



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
PhD-17 SHORT ABSTRACT OF THESIS

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**SHORT ABSTRACT**

The origin of high energy radiation from quasars, AGNs, and black hole (BH) X-ray binaries has drawn the attention to the scientific community. Accretion onto compact objects has emerged as a fundamental mechanism in explaining the observed luminosity from those sources. Since the emitted radiation carries imprints of the spacetime geometry near the compact object, the accretion dynamics provide crucial insights into both the nature of the central object and the accreting matter. There are various accretion models, such as Bondi flow, standard thin disk, two-temperature SLE disk, slim disks, ADAFs, but none of them can fully explain both the spectral and timing properties of compact objects. The TCAF model incorporates shock transition due to centrifugal barrier, which forms a post-shock corona (PSC) of hot and dense electrons. This corona can explain the observed high energy radiations via inverse Comptonization of the soft disk photons. Accurate modeling of such flow requires effective potential around compact objects to incorporate the strong gravity. Recently, DDMC potential has been developed to study relativistic hydrodynamics across the entire spin parameter range in stationary, axisymmetric spacetime.

Motivated by these, in Chapter-2, we present relativistic accretion flow around Kerr-Taub-NUT (KTN) BH, which is a general stationary and axisymmetric vacuum solution of Einsteins equations characterized by its mass, spin, and NUT charge. We solve the relativistic hydrodynamic equations to obtain both shock-free and shock-induced solutions. Shocks form when the flow experiences a centrifugal barrier and satisfies the relativistic Rankine-Hugoniot conditions. Shocked solutions are more physically viable due to higher entropy and generate significantly greater disk luminosity than the shock-free solutions.

BHs are not only the possible accreting compact objects, exotic compact objects like wormholes (WHs) remain theoretically viable. Therefore in Chapter-3, we investigate the relativistic accretion flow in a

stationary axisymmetric Kerr-like WH, which is characterized by spin parameter, dimensionless parameter, and its mass. This WH is characterized by a throat, that connects the two regular spacetimes. By solving the hydrodynamical equations, we identify four types of transonic flows as well as subsonic flow. The transonic solutions are more viable than the subsonic solutions because of their higher entropy. Finally, we compute the disk luminosities and show that our model reproduces the observed luminosity of Cygnus X-3 in its hypersoft state.

The flat galaxy rotation curves, galaxy velocities, and the Cosmic Microwave Background indicate the presence of Dark matter (DM) in the Universe. The Standard Model of particle physics cannot explain the nature of DM, which is crucial for large-scale structure formation. In Chapter-4, we study the relativistic accretion flow around a galactic BH surrounded by a cold DM halo. We consider various DM profiles, such as Hernquist, NFW, Einasto, and a DM spike. Our results show that DM halo shifts the critical point of the transonic flow inward and enhances the disk luminosity depending on the properties of the DM distribution. Since most luminosity comes from the inner disk, it may help probe the nature of DM near Bhs.

Magnetic fields play a crucial role in the dynamics and emission of accretion flows around compact objects. Motivated by the recent EHT observations of Sgr A\* , in Chapter-5, we investigate the properties of relativistic accretion flow around Kerr black using GRMHD framework to reproduce the EHT-constrained magnetic fields. By solving the magnetohydrodynamic equations with constant flow parameters, such as energy, angular momentum, magnetic flux and iso-rotation parameter, we find the accretion solutions. Finally, we see that for a wide range of parameter space, the solutions match the observed magnetic field strengths within  $\pm 10\%$  error of the reported by EHT observation. This provides a theoretical framework that explains the complex dynamics of the magnetized accretion flows around Sgr A\* .

In astrophysical scenario, the tilted accretion disk forms when the angular momentum of an accretion disk is misaligned with that of a rotating compact object. This misalignment causes Lense-Thirring (LT) precession due to frame-dragging, which significantly affect the observations. Therefore in Chapter-6, we analyze a tilted, thin accretion disk around a slowly spinning KTN BH. We compute the radial tilt profile up to the ISCO, which accounts the tug-of-war between LT torque and viscous torque. Our results show that the inner disk may align or remain tilted depending on BH parameters and viscosity. This analysis also infers the presence of the NUT parameter.

Finally, in Chapter-7, we summarize all the key findings of the thesis and propose some future works.