Identifying Jets in the Spectra of Accreting Black Holes

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Abstract

We study the spectra resulting from radiatively inefficient accretion flows, making a distinction between contributions from the disk and jet, using a general-relativistic radiative transport code based on `grmonty` [1]. The accretion flow data is supplied by the general-relativistic magnetohydrodynamic (GRMHD) code `HARM` [2]. We investigate different electron temperatures by varying the proton-to-electron temperature ratio independently in the disk and in the jet. We find the following observational signatures of jet emission (i) a flat X-ray spectrum, (ii) high-energy γ-rays produced by inverse Compton scattering of synchrotron photons. These signatures could be used to identify jets by their high-energy contributions.

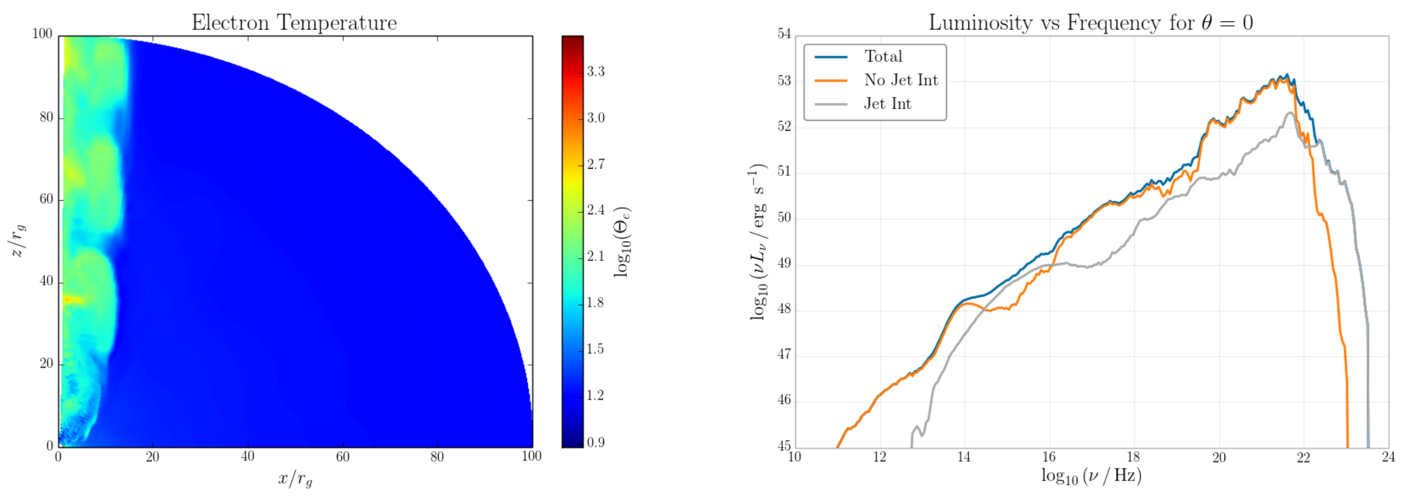
The Problem

Jets are ubiquitous in black-hole accretion systems, spanning a huge range of distance and mass scales. It is widely accepted that they significantly contribute to the radio emission in AGN, and to the low/hard state in XRBs. This work aims to determine the contributions of jets across a wide range of frequencies, with the specific goal of identifying their high-energy radiative signatures.

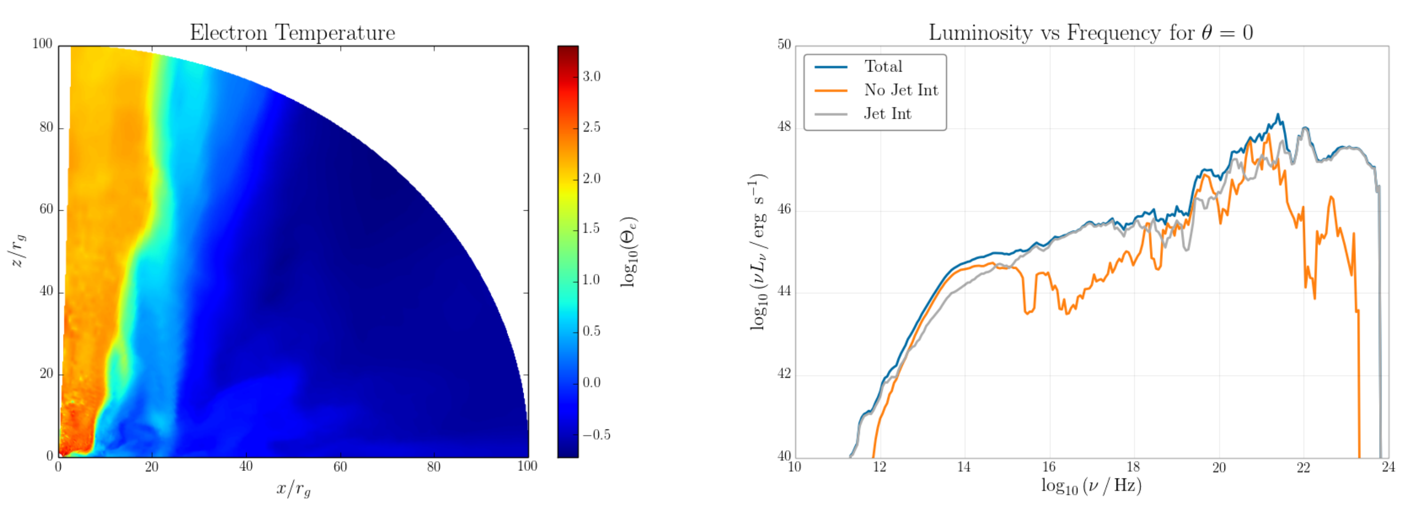
Results

The plots on the left show the dimensionless electron temperature, kT/mc^2, for the "Thickdisk" and "Thinnermad" models, and for different proton-to-electron temperature ratios Tp/Te. The plots on the right are the corresponding spectra. The colours distinguish between photons which had some interaction (synchrotron emission or Compton scattering) with the jet before escaping (Jet Int), and those which didn't (No Jet Int).

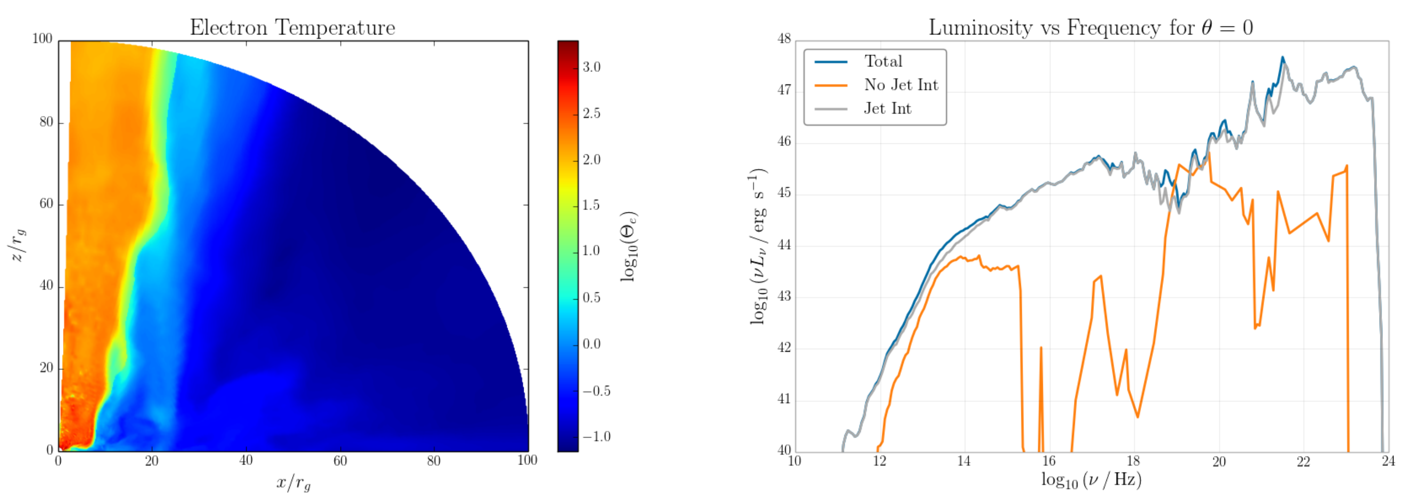
Thickdisk: Tp / Te = 10



Thinnermad: Tp / Te = 10



Thinnermad: Tp / Te = 30 (disk), Tp / Te = 10 (jet)



The main indications of jet contributions are:

1. **Flat/slowly rising slope in the X-rays.**
2. **High-energy γ-ray emission.**

The jet can contribute substantially to the NIR and optical, however, our results suggest that it would be difficult to distinguish the disk and jet contributions in these bands. A wide range of models and parameters will be presented in [5].

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This work was supported by the Irish Research Council under grant number GOIPG/2013/315.

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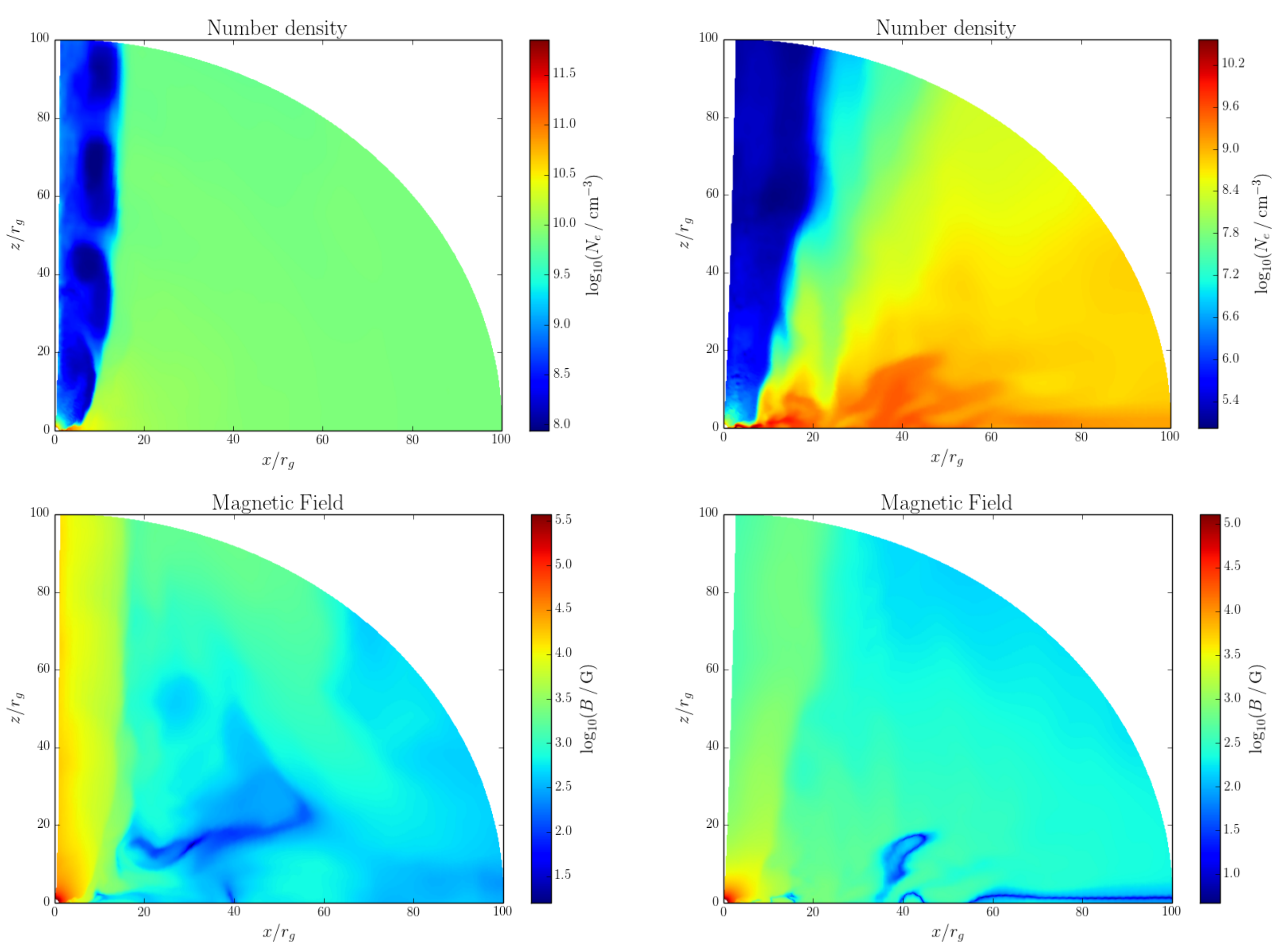
Methods

Fluid Models

The accretion flows are supplied by the fully 3D GRMHD code `HARM` [2]. `HARM` evolves the GRMHD equations using a conservative, shock-capturing scheme.

We consider snapshots of two different radiatively inefficient accretion flows (RIAFs) from [3, 4], which we refer to as "Thickdisk" and "Thinnermad". Both models are in the "magnetically arrested" disc (MAD) state. The following plots show the number density and magnetic field, in the disk and funnel regions, at t = 10^4M.

Thickdisk **Thinnermad**



Radiative Transfer

We use a general-relativistic radiative transport code based upon the freely available `grmonty` [1]. We modified the code to work with general 3D `HARM` grids, and to allow for different temperature prescriptions in the disk and in the jet.

The spectra are calculated assuming synchrotron emission and Compton scattering from a thermal distribution of electrons. The plasma is two-temperature, with a fixed ratio of proton-to-electron temperatures which we vary independently in the disk and in the jet. We track ~ 10^4 photons to an outer radial boundary of r = 200M. This choice for the boundary has little effect on the qualitative features of the results since the inner regions contribute most to the X-rays and γ-rays. The black hole mass is set to 10^6 solar masses. The results scale to arbitrary masses as explained below.

Conclusions

Our preliminary results indicate that (i) a flat spectrum in the X-rays is a signature of broad synchrotron emission from the jet, (ii) high-energy γ-rays, above the saturation frequency in the disk, are produced by inverse Compton scattering of photons in the jet. These high-energy signatures could be used to infer the existence of jets in the spectra of accreting black hole systems.

We expect similar results to hold for radiatively inefficient accretion flows across different black hole mass scales. Assuming that the accretion rate scales as the black hole mass M, the magnetic field, which determines the peak synchrotron frequency, scales like ~ $1/\sqrt{M}$, and the number density, which determines the overall normalisation, scales like ~ 1/M. The electron temperature is independent of M. Therefore, with appropriate scaling, these results are applicable to both AGN and XRBs.