Reconstructing multi-frequency movies of supermassive black holes with PRIMO

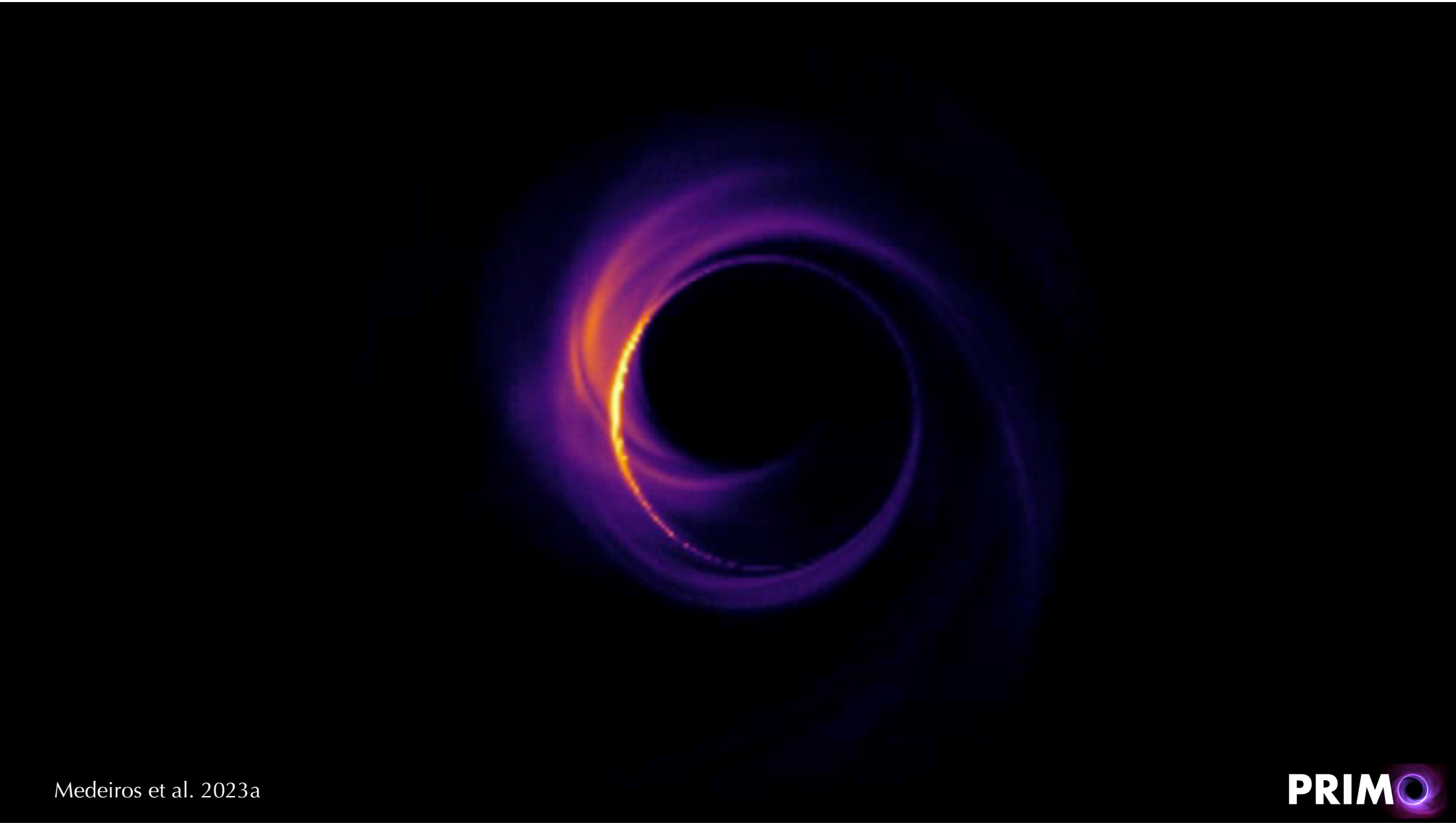
Lia Medeiros

NASA Einstein Fellow

Princeton University

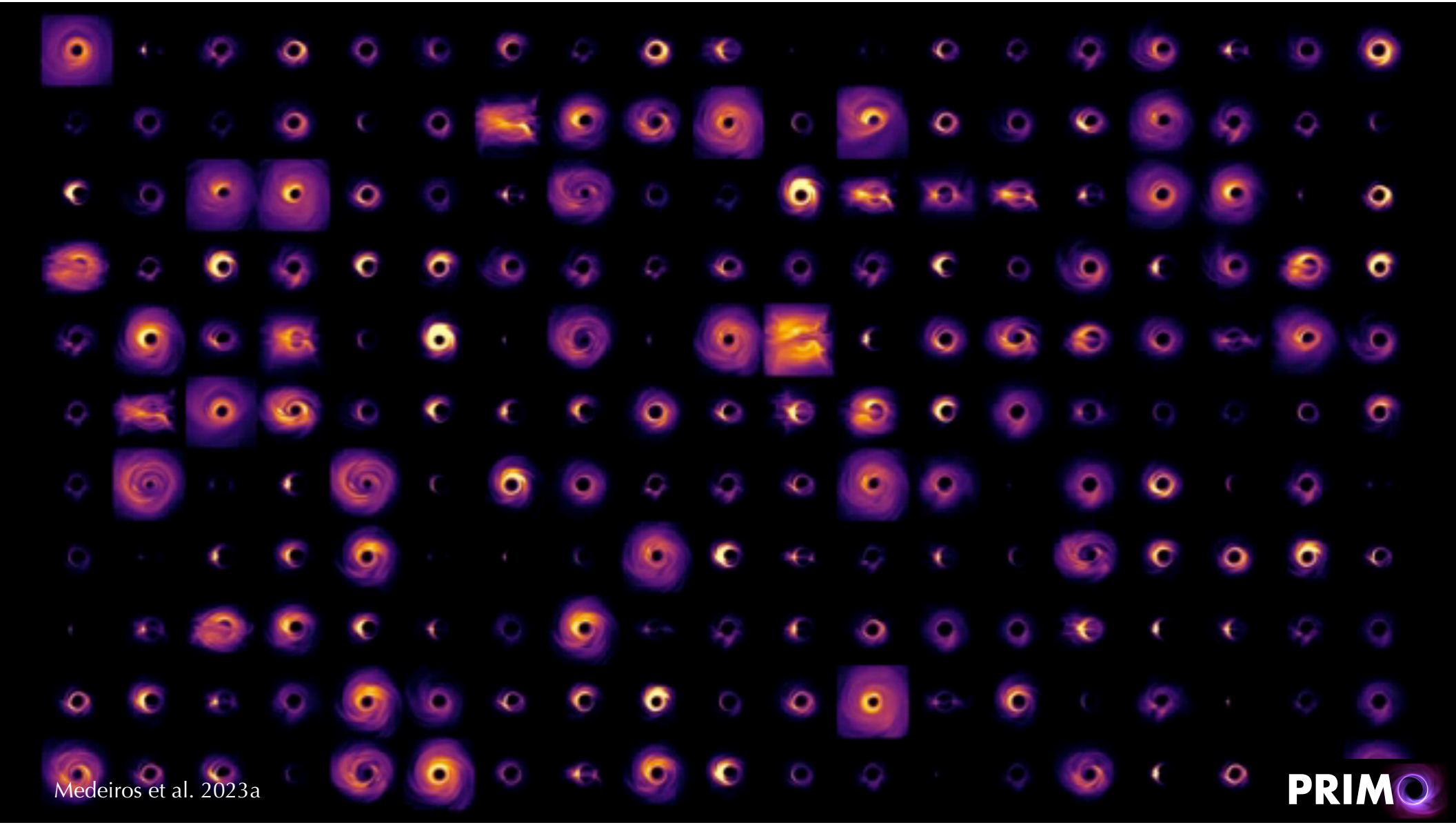
NHFP Symposium, September 17, 2024

Event Horizon Telescope

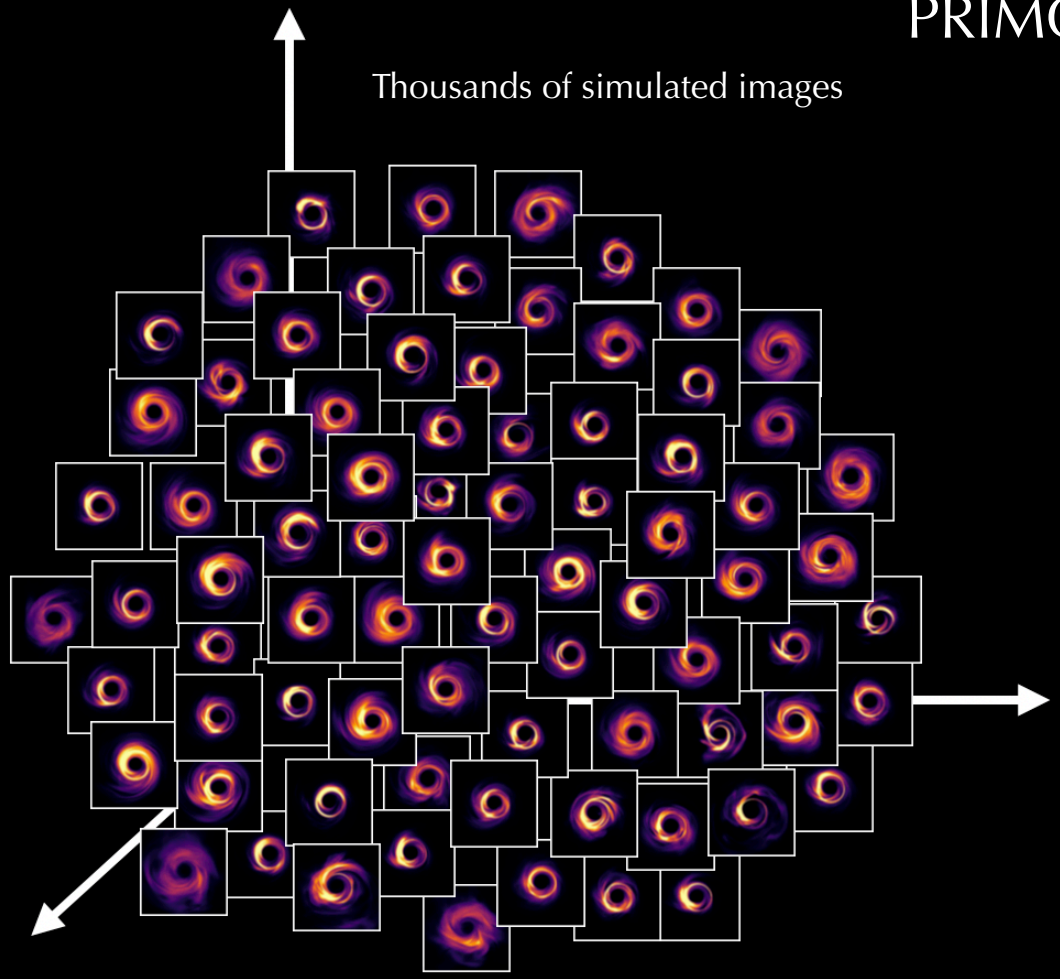


Medeiros et al. 2023a

PRIMO


Medeiros et al. 2023a
PRIMO

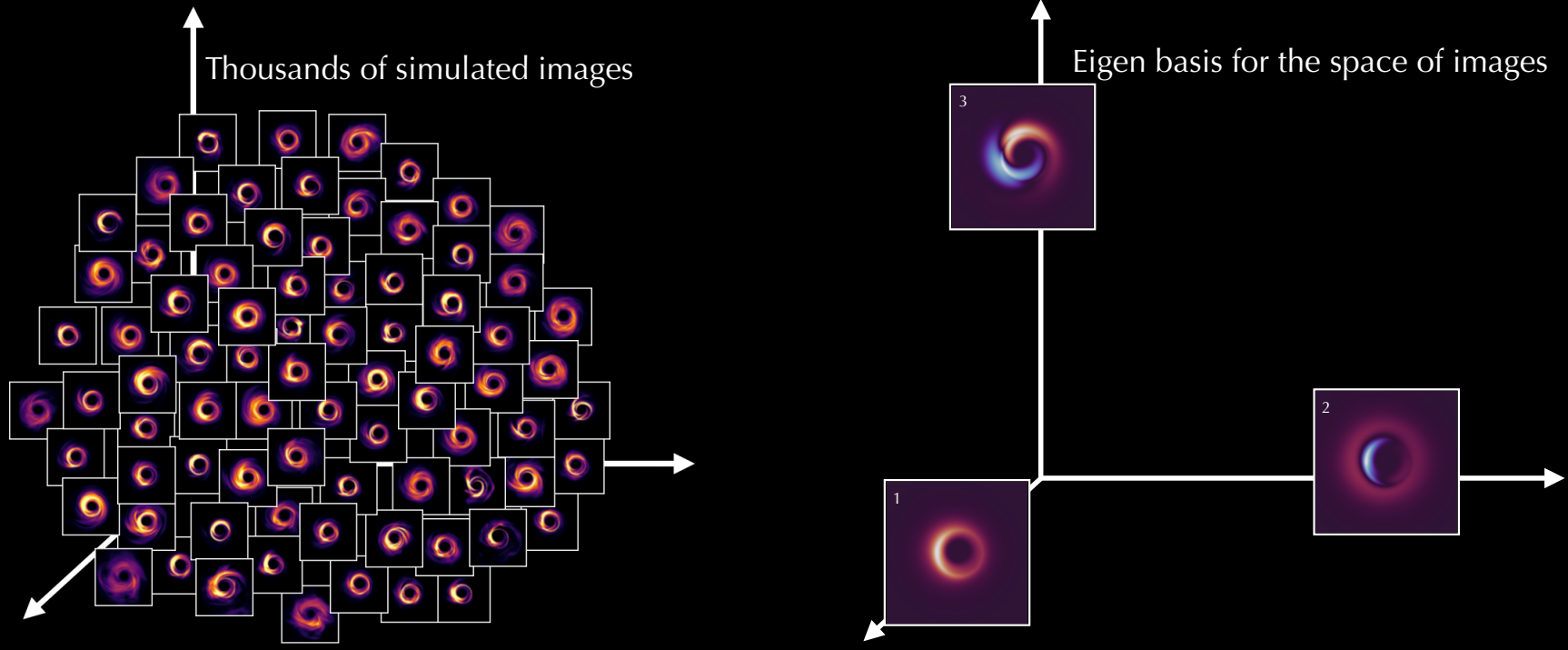
Principal-component Interferometric Modeling
PRIMO



Medeiros et al. 2018, 2023a, 2023b

PRIMO

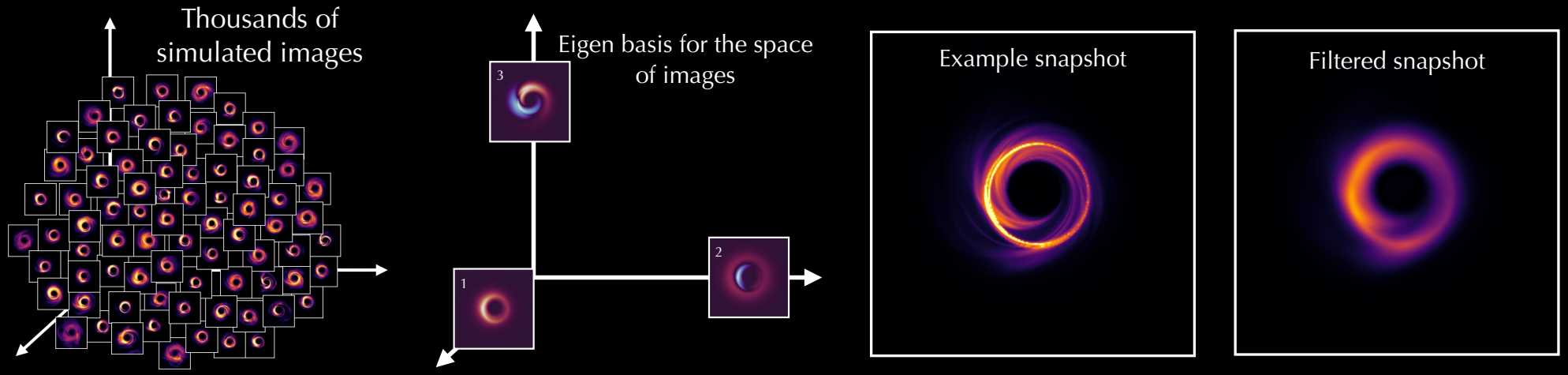
Principal-component Interferometric Modeling
PRIMO



Medeiros et al. 2018, 2023a, 2023b

PRIMO

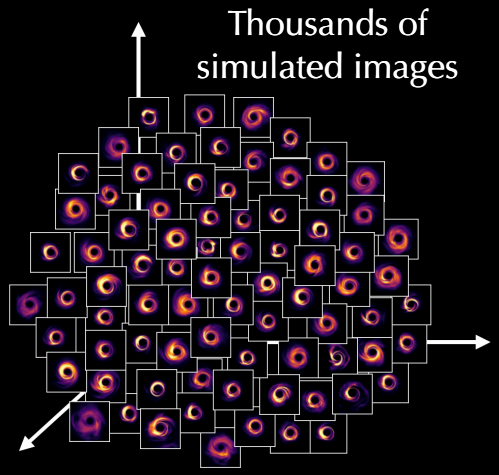
Principal-component Interferometric Modeling
PRIMO

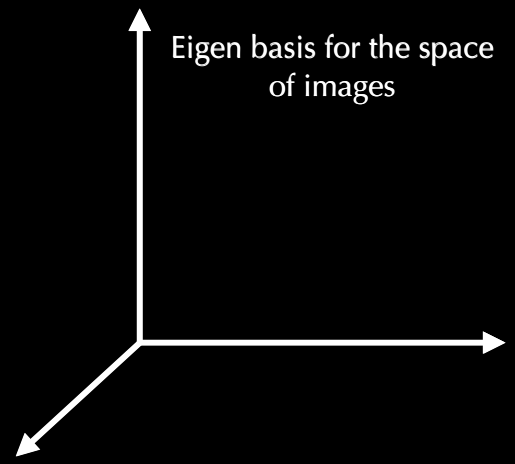


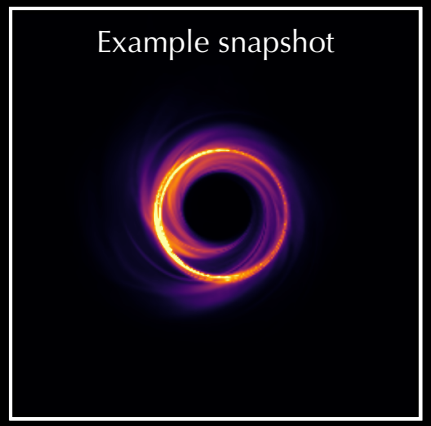
Medeiros et al. 2018, 2023a, 2023b

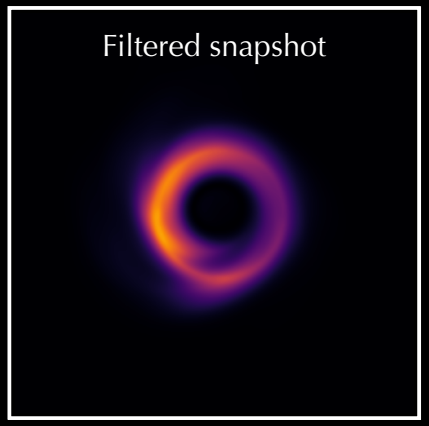
PRIMO

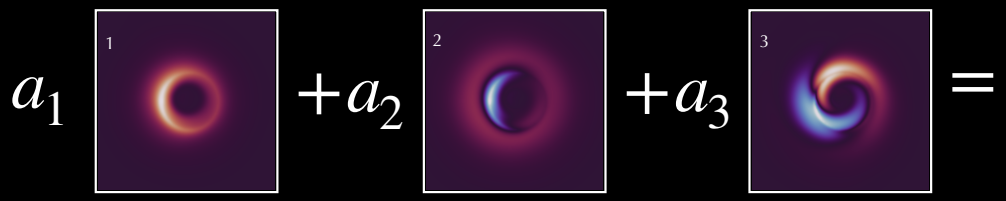
Principal-component Interferometric Modeling
PRIMO

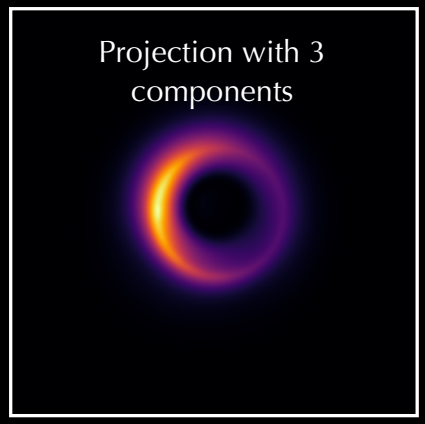








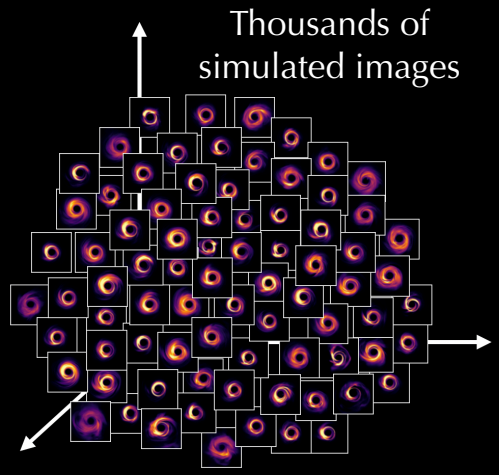


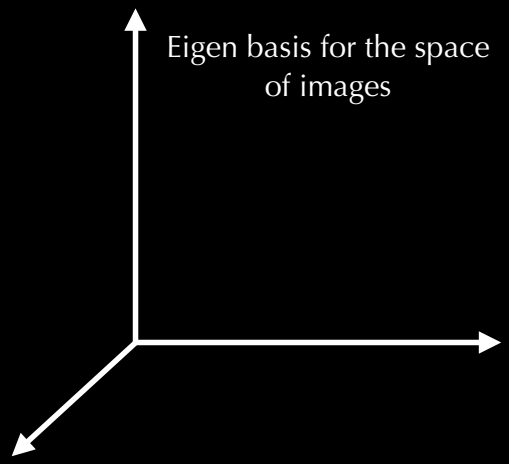


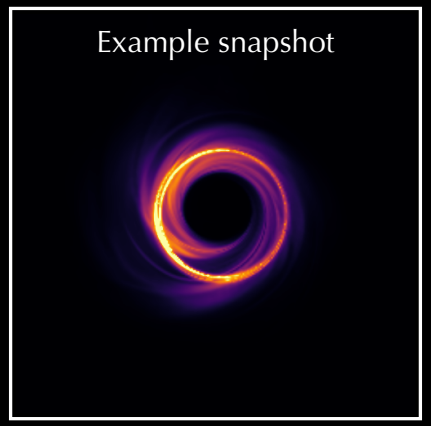
Medeiros et al. 2018, 2023a, 2023b

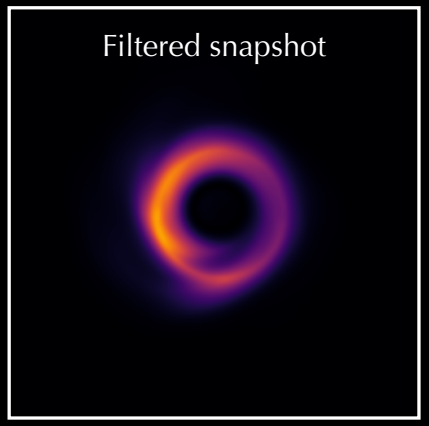
PRIMO

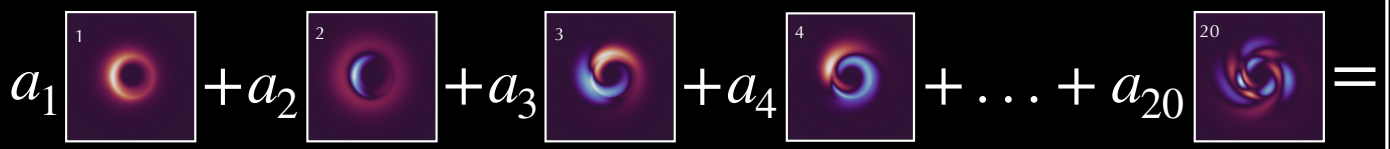
Principal-component Interferometric Modeling
PRIMO

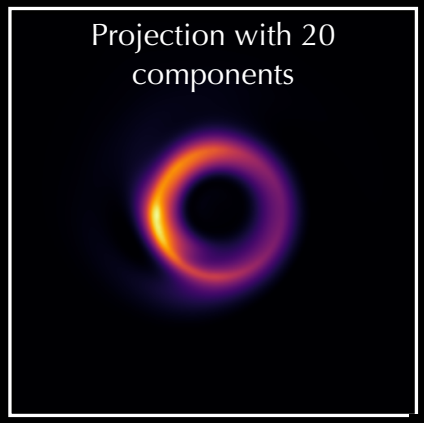








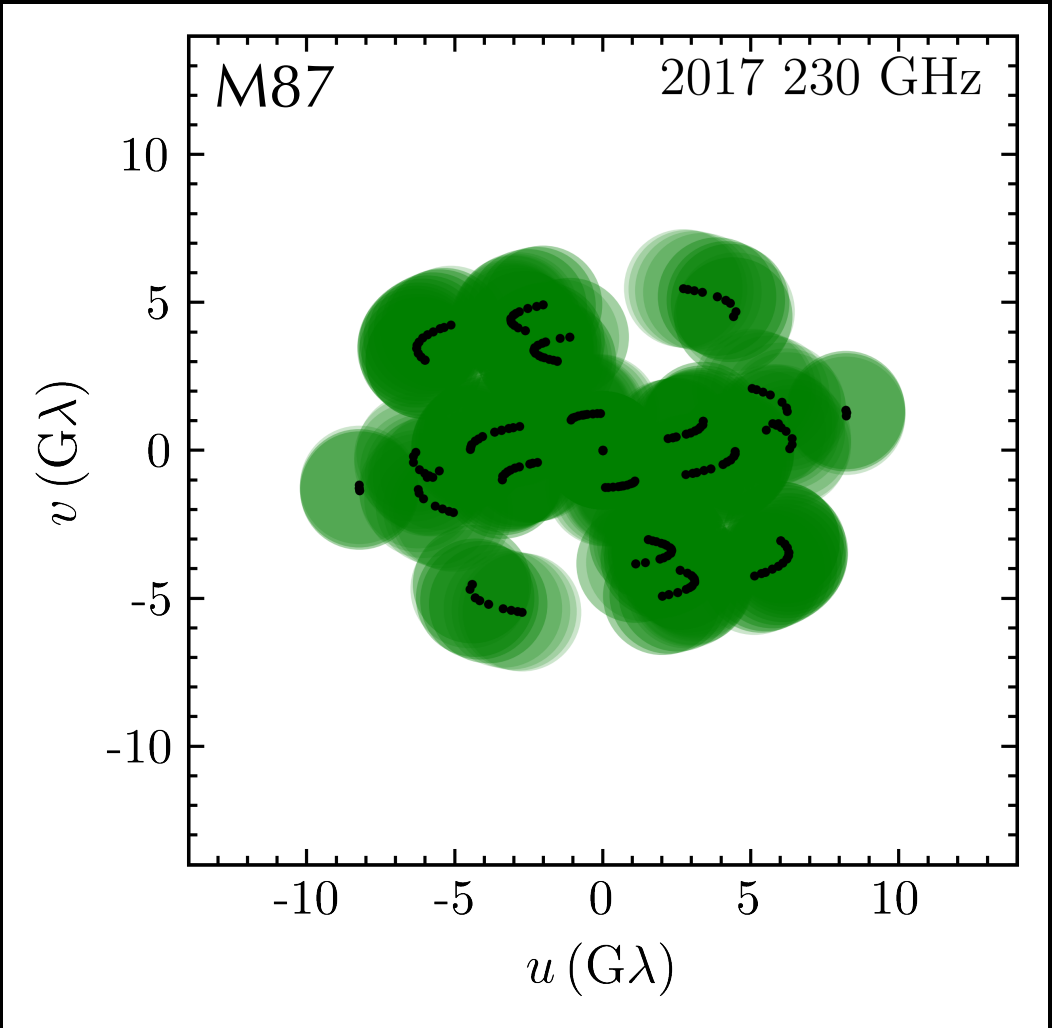




Medeiros et al. 2018, 2023a, 2023b

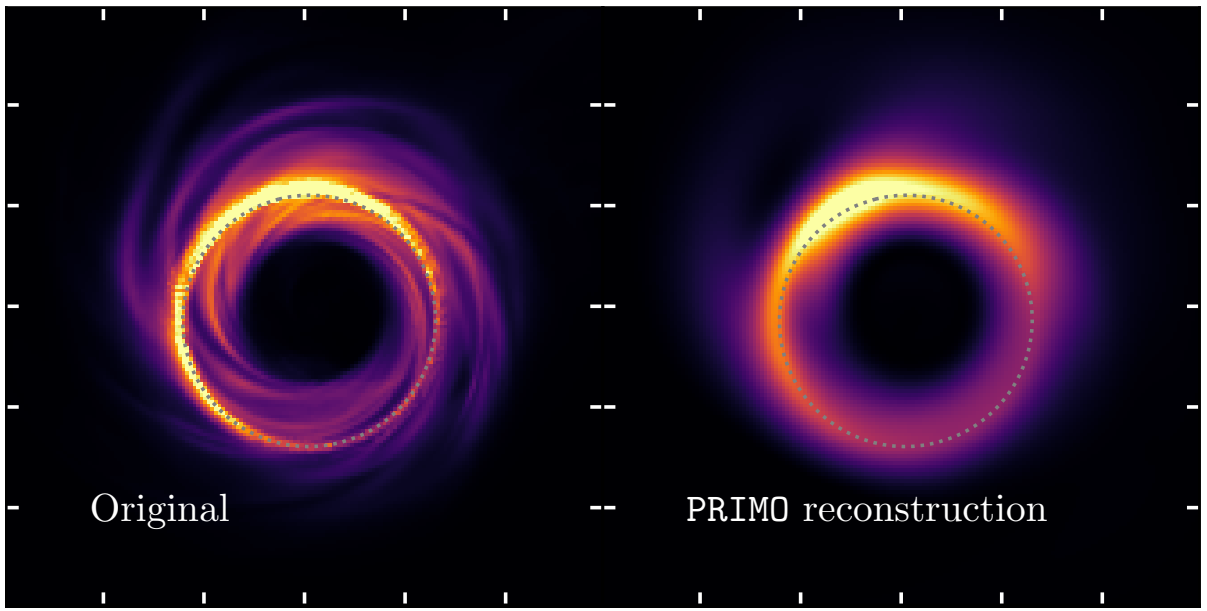
PRIMO

PRIMO “learns” the correlations between different regions in Fourier space



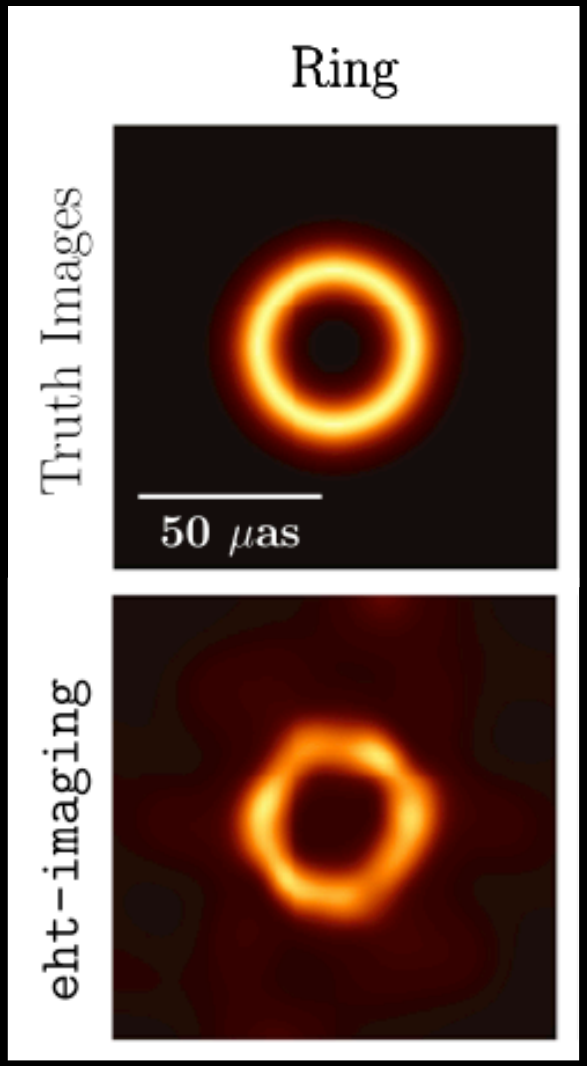
Psaltis, Ozel, Medeiros et al. Submitted to ApJ

PRIMO



Medeiros et al. 2023a

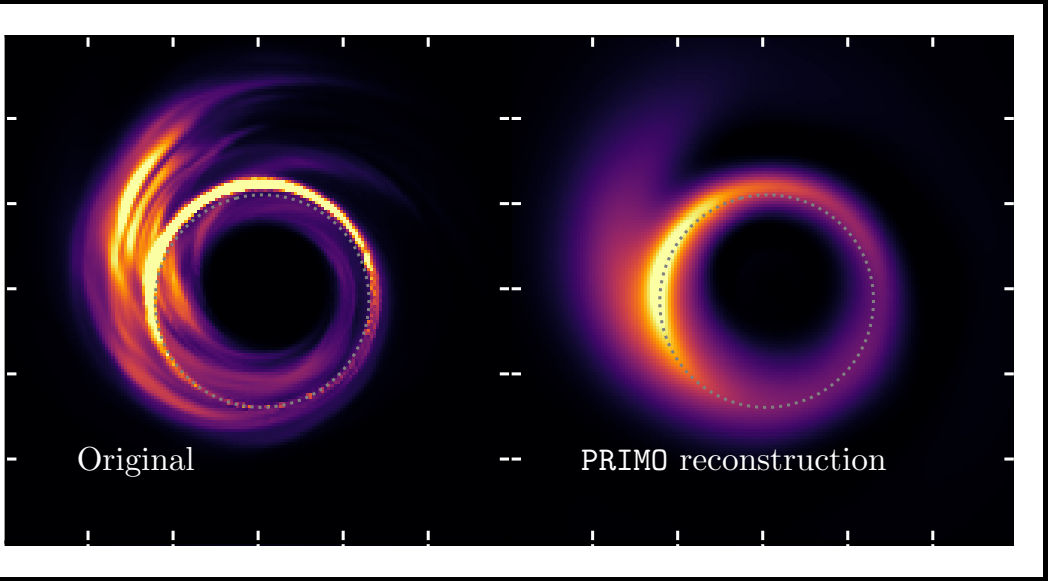
Unlike general purpose imaging algorithms, PRIMO does not create ‘knot’ artifacts along the ring



EHT Paper IV, 2019

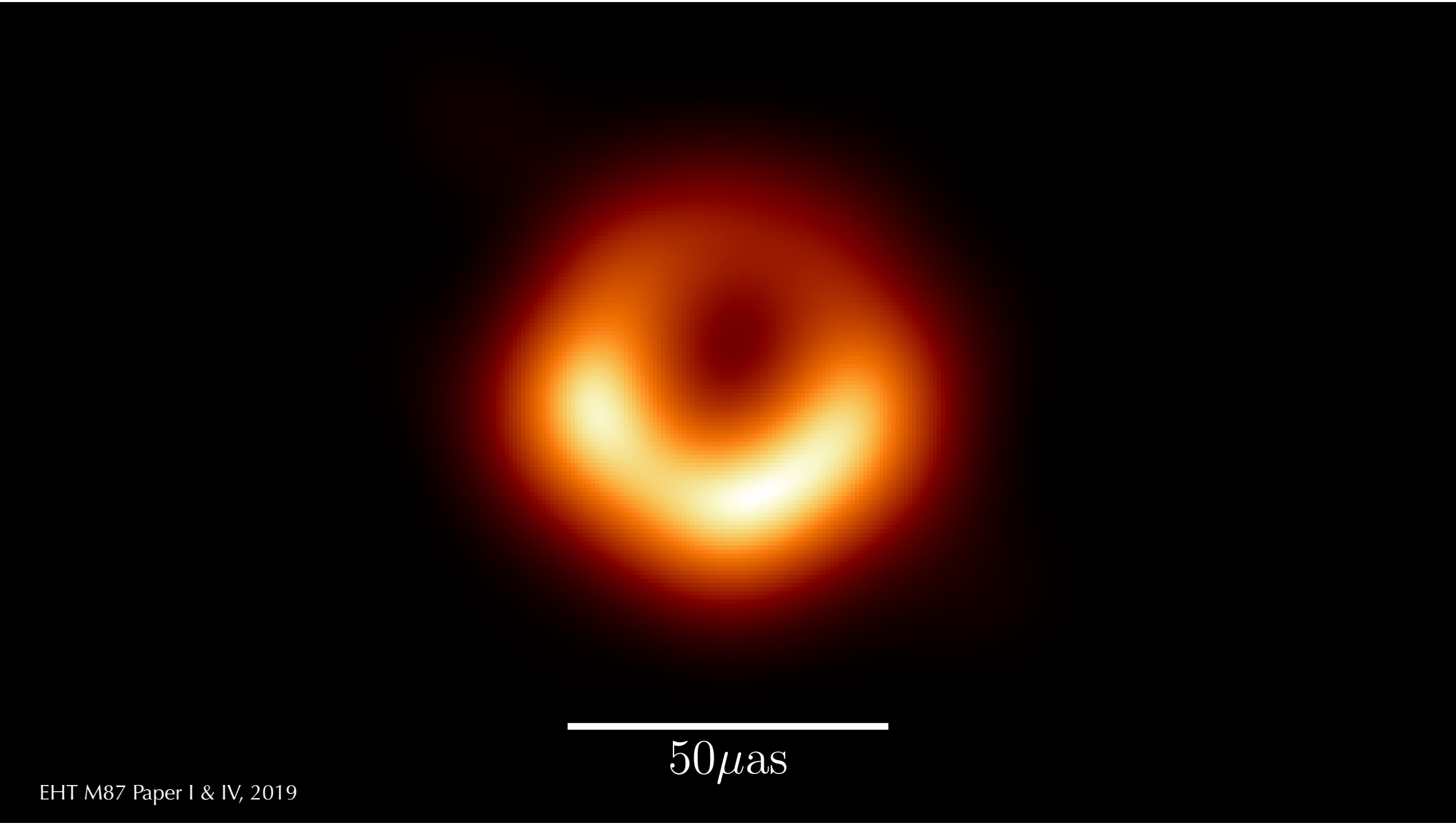
PRIMO

PRIMO Summary

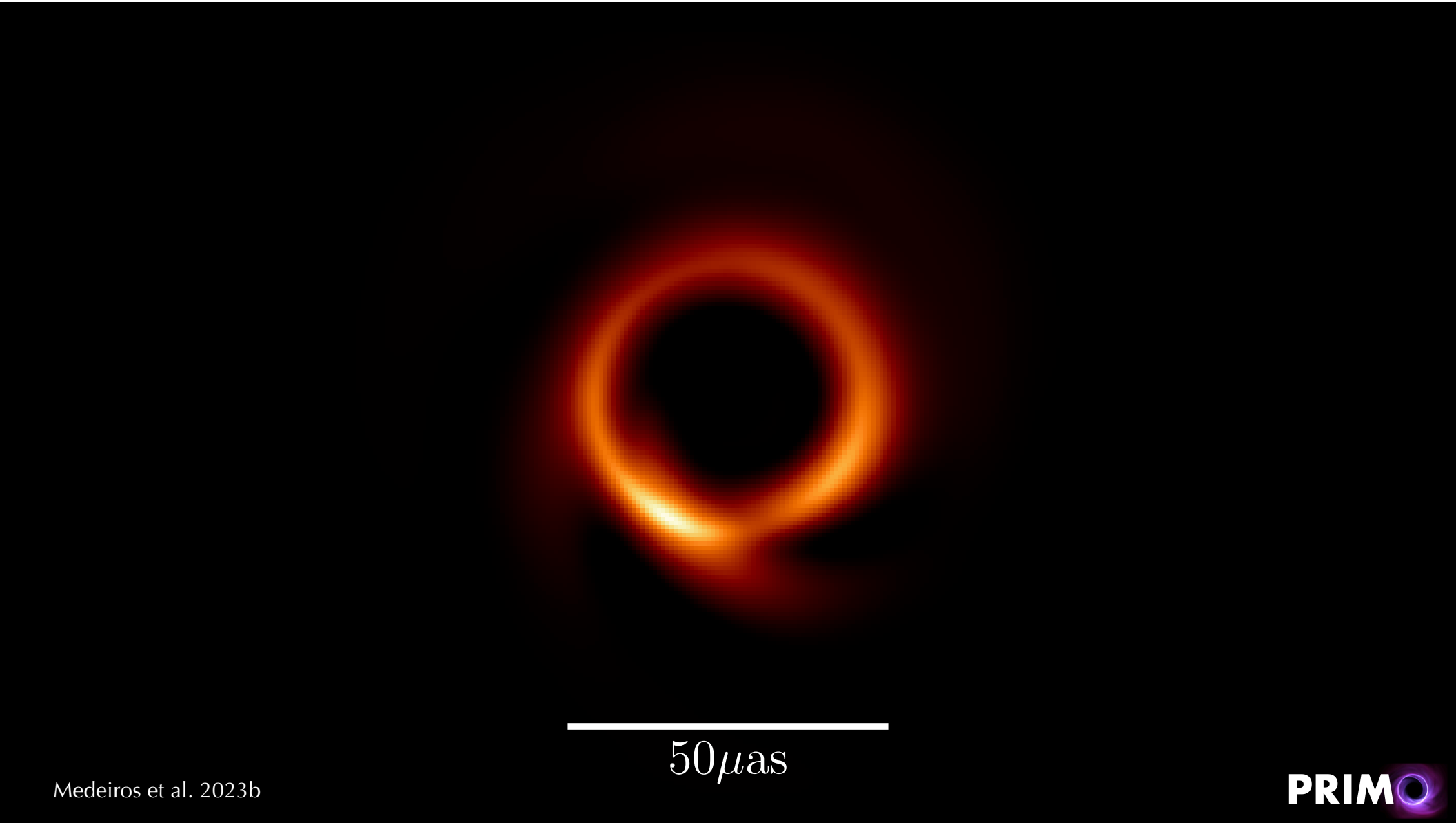


Medeiros et al. 2023a

- Does not create “knot” artifacts in the images
- Able to reconstruct complicated source structure
- Fills in Fourier space in a physically motivated manner
- Can reconstruct images that are not contained in original simulation data set
- Allows for comparisons with simulations

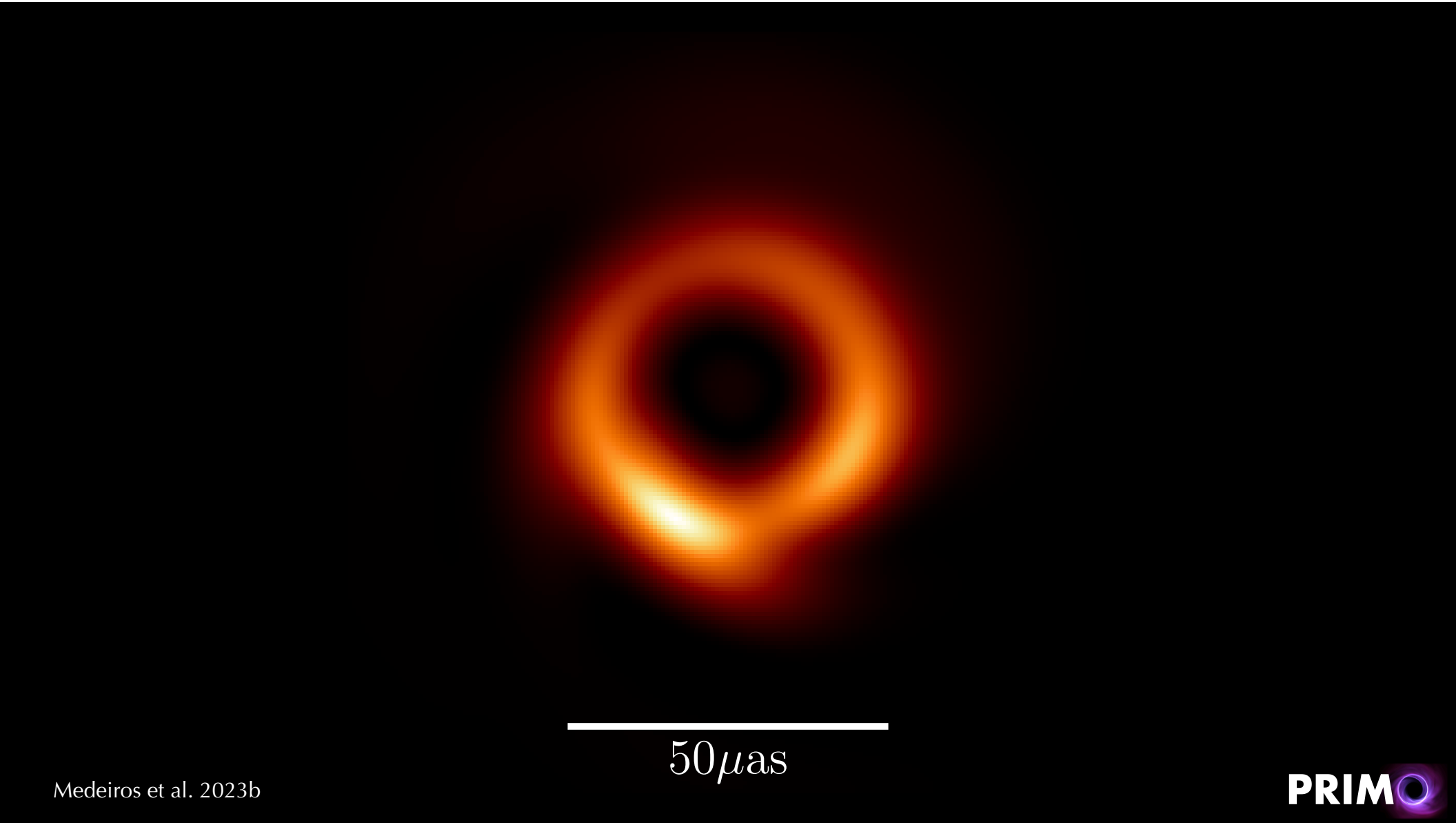


EHT M87 Paper I & IV, 2019



Medeiros et al. 2023b

PRIMO

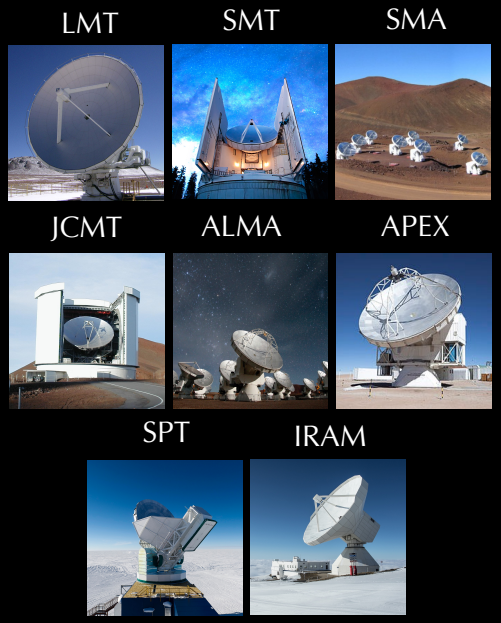


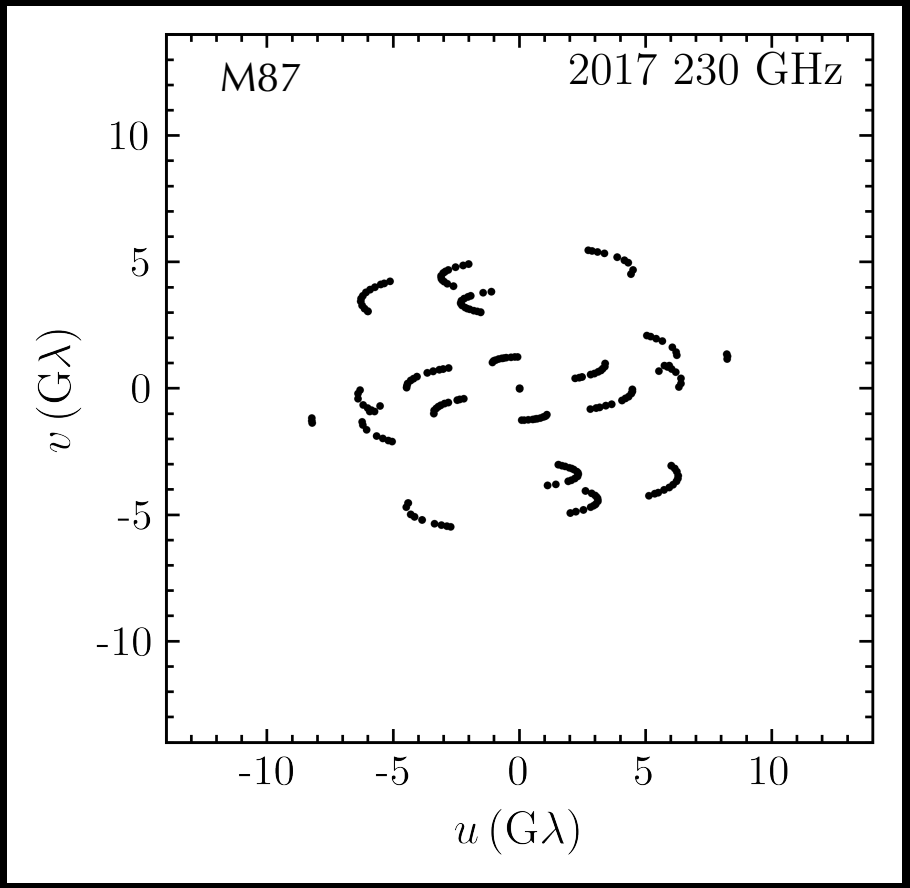
Medeiros et al. 2023b

PRIMO

On the horizon…

2017 EHT observations





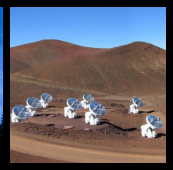
On the horizon…

2017 EHT observations

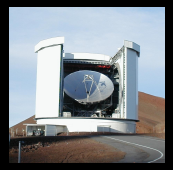
LMT

SMT

SMA



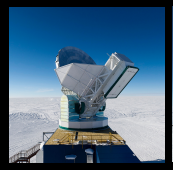
JCMT



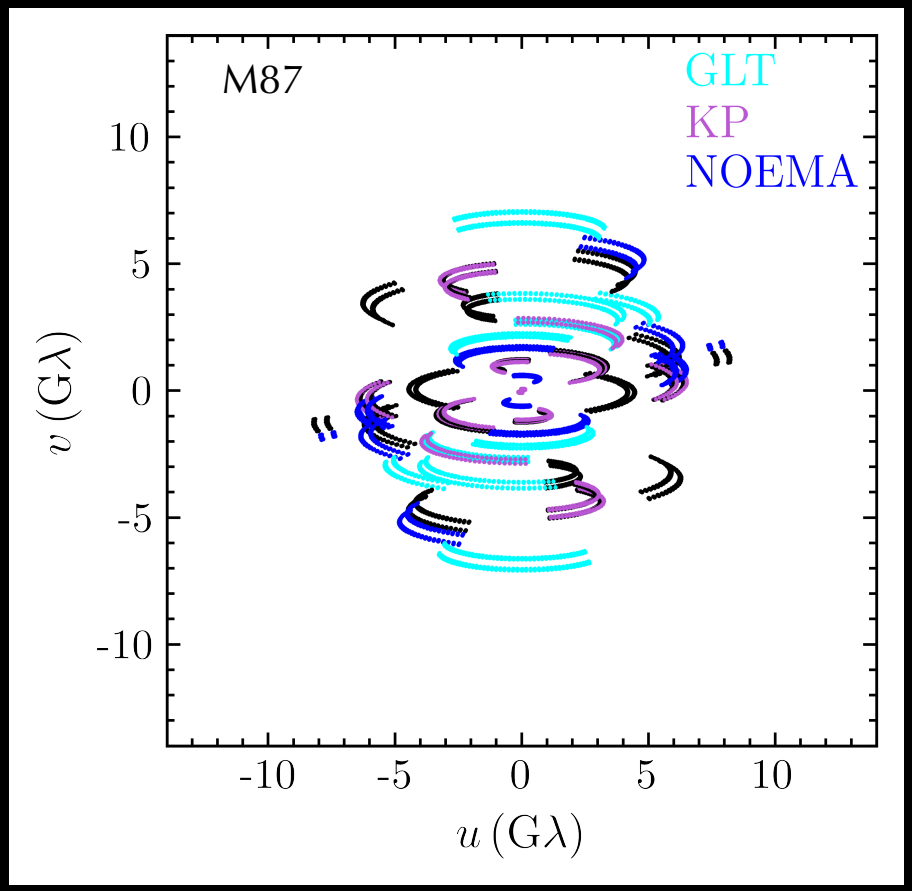
ALMA

APEX

SPT



IRAM



Greenland Telescope (GLT) Joined for 2018

NOEMA Joined for 2021

Kitt Peak 12-meter Telescope Joined for 2021

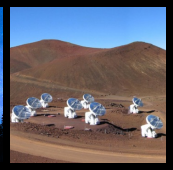
On the horizon…

2017 EHT observations

LMT

SMT

SMA



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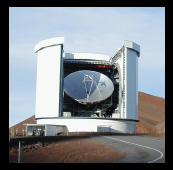
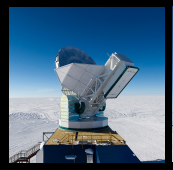


ALMA

APEX

SPT



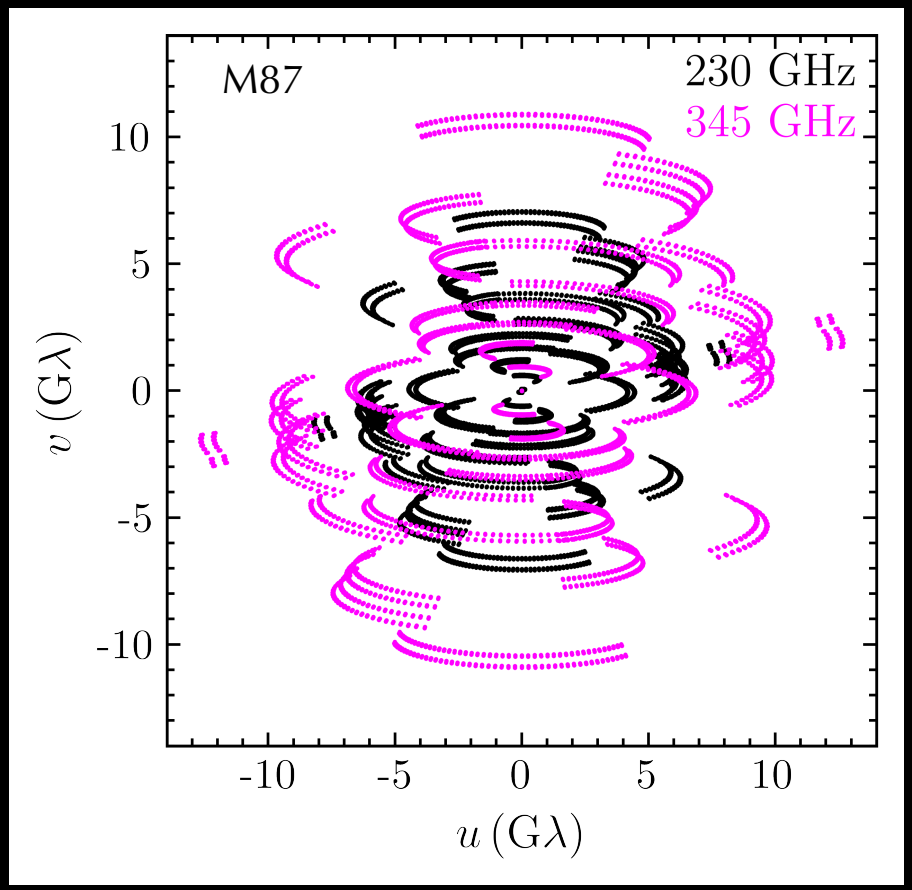
IRAM

Additions since 2017

GLT

KP

NOEMA



In 2023 we observed at 0.8 mm (345 GHz) as well as 1.3 mm (230 GHz)

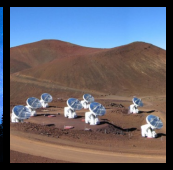
On the horizon…

2017 EHT observations

LMT

SMT

SMA



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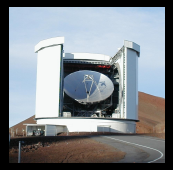
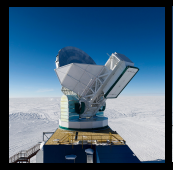


ALMA

APEX

SPT



IRAM

Additions since 2017

GLT

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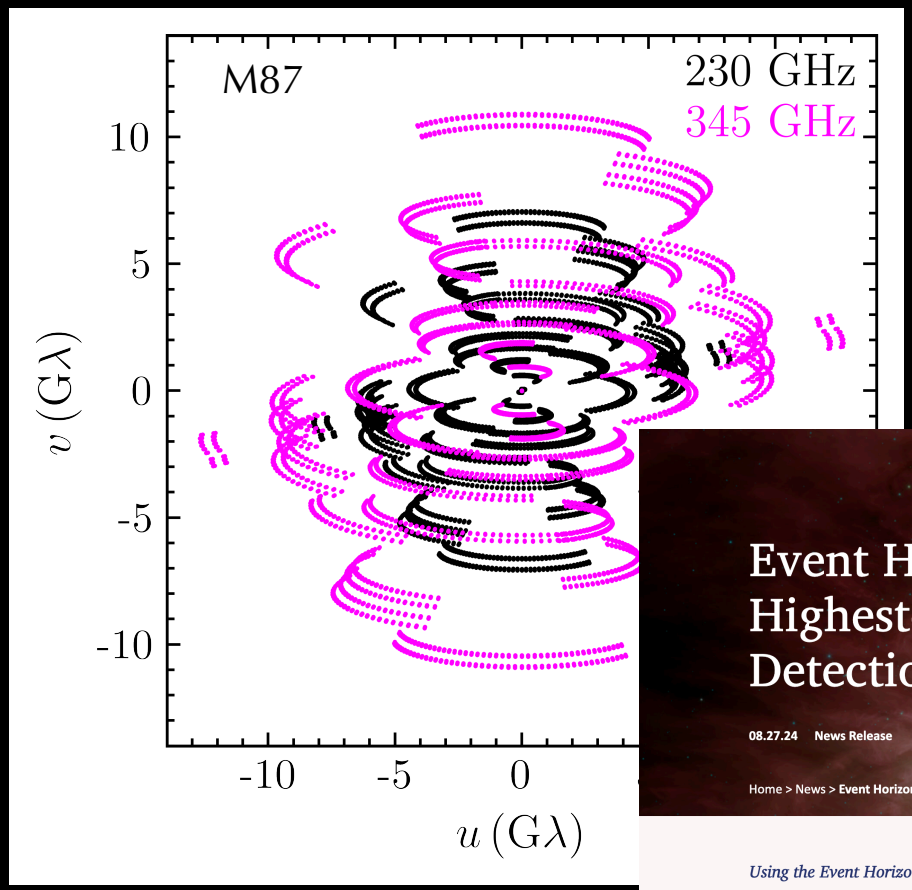
NOEMA



In 2023 we observed at 0.8 mm (345 GHz) as well as 1.3 mm (230 GHz)

Event Horizon Telescope Makes Highest-Resolution Black Hole Detections from Earth

08.27.24 News Release

Home > News > Event Horizon Telescope Makes Highest-Resolution Black Hole Detections from Earth

Using the Event Horizon Telescope (EHT), astronomers have achieved very-long-baseline interferometry test observations at 345 GHz, the highest-resolution such observations ever obtained from the

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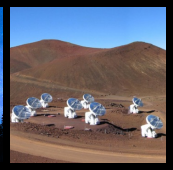
On the horizon…

2017 EHT observations

LMT

SMT

SMA



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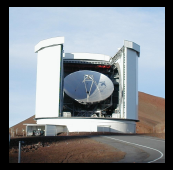
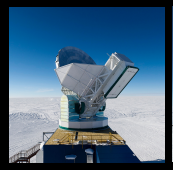


ALMA

APEX

SPT



IRAM

Additions since 2017

GLT

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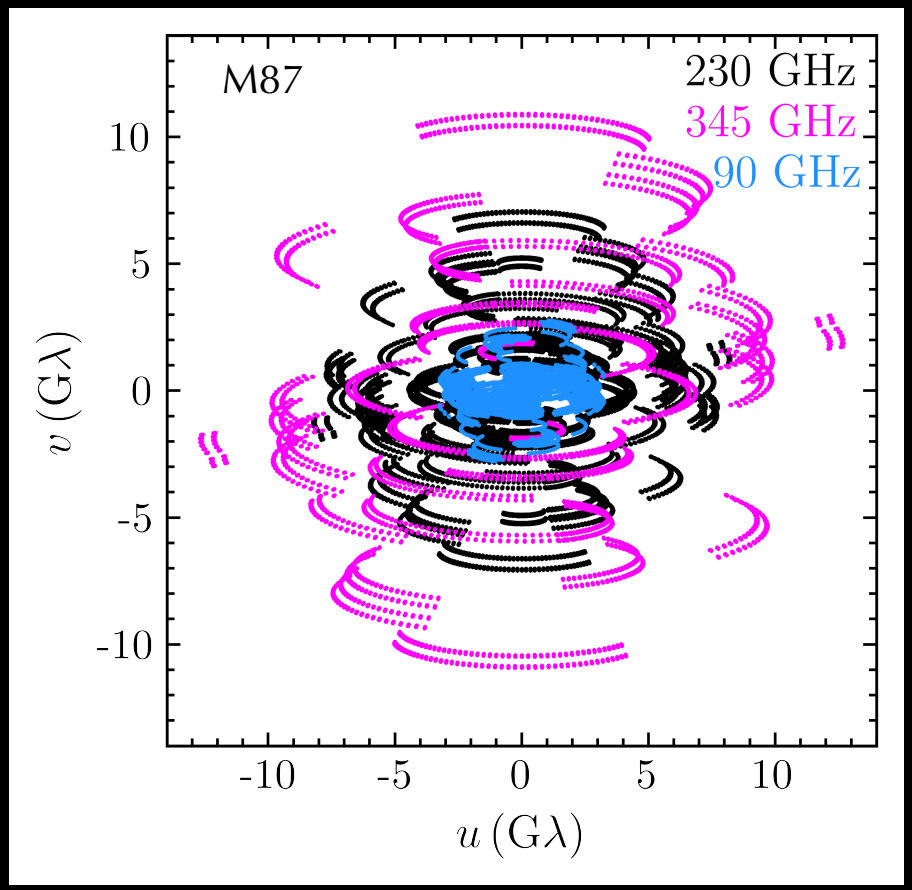


Plan to observe at ~90 GHz simultaneously at several sites

Planned additions

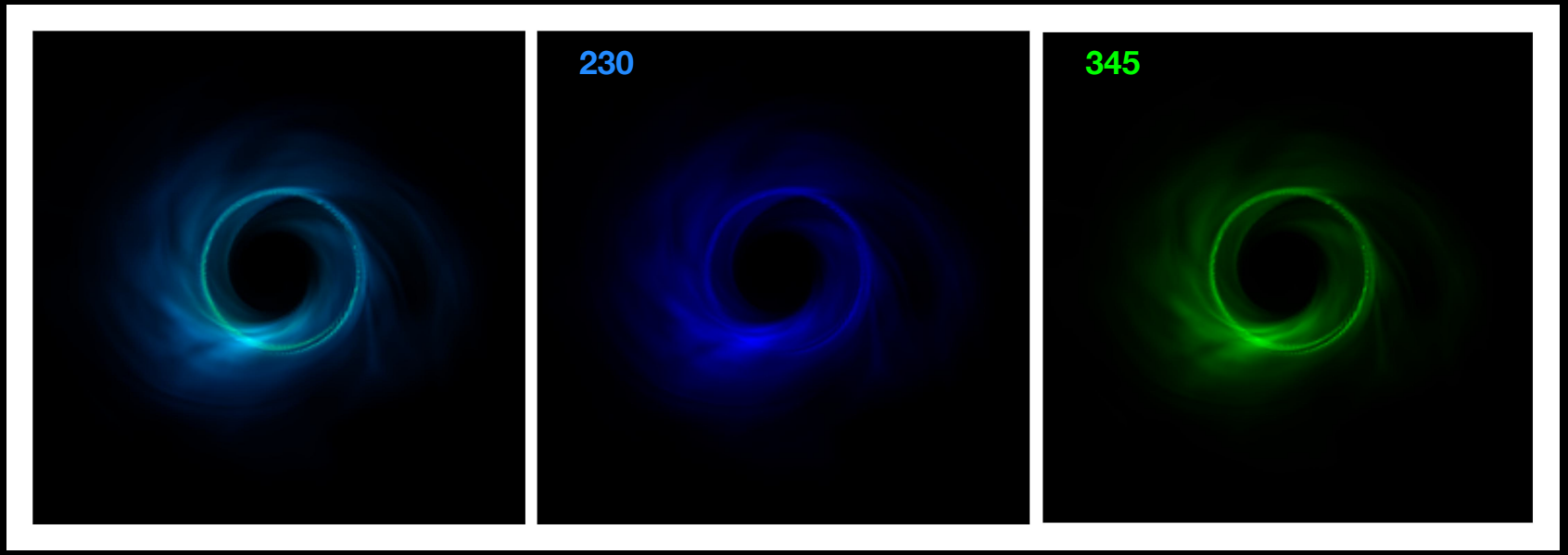
HAY

AMT

OV

Introducing Multi-Wavelength PRIMO

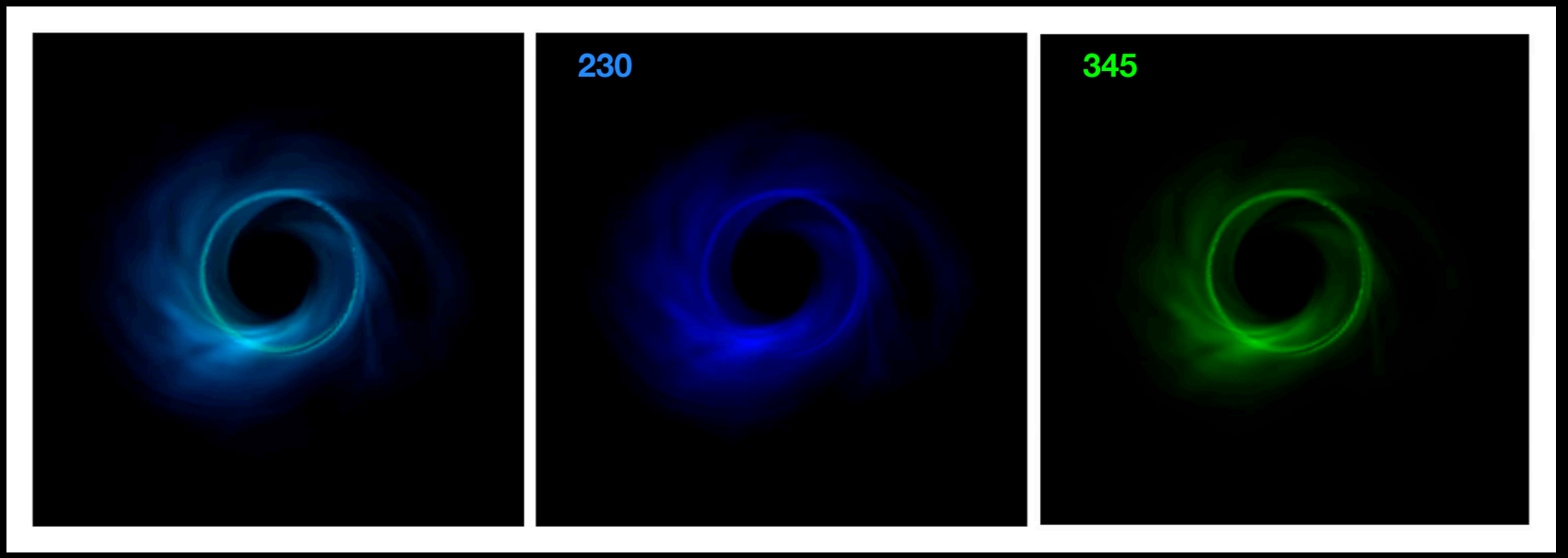
Fit simultaneous multi-wavelength observations, taking into account the correlations between the wavelengths, but generating a different image per wavelength



Medeiros 2024, in prep.

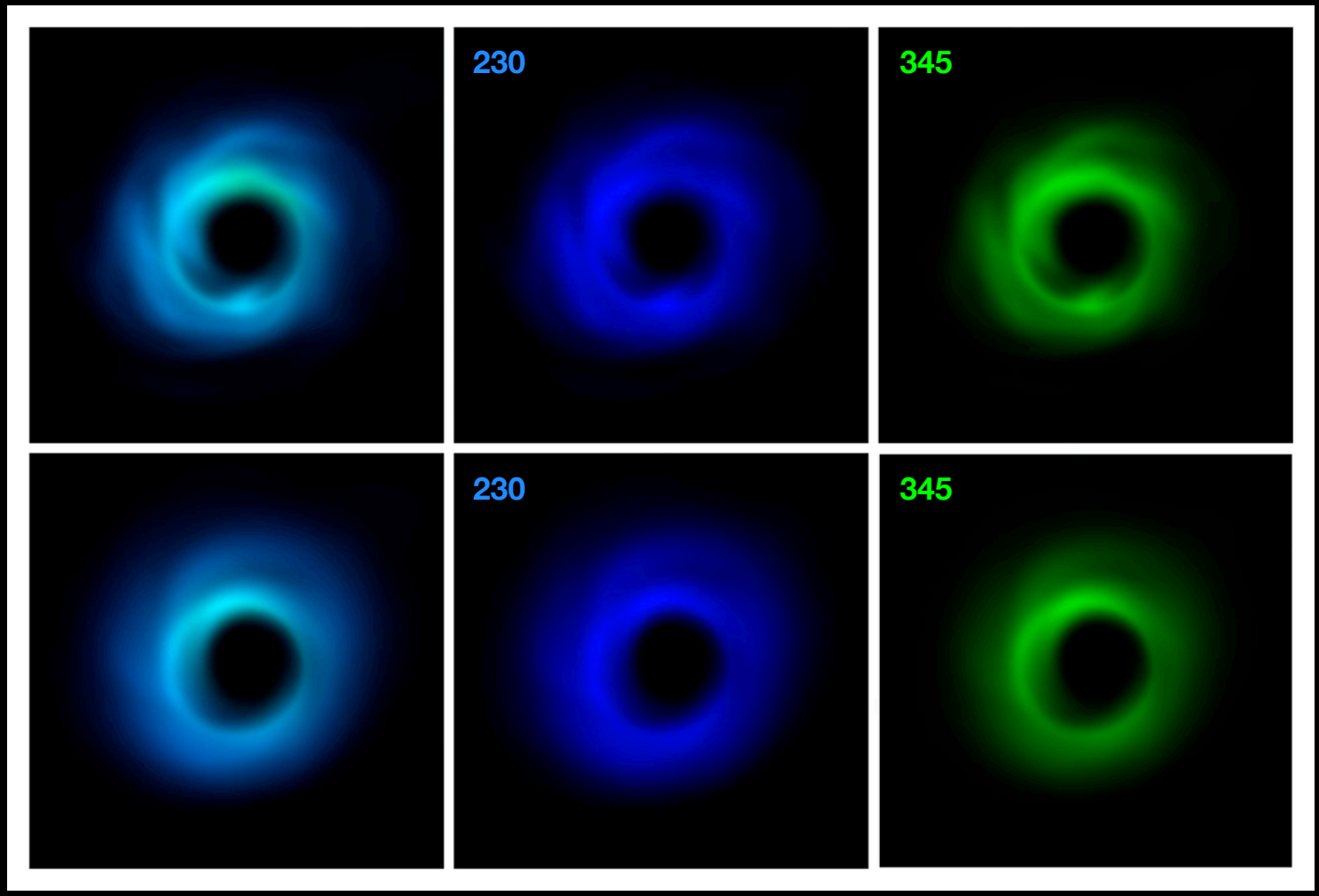
Introducing Multi-Wavelength PRIMO

Fit multiple epochs of observations, generating single posteriors on black hole parameters (mass/distance, orientation of spin axis) while allowing for variations in image features (a time-series of images, or movie)



Medeiros 2024, in prep.

Preliminary synthetic fits



Medeiros 2024, in prep.

M87 observations once a week for 16 weeks, 8 seconds long “movie”

Multi-Wavelength PRIMO Capabilities

- Multiple epochs, single M/D posterior
- Multi-wavelength, learns correlations between wavelengths
- Multi-band
- Time-series of images/movies, keeping BH params constant

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Multi-Wavelength PRIMO Capabilities

- Multiple epochs, single M/D posterior
- Multi-wavelength, learns correlations between wavelengths
- Multi-band
- Time-series of images/movies, keeping BH params constant

COMING SOON…

- polarization!
- improved priors for movies

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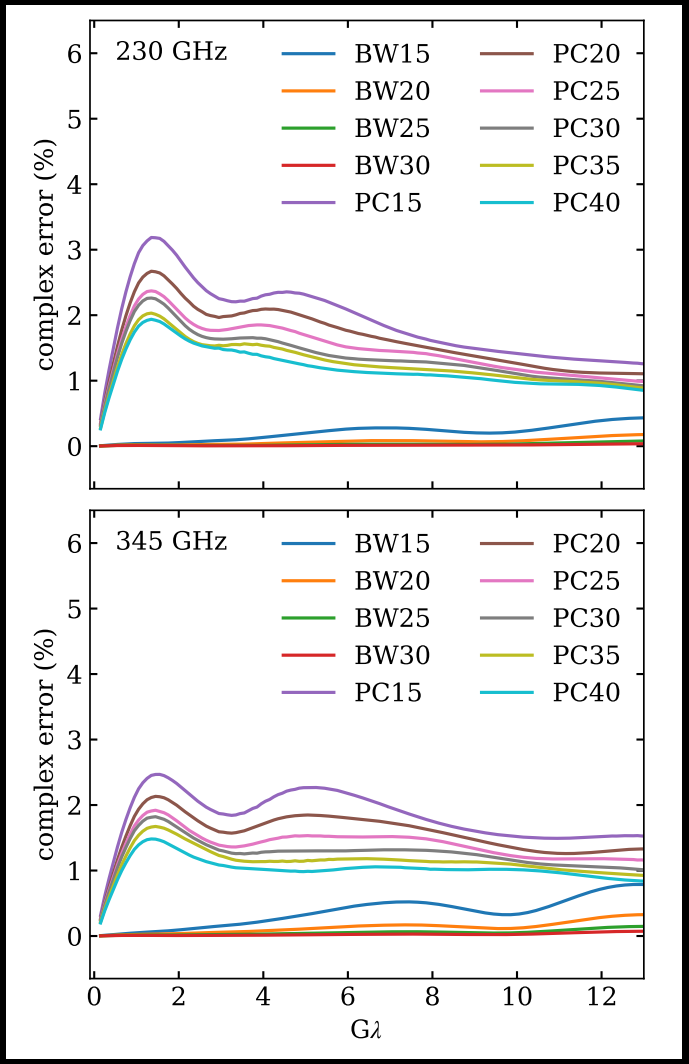
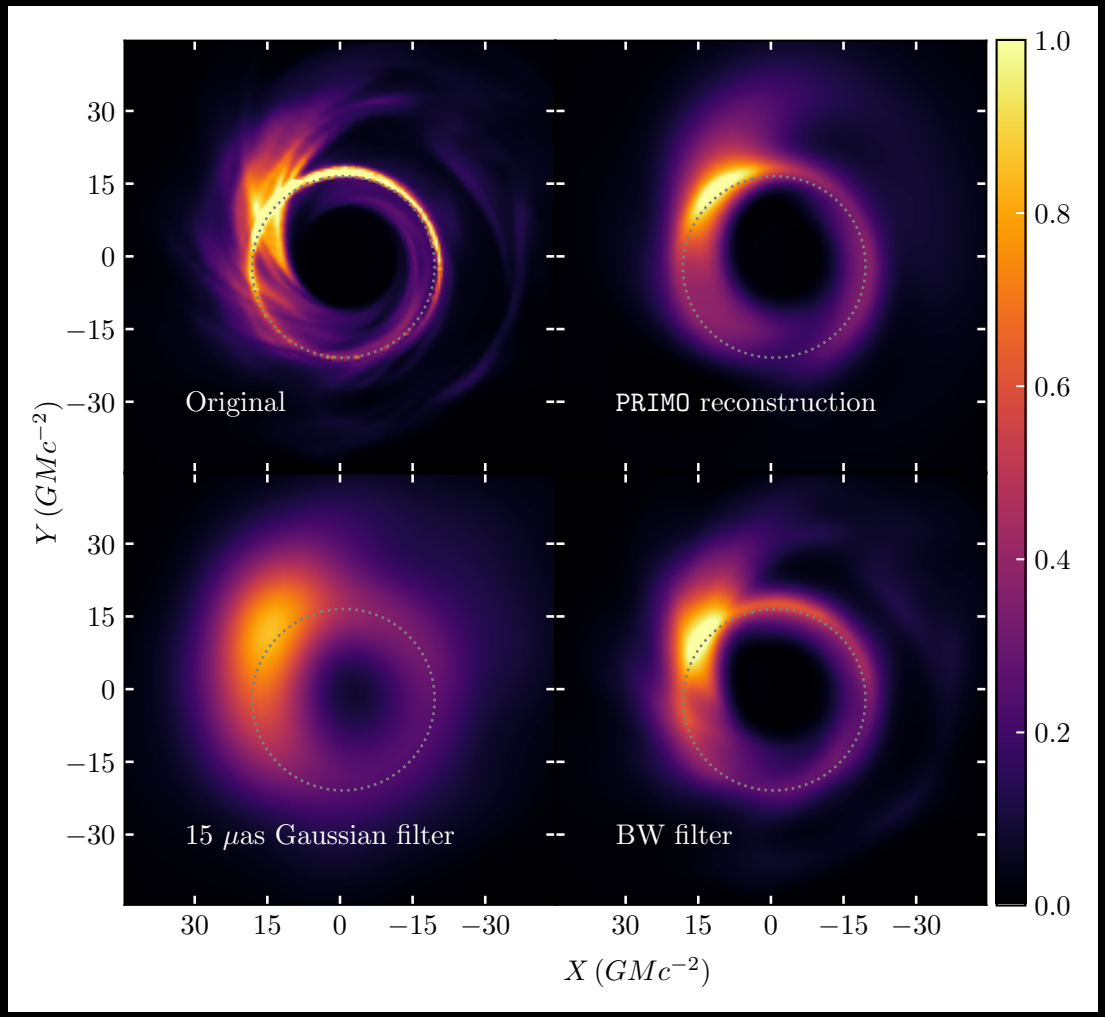


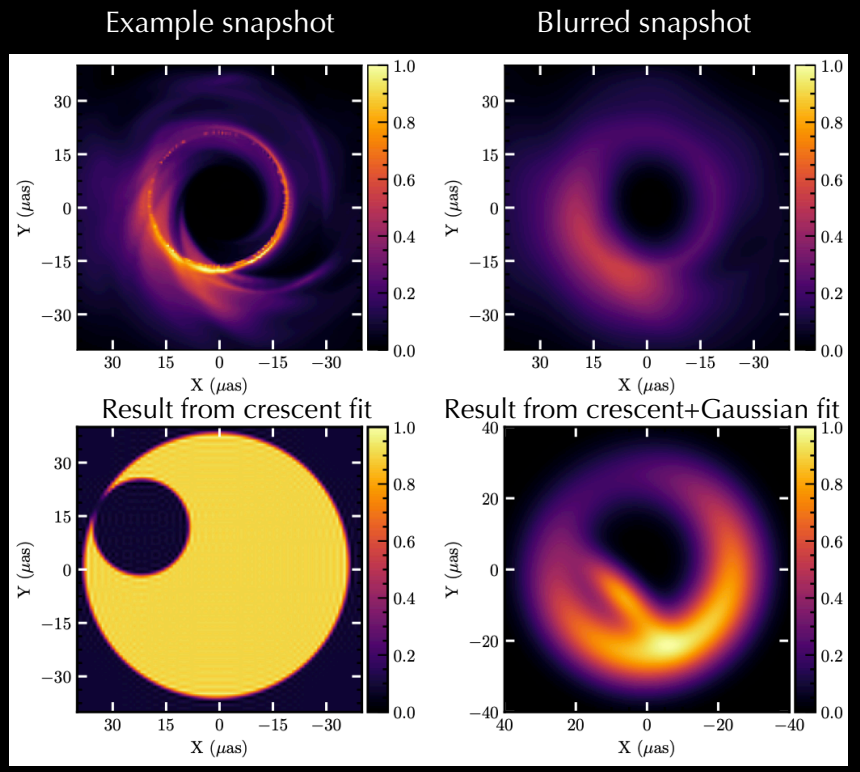
Errors are still <1% for Butterworth filter with radius 15G\lambda

even at 345 GHz

out to longest current EHT baselines (~12 G\lambda for 345)



Medeiros et al. 2023a

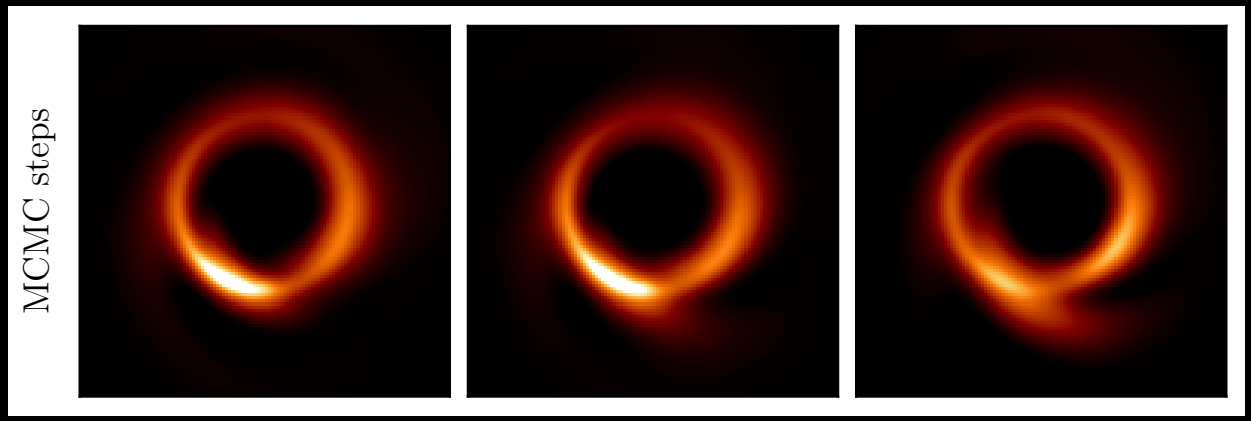


Psaltis, Ozel, Medeiros, et al. 2022

PRIMO can accurately reconstruct images that significantly differ from simple crescent shapes

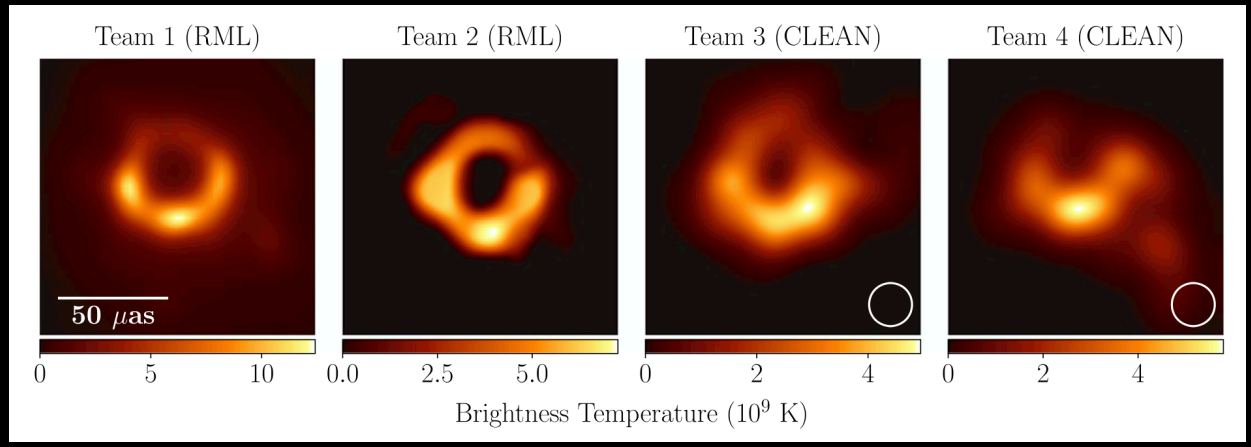
PRIMO

Salient image features are robust



Medeiros et al. 2023b

Uncertainty also present in other methods

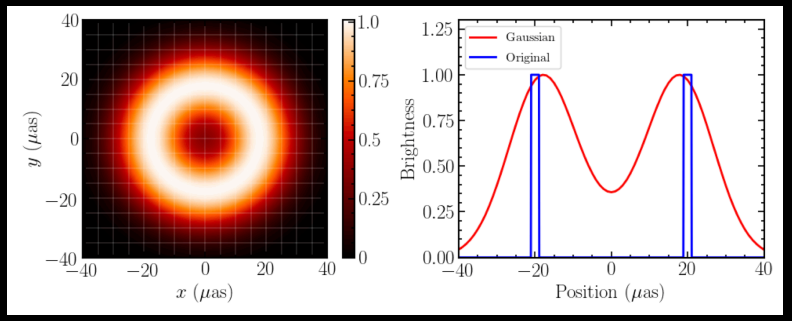


EHT M87 Paper IV, 2019

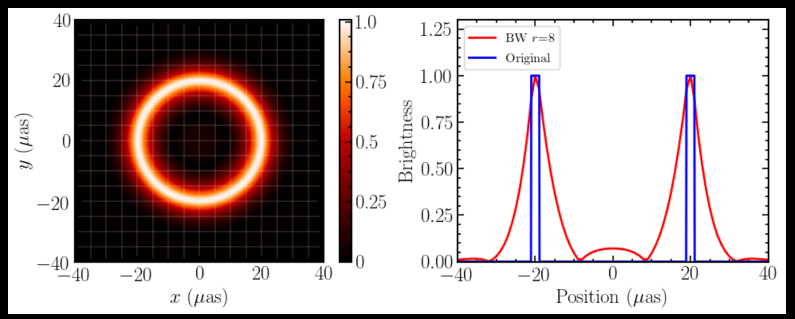
PRIMO

The previous Gaussian filter we used significantly suppressed the power at longer baselines

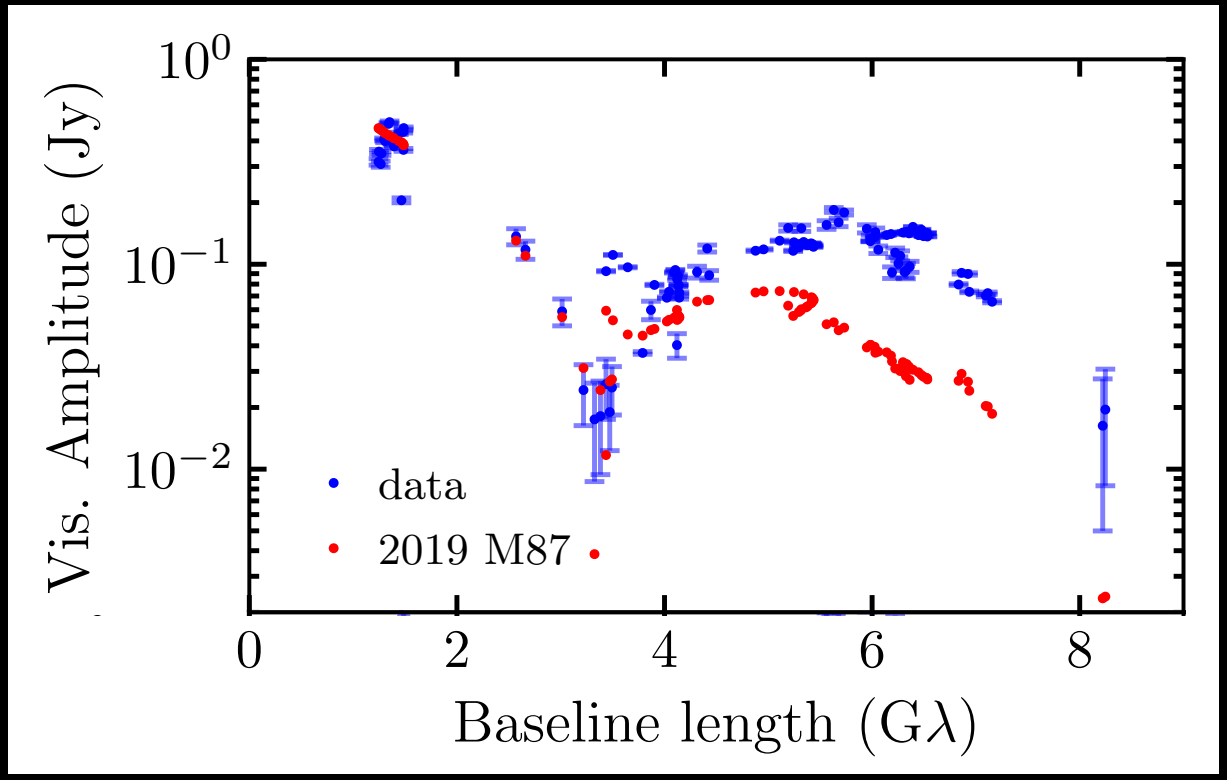
Gaussian filter



Butterworth filter

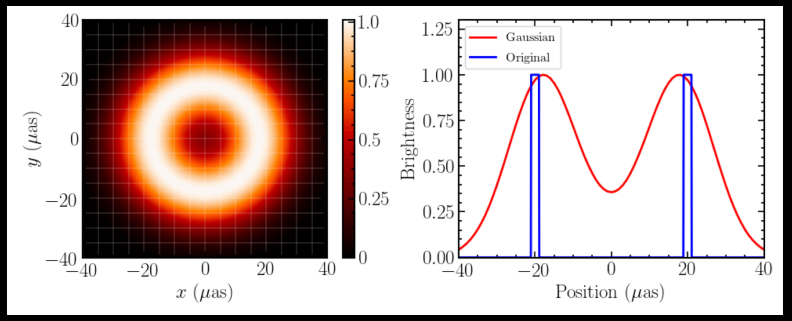


Psaltis, Medeiros, et al. 2020

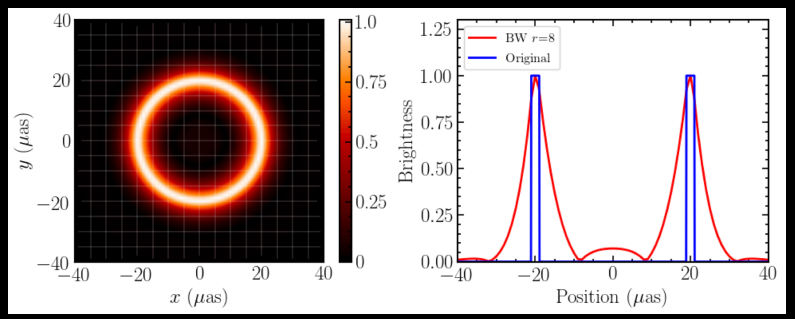


The previous Gaussian filter we used significantly suppressed the power at longer baselines

Gaussian filter



Butterworth filter



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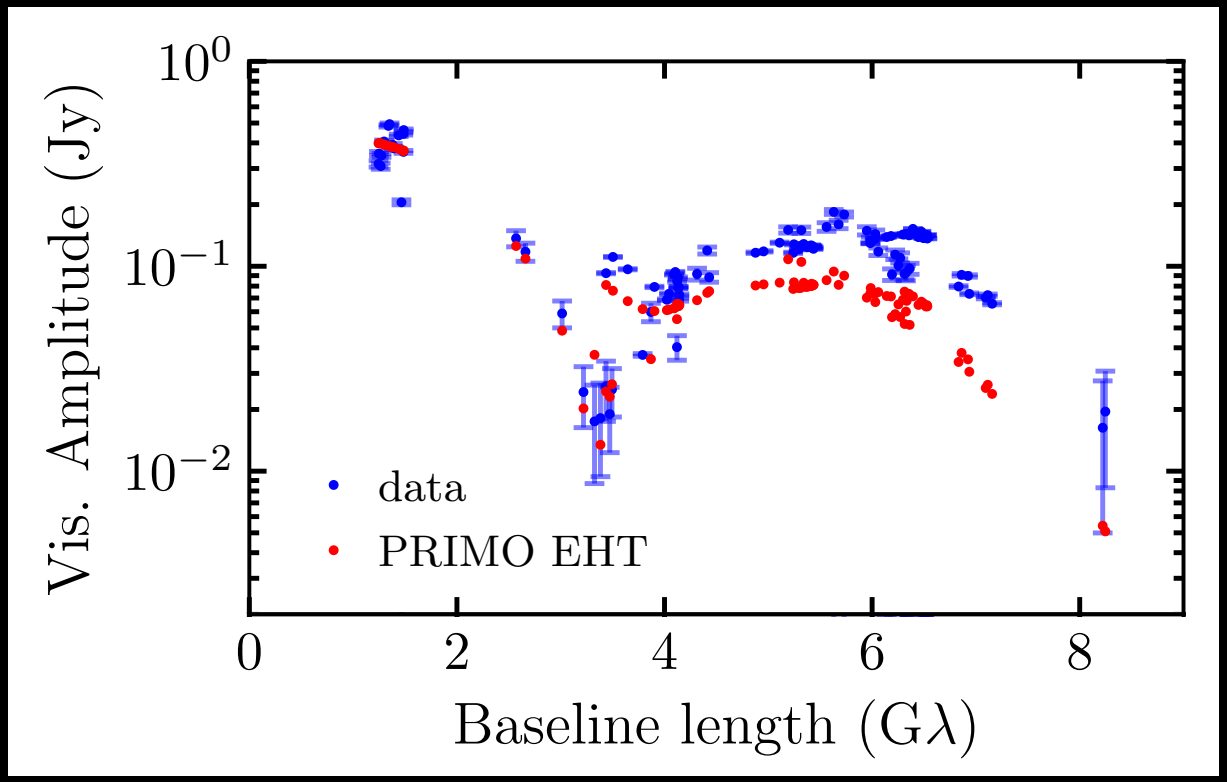
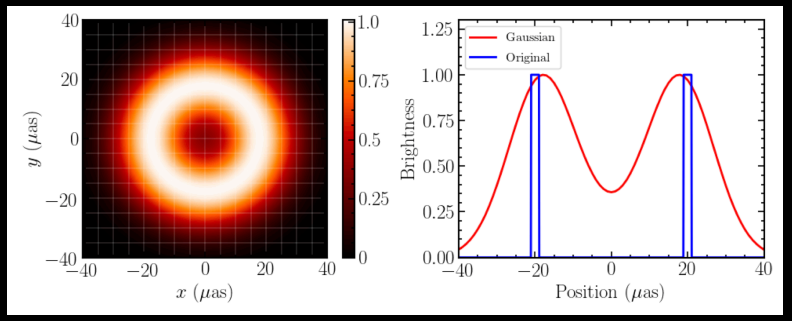
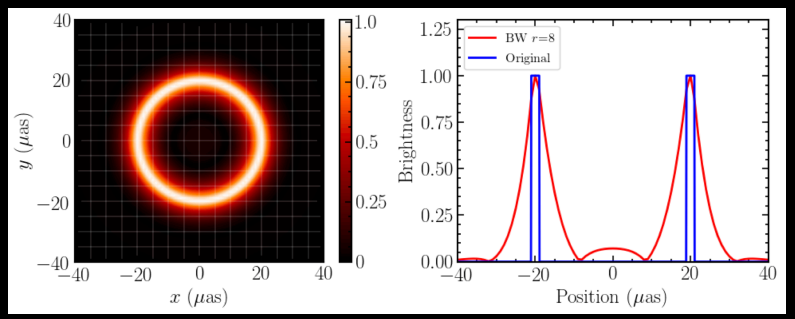


The previous Gaussian filter we used significantly suppressed the power at longer baselines

Gaussian filter



Butterworth filter



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