The Effects of Magnetic Flux on X-ray Binary Outbursts

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Introduction

The magnetic flux present in an accretion flow around a black hole can affect the structure of the flow as it undergoes an outburst. Recently, *H-AMR*, a two-temperature radiative GRMHD code, has been used to create the first simulations of accretion flows as a $10M_{\odot}$ black hole X-ray binary (BhXRB) undergoes a transition from the quiescent state to the hard-intermediate state, with luminosities ranging from $L \approx 10^{-10}L_{Edd}$ to $L \approx 10^{-2}L_{Edd}$. This transition was simulated for two different models: one unsaturated with magnetic flux (SANE) and one with higher amounts of magnetic flux (MAD). Here, we present our first results obtained by ray-tracing these *H-AMR* datasets (see accompanying poster by Emrah Kalemci for comparisons of these results to observational data).

Images of Simulation

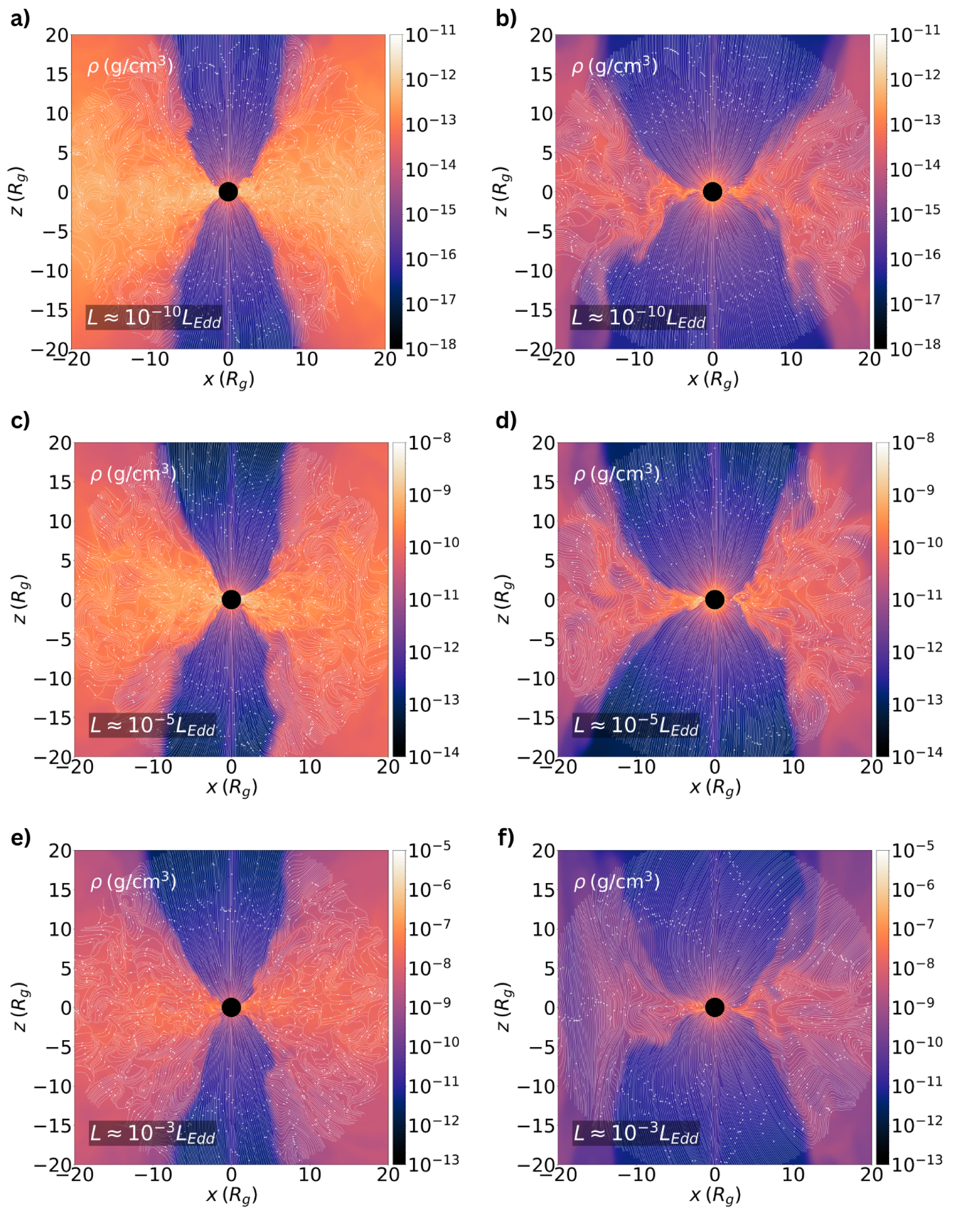

Figure 1. Plots illustrating density for *H-AMR* runs at $L \approx 10^{-10}L_{Edd}$ (a, b), $10^{-5}L_{Edd}$ (c, d), and $10^{-3}L_{Edd}$ (e, f), from top to bottom respectively. Streamlines illustrate the magnetic field in the system. Left: SANE, Right: MAD

Methods

Monte Carlo ray-tracing, or MCRT, is a method that allows for visualization of numerical simulations. We use *RAPTOR*, an MCRT code capable of handling synchrotron emission and Compton scattering and absorption, to create the following spectral energy distribution diagrams.

Spectral Energy Distributions

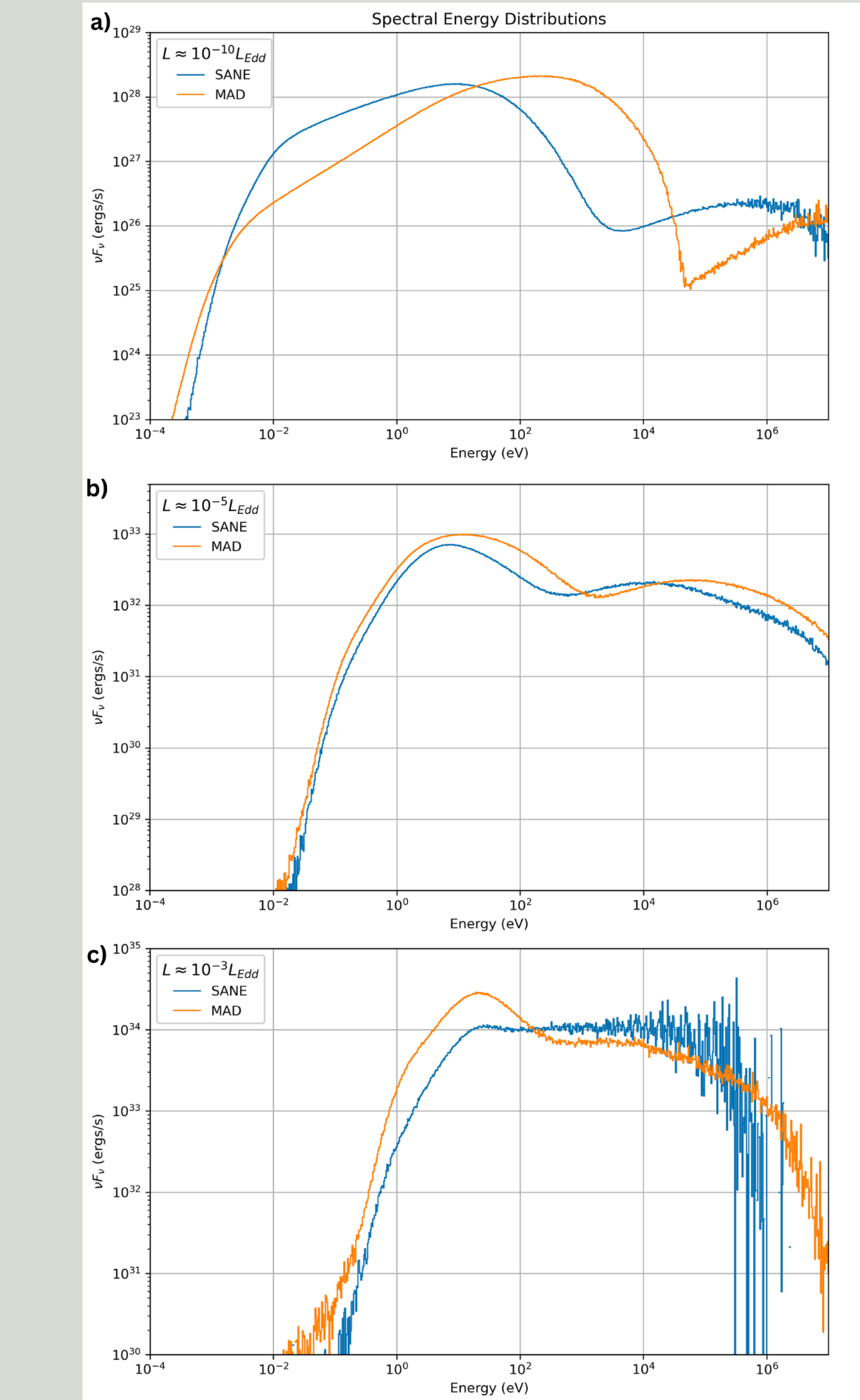

Figure 2. Spectral density diagram of BhXRB at $L \approx 10^{-10}L_{Edd}$ (a), $10^{-5}L_{Edd}$ (b), and $10^{-3}L_{Edd}$ (c), from top to bottom respectively.

Light Curves

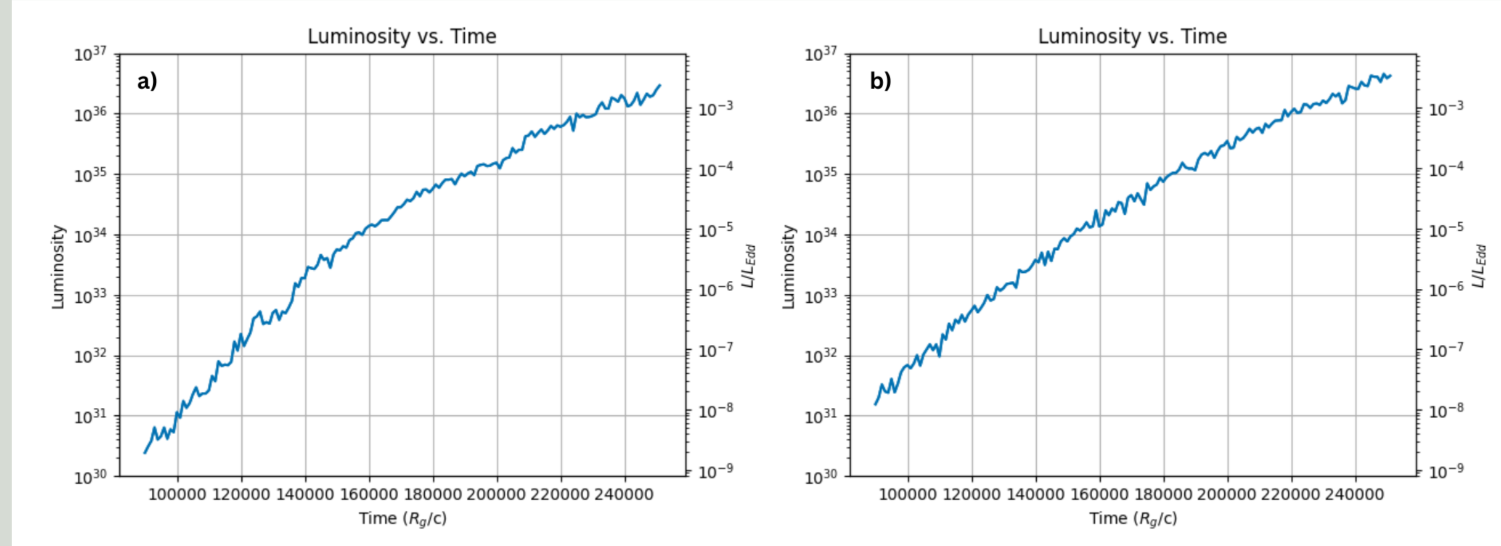

Figure 3. Change in luminosity for both SANE (a) and MAD (b) models over a period ranging from 90000 R_g/c to 250000 R_g/c.

Discussion

- Figure 2 shows us evidence of synchrotron emission, as is expected from an optically thin flow.
- Though we are currently incapable of capturing emission from the disk with *RAPTOR*, we expect to find evidence of a thin disk at high luminosities.
- The streamlines pictured in Figure 1 show the structure of the magnetic field. Specifically, we see a difference in how the magnetic flux is oriented around the densest parts of the flow between the SANE and MAD models.
- We see a slight shift to a softer spectrum from $L \approx 10^{-5}L_{Edd}$ to $L \approx 10^{-3}L_{Edd}$. A possible reason for this could be that, around this time, we start to see the optically thin accretion flow collapsing into an optically thick disk. As the simulation progresses, it is expected that this trend will continue.

Future Work + Connections to Observational Data

By continuing analysis on the current simulation, we can not only visualize the physical structure of the accretion disk at higher luminosities, but also understand how it reached this point from quiescence. We are currently in the process of creating spectra that take emission from thin disks into account, and thus future analysis will reveal an even more complete picture.

Comparisons to observational results will help benchmark the amount of magnetic flux present in physical systems. In addition, further analysis of light curves and the time variability of the system might shed light on the origin of quasi-periodic oscillations (QPOs). Future studies will also include simulations with other varied parameters such as tilt, leading to more observational predictions of the factors affecting a BhXRB outburst.

References

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