Formation of Overheated Regions and Truncated Disks around Black Holes; Three-dimensional General Relativistic Radiation-magnetohydrodynamics Simulations

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It is believed that the black hole accretion flows are the central engine of the luminous compact objects like active galactic nuclei and black hole binaries (BHBs). The X-ray spectra of such objects are mainly composed of the soft component and the power-low component. The soft component is dominant over the power-low component in the high-soft state as well as in the slim disk state. In contrast, the power-low component is quite prominent in the low-hard state and in the very high state.

The soft component is explained to be multi-color disk blackbody model, which is emitted from the relatively cold, optically thick accretion disk. On the other hand, the power-low component is thought to be produced due to the Compton upscattering in the hot and less-dense regions (so-called disk corona). These features are motivated from observations, but both the structure and the formation mechanism of the hot, rarefied plasma around the cold disk are not understood yet.

In this paper, we perform the three-dimensional General Relativistic Radiation Magnetohydrodynamic simulations to study the formation of the hot, rarefied corona. Figure 1 shows global structure of accretion disk. The radiation pressure dominated accretion flow is formed around the black holes. Due to the strong radiation generated in the accretion disks, strong bipolar jets are formed, which are accelerated by the radiation force. We found that far from the black hole, the gas temperature of the disk gas is about a few 10^7 K. The radiation temperature coincides with the gas temperature due to the strong coupling between the gas and radiation through the absorption and emission processes. Close to the black hole, however, the gas temperature deviates from the radiation temperature and it increases with approaching to the black hole. The maximum gas temperature reaches 10^{11} K close to the black hole. This indicates the fact that the high temperature gas cloud is formed near the black hole. Then we investigate the reason why such a high temperature cloud is formed. We compare the cooling timescale and dynamical timescale that gas falls onto the black hole. Far from the black hole, the cooling time is much shorter than the dynamical time, so that the gas and radiation are in local thermodynamic equilibrium. This situation is violated close to the black hole since the infall timescale becomes shorter as approaching to black hole due to the strong gravity. As a result, high temperature corona is formed around the black hole. This feature is more manifest for the low accretion rate case since the cooling time is reciprocal to the square of the density. Also we find that the coronal temperature is higher for the case of rapidly rotating black hole. We do not have a confidence, but this result would indicate that the black hole rotation energy is transported to the accretion disk and it would be responsible for disk heating.

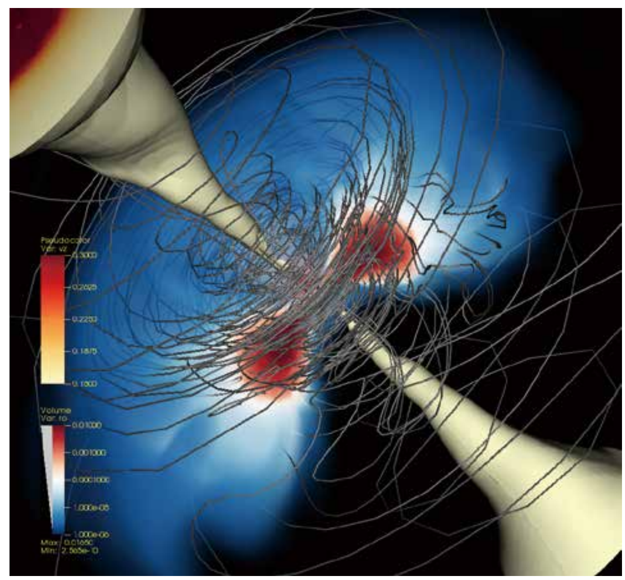

Figure 1: Global structure of radiation dominated accretion disks near the black hole at t = 0.3 s. The Figure shows the density (blue-white-red volume rendering), the outflow velocity (white-red volume data), and the magnetic Field lines (gray lines).

Reference

[1] Takahashi, H. R., et al.: 2016, *ApJ*, **826**, 23.