

driven by some type of **resonance** condition. Abramowicz and Kluzniak (2001) proposed that orbiting blobs of accreting matter could generate the harmonic frequencies via a resonance between a pair of the coordinate frequencies given by GR. Earlier work had used GR coordinate frequencies and associated beat frequencies to explain fast QPOs in both neutron-star and BH systems (Stella et al. 1999), but without invoking a resonance condition. Current work on resonances as a means of explaining HFQPOs includes more realistic models for fluid flow in the Kerr metric. Resonance models are considered in more detail in §8.2.4.

7 Physical Models for X-ray States

We briefly describe some physical models for the three active emission states (§4) and QPO phenomena (§6). Our focus is on basic principles and the current interface between observations and theory.

7.1 Thermal State

For the thermal state there is a satisfactory paradigm, namely, thermal emission from the inner regions of an accretion disk. Observations and magnetohydrodynamic (MHD) simulations continue to increase our understanding of accretion disks. Also, fully-relativistic models of disk spectra have recently become publicly available, and results from this advance are discussed below.

The best-known hydrodynamic model of a radiating gas orbiting in the gravitational potential of a compact object is the **steady-state, thin accretion disk model** (Shakura & Sunyaev 1973; Pringle 1981). A central problem for this model is a prescription for the viscosity that is required to drive matter inward and heat it, while transporting angular momentum outward. Initially, the viscosity was modeled using an ad hoc scaling assumption (Shakura & Sunyaev 1973). This model leads to a temperature profile $T(R) \propto R^{-3/4}$ and the conclusion that the inner annulus in the disk dominates the thermal spectrum, because $2\pi R dR \sigma T^4 \propto L(R) \propto R^{-2}$. This result has a striking observational consequence: X-ray astronomy is the window of choice for probing strong gravity near the horizon of an accreting **stellar-mass BH**.

The cardinal importance of the inner disk region highlights the need for an accurate model for the radiation emitted near the inner disk boundary associated with the ISCO (see §1). The ISCO lies at $6R_g$ for a Schwarzschild BH ($a_* = 0$), decreasing toward $1R_g$ as a_* approaches 1. Observationally, the thermal-state spectra of BHBs are well fitted using the classical model for a multitemperature accretion disk (Mitsuda et al. 1984; Makishima et al. 1986; Kubota & Makishima 2004; Kubota et al. 2005). However, the derived spectral parameters (i.e., the temperature and radius of the inner disk) cannot be interpreted literally for several reasons. The model neglects the physically-motivated torque-free **boundary condition** at the ISCO (see Gierlinski et al. 2001; Zimmerman et al. 2005). Furthermore, the classical model ignores the sizable effects due to GR and radiative transfer (e.g., see Zhang, Cui, & Chen 1997). Fortunately, accretion disk models for Kerr BHs have recently become publicly available (Li et al. 2005; Dovčiak et al. 2005), and there now exists a fully-relativistic treatment of the effects of **spectral hardening** (Davis et al. 2005). Applications of these models are discussed in §8.