

In parallel with these developments, MHD simulations have advanced our understanding of the nature of viscosity in accretion disks. The **magnetorotational instability (MRI)** has been shown to be a source of turbulent viscosity (Balbus & Hawley 1991), a result that has been confirmed by several global GR MHD simulations (e.g., DeVilliers et al. 2003; McKinney & Gammie 2004; Matsumoto et al. 2004). Investigators are now considering how MRI and MHD turbulence influences disk structure (e.g., Gammie 2004), the emerging thermal spectrum (e.g., Merloni 2003), and Comptonization effects (e.g., Socrates et al. 2004). MHD simulations of accretion disks are currently three-dimensional, global and based on the Kerr metric. They will soon include dissipative processes (i.e., radiation; see Johnson & Gammie 2003), and it is hoped that they will then connect more directly with observation.

## 7.2 *Hard State*

The association of the hard state with the presence of a steady radio jet marked a substantial advance. Indirect signatures of this jet can now be recognized in the X-ray data (§§4–5). However, the relationship between the disk and jet components and the origin of the X-ray properties of the hard state remain uncertain.

Difficulties in understanding the hard state are illustrated by results obtained for XTE J1118+480, a BHB with an extraordinarily small interstellar **attenuation** (e.g., only 30% at 0.3 keV) and a display of weak outbursts confined to the hard state. This source provides the best direct determination of the apparent temperature and radius of the inner disk in the hard state. Using simultaneous **HST**, **EUVE**, and *Chandra* observations (McClintock et al. 2001), the disk was found to be unusually large ( $\sim 100R_g$ ) and cool ( $\sim 0.024$  keV). Slightly higher temperatures ( $\approx 0.035$ – $0.052$  keV) were inferred from observations with BeppoSAX (Frontera et al. 2003). Though it seems clear that the blackbody radiation is truncated at a large radius, the physical condition of material within this radius remains uncertain. Alternative scenarios include a thermal **advection-dominated accretion flow (ADAF)** (Esin et al. 2001), a radiative transition to synchrotron emission in a relativistic flow that is **entrained** in a jet (Markoff et al. 2001), and a radiative transition to a Compton corona (Frontera et al. 2003), which must then be sufficiently optically thick to mask the  $\sim 1$  keV thermal component normally seen from the disk. Such a corona might be a hot wind leaving the disk (Blandford & Begelman 1999; 2004).

Recent investigations of other BHBs in the hard state suggest that both synchrotron and Compton components contribute to the broadband spectrum, with the Compton emission presumed to originate at the base of the jet (Kalemci et al. 2005; Markoff, Nowak, & Wilms 2005). It is also possible that the jet is supplied by hot gas from a surrounding ADAF flow (Yuan, Cui, & Narayan 2005).

Guidance in understanding the accretion flow in this inner region may eventually come from other types of investigations, such as the study of correlated optical/X-ray variability (Malzac et al. 2003). Also promising are spectral analyses that focus on features indicating densities higher than that expected for an optically thin flow, such as the ADAF mentioned above. One such feature is the broad Fe emission line (e.g., Miller et al. 2002b; 2002c). The Fe line profile can provide information on the Keplerian flow pattern and constrain the inner disk radius (see §8.2.3). Another diagnostic spectral feature is an X-ray reflection component (Done & Nayakshin 2001). In one study of the reflection compo-