# Turbulent-Convection Accretion Disk Model with Super-Critical Accretion


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Abstract

A self consistent model for an accretion disk is presented, in which the turbulent viscosity is due to turbulent convection and the vertical flux is the sum of the radiative and convective fluxes.
The model allows for both gas pressure dominated region and radiation pressure dominated region also for highly super-critical accretion. The disk in both regions is **geometrically thin** and **optically thick**. For super-critical accretion rate, the vertical flux equals the convective flux. On the two faces of the disk, outside the convective layer, the vertical flux is radiative and is capable of ejecting massive Jets.


## Introduction

Jets from accreting black holes are commonly observed. The accretion luminosities required to accelerate the jets are highly super-critical.However, super-critical accretion tends to produce thick disk (even spherical) where the lion share of the accreted matter is advected onto the black hole. There has been recent work to get around this problem (e.g. Dotan& Shaviv; Sadowski & Narayan) but this requires special circumstances. Here, is presented a model that may overcome the difficulty in a natural way.

## The model

- The present work is based on a self-consistent model for a geometrically thin accretion disk with turbulent convection derived by Goldman & Wandel (1995). The turbulent convection plays a double role: it provides the disk viscosity and takes part in the vertical transport of the released energy. Rather than assuming arbitrary phenomenological parametrization for the disk viscosity, the latter is derived from a physical model for turbulence. Employing this model, the turbulent viscosity and the vertically averaged convective flux in terms of the local physical conditions of the disk which, in turn, are controlled by the former two.
  Recent works showed that a turbulent convective disk can transfer angular momentum in the outer direction (Käpylä et al.2010; Oglive & Lesur 2010).
- The focus is on the case of hypercritical accretion rate. In this case the inner part of the disk is radiation pressure dominated and the outer part is gas pressure dominated.
- In both regions the vertical flux is essentially *purely convective*.
- In both regions the disk is geometrically thin and optically thick.

## The Radiation Pressure Dominated Region

Below are presented the parameters of the radiation pressure dominated region. Here $M_8$ is the black hole mass in units of $10^8\ M_{sun}$, $r$ denotes the radial coordinate in units of the gravitational radius $r = Rc^2/(GM)$, $L_*$ is the luminosity in units of the Eddington luminosity, and $C_{bf}$ is the bound free enhancement factor.
The quantities below are vertical averages over the convective layer of width $2h$. In this layer, the turbulent viscosity is due to turbulent convection. The vertical flux is purely convective.
Note that for the entire radial extent of the radiation pressure zone, the disk is geometrically thin and optically thick.
The logarithmic derivative of $\tau_{es}$ versus $L_*$ is positive, implying that the disk is stable.

$$r \leq 2.15 \times 10^3 \left(\frac{L_*}{10^2}\right)^{64/93} M_8^{2/93} \left(\frac{C_{bf}}{30}\right)^{-16/93}$$

$$\rho = (0.015 gcm^{-3})\ M_8^{-10/11} \left(\frac{L_*}{10^2}\right)^{10/11} \left(\frac{r}{10}\right)^{-30/11} \left(\frac{C_{bf}}{30}\right)^{-8/11}$$

$$\tau_{es} = 8.7 \times 10^9 M_8^{2/33} \left(\frac{L_*}{10^2}\right)^{31/33} \left(\frac{r}{10}\right)^{-29/22} \left(\frac{C_{bf}}{30}\right)^{-16/33}$$

$$T = (1.5 \times 10^7 K)\ M_8^{-8/33} \left(\frac{L_*}{10^2}\right)^{8/33} \left(\frac{r}{10}\right)^{-8/11} \left(\frac{C_{bf}}{30}\right)^{-2/33}$$

$$\frac{h}{R} = 8.6 \times 10^{-3} \left(\frac{L_*}{10^2}\right)^{1/33} M_8^{-1/33} \left(\frac{r}{10}\right)^{9/22} \left(\frac{C_{bf}}{30}\right)^{8/33}$$

## Relevance for Jets

The fact that the vertical energy flux is convective allows for a stable geometrically thin, optically thick disk.
However, outside the convective layer of width $2h$ the flux becomes radiative. The highly super-critical radiative flux can easily accelerate jets, from the two sides of the disk.
Because the concave geometry of the disk, the jet will be focused along the disk axis.
An estimate of the mass outside the convective layer yields enough mass to produce observational jets. A numerical solution for the jet formation is in progress. We expect the spectrum to be a mixture of electron scattering modified blackbody and bremsstrahlung.

## References


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