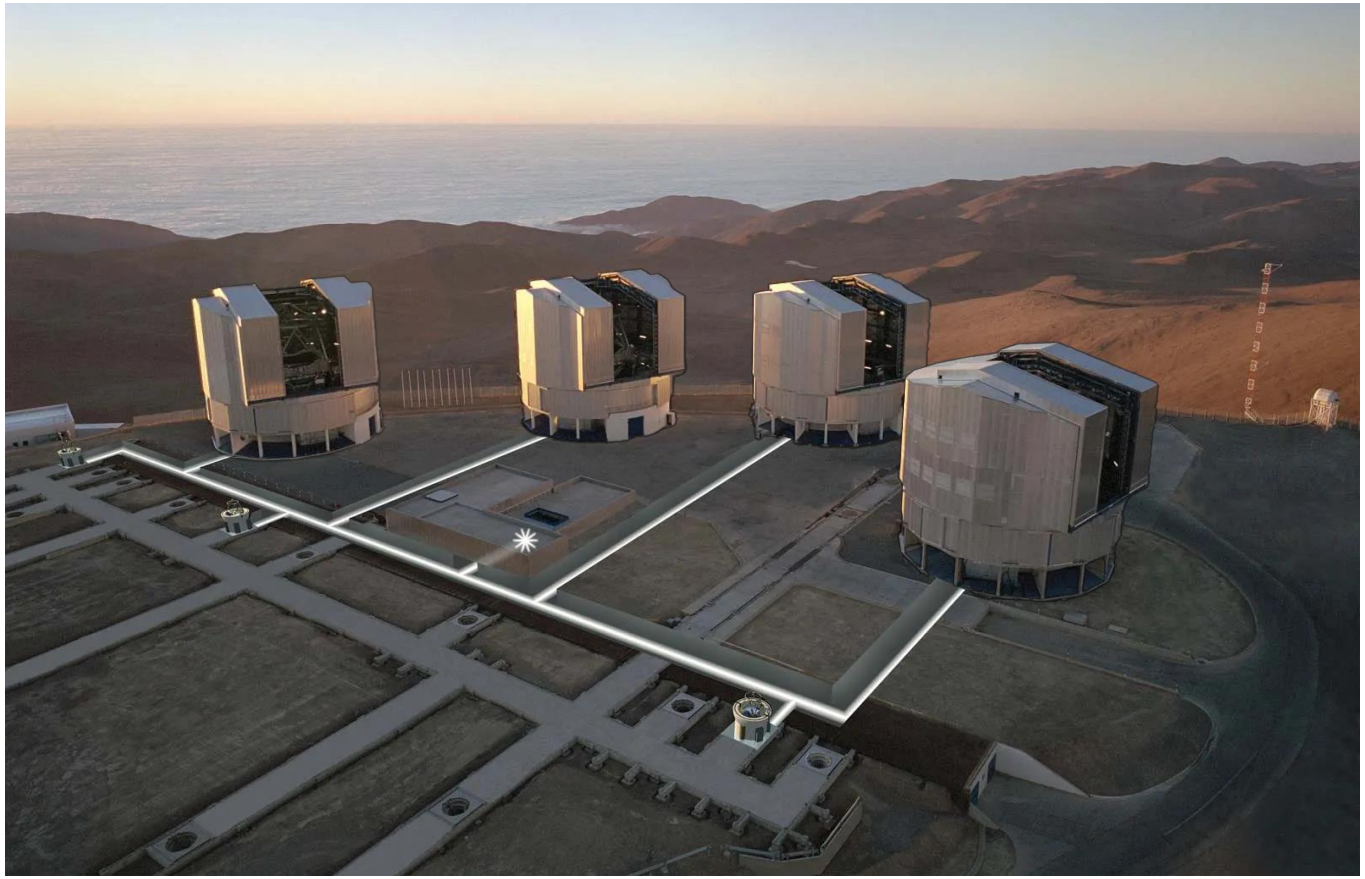



# Pupil Plane

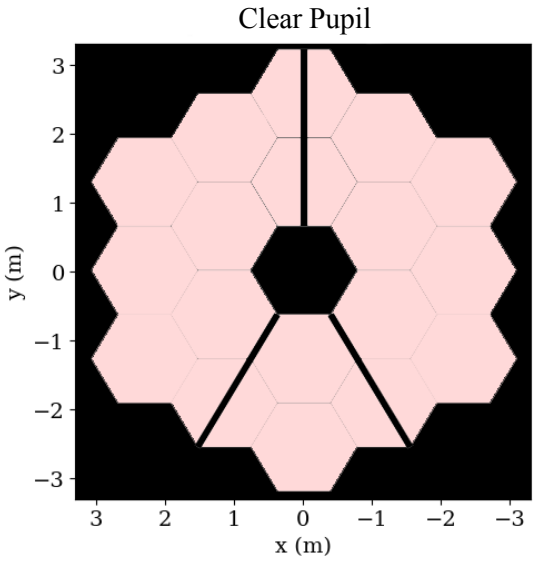


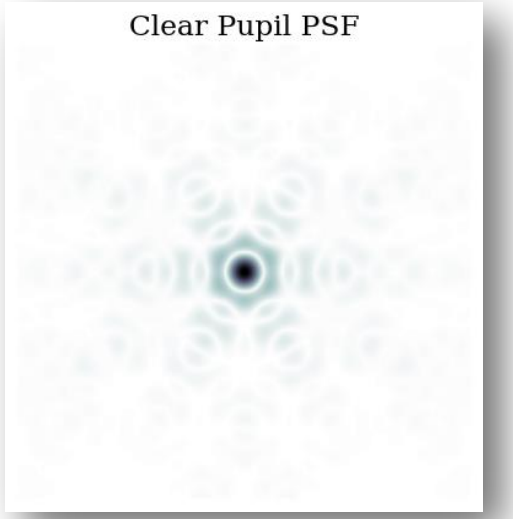



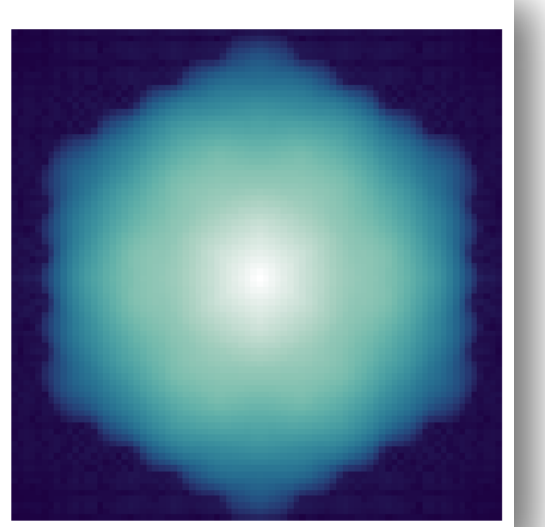
*VLTI — Image Cred: ESO / Britannica*

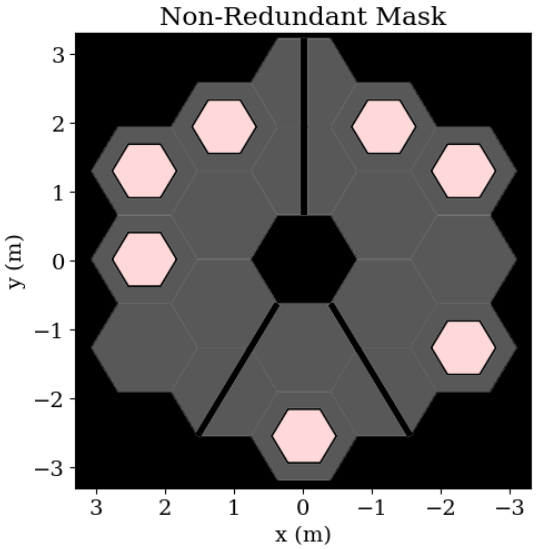
# Pupil Plane



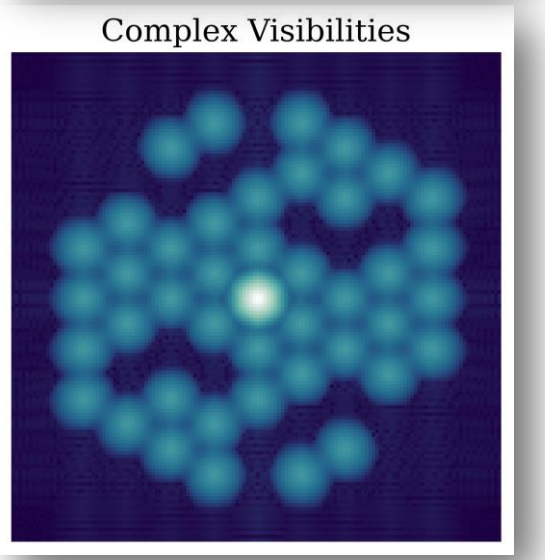

FFT







FFT

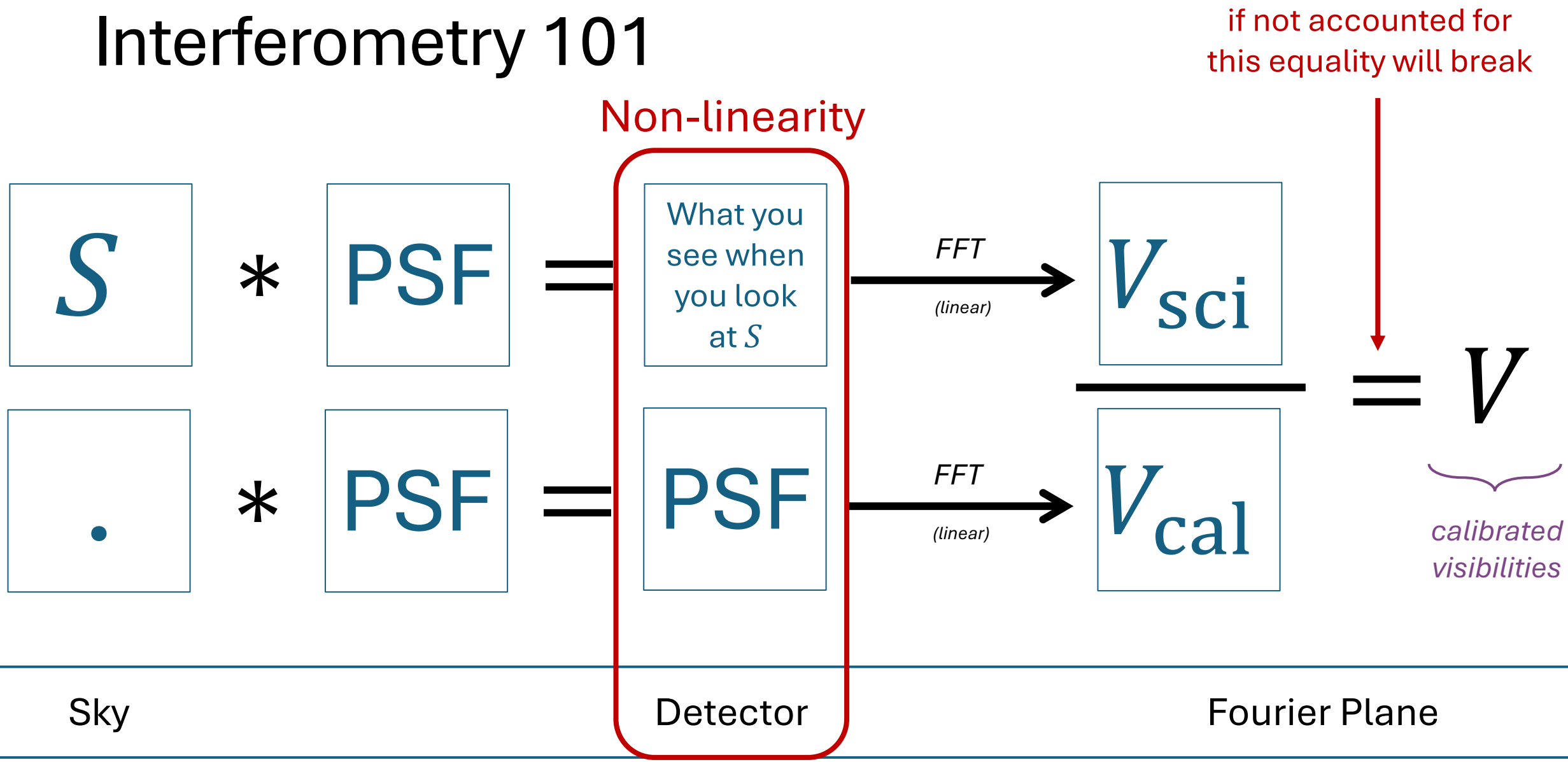



Pupil Plane

Focal Plane

Fourier Plane

# Interferometry 101



Part 2

# Inverse vs Forward Modelling

# Inverse vs Forward Models

$$\underbrace{y}_{\text{thing we measure}} = f(\underbrace{x}_{\text{thing we want}})$$

**Inverse model approach:**

Construct an inverse model $f^{-1}$, such that $x = f^{-1}(y)$

Pros:
- Simple

Cons:
- Intractable if $f$ is non-linear

**Forward model approach:**

Construct the forward model $f$, then *infer* $x$ from the data $y$

Pros:
- Non-linear functions are possible

Cons:
- More complex
- Computationally expensive

Part 3

# AMIGO:
## A Forward-Model Approach

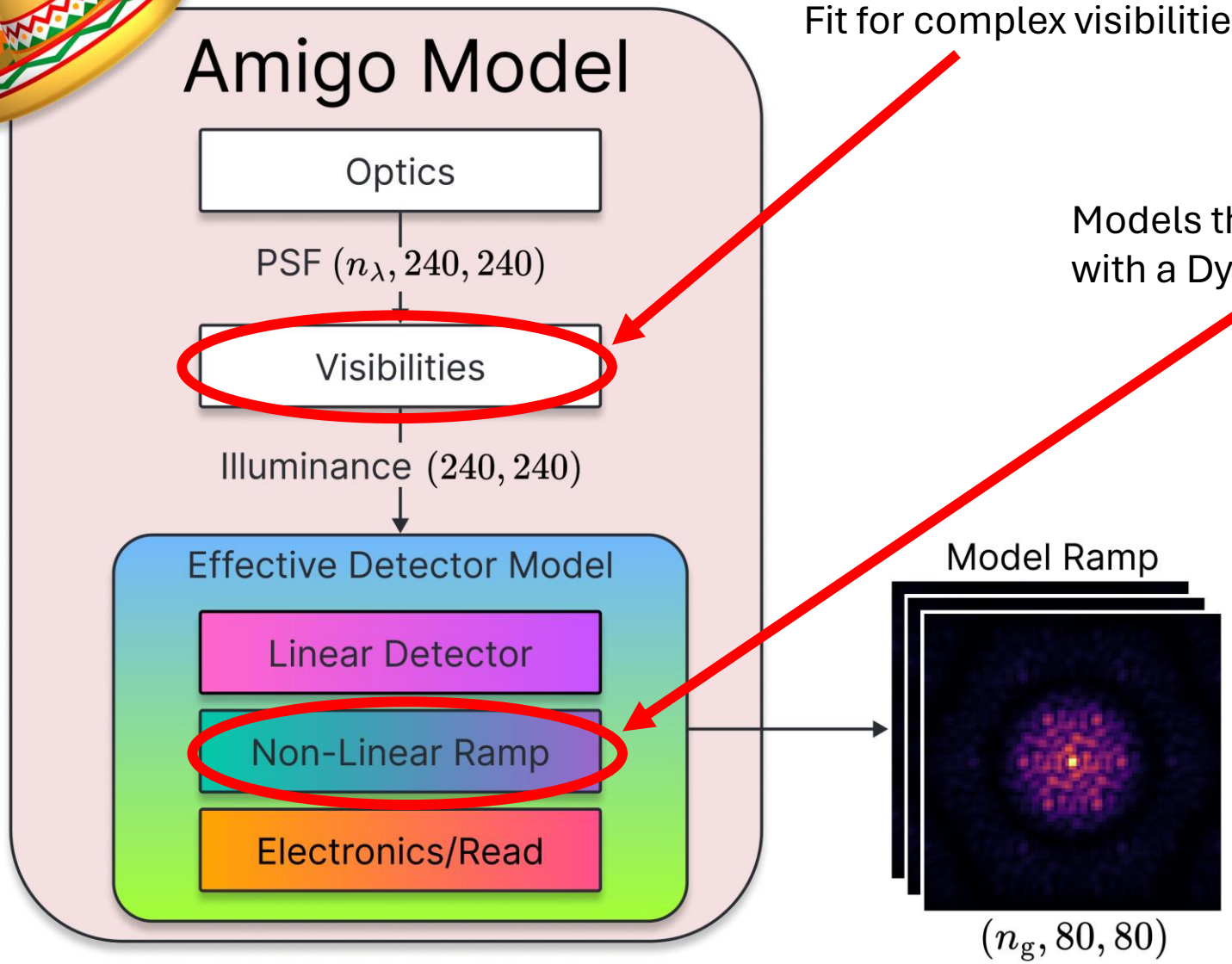


- Image reconstruction framework interfacing with AMIGO [me]
- Optics, visibility, and detector forward-models of JWST / AMI [Louis Desdoigts]
- Differentiable optical modelling framework [Louis Desdoigts]
- Lightweight Equinox extension with simpler API [Louis Desdoigts]
- Scientific framework for JAX differentiable classes [Patrick Kidger]
- Automatic differentiation, GPU-acceleration, numpy API [Google]
- Programming language

Louis Desdoigts

Fit for complex visibilities

Models the Brighter-Fatter Effect with a Dynamic Filter CNN





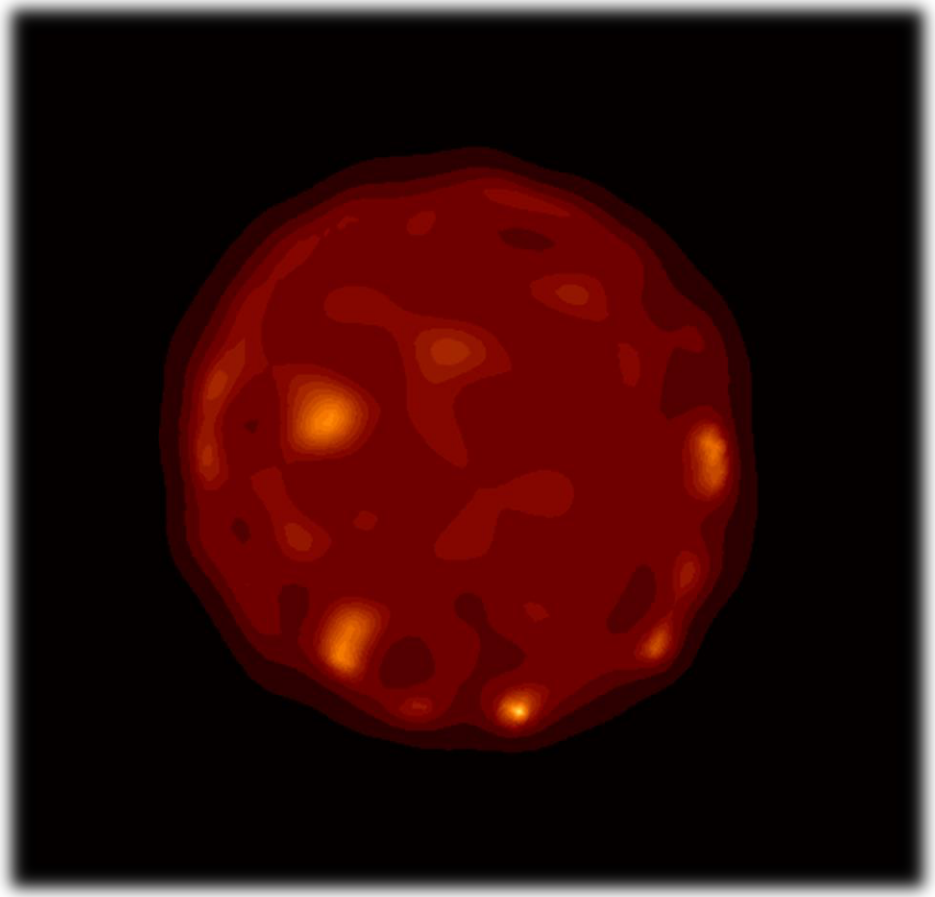


DATA

Estimators such as:
- Gradient Descent
- HMC

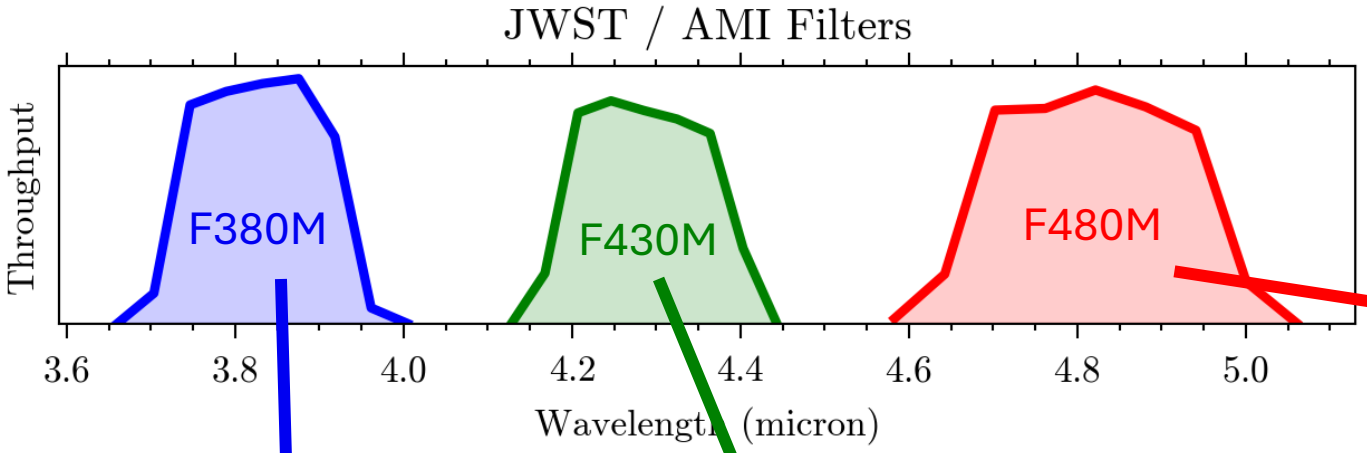
Part 5

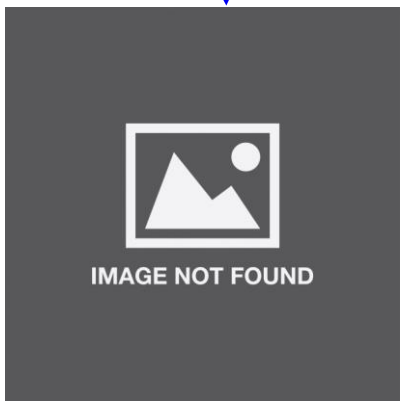
# AMIGO Results

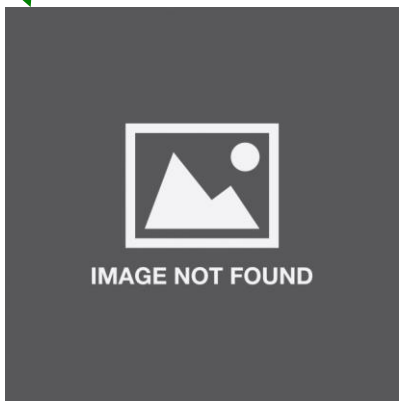


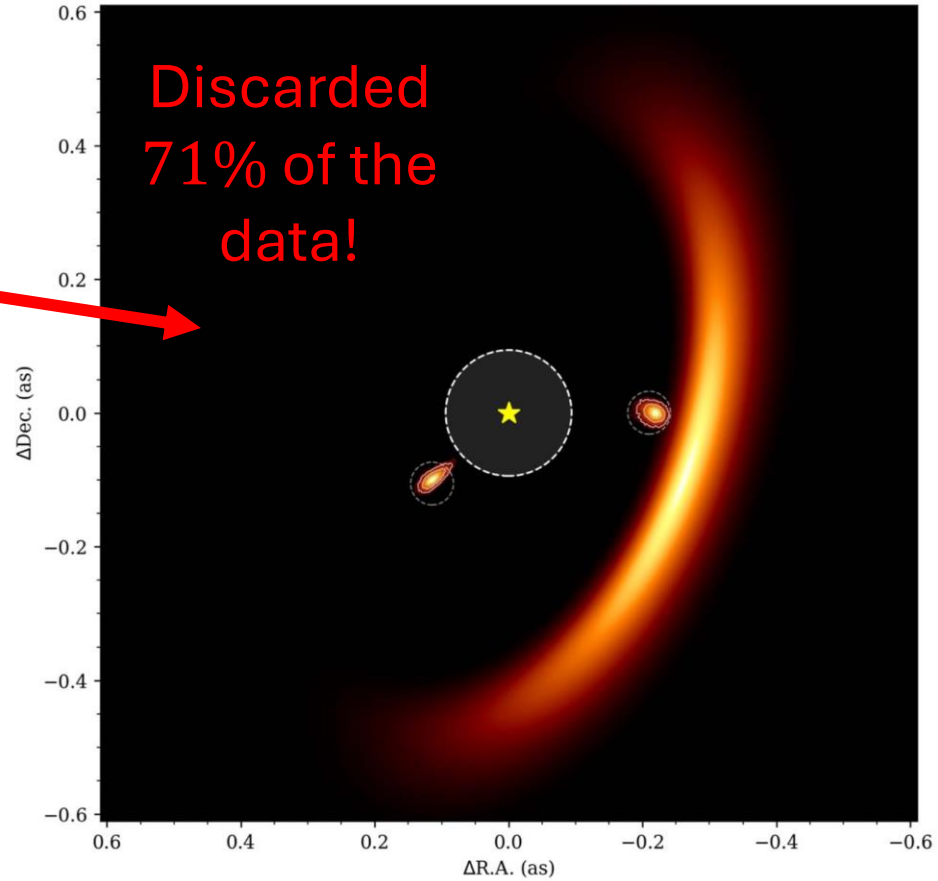
Dori Blakely

# PDS 70 Pre-AMIGO Results



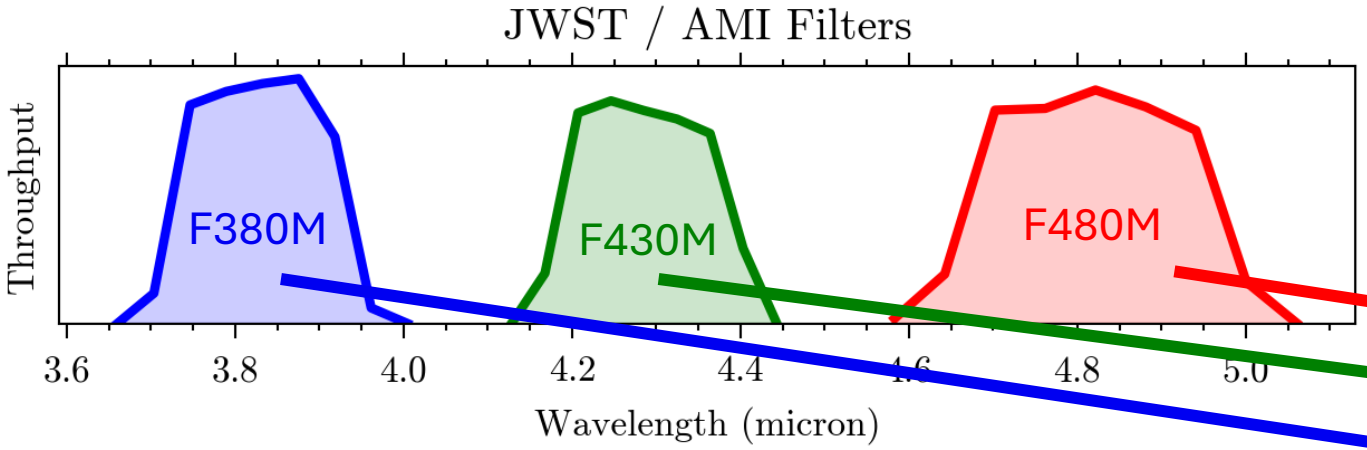



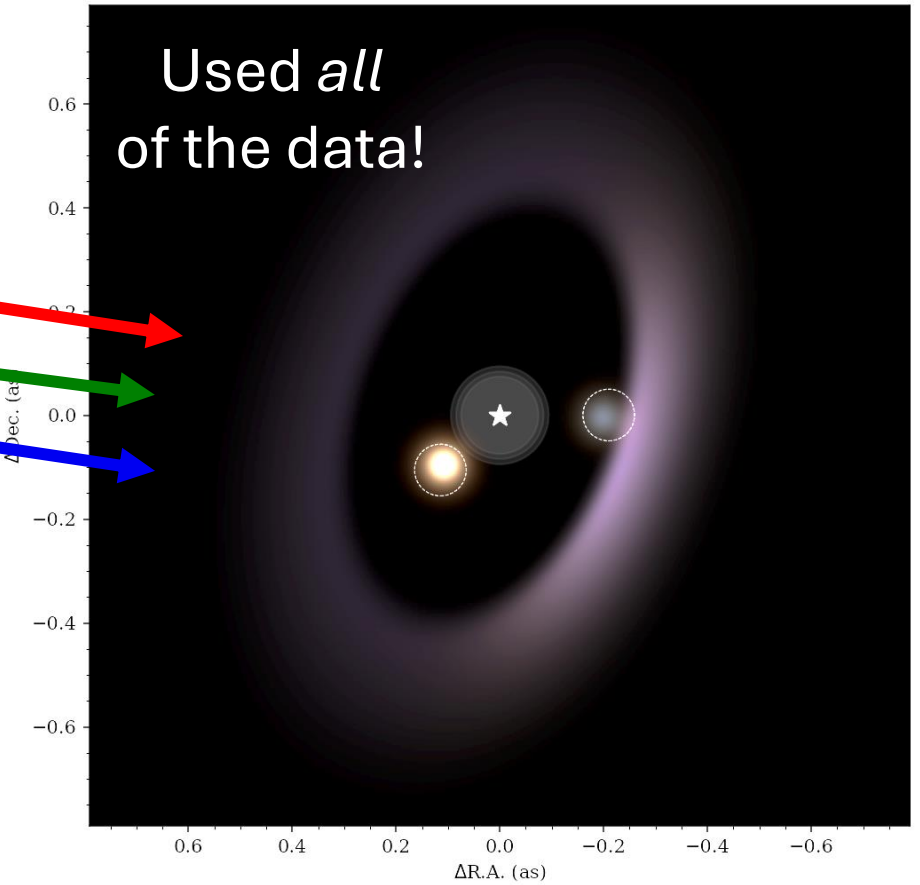




*Blakely+ 2025*

Dori Blakely

# PDS 70 Post-AMIGO Results

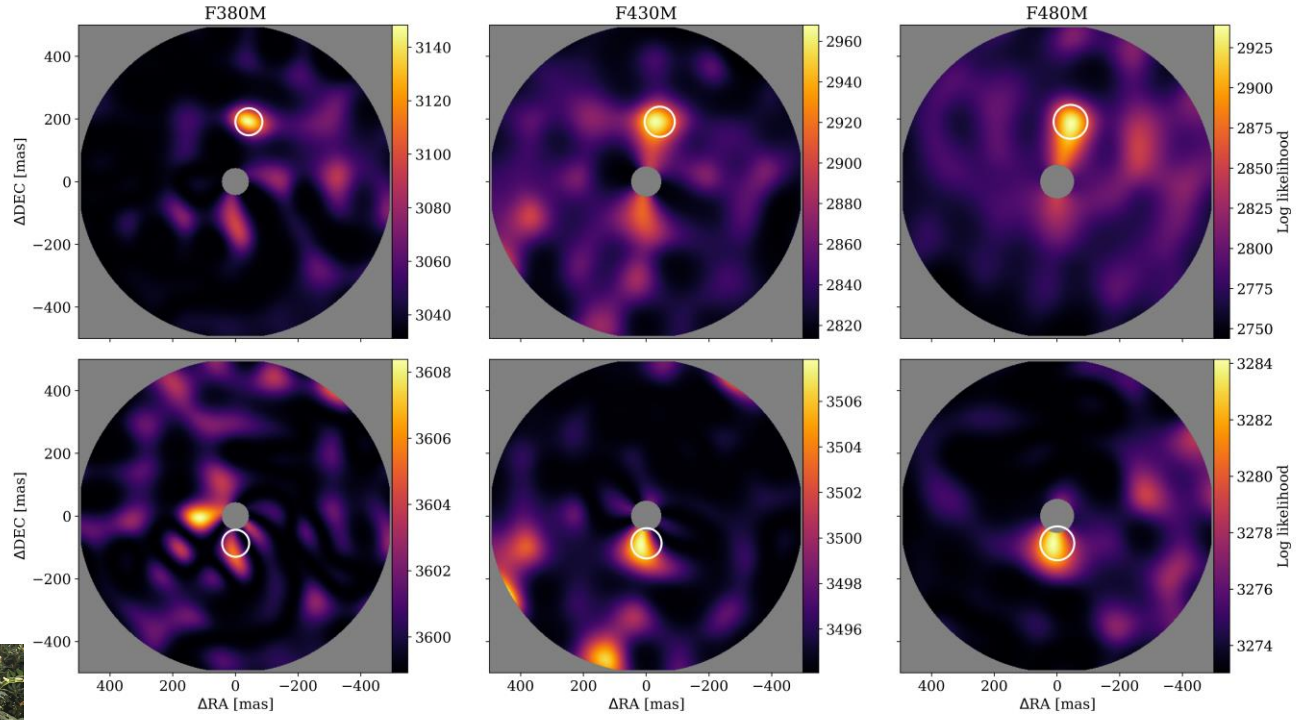



*(very) preliminary results*
*Correspondence from Blakely*

# HD 206893 Companion Detections

- Star + Brown Dwarf + Planet



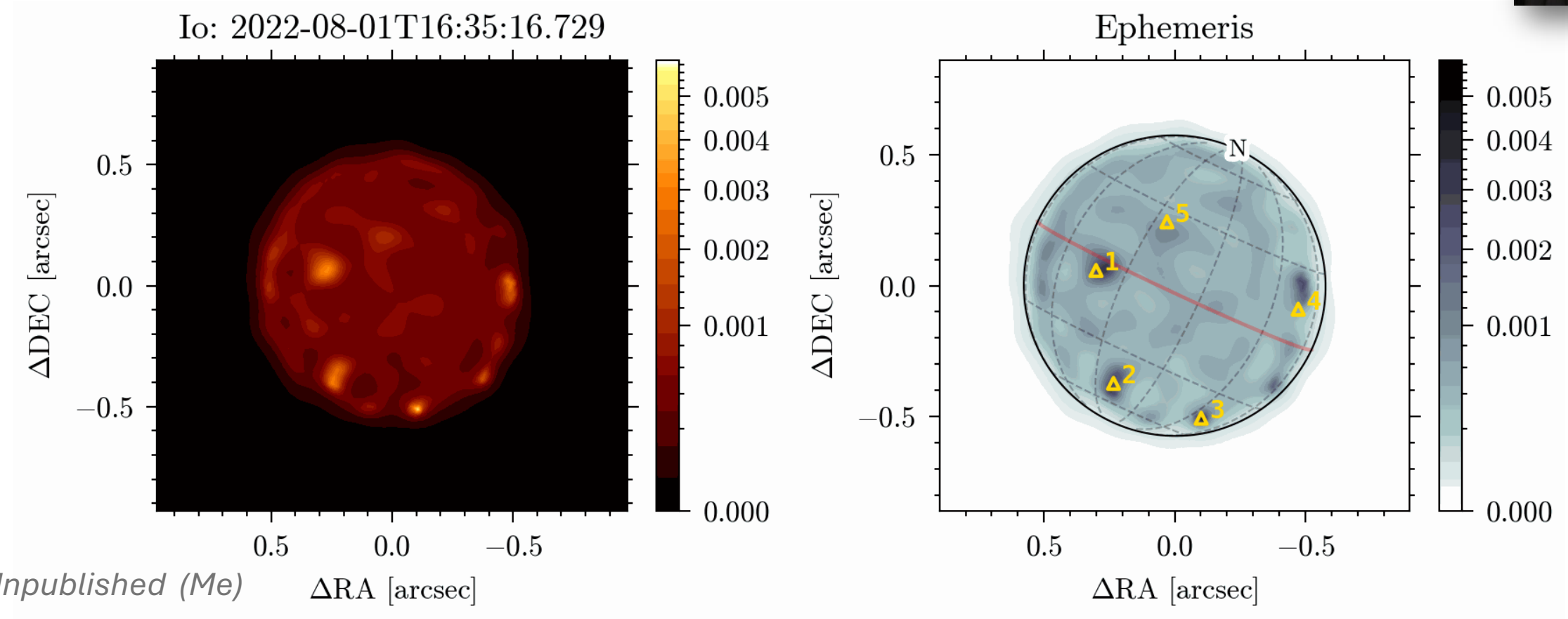

*Desdoigts+ 2025 (Submitted)*

# HD 206893 Companion Detections

- Star + Brown Dwarf + Planet

Max Charles

# Volcanoes on Io




*Unpublished (Me)*


Peter Tuthill

Louis Desdoigts

Max Charles

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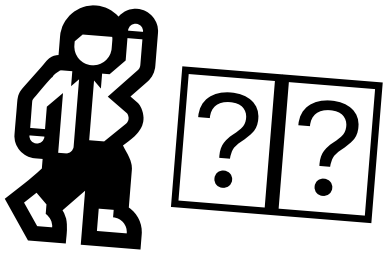
AMI is back!




Ben Pope

Shrish Ray

MACQUARIE University

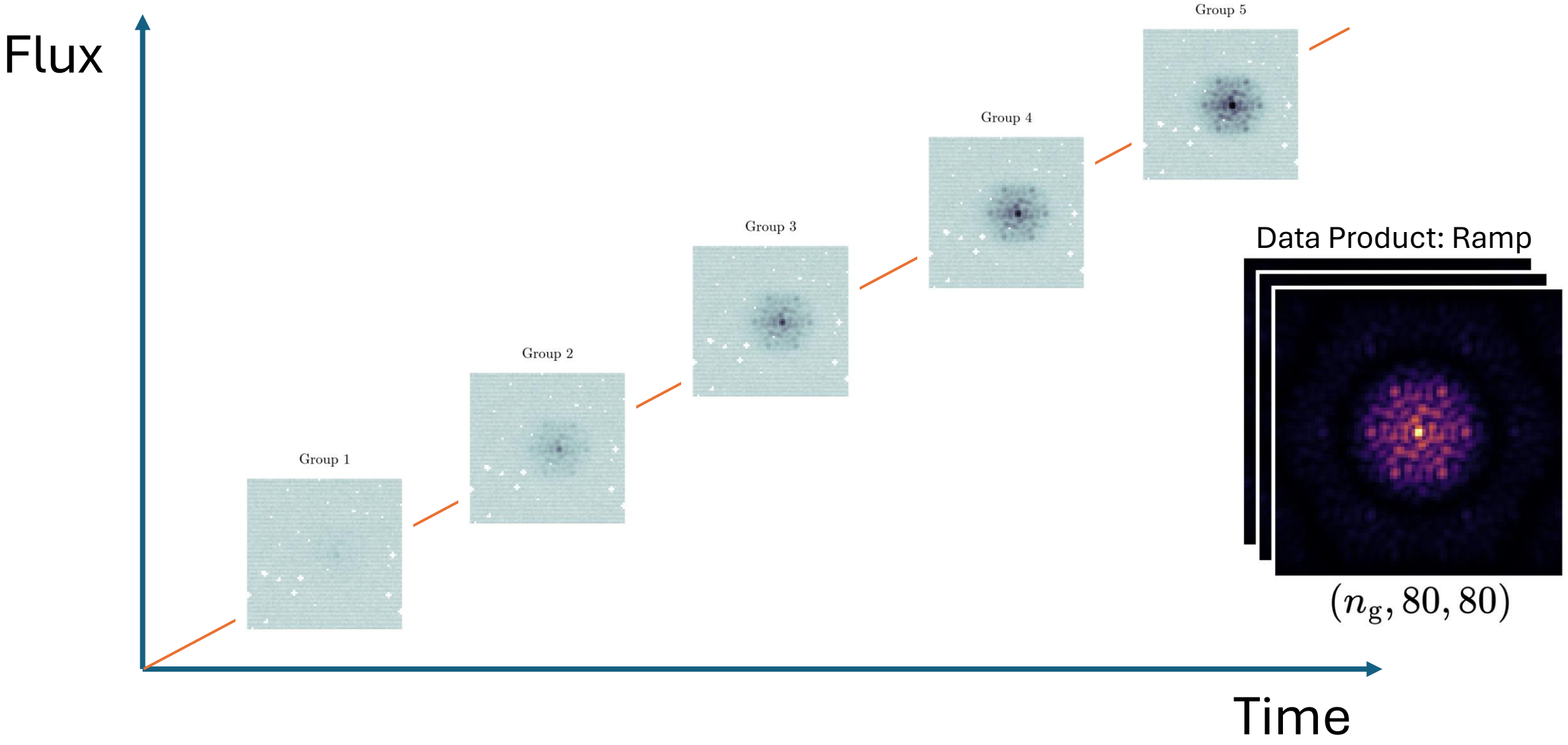
THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Doug Johnstone

Dori Blakely

University of Victoria

# JWST's "Up-the-Ramp Readout"



# *Coming up…*

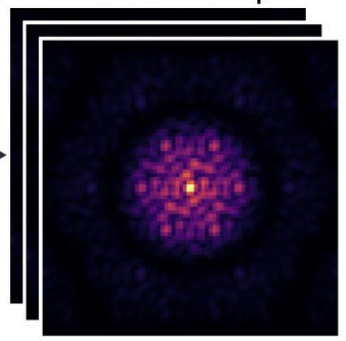
Detector non-linearities: 👎

Amigo Model

*…until now

millions of $$$ of data *unusable*!*

Model Ramp



$(n_g, 80, 80)$


Peter Tuthill

Louis Desdoigts

Max Charles

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Shrish Ray

MACQUARIE University

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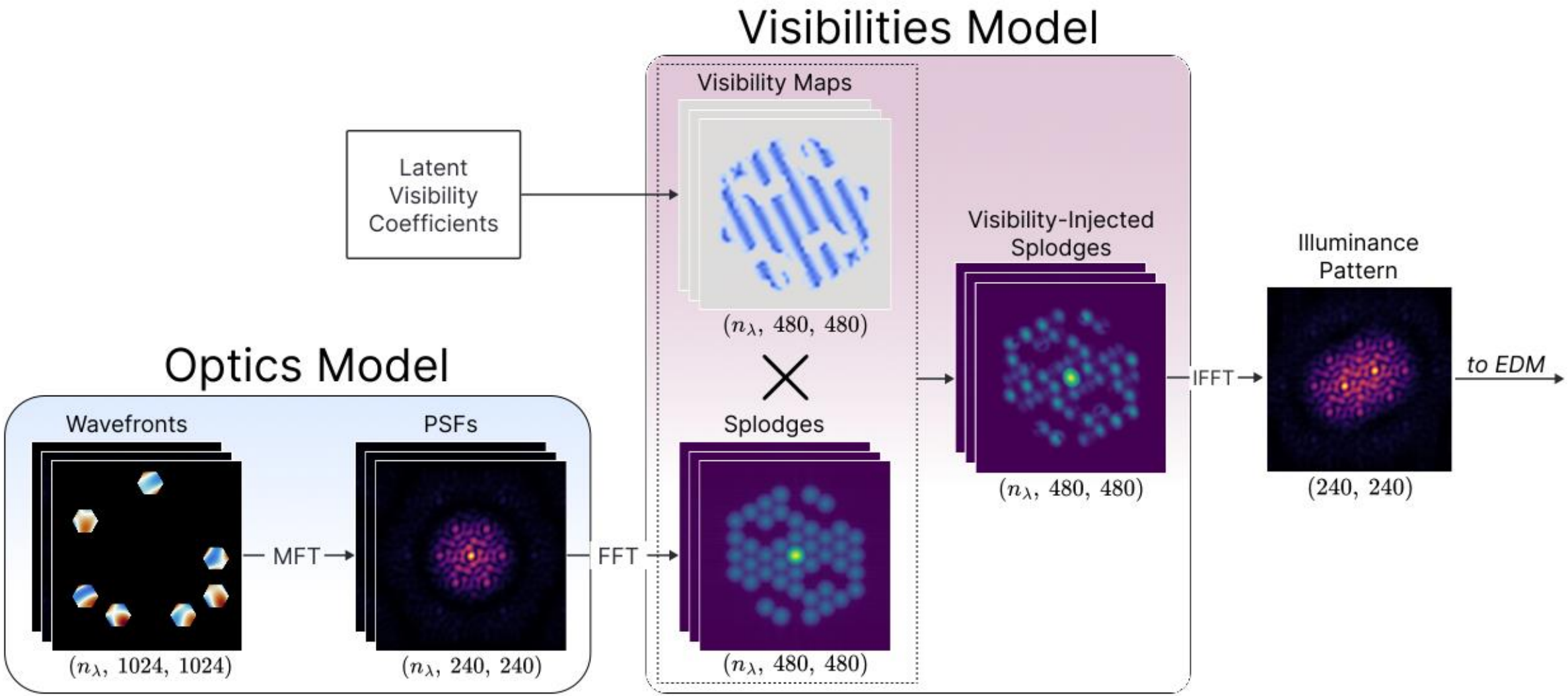
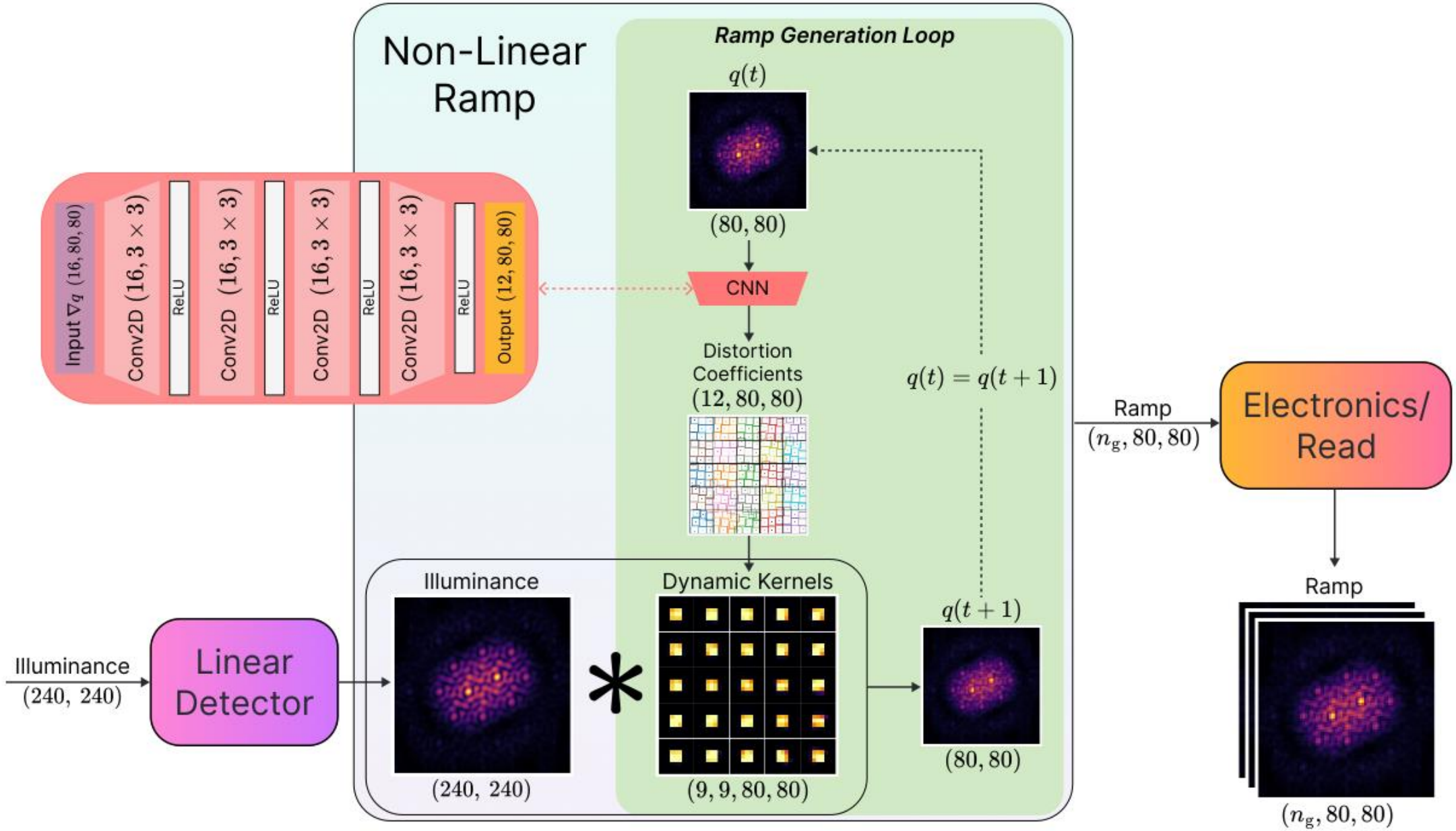
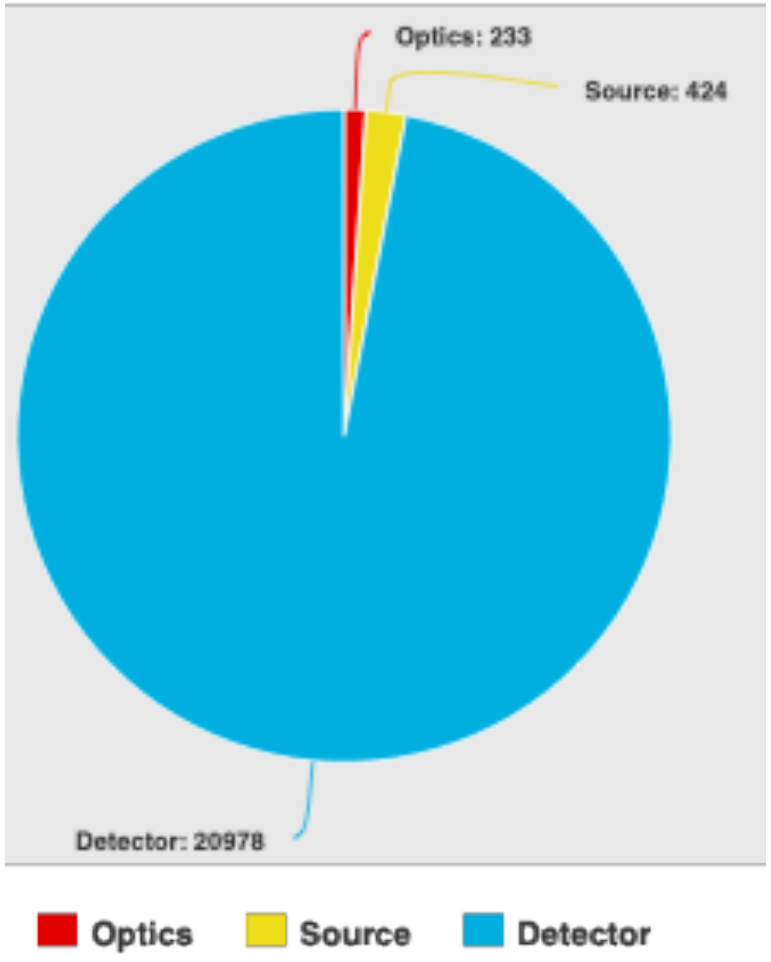
Dori Blakely

University of Victoria


Visibilities Model
Visibility Maps
Latent Visibility Coefficients
$(n_\lambda, 480, 480)$
Visibility-Injected Splodges
$(n_\lambda, 480, 480)$
IFFT
Illuminance Pattern
$(240, 240)$
to EDM
Optics Model
Wavefronts
$(n_\lambda, 1024, 1024)$
MFT
PSFs
$(n_\lambda, 240, 240)$
FFT
Splodges
$(n_\lambda, 480, 480)$


Non-Linear Ramp
Ramp Generation Loop
$q(t)$
$(80, 80)$
CNN
Distortion Coefficients
$(12, 80, 80)$
$q(t) = q(t+1)$
Input $\nabla q$ $(16, 80, 80)$
Conv2D $(16, 3 \times 3)$
ReLU
Conv2D $(16, 3 \times 3)$
ReLU
Conv2D $(16, 3 \times 3)$
ReLU
Conv2D $(16, 3 \times 3)$
ReLU
Output $(12, 80, 80)$
Illuminance
Dynamic Kernels
$(240, 240)$
$(9, 9, 80, 80)$
$q(t+1)$
$(80, 80)$
Illuminance
$(240, 240)$
Linear Detector
Ramp
$(n_g, 80, 80)$
Electronics/ Read
Ramp
$(n_g, 80, 80)$

# AMIGO Model Parameters




## Optical Parameters

- Mirror aberrations (70)
- Fresnel defocus (1)
- Mask distortion (144 + 18)

## Source Parameters

- Complex Visibilities (420)
- Positions (2)
- Fluxes (1)
- Spectral slope (1)

## Detector Parameters

### Linear Detector

- Jitter (1)

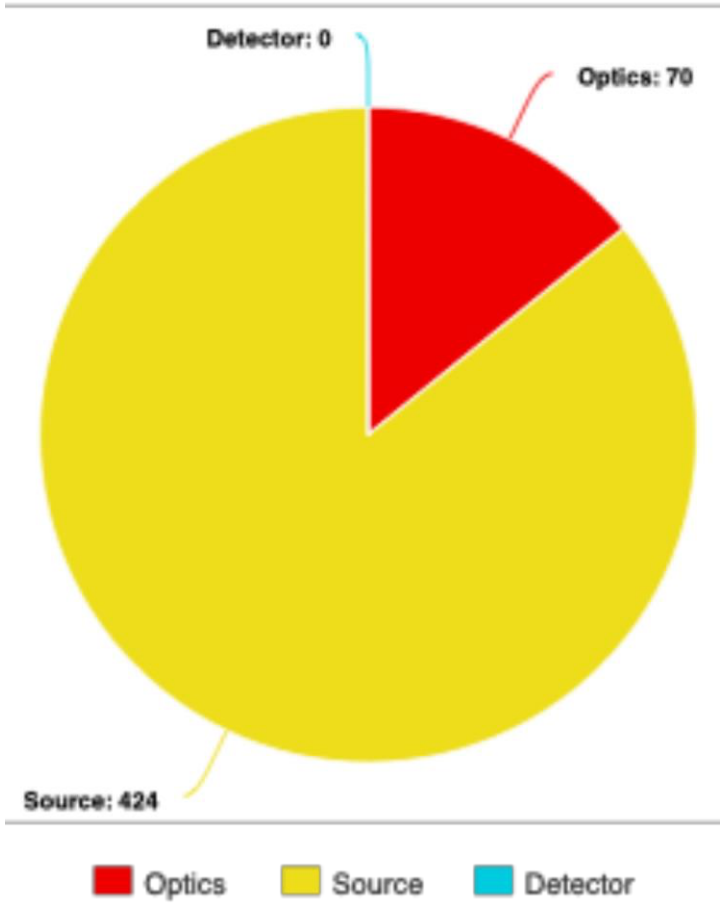
### Non-Linear Ramp

- CNN Weights (8150)
- Flat field (6400)
- Subpixel response (1)

### Electronics/Read

- Dark current (1)
- Interpixel capacitance (25)
- Pixel gain non-linearity (6400)
- $1/f$ amplifier (80)

# AMIGO Model Parameters

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- Pixel gain non-linearity (6400)
- $1/f$ amplifier (80)

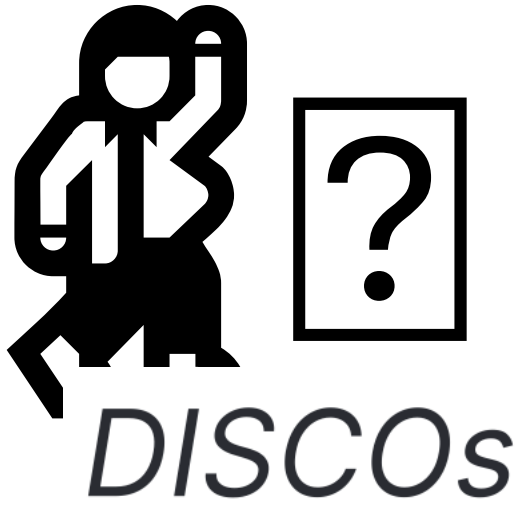
# DISCO Basis

***D**elay-**I**nvariant **S**ubspace of **C**alibrated **O**bservables*

*we do science with these*

Complex Visibilities
(Fourier Basis)

*change of basis*
*(fancy matrix multiplication)*




- Extension of *Kernel Phase*
- A basis that is *invariant to wavefront error*

# Data to DISCOs workflow