Investigation of Corrugation Modes as a Mechanism for X-Ray Variability

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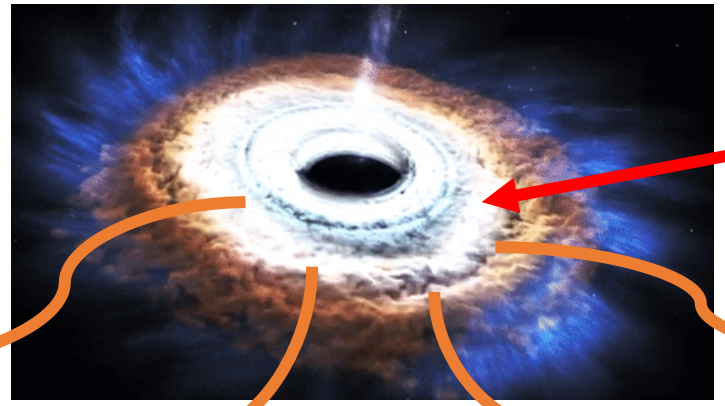
Black Holes

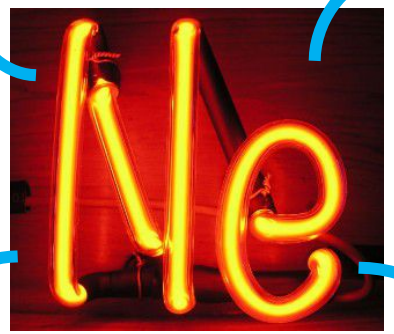
Extremely hot matter accreting onto spinning black holes



Accretion Disk

https://media.giphy.com/media/wyBcwFyH2EpO8/giphy.gif

High-Energy X-Rays



Visible Light

The Mystery: Periodic X-Ray Pulses

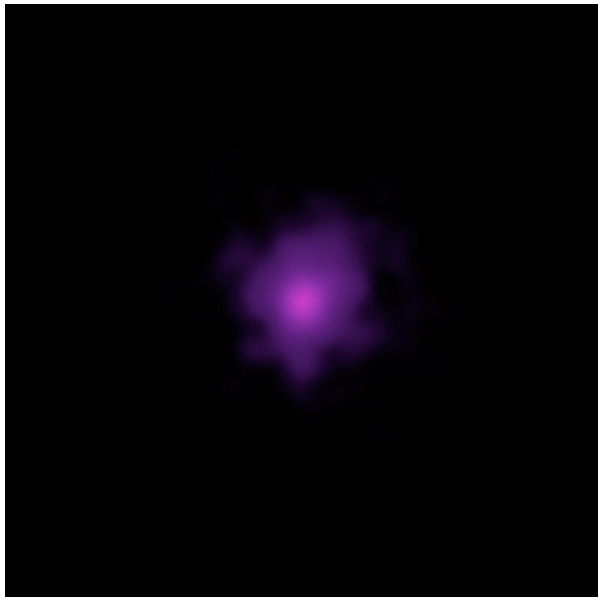


Image courtesy of NASA

Testing the Theory: Numerical Simulations

Theory:

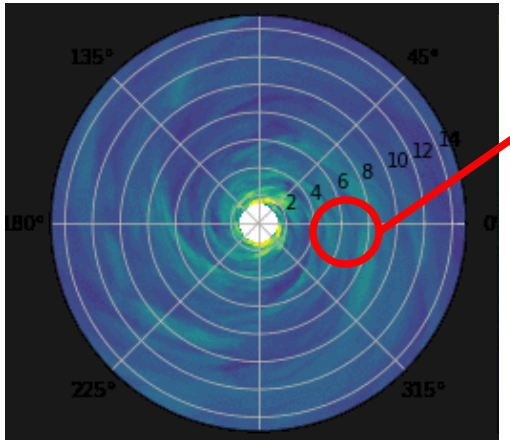
X-Ray pulses are caused by **trapped density waves** in the accretion disk

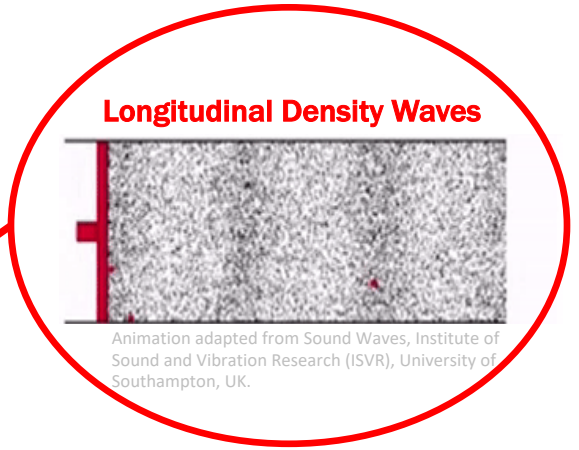
Numerical Simulation:

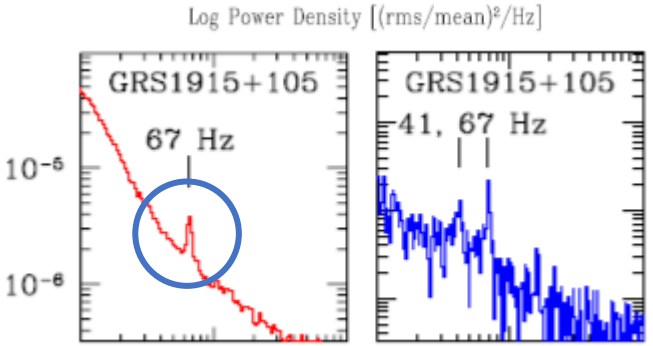
Generate “virtual” black hole & **compare simulation data with mathematical prediction**

Observation:

Model physical black hole and **compare X-ray pulses with real X-ray data**





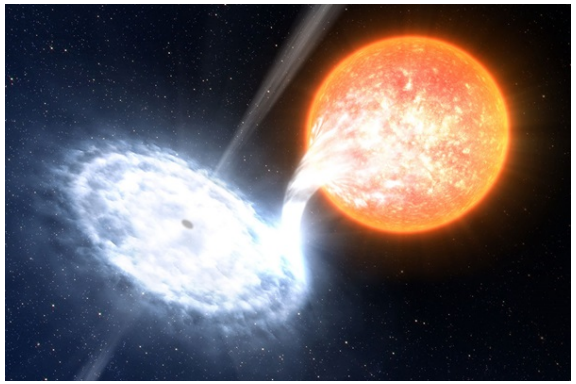


Example: Observational X-Ray Power Data from Black Hole Binary System GRS1915+105

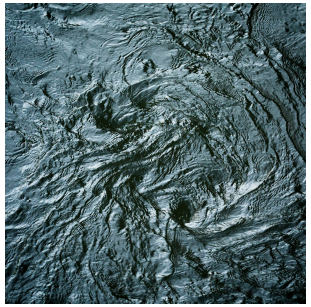
(Cui et al. 2000a; Homanet al. 2003; Remillard 2004).

Searching for Structure

Accretion Disk – Hot, ionized material falling onto black hole



Waves: Structures Amidst Chaos



Goal 1

Look for Patterns in Simulation Data

Approach

Use Fourier Analysis on Simulation Data

Difficult to Resolve Patterns

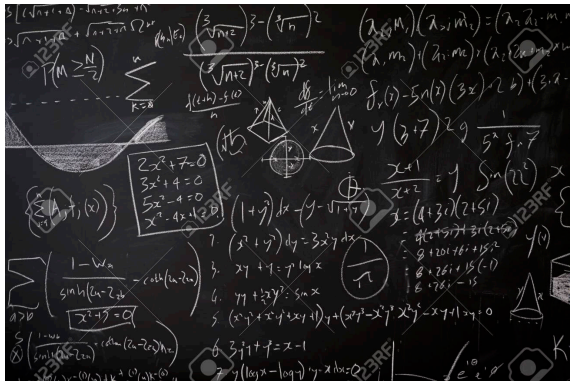
Patterns are Extracted and Listed by Frequency

Goal 2

Develop an Analytical Model

Approach

Find Equation that Fits with the Patterns

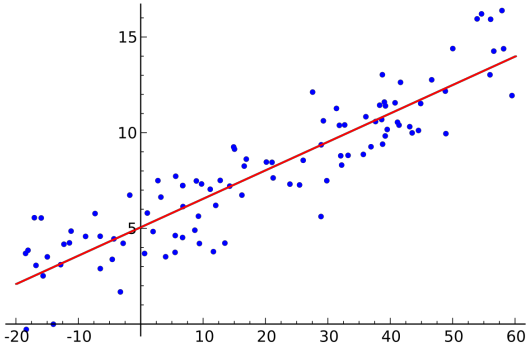


Goal 3

Compare Results of Model to Simulation Data

Approach

Directly Compare with Simulation Data

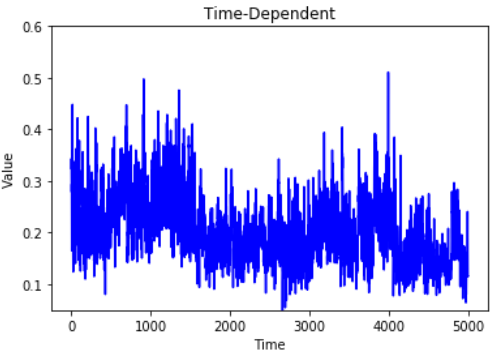


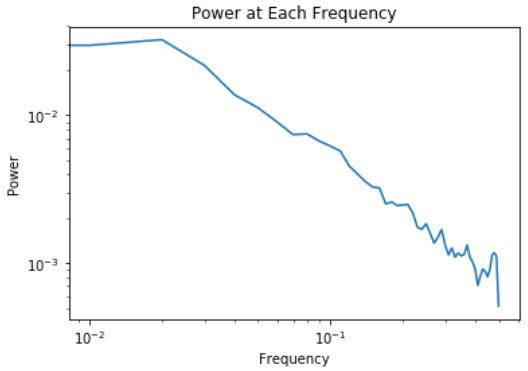
Collecting the Clues

Use Fourier Analysis to Identify Coherence

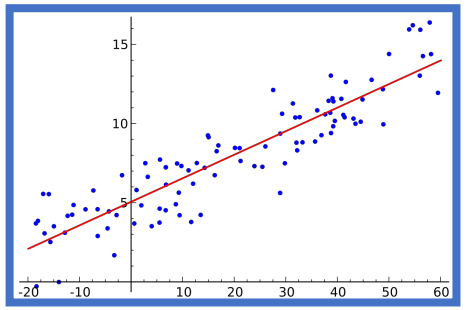
$f(t)$ → $f(\omega)$

Time-Dependent → **Frequency-Dependent**

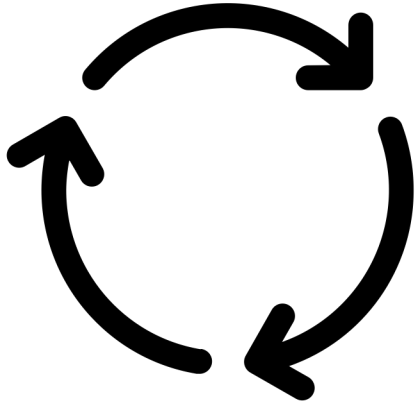




Build on Existing Theory



Develop Consistent Analytical Result

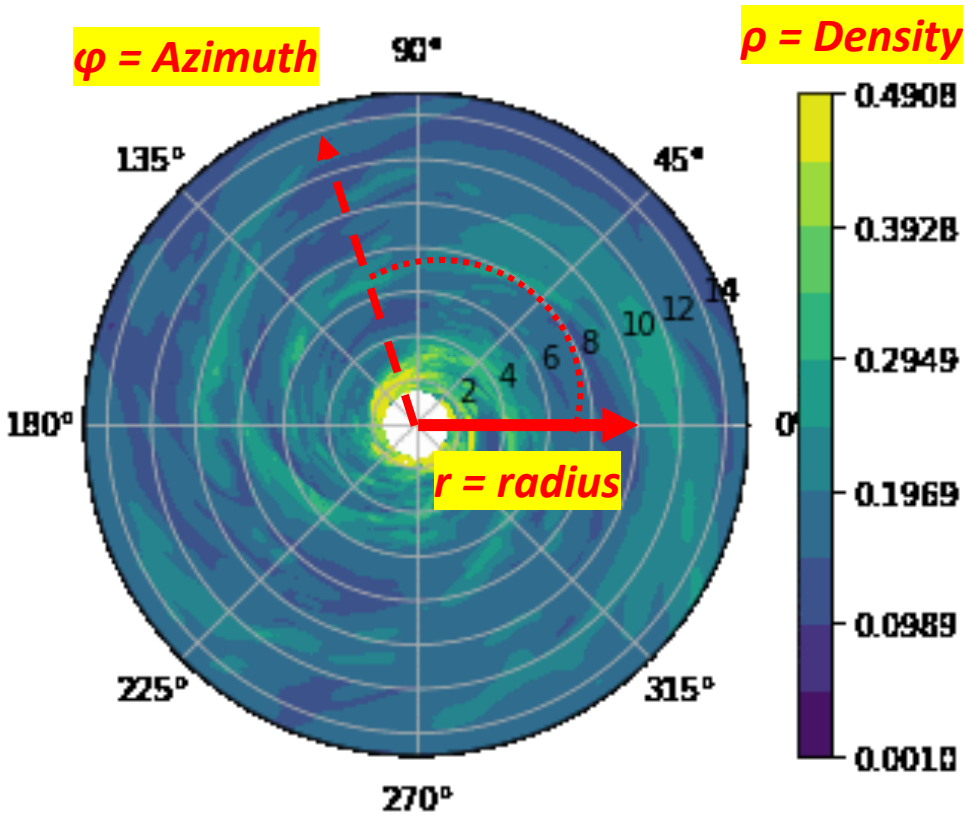


Search Literature

Compare Analytical Predictions with Simulation Data

Probing the Black Hole

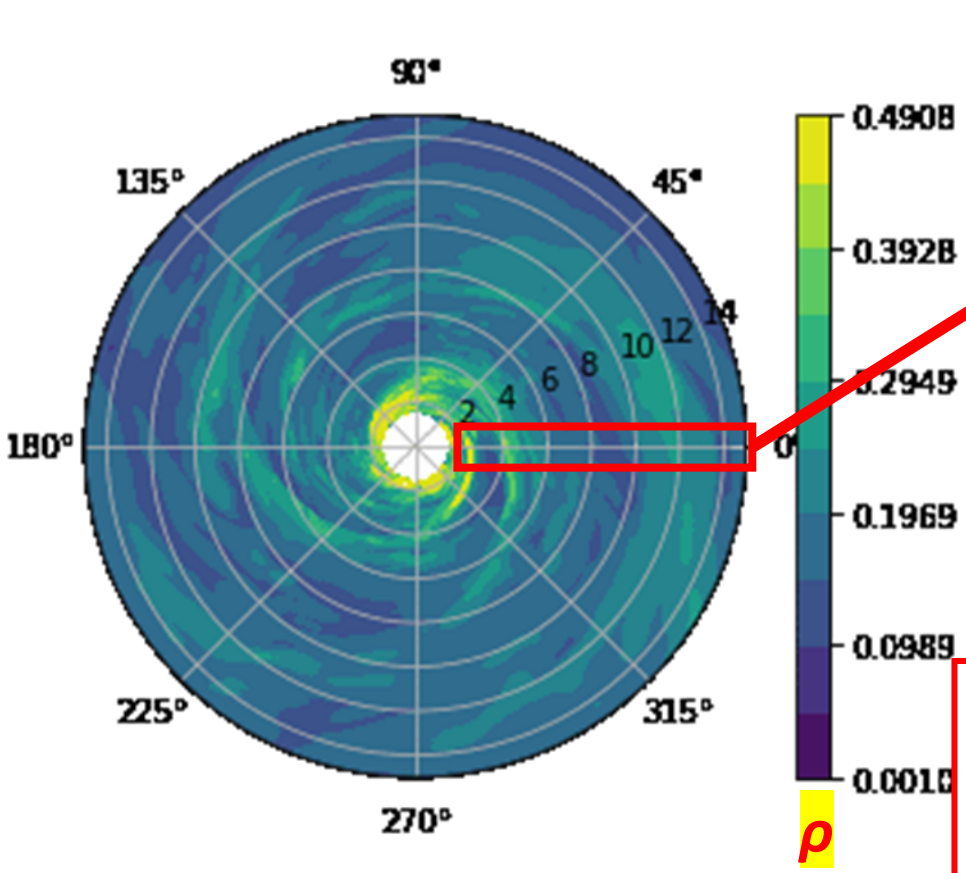
Sorting out the Variables

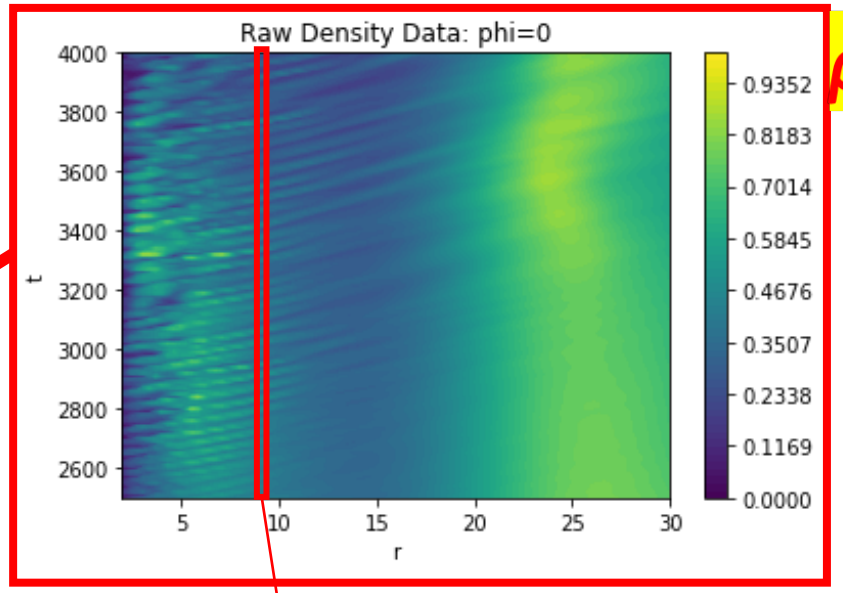


t = time

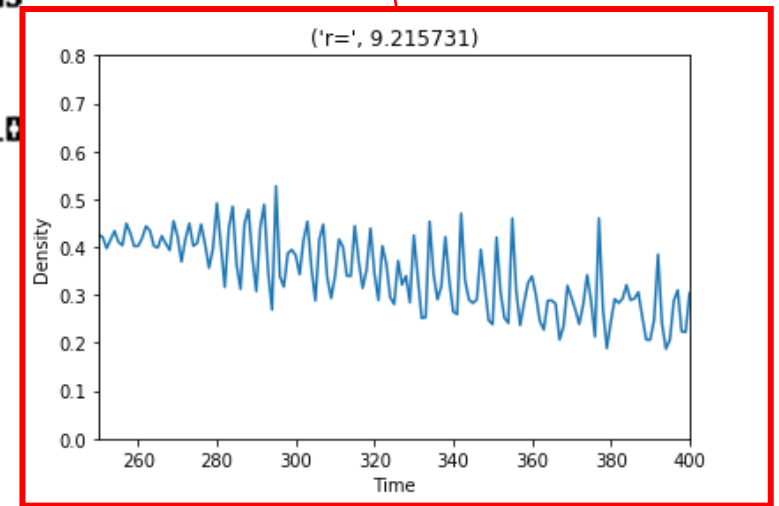
$\rho\ (t,\varphi,r)$

Goal: Density as a Function of Time



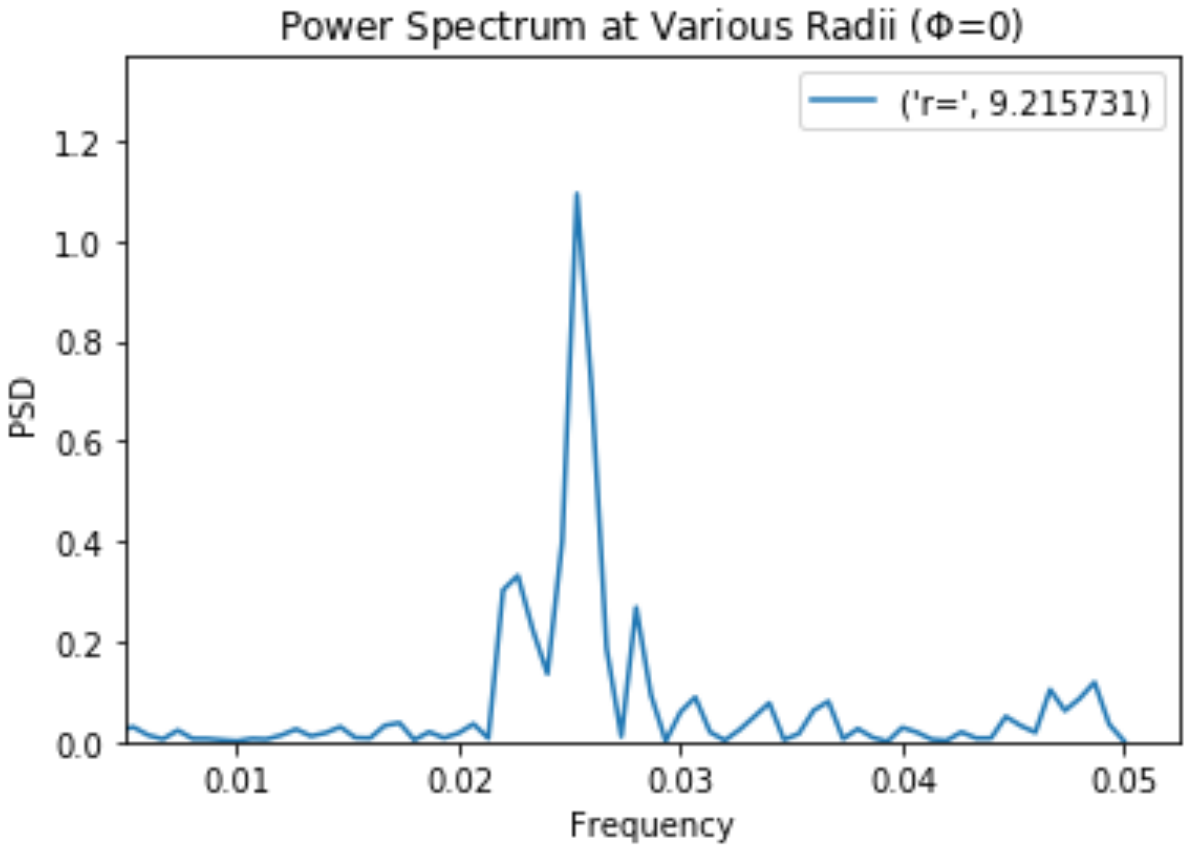


ρ (t , r)



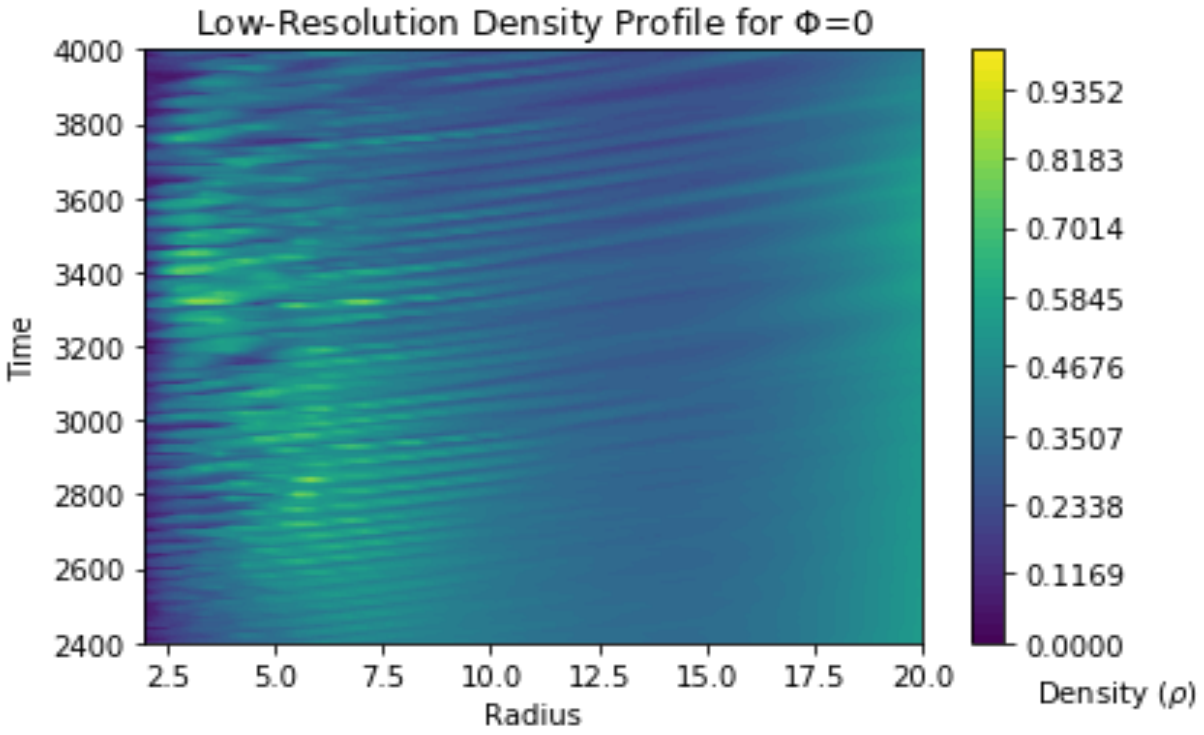
ρ (t)

There's a Peak!

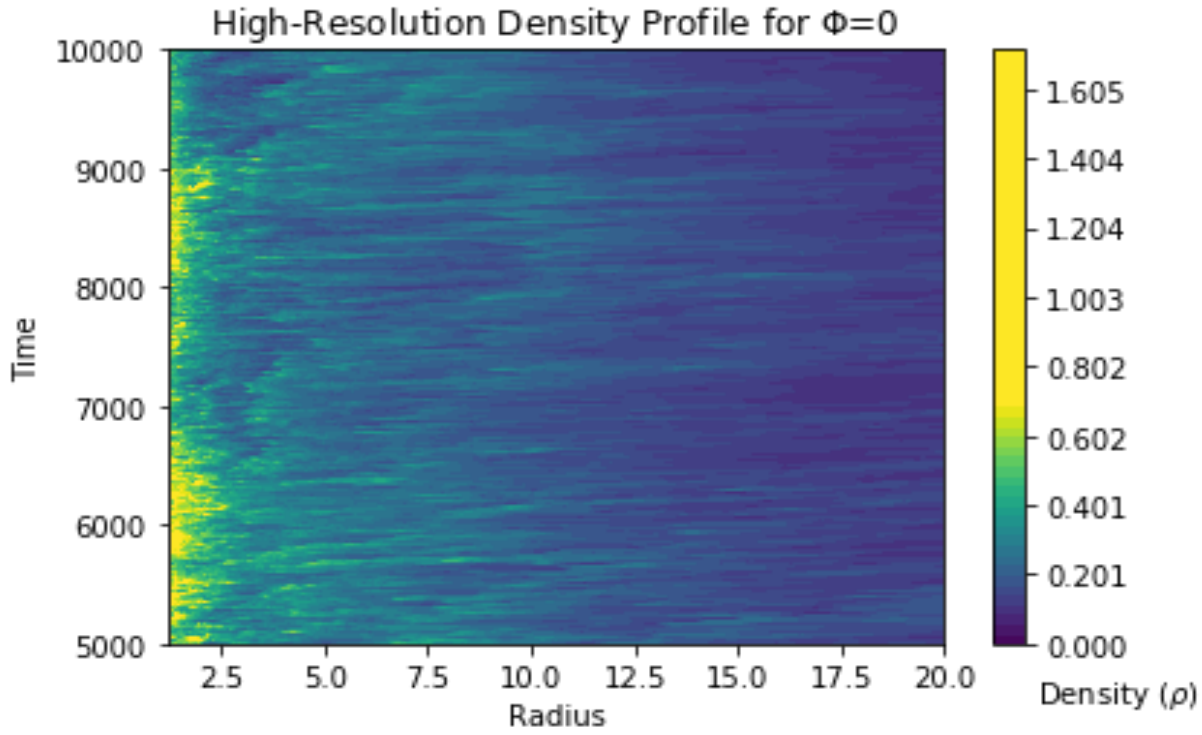


… At Low-Resolution

Hypothesis: Turbulent Shredding

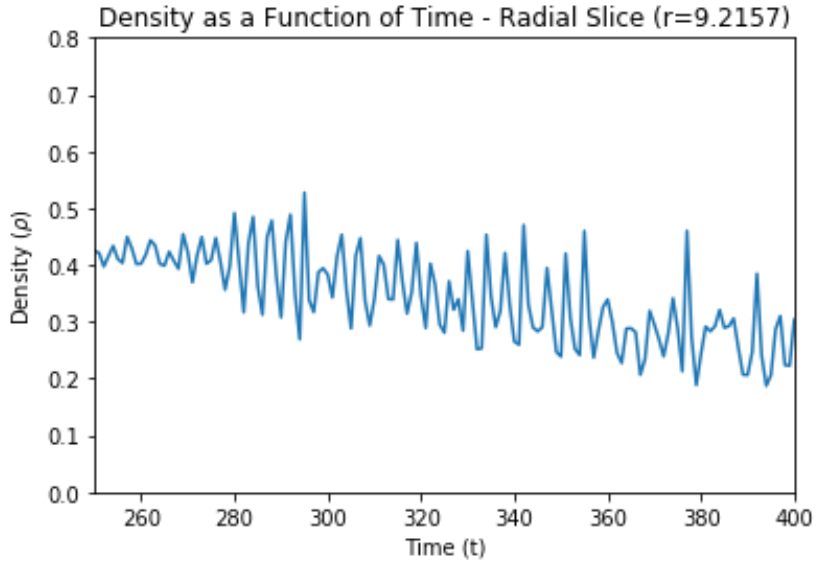


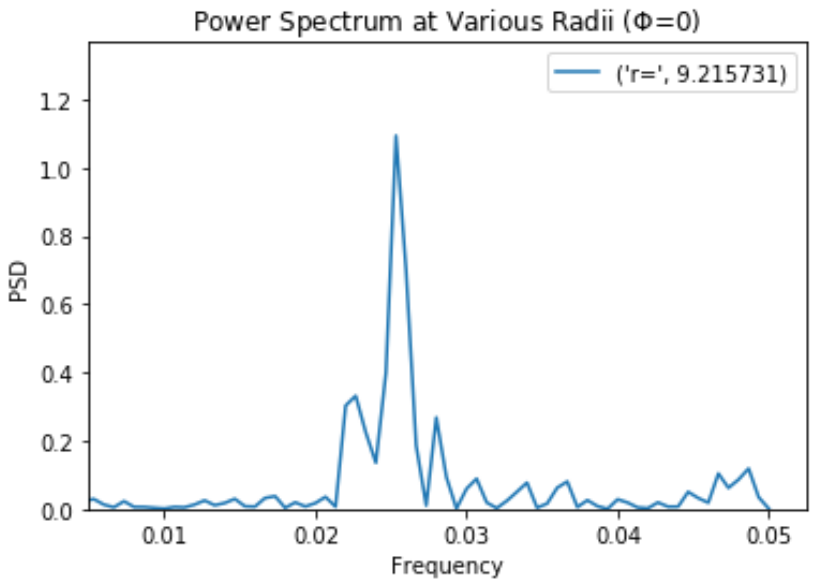
Low-Resolution



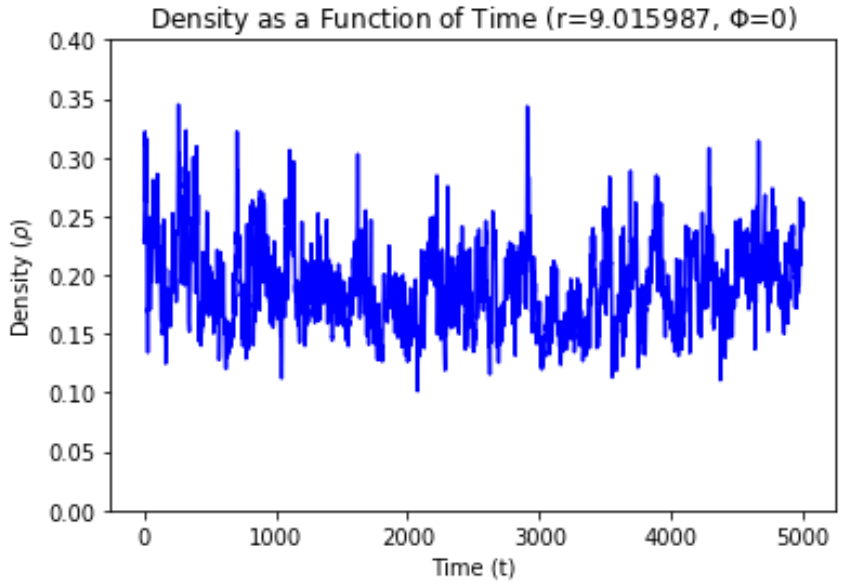
High-Resolution

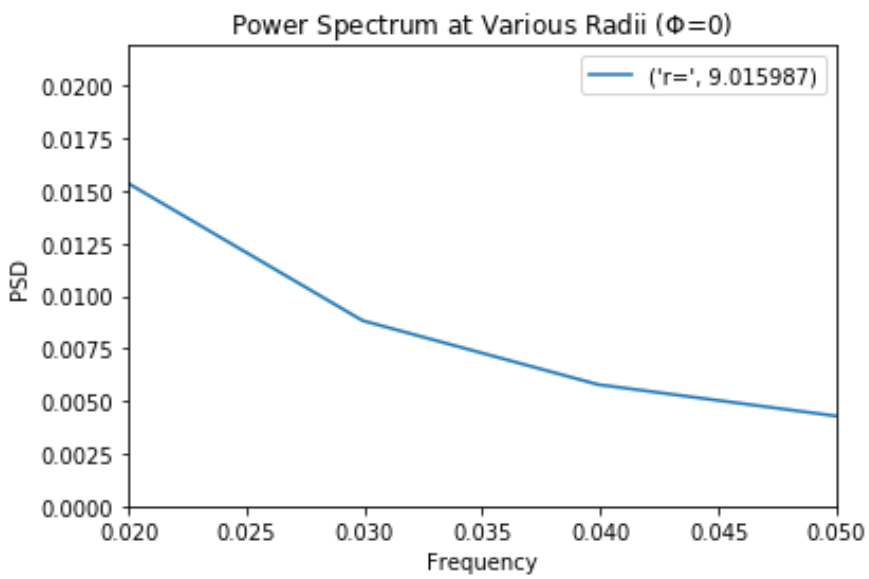
Low – Resolution





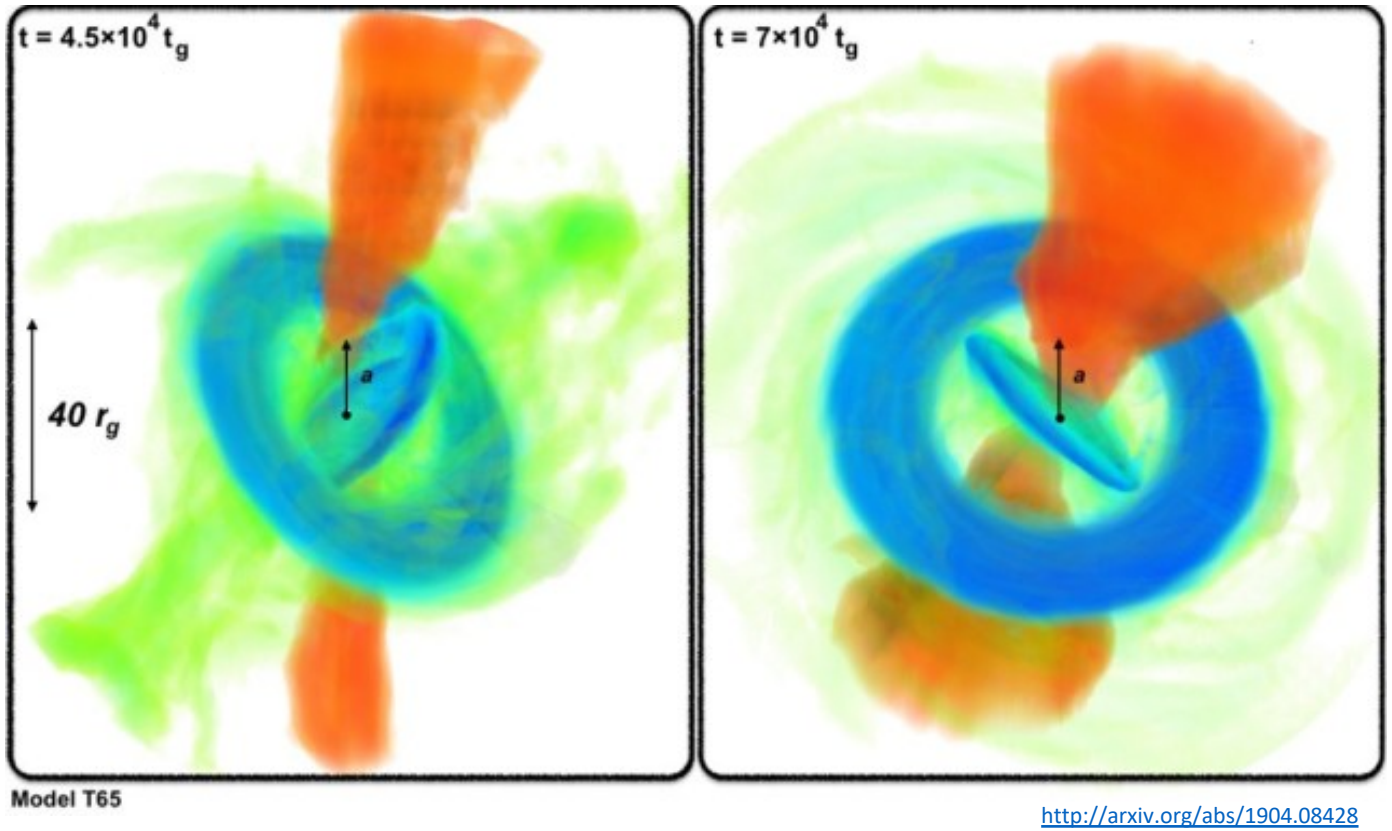
High – Resolution





Looking Ahead

Next Goal: Tilted Disks



Model T65

http://arxiv.org/abs/1904.08428

Overview: New Knowledge

- Visualize complicated data sets using creative plot techniques
- Use Fourier Analysis to separate signal from noise
- Search scientific literature effectively

Acknowledgements

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