Does GRMHD recover the fundamental plane of Black Hole activity?

Testing Sgr A GRMHD Models Against the Population of Low-Accreting Black Holes*

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Abstract

In this work, scale-free radiatively inefficient (RIAF) GRMHD simulations from Vos et al. (2024) are used to compute synthetic radio and X-ray luminosities across a range of black hole masses and accretion rates. By comparing the resulting best-fit correlations between black hole mass and radio-/X-ray luminosities, we assess to what extent different GRMHD simulations can reproduce the observed scaling relations of low-accreting black holes.

Introduction: The (simple) theoretical jet model ...

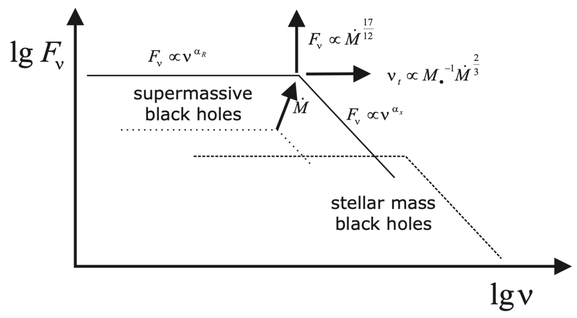


Figure: A schematic jet spectrum and its theoretically expected scaling with mass and accretion rate. Credit: Falcke+04

Freely expanding, conical, isothermal jets naturally reproduce the observed flat radio spectra in radio-loud AGN (Falcke&Biermann, 95). Scalabilities from this model in radio flux and turnover frequency are able to explain the observed correlation between radio and x-ray luminosity in AGN and XRBs, i.e. the fundamental plane of black hole activity (Falcke et al. 2004)

... vs General Relativistic MagnetoHydroDynamics (GRMHD) from first principles

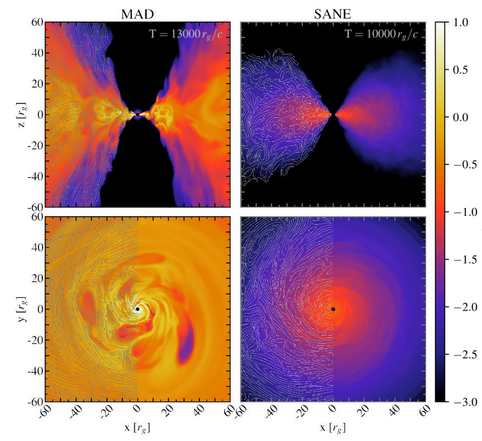
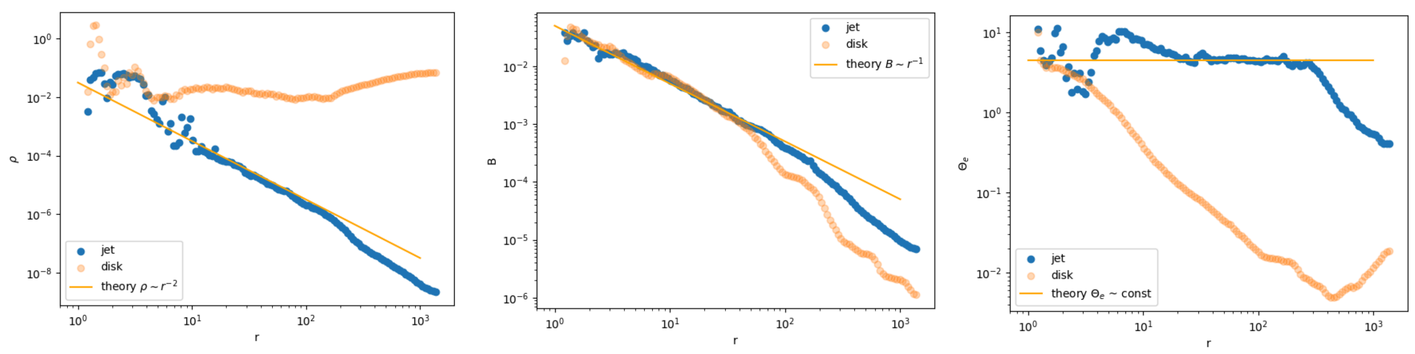


Figure: Two different GRMHD simulations used in this research. Credit: Vos+24

GRMHD evolves magnetised plasma in the curved spacetime around the BH. In low accreting regimes, the radiation and plasma dynamics can be decoupled, making the simulation scale free in mass and accretion rate. I.e, GRMHD models initially developed for horizon scale fits to SgrA* or M87*, can be scaled to any black hole with similar properties (within the RIAF regime). This begs the question: ***To what extent does GRMHD reproduce the general properties of low-accreting black holes?***

Jet profiles

How do shell-averaged jet profiles influence the resulting (ray-traced) spectra? Can GRMHD jets be described as conical, freely expanding, and isothermal outflows as in Blandford&Königl (1974), Falcke&Biermann (1995)?



(Jet-) spectra

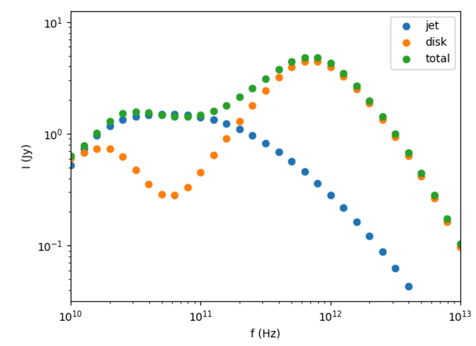
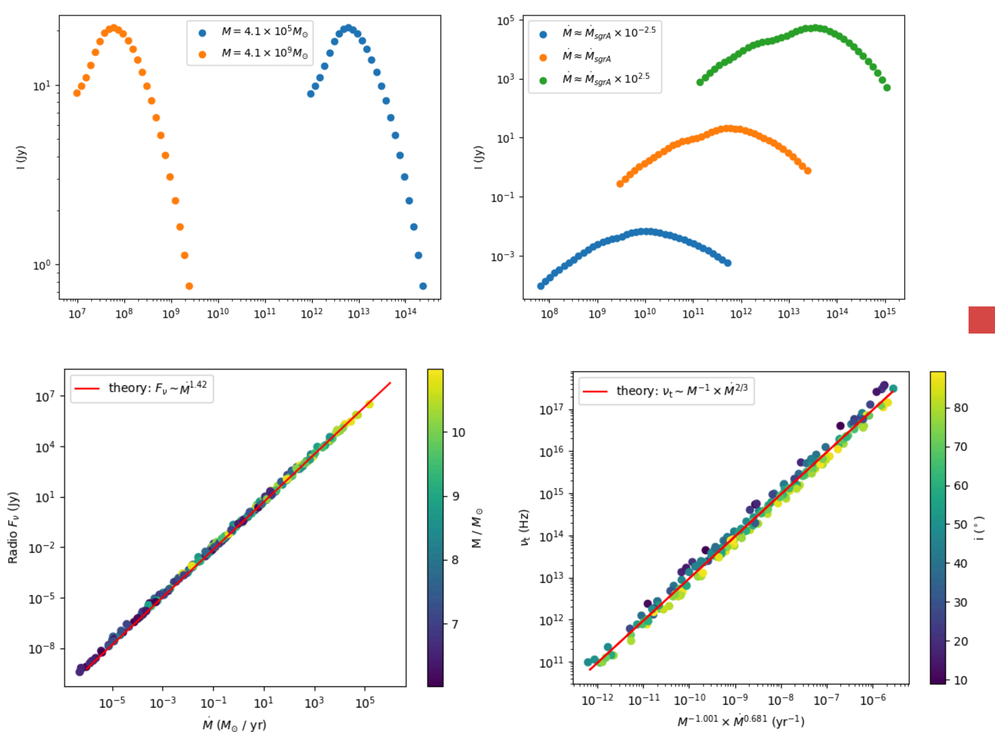


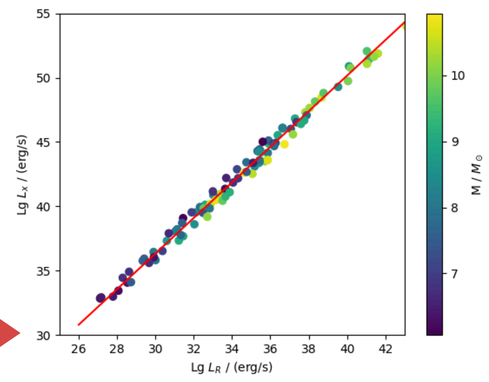
Figure: A synthetic jet spectrum for a SANE GRMHD model split between jet and disk contributions.

Scalabilities

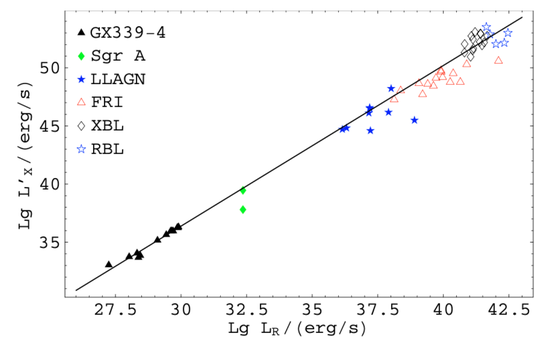
Do the scalings of RIAF GRMHD models coincide with theortetical predictions? Can we reproduce a synthetic Radio/X-ray fundamental plane with the same correlation coefficients as for observational data?



Radio - X-ray fundamental plane



Figures: The best fit correlations between X-ray and Radio luminosity (after applying a correction factor for black hole mass). Bottom: The observational correlation found by Falcke et al. (2004)



Conclusions & further steps

Scale-invariant, radiatively inefficient GRMHD models developed for horizon scale fits to M87* and SgrA* provide an excellent framework for developing generic models applicable to the whole range of low accreting black holes. General properties of radio-loud AGN (and possibly hard state XRBs) such as often observed flat radio spectra, and observed correlation coefficients in the fundamental radio- x-ray plane bring constraints on electron temperature prescriptions, magnetization regimes, inclination angles and possibly spin.

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