This thesis explores the formation, spatial structure, and temporal variability of the jet launched from a magnetized accretion flows around black holes in the central engine of active galactic nuclei and gamma-ray bursts. The study was performed by general relativistic magnetohydrodynamic (GRMHD) simulations of accretion flows base on the Kerr geometry around a black hole. These topics have been of great interest and importance in high-energy astrophysics for many years and still are the hot topics in this field.

In the first part of the thesis, the study tries to explain the observed correlation between the jet variability and the Lorentz factor, which spans several orders of magnitude of the central engine mass, covering both GRB and blazar samples. It mainly takes into account the disk magnetization and the black hole spin by performing axisymmetric calculations of the structure and evolution of a central engine, composed of a magnetized torus around a Kerr black hole that is launching jet. The jet energetics at different points along the line of sight and the jet-time variability as localized in these specific regions are studied. Their results are quantified by computing the minimum variability timescales and power density spectra. The authors find that the power density spectral slope is not strongly affected by the black hole's spin, while it differs for various viewing angles.

In the second part of the thesis, the author investigates the dependence of the jet structure and its evolution on the properties of the accreting torus in the central engine. This study was performed by three-dimensional general relativistic magnetohydrodynamic simulations, which is technically very challenging. For their aim, two different analytical hydrodynamical models of the accretion disk as their initial states was used and poloidal magnetic fields of two different geometries upon the initial stable solutions were adopted. They study the formation and evolution of the magnetically arrested disk state and its effect on the properties of the emitted jet. The jets produced are found to be structured and have a relatively hollow core and reach higher Lorentz factors at an angle $\gtrsim 9^\circ$ from the axis. They also study the time variability of the jets and provide an estimate of the minimum variability timescale.

These works are very timely and the GRMHD simulation of black hole accretion and jet formation are very challenging. The scientific results obtained have significant scientific significance and have explained several puzzling and important observational results. Given these, I concluded that the presented dissertation meets the formal requirements for a PHD thesis and recommend admission of the Candidate to the subsequent stages of the procedure, including the public defense. I think this is a distinguish dissertation.

Feng Yuan

Feng Yuan

Shanghai Astronomical Observatory, Chinese Academy of Science

August 7, 2023