Abstract

One of the features present in the X-ray spectra of both black hole X-ray binaries (BHXBs) and active galactic nuclei (AGNs) is excess of soft X-ray photons around 1-5keV. Many studies have demonstrated that it is well-described by Comptonization of soft photons in a warm (around 1 keV) and optically thick (τ = 10-50) coronal layer above the accretion disk. Alternative explanations have been proposed, such as relativistically smeared reflection from the disk illuminated by a hard X-ray continuum. The true origin of soft X-ray excess is still a topic of debate, and this thesis is dedicated to explore the scenario of warm, optically thick and scattering-dominated corona as its possible origin. Theoretical and observational background of this work, together with the aim of my research and most important conclusions are given in the Introduction.

Physical models show that the warm corona consistent with observations cannot be sustained unless some mechanism heating the atmosphere is provided, and this process is very likely driven by the magnetic field. I developed a new numerical code to calculate structure of the magnetically supported disk and corona with all relevent physical processes, which I describe in Paper I. Input parameters for the code are: mass of the black hole, accretion rate, radius and magnetic dynamo parameter. The code computes: gas density, temperature, radiative pressure and flux as well as magnetic pressure as a function of height above the disk equatorial plane. I implemented numerical relaxation method allowing to solve non-linear ordinary differential equations. I showed that if magnetic pressure and heating are included in the vertical structure, a warm and optically thick corona with properties consistent with the observations of black hole X-ray binaries is naturally formed above the accretion disk. I was able to calculate density and temperature structure of the accreting matter for a wide range of parameters.

Using my code I performed analogical computations in the case of supermassive black holes in AGN and presented the results in Paper II. I showed that free-free opacity at the base of the corona causes favorable conditions for the local thermal instability, which may result in matter collapsing into two-phase medium. I computed disk/corona models for a very wide range of parameters, such as black hole mass, magnetic field strength and the accretion rate. I determined that increasing the magnetic field support can stabilize the accretion disk, eliminating the radiation pressure instability. By generating a synthetic population of accretion disk models, I was able to reproduce the distribution of soft excess parameters in AGN in good agreement with observations recently published in the literature. Although my initial assumption to take the temperature minimum as the base of the warm corona overestimated the optical depth of the warm corona, partial collapse of the warm skin due to thermal instability could remove this discrepancy.

The aim of Paper III, is to compute a realistic spectrum of a internally heated warm corona which is simultaeously illuminated by hard X-ray radiation. I use photoionization code TITAN coupled with Monte Carlo photon tracing code NOAR to determine the temperature and ionization structure of the plane-parallel constant-density slab. Thanks to using Monte Carlo method, I am able to study separately the spectrum of the reflection from the ionized atmosphere and warm Comptonization. I determine that the warm Comptonization spectrum is featureless and does not contain emission nor absorption features. By computing models over a large parameter space of internal heating rate and optical thickness of the layer, I confirm that internal heating must be present Comptonization must be the dominating cooling process to obtain soft X-ray spectrum which is consistent with observations.