Realistic modeling of black hole emission

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High energy X-rays are an observational signature of compact accreting sources, which is notably how the first black hole (Cygnus X-1) was discovered [1–5]. Before being completely engulfed by a black hole, matter caught in its gravitational pull begins spiraling around the black hole, forming an accretion disk. Accreting matter is subject to intense friction from magnetic fields and gravitational forces, raising the inner disk temperature to between 10^4 K - 10^7 K [6, 7]. This hot, turbulent environment of plasma allows detectable X-rays to be emitted from the particles in the disk, reaching the telescopes orbiting the Earth. The spectrum of the emitted X-rays allow us to determine the properties of an accretion disk, such as the absorbing gas density, ionization, and elemental abundances, among other parameters. We determine these properties by fitting the X-ray data with reflection models.

Current models of the X-ray spectrum are often simplified to tractably compute the highly complex accretion environment, despite the numerous variables. This project explores the observable features of an accretion disk via the reflection model `relxill` [8–10]. Implemented in the X-ray spectral fitting program `XSPEC` [11], `relxill` incorporates both the varying degrees of ionization of the disk and the relativistic optical ray tracing patterns. Through examining the behaviors of the accreting matter and emitted light spectra around a black hole, the results reveal imprints of the actual properties of the system itself, such as its spin or the inclination of the disk [12].

This project assesses some of the underlying assumptions of these models by modifying the properties that `relxill` assumes in the accretion disk. Despite previous work approximating the disk density and ionization as smooth functions of radius [8, 10, 12, 13], more realistic magneto-hydrodynamic simulations suggest these functions may not be so smooth [14–16]. Modifications to the original model are implemented by adding fluctuations to the densities and ionization profiles. A comparison between the original model and our modified version provides a snapshot of how fluctuations in these parameters influence the spectrum. Our findings will more reliably simulate the effects of varying gas densities and ionization levels on the appearance of the accretion disk.

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