

Accretion Flows in the Wind-fed Black Holes

Background: It is commonly believed that the accretion discs are truncated and replaced by advection dominated accretion flows (ADAFs) in the hard spectral state of black hole X-ray binaries (BHXBs). However, the increasing occurrence of relativistically blurred Fe $K\alpha$ line together with a hard continuum points to the existence of a thin disc near the innermost stable circular orbit in the hard state.

Corona condensation: In a wind-fed black hole binary system (i.e., high-mass X-ray binaries), the hot wind captured by the black hole can naturally form an ADAF, which, as it flows towards the black hole, partially condensates into a cold disc as a consequence of efficient radiative cooling at small distances, and then accretes to the black hole via a disc-corona configuration. Note that such a model and related conclusions can also be extended to the hard state of Roche-lobe over flow (RLOF) accretion systems (i.e., low-mass X-ray binaries), as it is possible for the initial RLOF-fed disc to be fully evaporated to form an ADAF at distances larger than 200 Schwarzschild radii (R_S).

Conclusions:

- A condensation-fed inner disc is present with a hard-state spectrum, which explains the broad Fe $K\alpha$ lines observed in the hard state of black hole X-ray binaries (see Fig. 1 & Fig. 2).
- The theoretical and observed spectrum of Cyg X-1, as well as the predicted and observational $\Gamma_{2-10\text{keV}} - L_X/L_{\text{Edd}}$ correlation from multiple sources, are in good agreement (see Fig. 3 & Fig. 4).

Figure 1. The outer radius (R_{disc}) of the condensation-fed inner disc at different Eddington ratio. From left to right, the mass-supply rate is $\dot{m} = 0.02, 0.03, 0.04, 0.05$. Other parameters are the typical values of BHXBs.

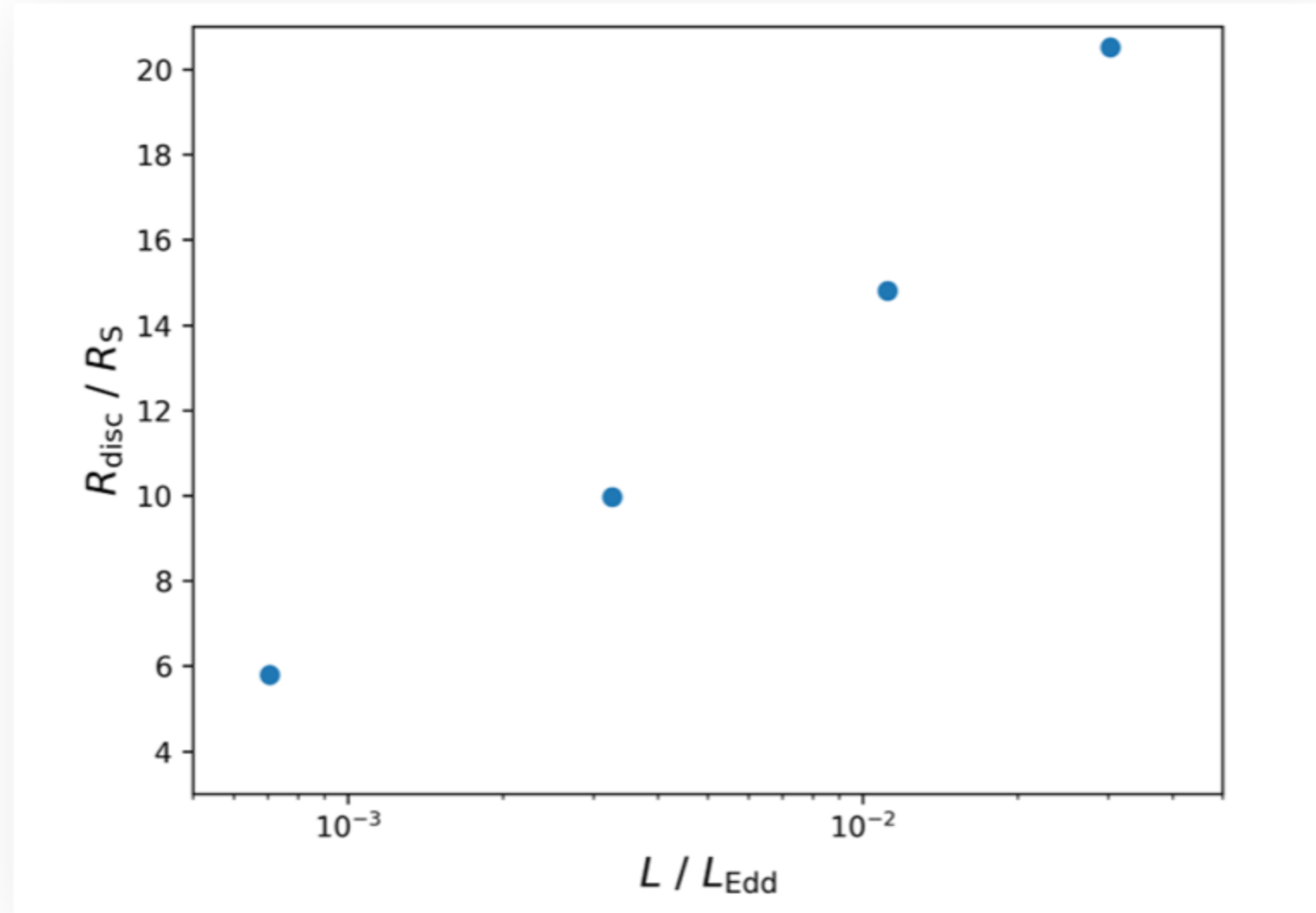


Figure 3. The theoretical $\Gamma_{2-10\text{keV}} - L_X/L_{\text{Edd}}$ (L_X is the X-ray luminosity in the 2-10 keV band) correlation with different viscosity parameter and the observed correlation from Yang et al. (2015).

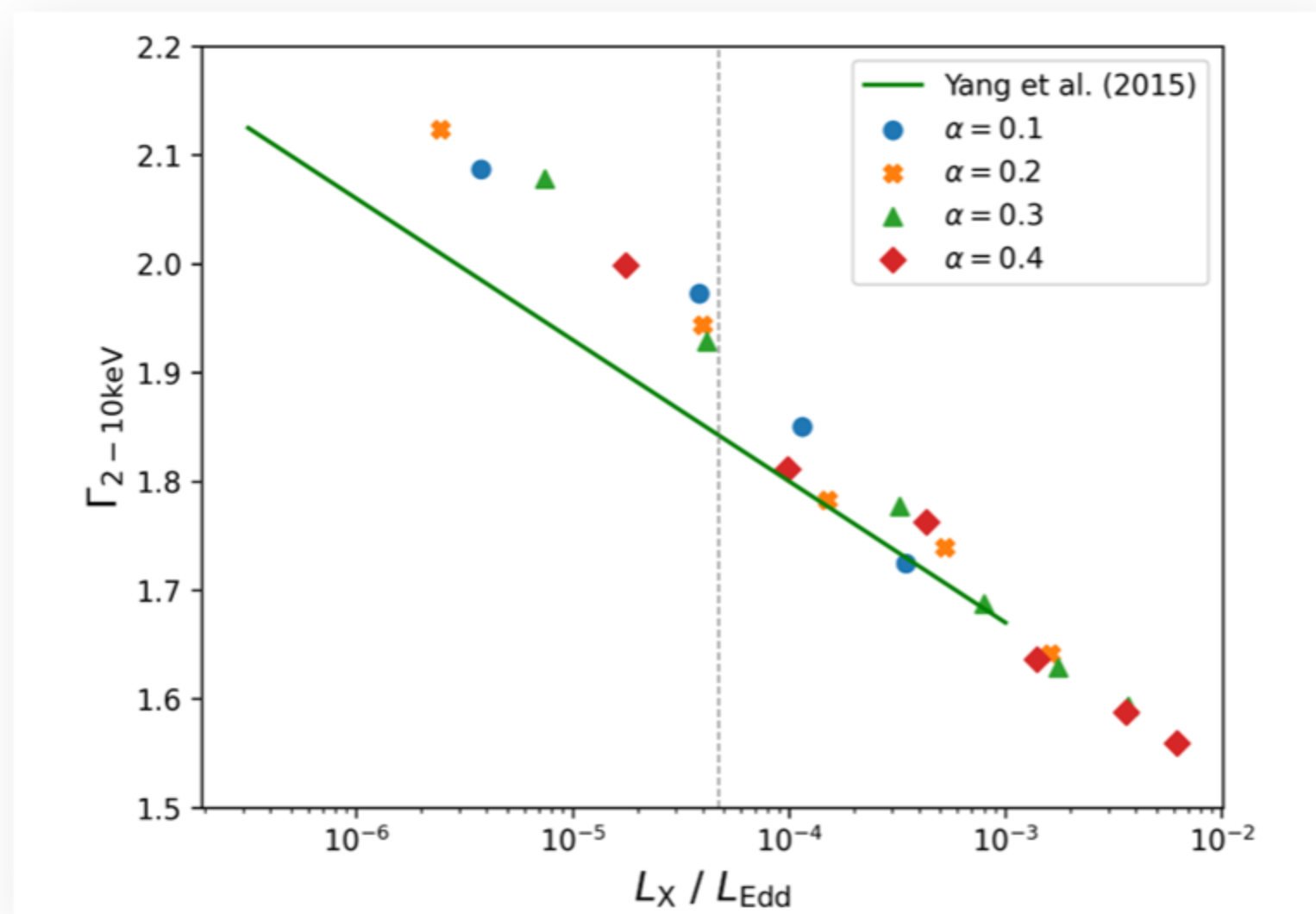


Figure 2. The emergent spectra calculated with Monte Carlo simulations. Same parameters as Fig. 1 are adopted. From bottom to top, the mass-supply rate is $\dot{m} = 0.02, 0.03, 0.04, 0.05$.

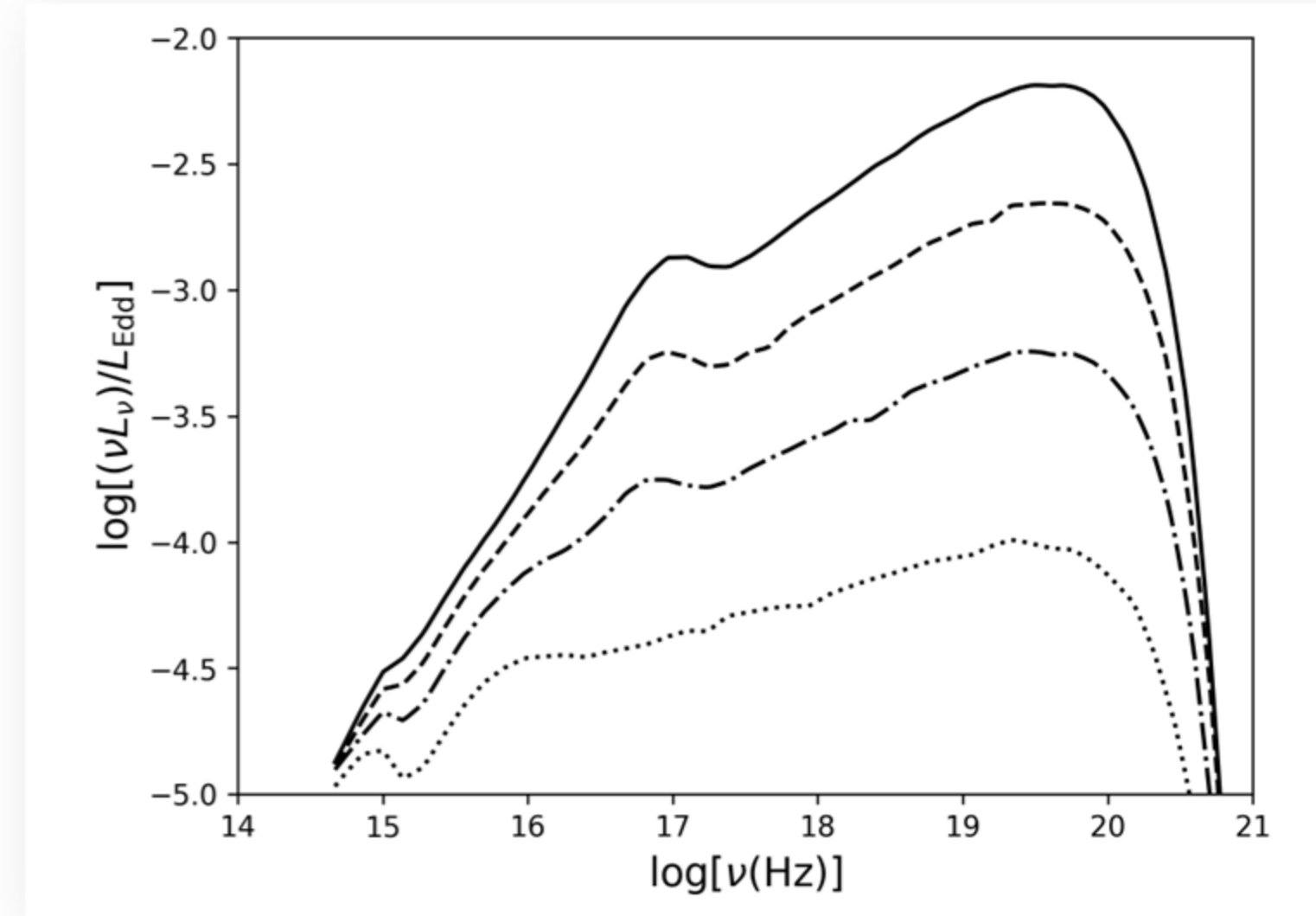


Figure 4. The theoretical and observed spectrum of Cyg X-1 in the hard state. The HXMT data is taken from Feng et al. (2022).

