A Study of the Continuum Emission Spectrum from the Central Engine in Narrow-line Seyfert Galaxies

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Abstract

In the vicinity of a black hole, when the radiation pressure exceeds the gravitational pull, it drives the gas away from the accretion disk and forms an outflow. This paper discusses a model of radiation-driven outflows in supercritical accretion disks and simulates the accretion disk's structure at different positions where radiation pressure dominates. We quantitatively investigate the intensity of the outflow and the mass accretion rate into the black hole, finding that under high accretion rates, the outflow can be very strong, resulting in relatively less matter falling into the black hole. We introduce an empirical correction to the accretion disk's spectrum due to the presence of the accretion disk corona. We find that considering the thermal, emission from the corona stretches the overall spectrum of the accretion disk towards higher energies and leads to a more uniform distribution across different wavelength bands. Finally, we use this model to fit and analyze the spectra of narrow-line Seyfert galaxies RX J0134.2-4258 and RX J0439.6-5311, obtaining good fitting results with accretion rates of $167.298\dot{M}_{Edd}$ and $6.809\ \dot{M}_{Edd}$, respectively. We also analyze the fitting results of the AGN slim model and perform a comparative analysis between them.

Theory

- *Basic assumption :* The power added into the radiation flux is proportional to the gas density in the disk.

$$\frac{\mathrm{d}f_{rad}(z)}{\rho(z)\,\mathrm{d}z}=\frac{f_{rad}(H)}{\bar{\rho}H}$$

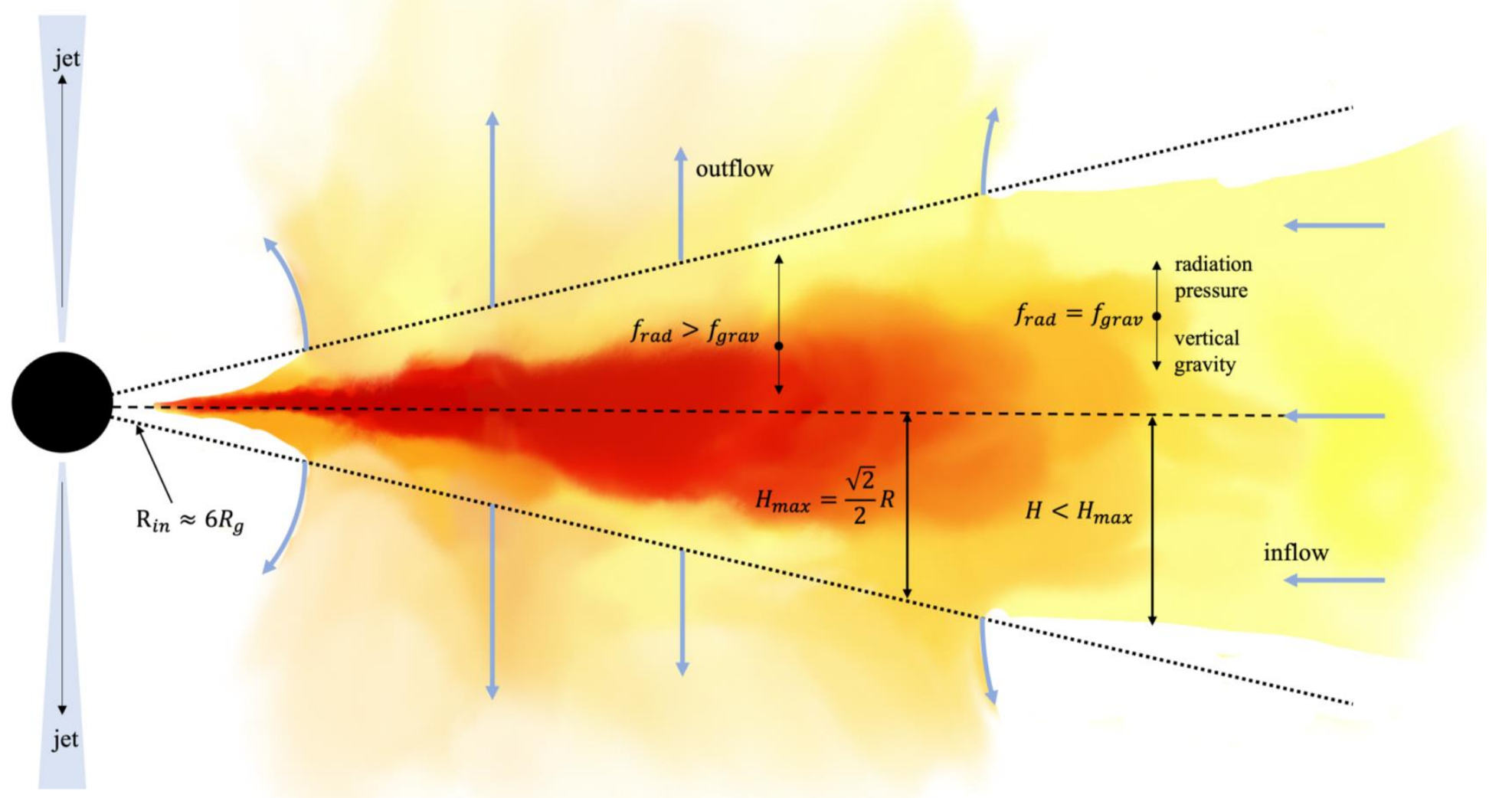
- *Momentum equation:* In the case of super-Eddington, the pressure is dominated by radiation.

$$\rho v_z\frac{\partial v_z}{\partial z}=\rho\left(\frac{\kappa_T}{c}f_{rad}-\frac{GMz}{(r^2+z^2)^{3/2}}\right)$$

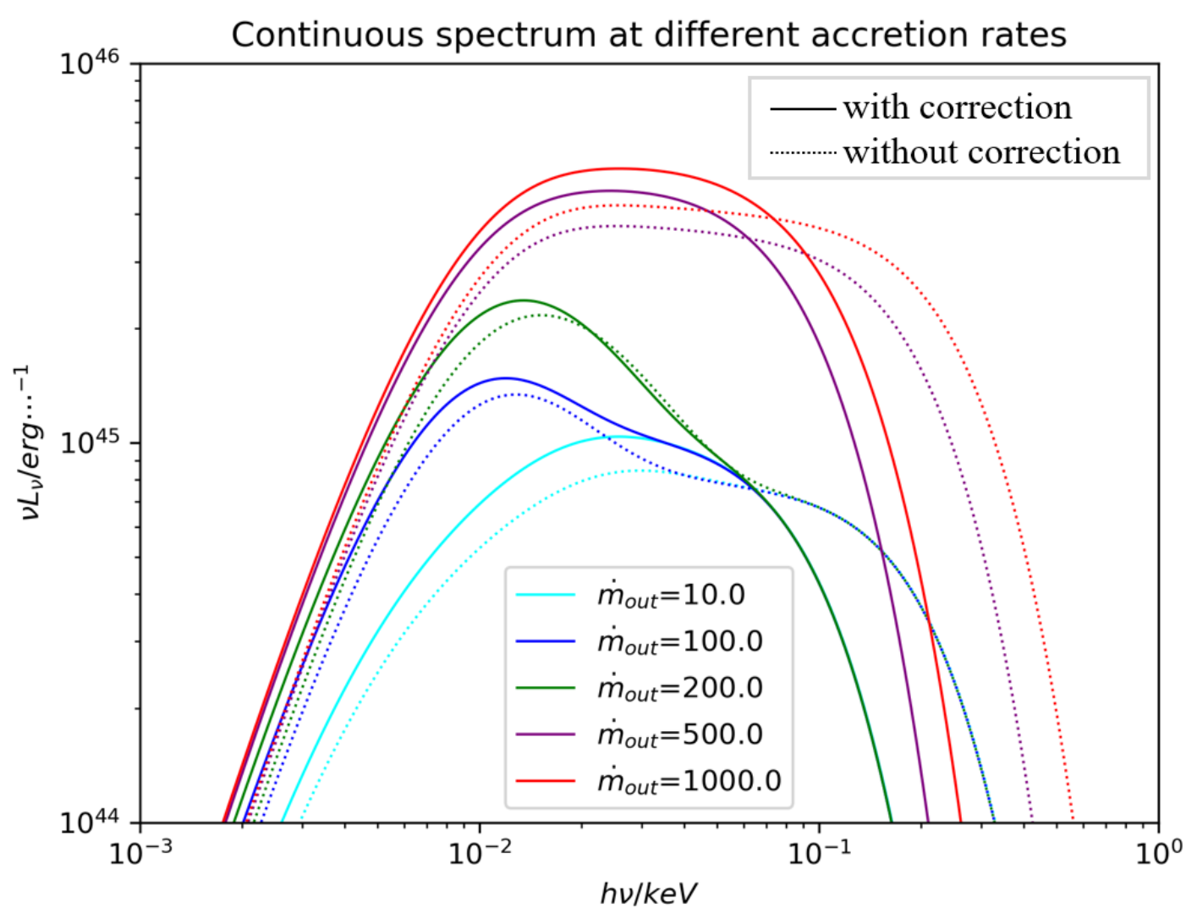
- *Energy equation:* The viscous energy becomes kinetic energy of the outflow, advection power, and radiation emitted.

$$Q^+=\frac{1}{2}\rho(H)v_z^3(H)+Q_{adv}+f_{rad}$$

- *Emission spectrum :* The deviation of the spectrum from the blackbody in the Seyfert Galaxy is given by an empirical coefficient acting on the frequency. At high energy, the spectrum shifts blue.



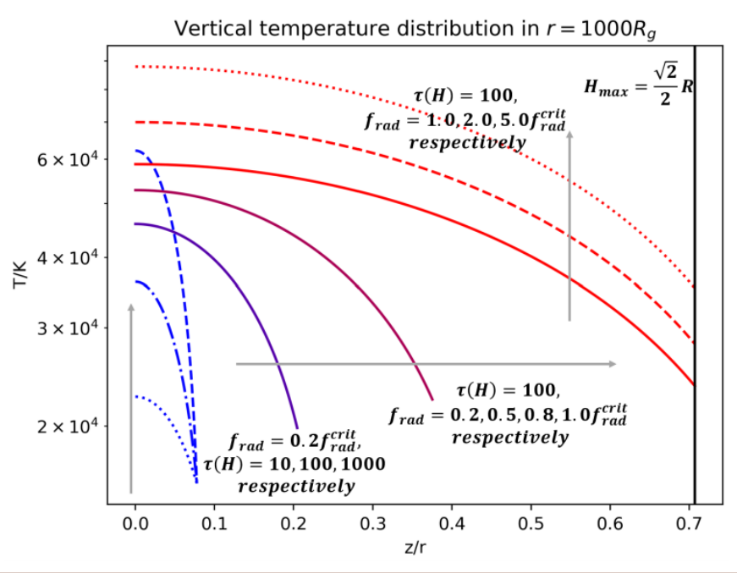
Continuous spectrum at different accretion rates



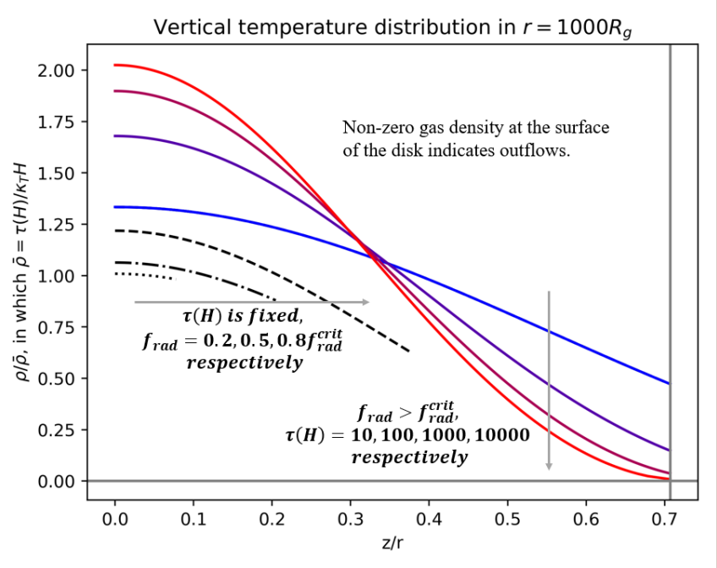
Vertical structure

- $T(Z)$ can be obtained from the radiation F_{rad} and is directly related to the gas density.
- ρ and $\frac{d\rho}{dz}$ is determined by τ, with outflows, and by f_{rad}, without outflows, respectively.

Vertical temperature distribution in $r = 1000R_g$



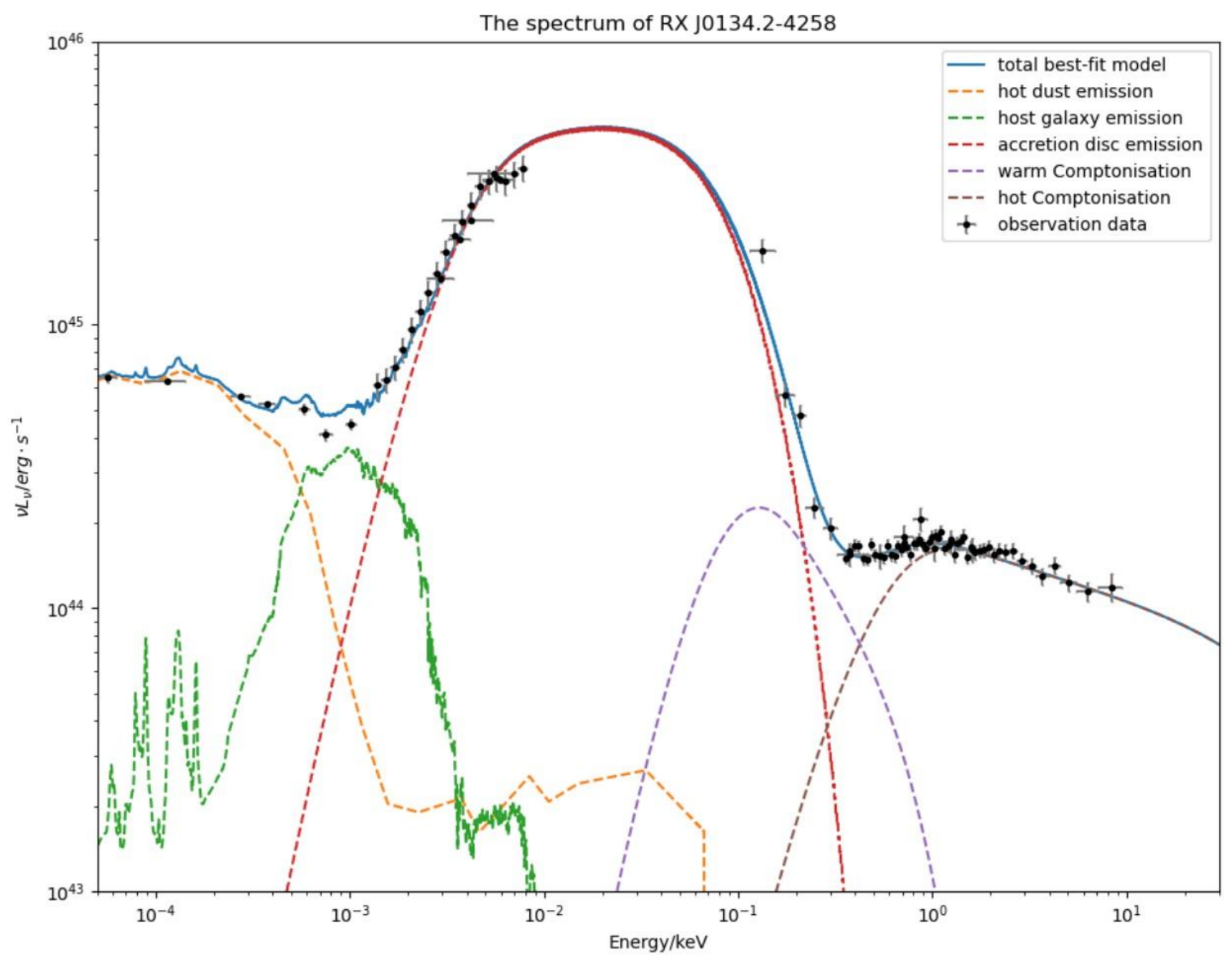
Vertical temperature distribution in $r = 1000R_g$



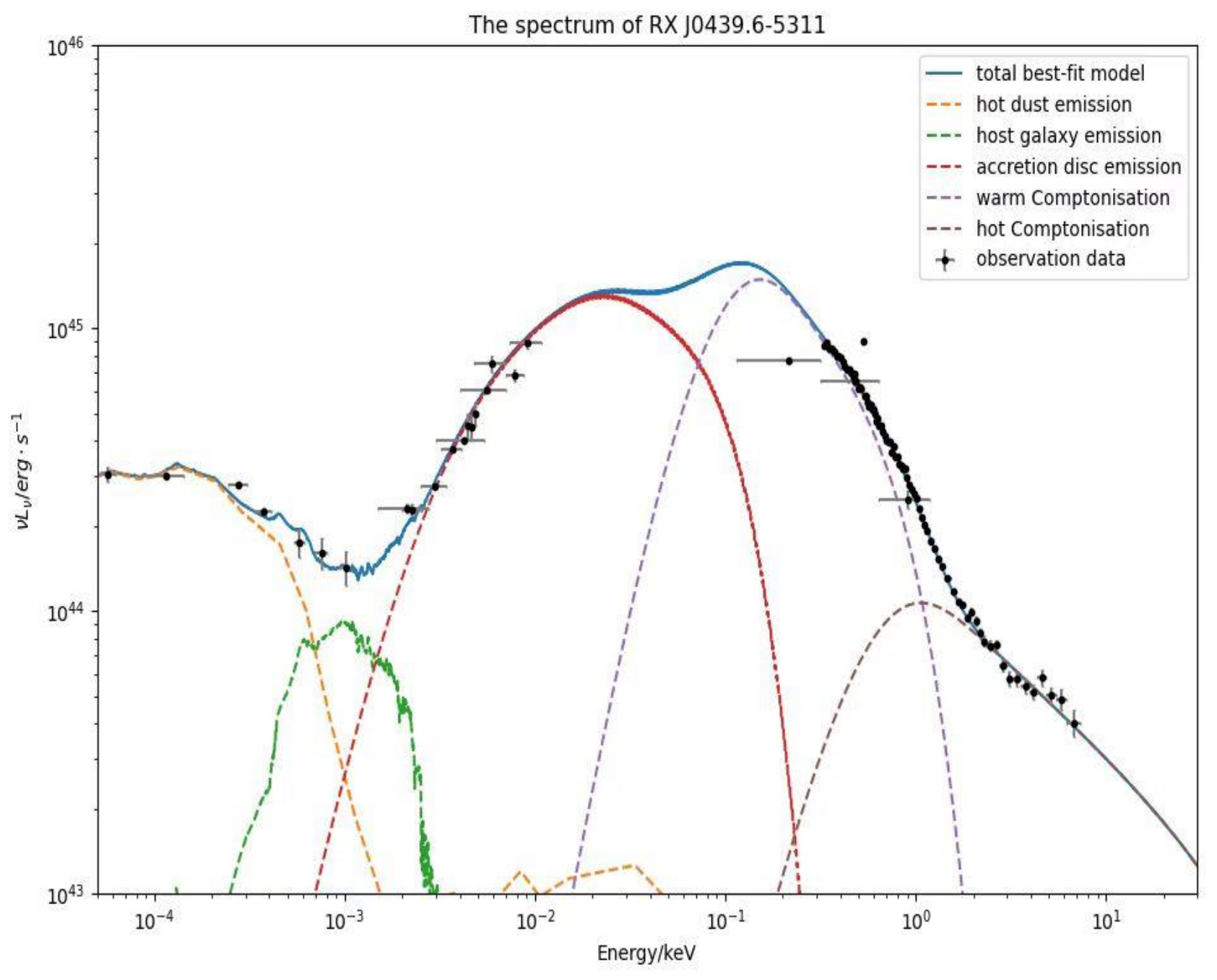
Results

Analysis of the fitting results of two sources

The spectrum of RX J0134.2-4258



The spectrum of RX J0439.6-5311



In AGN slim model, the disk is a slim disk, where the surface luminosity is kept at the local Eddington limit.

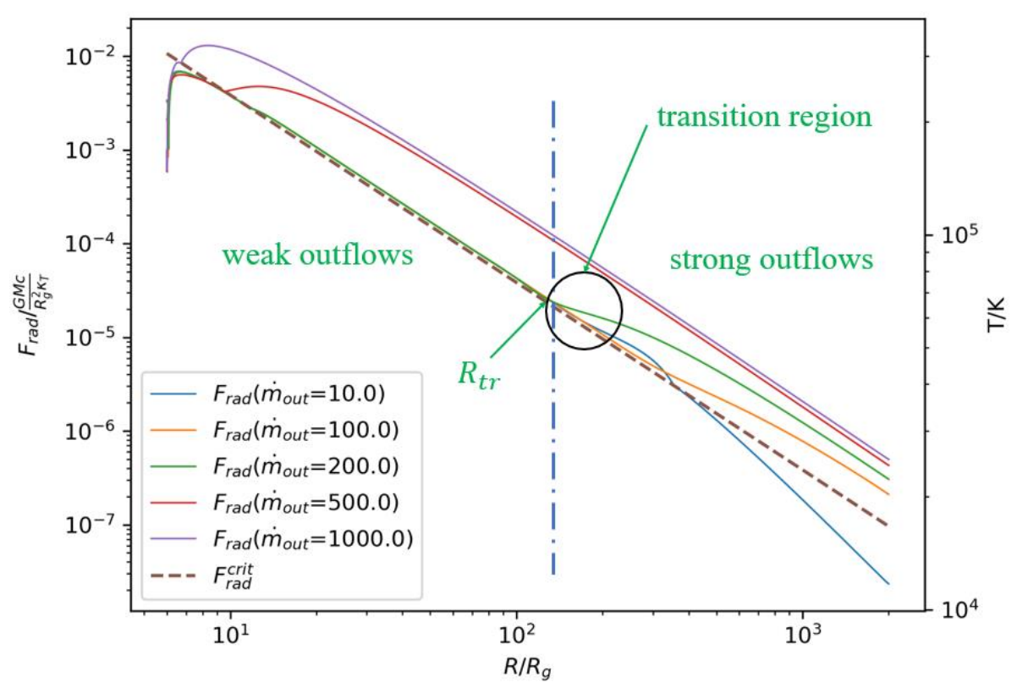
In this model, the surface luminosity can exceed the Eddington limit, creating an outflow to carry away accretion material.

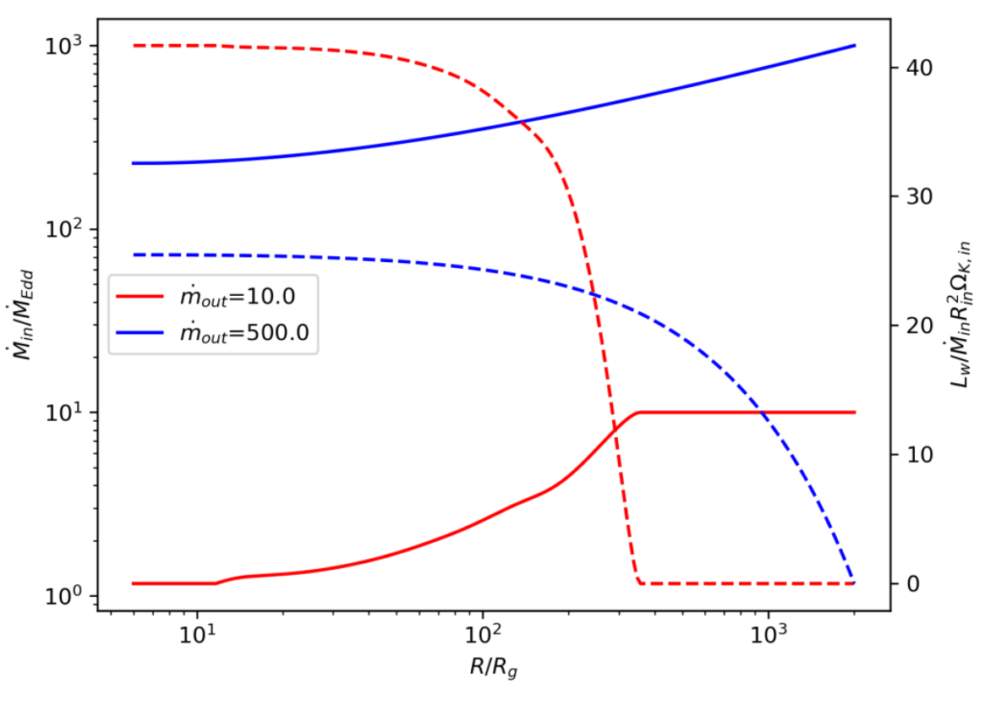
Due to the outflows, this model requires a higher $\dot{m}$ in order for the inner disk to have the same properties as the standard slim disk.

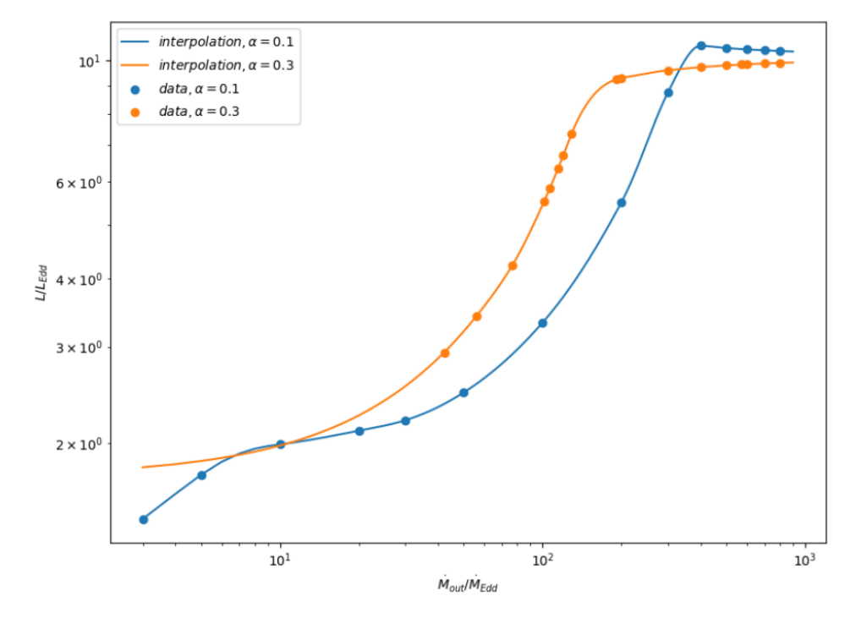
accretion disk parameters (spin is set to 0, * means frozen)

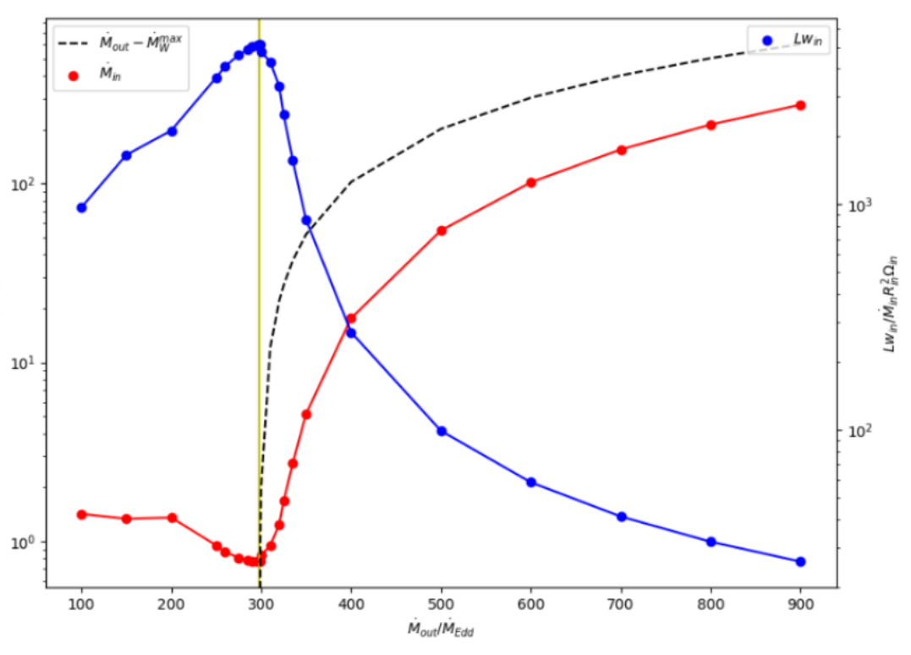
	AGN slim (L)	this model	AGN slim (R)	this model
$M_{BH}/M_\odot$	2×10^7*	3.65×10^7	1×10^7*	2.21×10^7
α	/	0.3*	/	0.3*
$\dot{M}/\dot{M}_{Edd}$	20.6	167.3	5.9	6.81
R/R_g	93325	2377	670	1782
θ_{inc}	60°*	$60^\circ45'$	30°*	$28^\circ40'$

Other calculation results









Outflow occurs when radiation intensity exceeds a critical value.

Outflows decrease $\dot{m}$ and carrie away $\boldsymbol{L}$.

α can affect the $\dot{m}_{sat}$ required to achieve saturation luminosity, which is almost the same in different α.

When the outflow is strong enough, gas does not carry much angular momentum

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