Modeling Emission of Jet/Accretion Flow/Black Hole (JAB) Systems in GRMHD

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Introduction

- Modeling emission in jet/accretion flow/black hole (JAB) systems is a crucial part of understanding the dynamics behind active galactic nuclei.
- An established emission model emulating turbulent heating, the R-β Model, expresses the ion-to-electron temperature R as a function of plasma beta.
- Our alternative Critical β Model has an exponential transition from preferential electron to proton heating as a function of β; Our inclusion of magnetic-to-particle energy reconnection based emission in jet regions for both turbulent heating models are key advances in JAB emission model accuracy.
- We look at two distinct flow states for the accreting plasma surrounding the black hole: standard and normal evolution (SANE) and magnetically arrested disk (MAD).
- We model two large, well-studied Event HorizonTelescope (EHT) targets (M87 and Sgr A*), to create a pattern of emission properties and compare with observational evidence.

Turbulent Heating Models

- R-β Model is primarly used by EHT, introduced by Moscibrodzka et al. 2016. It notes the tendency of plasma turbulence to preferentially heat electrons at low β and ions at high β. R_{high} and R_{low} are temperature ratios that describe the electron-to-ion coupling in the weakly magnetized (disk/high β regions) and strongly magnetized regions (jet/low β regions), respectively.
- Critical-β Model was introduced in 2020 by Dr. Richard Anantua as an alternative heating model. The exponential β parameter now controls the transition between electron and ion dominated heating. The transition behavior at intermediate β's are controlled by βc, leading to a larger variety of intermediate β emission regions probed between the same temperature ratio compared to R-β.

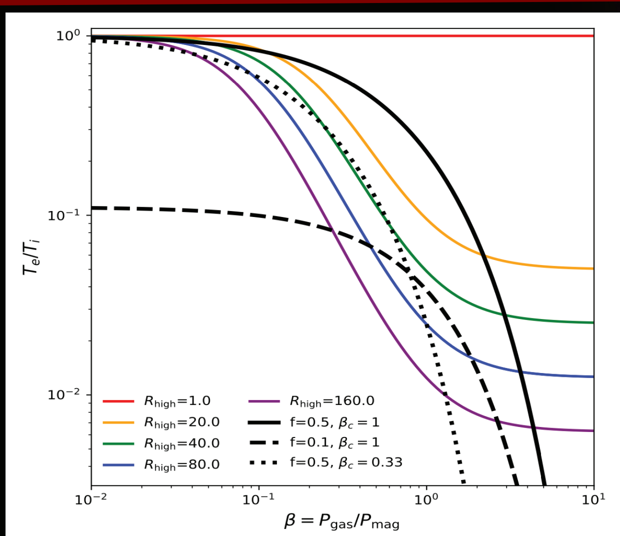

Figure 1. R-β (solid lines) compared to Critical-β (dashed lines) for reasonable parameters

Critical - β Model at T = 25,000M

$$\frac{T_i}{T_e + T_i} = f e^{-\beta/\beta_c}$$

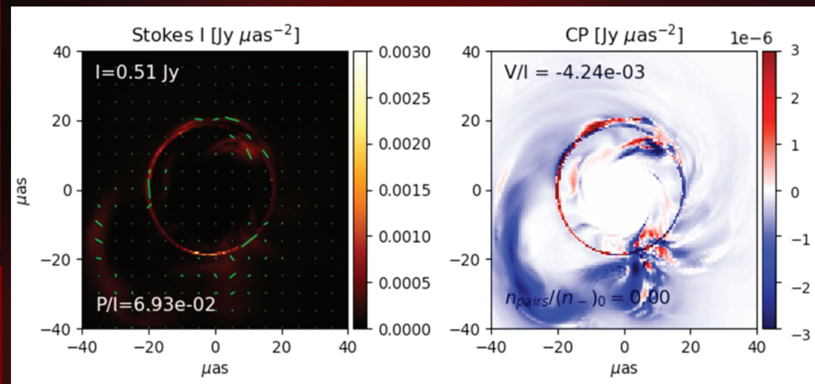

Figure 2. Critical-β intensity at target flux of 0.5 Jy (left) and circular polarization for MAD -0.5 spin of M87

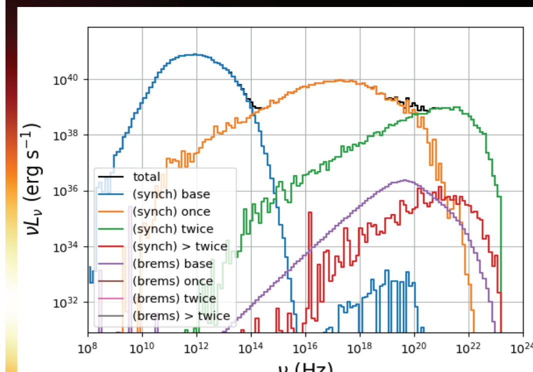

Figure 3. Preliminary SED of M87 with Rlow =1 and Rhigh = 20 showcasing synchrotron, bremsstrahlung, and compton scattering effects

R - β Model at T = 25,000M

$$\frac{T_i}{T_e} = R_{high}\frac{\beta^2}{1+\beta^2} + R_{low}\frac{1}{1+\beta^2}$$

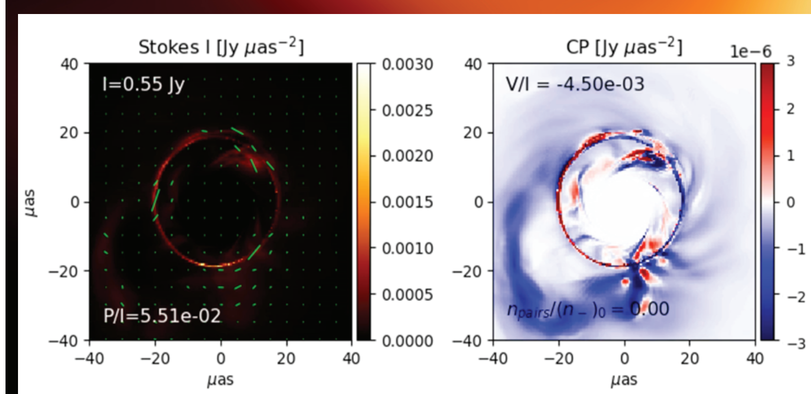

Figure 4. R-β intensity at target flux of 0.5 Jy (left) and circular polarization for MAD -0.5 spin of M87

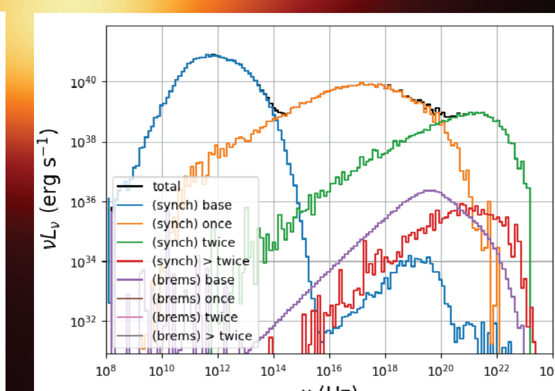

Figure 5. Preliminary SED of M87 with Rlow =1 and Rhigh = 20 showcasing synchrotron, bremsstrahlung, and compton scattering effects

Methods

We perform computations with two general relativistic radiative transfer (GRRT) codes to depict different morphological features throughout the evolution of the outflow and modeling of the spectral energy distribution (SED).

- IPOLE was developed for covariant polarized GRRT mainly to analyze the EHT sources.
- GRMONTY produces spectra of hot accretion flows by utilizing the Monte Carlo method to investigate relativistic radiative transport.
- We focus on one dimensonless spin throughout the evolution of our simulation at a = -0.5. We fix R_{low} at 1 (consistent with long cooling time of Sgr A*) and R_{high} at 20.

Conclusions

- R-β and Critical-β turbulent heating models produce a ring-like intensity profiles
- MADs produce a prominent flux eruption loop outside of the photon ring for certain fiducial times (T = 17,730M, 27,110M, and 25,000M), affecting the polarized emission in observationally distinguishable ways including dominance of intrinsic circular polarization over Faraday effects.
- MAD turbulent heating models satisfy linear polarization constraints, mainly $|m_{net}|$ unresolved magnitude, and all satisfy preliminary circular polarization upper bounds

Future Directions

- We will extend this work to include positron modeling, a feature often overlooked as an inclusion in EHT moeling
- While this presentation focuses on M87, we will extend this deep dive to Sgr A* as a continuation of Anantua et al. 2020b.
- We will extend this study to include a larger parameter space of varying R_{high}, temperature ratio, and spin in comparison to Moscibrodzka et al. 2009.
- We will work to understand why MADs and SANEs behave as characteristicly different as they do based on results in this paper while following EHT boundary constraints on circular and linear polarization.

References

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