Thesis title:

Modeling Magnetized Jets from Accreting Black Holes

Abstract

Relativistic jets are a very common phenomena in high energy astrophysics, observed in many sources including active galactic nuclei (AGNs) and gamma-ray bursts (GRBs). Some of the largest and most active jets are produced by supermassive black holes residing at the center of active galaxies and extend to millions of parsecs in length. The gamma-ray bursts, which are the most luminous electromagnetic events after the big bang, are thought to be highly focused explosions with most of their energy collimated to narrow relativistic jets. The formation of these jets can be attributed usually to the dynamical interactions within the accretion flows onto a central compact object such as a black hole or a neutron star. This thesis aims to explore the connection between the magnetized accretion flows in the central engine of these sources and the associated jet properties, and provide a clearer description of the origin, spatial structure and temporal variability of the observed jets. The studies are carried out with general relativistic magnetohydrodynamic (GRMHD) simulations of accretion flows and the associated jet base in the Kerr geometry.

Observational studies have found correlations between the measured jet variability and the Lorentz factor, which span several orders of magnitude of the central engine mass, covering both GRB and blazar samples. The first part after the introductory chapters of this thesis (Chapter 3) presents an investigation into the possible connections between the jet energetics and temporal variability taking mainly into account the disk magnetization and the black hole spin.

The study is conducted by performing axisymmetric ideal GRMHD simulations and probing the jet energetics along different points of the line of sight. The time variability of jet is also measured at these chosen locations. The results are quantified by computing the minimum variability time scale (MTS), the power density spectra and the jet Lorentz factors (Γ) and the MTS-Γ anti-correlation is qualitatively obtained in our models. The black hole spin can be attributed as the main driving parameter of the engine which is reflected in the jet Lorentz factors.

The second part of the thesis (Chapter 4) focuses on the jet properties of gamma-ray bursts by considering a magnetically arrested disk (MAD) as the central engine. This work explores the possible dependence of the jet structure and temporal variability in the gamma-ray burst jets to the MAD state. The simulations are done in 3D with a non-axisymmetric time evolution, by introducing random perturbations in the gas internal energy to the axisymetric initial conditions. The models described in this work reach a MAD state and self consistently produce structured jets with very fast variability in time. The models from this work are applied to the particular cases of short and long GRB systems and the results are analyzed in comparison with the observations.

The third part of the thesis (Chapter 5) focuses on outflows driven by large-scale magnetic fields in the vicinity of a black hole. This work examines the competing effects of inflows and outflows driven by a large-scale asymptotically uniform magnetic field in the Kerr geometry starting from a spherically symmetric inflow. This in turn results in the magnetic field lines being accreted with the plasma while intermittent outflows develop mainly in the equatorial region. This work provides an insight into the effects of magnetized accretion onto rotating black holes and the associated outflows.