

Do black holes sleep under warm blankets?

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Compact objects (black holes, neutron stars) are the most extreme celestial bodies. Their exotic nature means that by trying to explain their existence we reach the limits of modern physical knowledge. Despite their different properties, they have one thing in common: they are compact and very dense, so that the gravitational force near their surface is extremely strong. This causes a lot of trouble in the vicinity of such an object: all matter passing by will be strongly pulled towards it.

Contrary to our intuition, in space there is no friction, so is not so easy to fall: it is much easier to find yourself in the orbit of the celestial body than to hit its surface. The body must first lose its energy. Therefore, the matter is not sucked in by the central object like a vacuum cleaner, but similar to the vortex forming above the draing in the water tank, it forms a structure called **accretion disk**. According to Kepler's law, such a gas disk rotates fastest near the central object: as a result of this difference in speed, it heats up and gives off the energy in the form of brilliant light emission. In the case of **black holes**, which case we study in this project, matter can reach the temperature of tens of millions of degrees Celsius before it plunges into the black hole!

We know about the existence of accretion disks around black holes from optical and X-ray observations, but the latter provide the most valuable insight into the hottest area in the central region. With the development of technology and increasingly better data from space X-ray observatories, it quickly turned out that in some cases the disk shines *brighter* than it would appear in theory, especially in the range between X-rays and ultraviolet. This phenomenon was called **soft X-ray excess**, and two scenarios were proposed for its explanation. The first of these is the possibility that the disk is additionally illuminated by the source of very energetic radiation above, and the observed feature is a reflection from the disk. Nevertheless, the only illumination by external source is not enough to produce Soft X-ray excess in some sources. The scenario we study in this project is that the disk is covered with a slightly hotter gas layer (**warm corona**), which boosts the energy of photons leaving the disk, thus producing an excess.

From the perspective of observation, currently both models seem to fit the X-ray spectra well. However, the physical mechanisms that are supposed to drive them are still unclear. Recently, we have carried out calculations of the disk structure, taking into account the magnetic field, and it turned out that in the case of a strong magnetic field, the corona over the disk is formed in a natural way. More importantly, its properties – thickness and temperature – are exactly as shown by the observational data!

This is an important step in explaining the problem of the soft X-ray excess. First, we are going to compute the corona structure for disks around supermassive black holes. Then we will determine typical disk atmosphere densities for various models and masses of black holes. In the following step, we would like to accurately reproduce the spectrum in the X-ray range, which according to our model would emit a disk and a corona. Such calculations have never been carried out based on a physical model and using such advanced tools. In the last step, we will analyze the observational data for two classes of objects in which there is a soft X-ray excess: small black holes in our Galaxy, which are characterized by a fast rate of variation, so you can trace how the excess depends on the brightness of the object and supermassive black holes in the centers of other galaxies, where the excess phenomenon is much stronger and more common.

We examine the issue of warm coronae for different object classes and in two different ways: with an observational and theoretical approach. As a result, we will significantly broaden our knowledge in this topic, and we will come closer to the final answer to the question: how is a soft X-ray excess created in accretion disks around black holes?