Black Holes from Stars to Galaxies – Across the Range of Masses
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Accreting corona model of the X-ray variability in soft state GBH and AGN

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Abstract. We develop a two-flow model of accretion onto a black hole which incorporates the effect of the local magneto-rotational instability. The flow consists of an accretion disk and an accreting corona, and the local dynamo affects the disk/corona mass exchange. The model is aimed to explain the power spectra of the sources in their soft, disk-dominated states. The local perturbations of the magnetic field in the disk are described as in King *et al.* (2004) and Mayer & Pringle (2006), but the time-dependent local magnetic field is assumed to affect the local supply of the material to the corona. The accreting corona model can reproduce the broad power spectra of Soft State X-ray binaries and AGN. The model, however, predicts that (i) sources undergoing radiation pressure instability (GRS 1915+105) should have systematically steeper power spectra than other sources, (ii) AGN should have systematically steeper power spectra than GBH. More measurements of power spectra of Soft State sources are clearly needed.

Keywords. Accretion, accretion disks – galaxies: active – X-rays: binaries – X-rays: galaxies

1. Introduction

The X-ray emission of the Galactic Black Holes (GBH) and active galactic nuclei (AGN) is strongly variable. Aperiodic character of this variability makes the interpretation of the physical nature of the phenomenon rather difficult. The key question is : why long timescale variability, plausibly related to the processes in the outer parts of the disk contributes so significantly to the overall variability although the energy dissipated in the outer parts of the disk is very low?

Here we propose to accommodate the basic picture of Lyubarskii (1997) within the frame of the accreting corona model. In our model the variations due to the local dynamo modify the accretion rate within the corona. The disk perturbations propagate in disk viscous timescale and therefore are smeared out, but the viscous timescale in the corona is much shorter than in the disk. This allows the coronal perturbations to be observed.

2. Model

We consider the case of an accretion disk extending down to the marginally stable orbit, surrounded by the hot optically thin corona. We postulate that the corona itself can also transport the angular momentum and can exchange mass and angular momentum with the underlying optically thick disk. The model was originally proposed in the context of disk evaporation in cataclysmic variables by Meyer-Hofmeister & Meyer (1994).

Since the exact mechanism is under discussion, we adopt three viable parameterizations of the evaporation process: $\dot{m}_z$ equal to $\frac{B^2}{8\pi} v_A \frac{\mu H}{kT_{vir}}$ (case A), $\frac{B^2}{8\pi} c \frac{\mu H}{kT_{vir}}$ (case B), or $\frac{B^2}{8\pi} v_A \frac{\mu H}{kT_{vir}} \frac{1}{f(r)}$ (case C). The variations of the local magnetic field, B, are described with

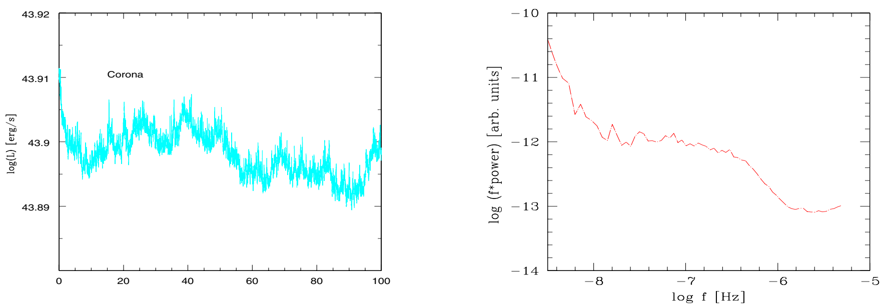

Figure 1. Model: $M = 10^8 M_{\odot}$, $\dot{m} = 0.22$, type Cb, with $\alpha P_{\rm gas}$ viscosity law.

the use of the Markoff chain, as in King *et al.* (2004) and Mayer & Pringle (2006). We consider three choices of the size of a magnetic cell: Δr equal to $\sqrt{r}$ case (a), $h(r)$ case (b), or r case (c). The disk structure is described assuming either αP_{tot} or αP_{gas} torque, so some models undergo radiation pressure instability and show a limit cycle behaviour.

The time evolution of the disk-corona system is followed using the modified code of Janiuk & Czerny (2005). The disk and corona lightcurves are obtained, and the power spectra (PSD) are calculated for each model.

3. Results and Discussion

Fig. 1 (left) shows an example of a lightcurve (left) and PSD (right) for a corona above a stable disk ($\alpha P_{\rm gas}$ viscosity law), so all the variability is due to the dynamo action.

We calculated many more examples of the disk and corona lightcurves. The evaporation law (B) overproduced the strength of the corona and can be rejected. Some of the models (A) and (C) are acceptable both from the point of view of the disk/corona luminosity ratio and the PSD slope. Observed slopes in GBH and AGN in their soft states are typically within the range 0.8–1.3. However, for a given evaporation law, viscosity prescription and the magnetic cell size, *the results are never universal*, i.e. the PSD slope depends on the black hole mass and accretion rate since these parameters affect the disk structure, and consequently, the corona variability.

The radiation pressure instability in the underlying accretion disk leads to steeper power density spectrum of its fluctuations, as well as to the larger amplitudes.

The PSD spectra corresponding to the accreting supermassive black holes are systematically steeper than for the galactic black holes. Further verification of the models requires more detailed observations and analysis of the long-term variability in AGN.

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