

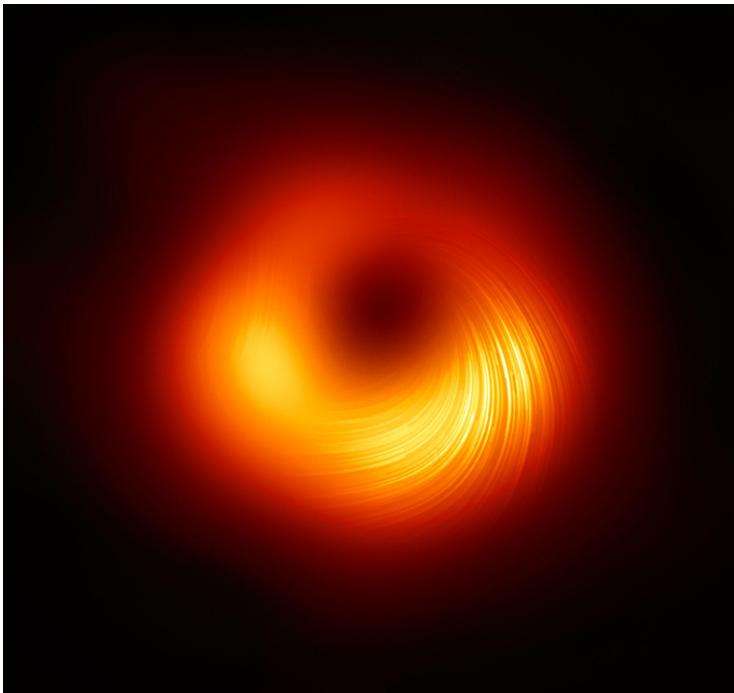
# Characterising the Variability of Black Hole Accretion Flows

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Undergraduate

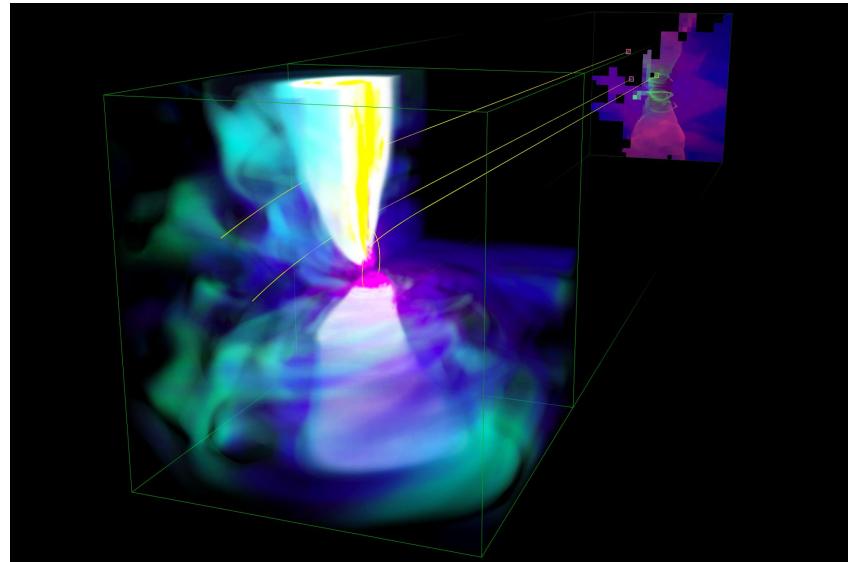


# Motivation and Background

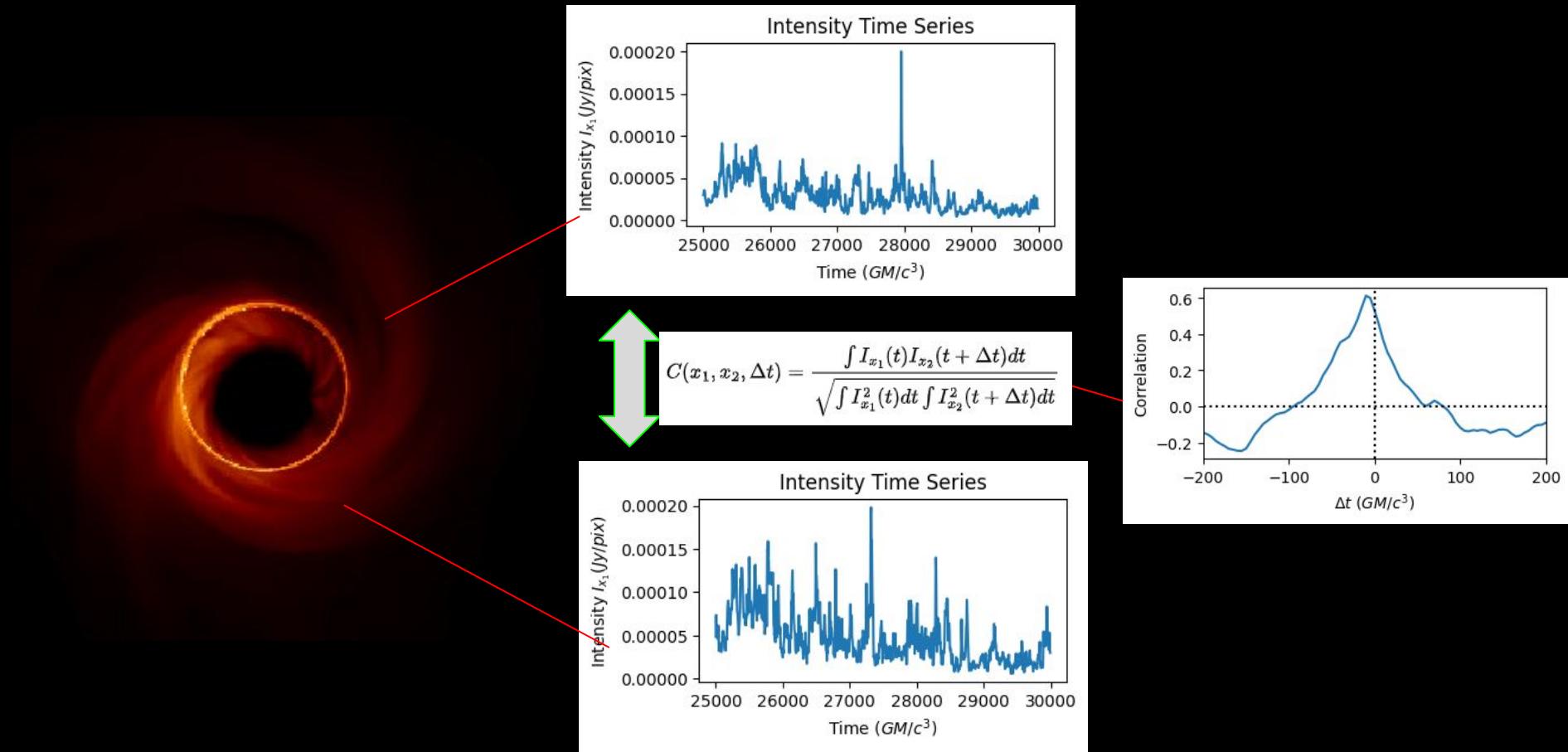


The Event Horizon Telescope (EHT) enables black hole imaging (M87\*, Sgr A\*).

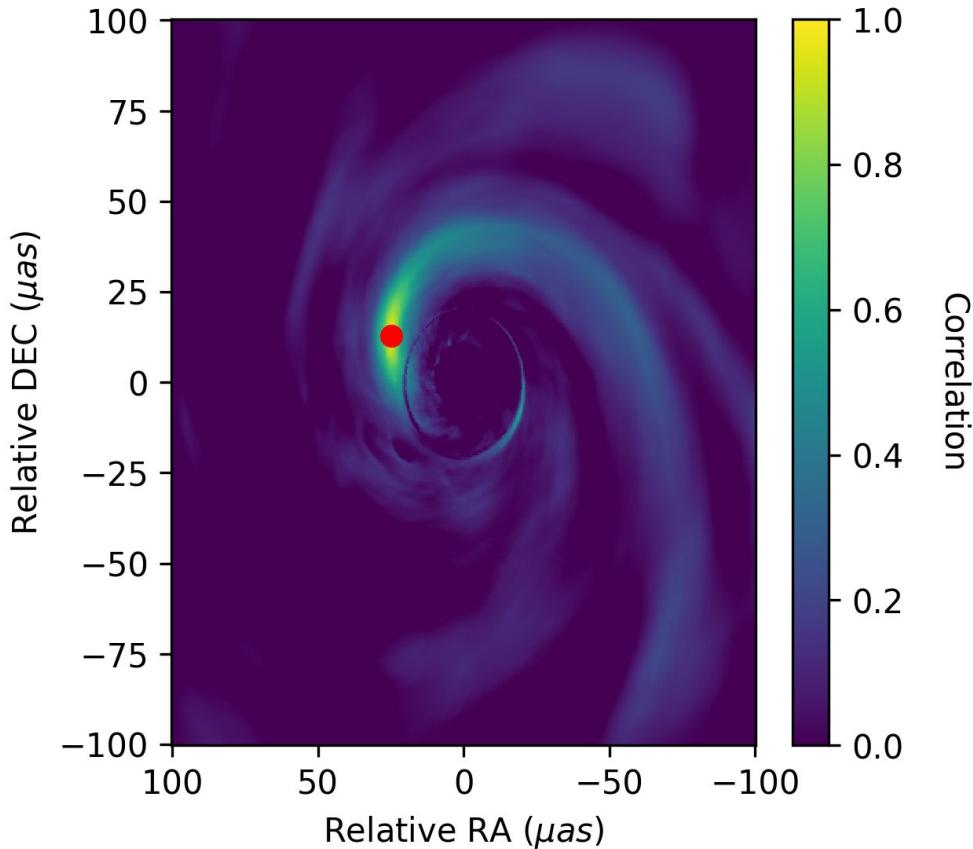
GRMHD simulations are crucial to interpret these observations.



# Quantifying the Variability

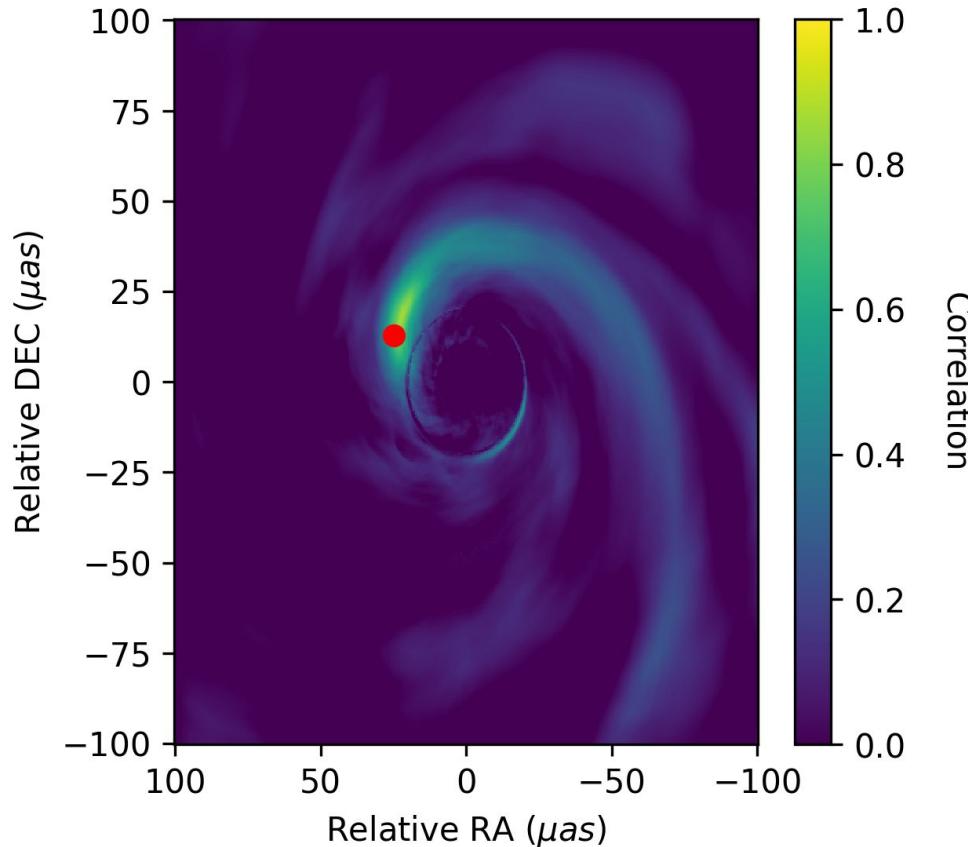


# Plotting the Variability with all pixels



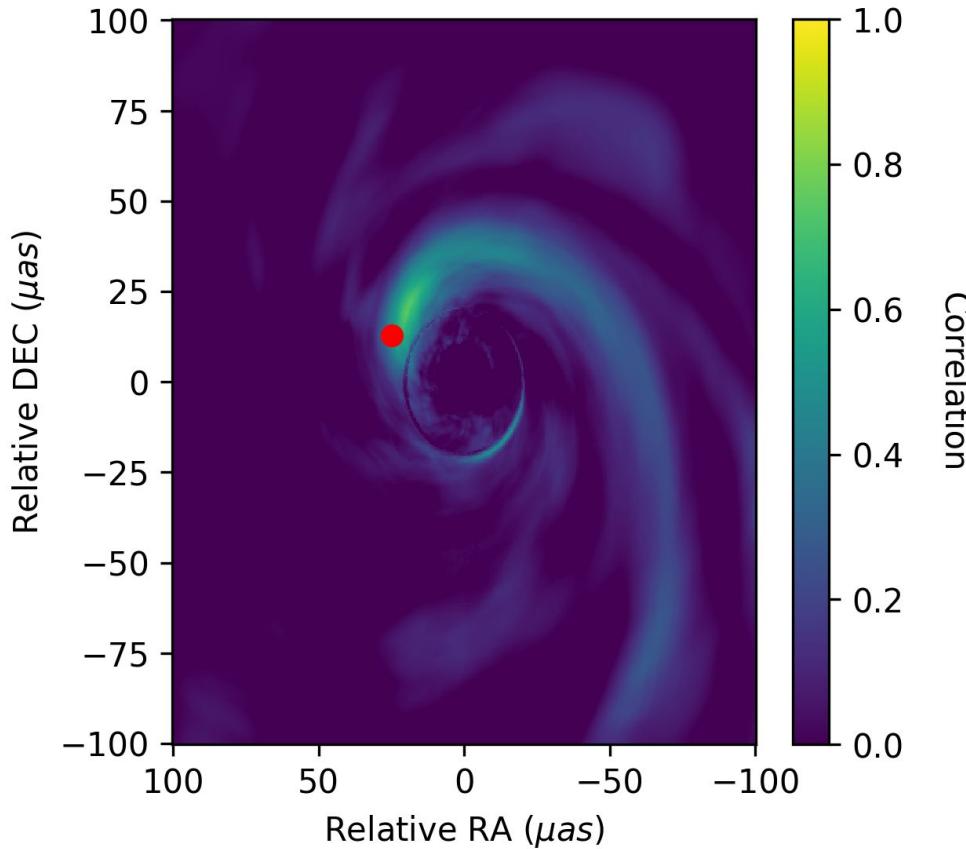
$$\Delta t = 0$$

# Plotting the Variability with all pixels



$$\Delta t = GM/c^3$$

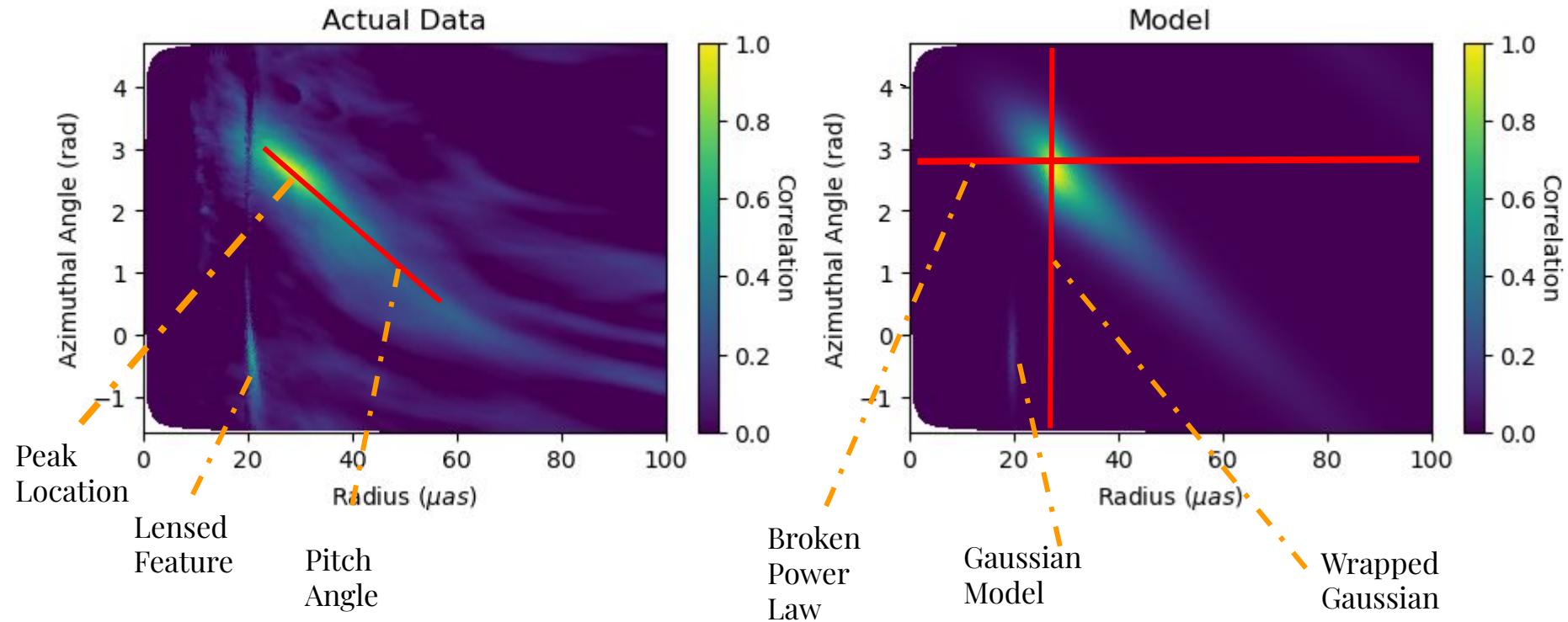
# Plotting the Variability with all pixels



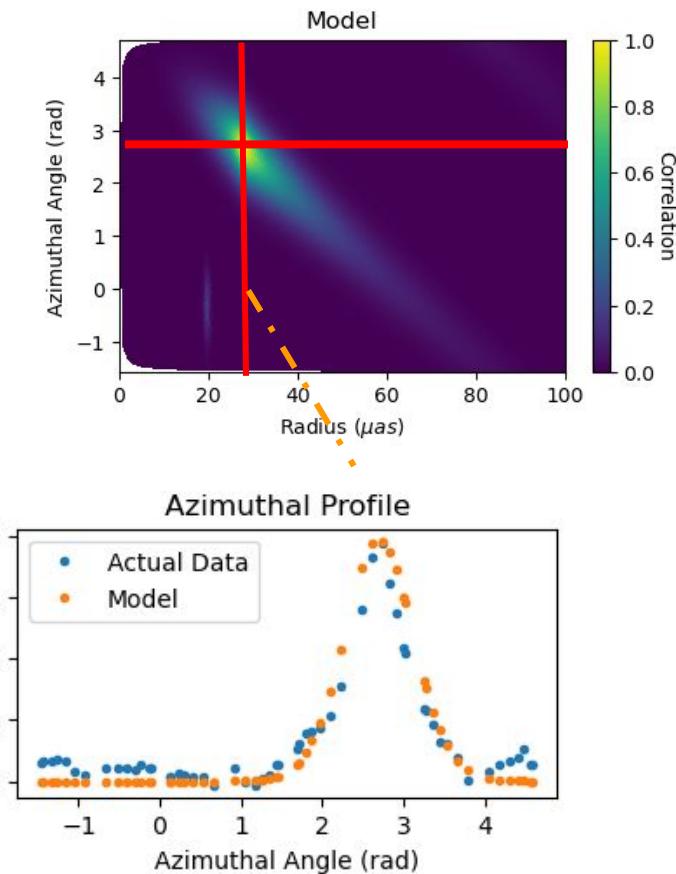
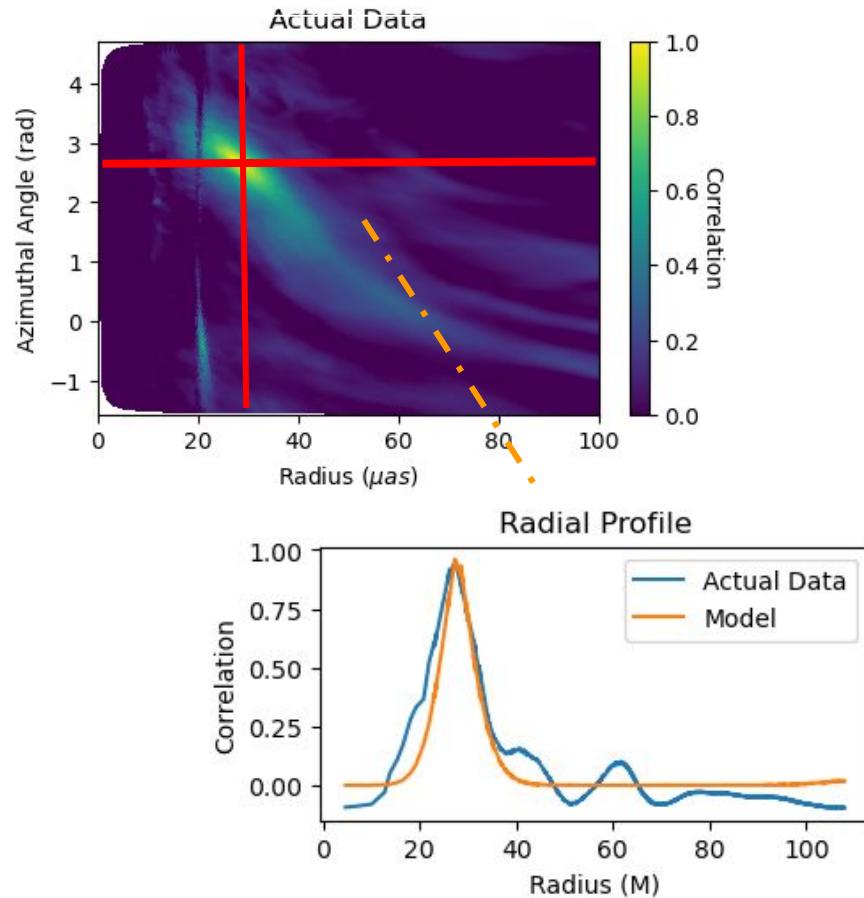
$$\Delta t = 2GM/c^3$$

# Modelling this Structure

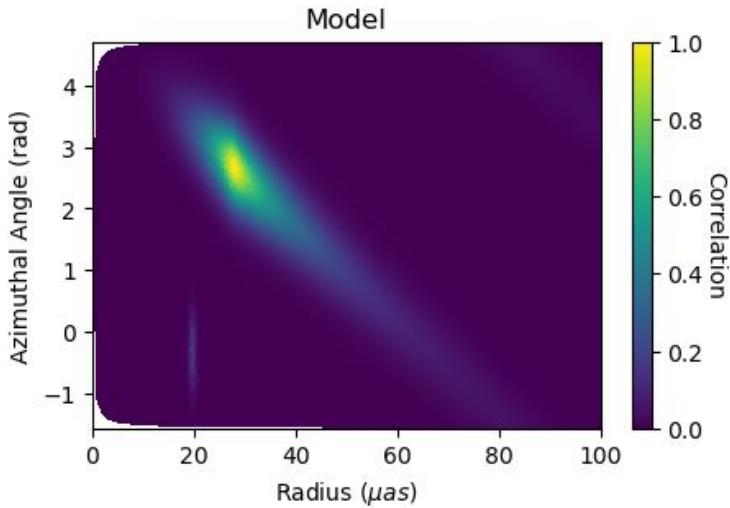
Parameters: Peak Location, Lens Location, Pitch Angle



# Modelling this Structure



# Conclusion

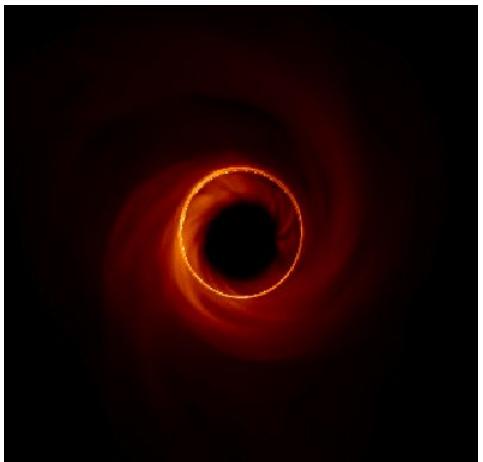


Use of GRMHD simulations to characterise the variability and obtain a Broken Power law and Azimuthal Wrapped Gaussian model

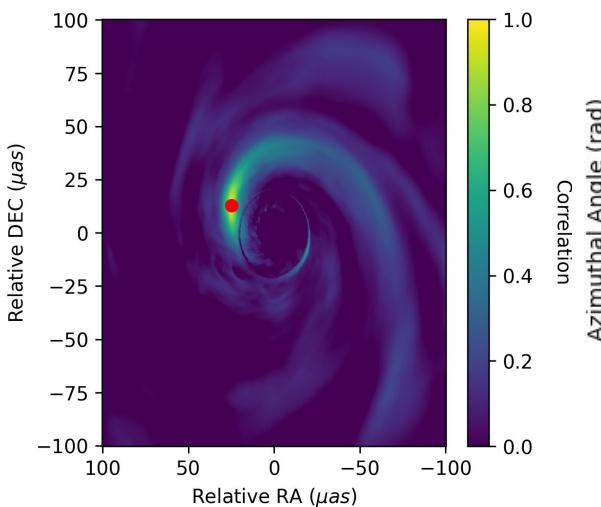
## What's next

- Apply this model to more GRMHD simulations
- Use this model to characterize turbulence and disentangle it with the mean image.
- Application to real data and upcoming EHT movies.

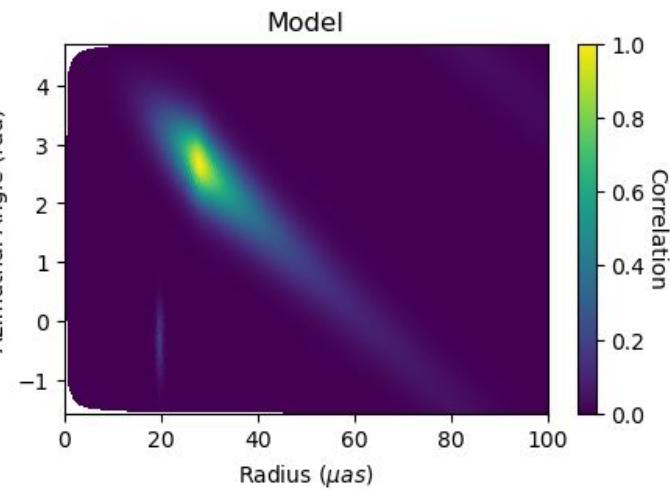
# Conclusion



Use of GRMHD simulations to characterise the variability



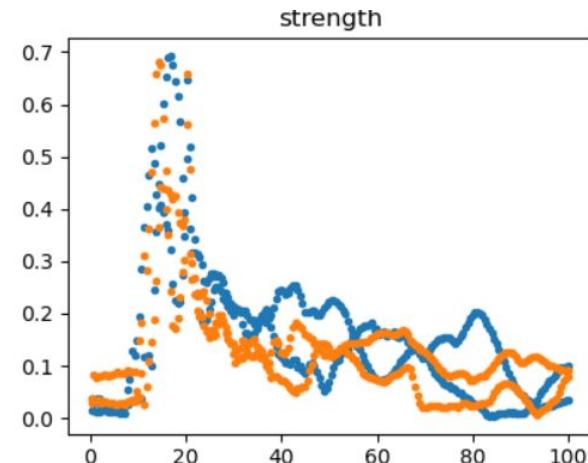
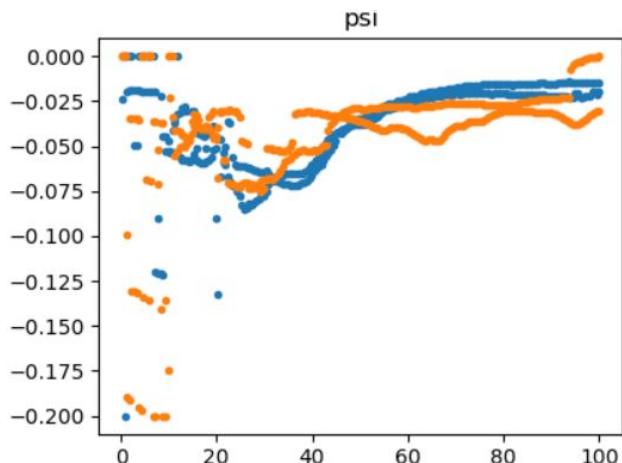
Correlation across all pixels



Radial Broken Power law and Azimuthal Wrapped Gaussian Function

## Applying across the images

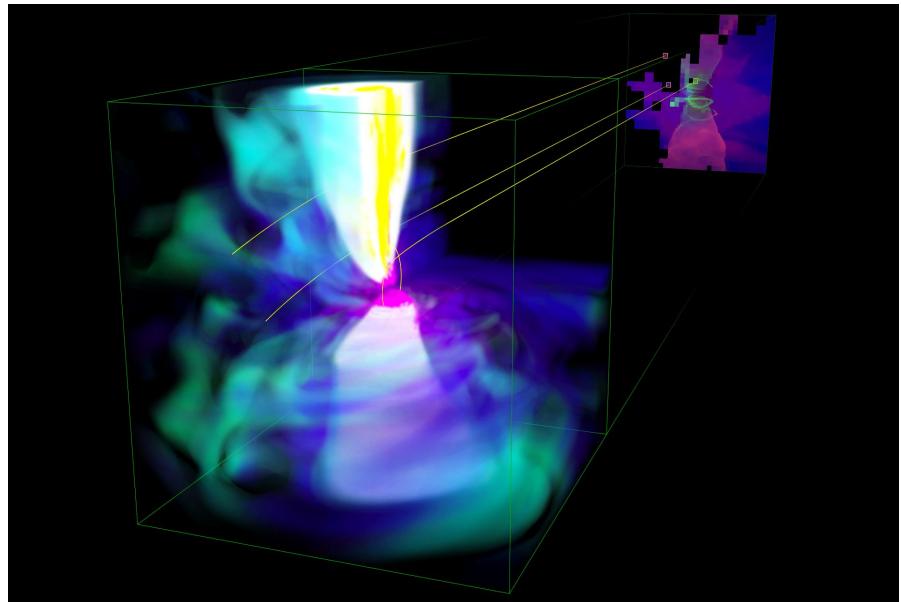
- Model applied pixel-by-pixel to entire frames
  - Reveals how variability parameters change with radius
- Enables radial profiling of dynamic behavior.



# GRMHD Simulations

- GRMHD = General Relativistic Magnetohydrodynamics
- Simulates:
  - General relativity (gravity)
  - MHD (magnetic plasma)
- Captures time-dependent accretion flows behavior

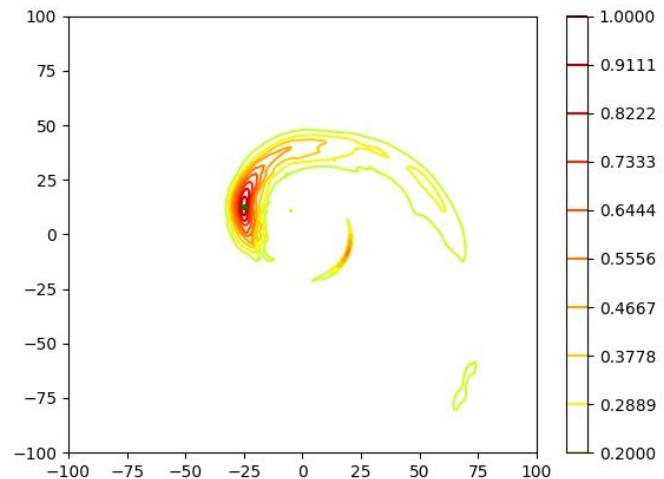
General Relativistic Ray Tracing (GRRT) turns plasma configuration from GRMHD to image.



# Quantifying the Variability

- Captures how intensity varies across space/time in simulation images
- Detects patterns, turbulence, and coherence

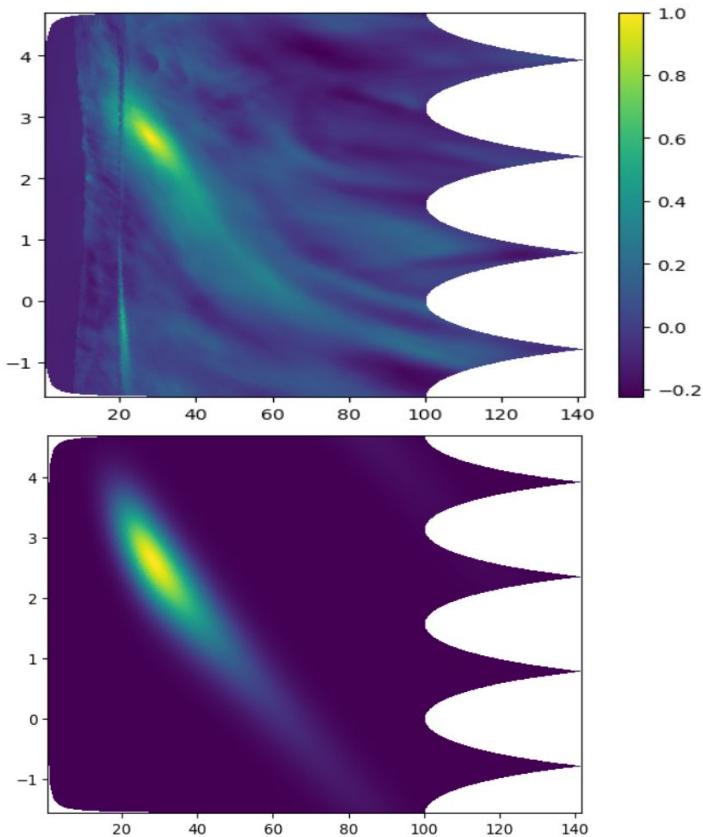
We calculate pixel-to-image correlations to reveal structure.



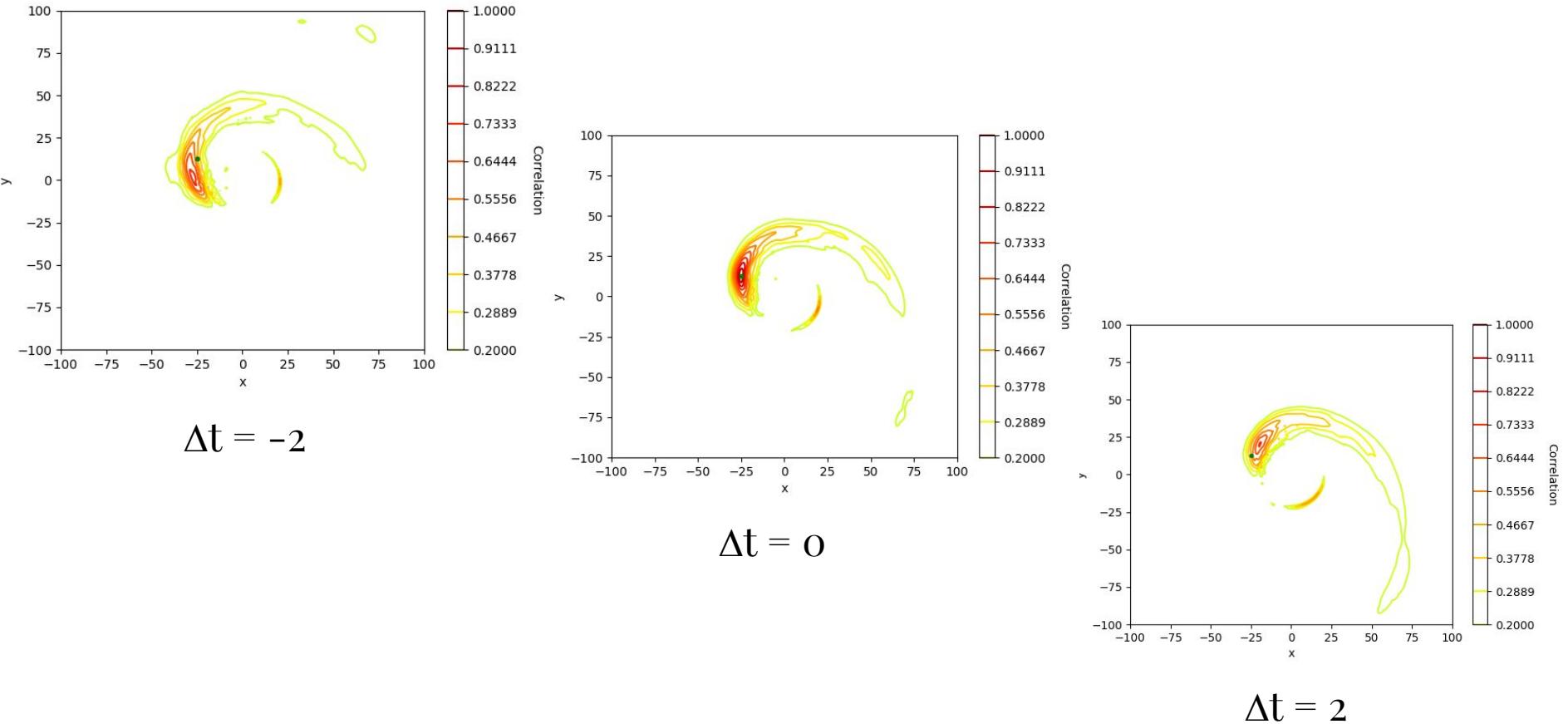
# Modelling this Structure

Correlation structure modeled using Bayesian statistics:

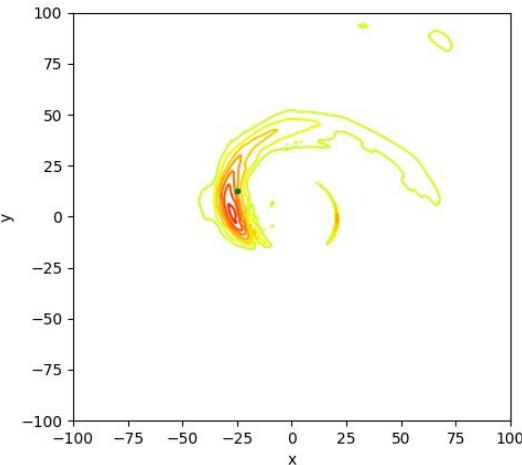
- Radial: Broken power-law
- Angular: Exponential cosine
- Parameters: Peak location, Pitch angle, Feature strength, Peak width, lensed feature strength,



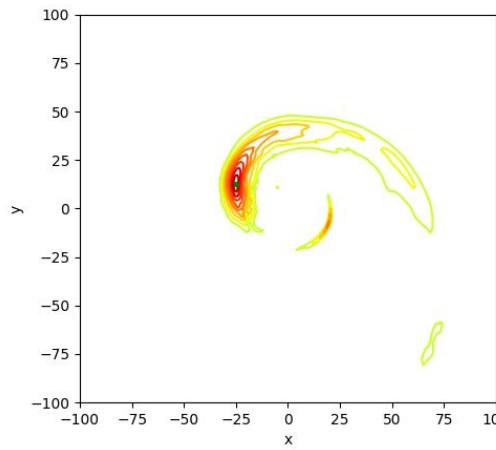
# Plotting the Variability with all pixels



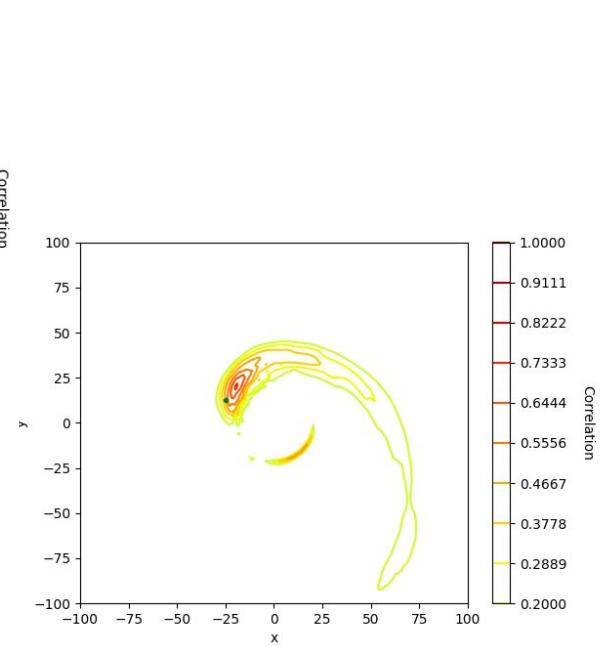
# Plotting the Variability with all pixels



$\Delta t = -2$



$\Delta t = 0$

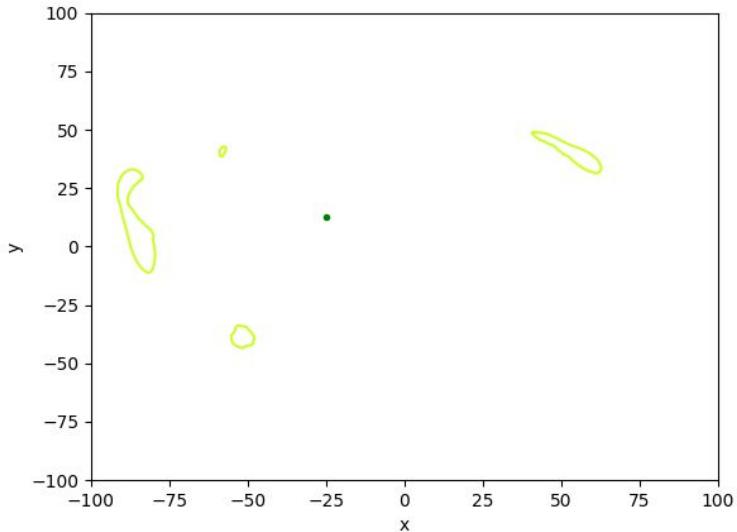


$\Delta t = 2$

# Plotting the Variability with all pixels

- Captures how intensity varies across space/time in simulation images.
- Detects patterns, turbulence, and coherence.

We calculate pixel-to-image correlations to reveal structure.



# Plotting the Variability with all pixels

