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Radiation MHD Simulations of the Formation of Soft X-ray Emitting Regions in Luminous Active Galactic Nuclei

Taichi Igarashi[12], Hiroyuki R. Takahashi[3], Tomohisa Kawashima[4], Ken Ohsuga[5], Yosuke Matsumoto[6], Ryoji Matsumoto[6]
[1] Division of Science, National Astronomical Observatory of Japan
[2] Department of Physics, Rikkyo University
[3] Department of Natural Science, Komazawa University
[4] Institute for Cosmic Ray Research, The University of Tokyo
[5] Center for Computational Sciences, University of Tsukuba, Tennodai
[6] Institute for Advanced Academic Research, Chiba University
[7] Digital Transformation Enhancement Council, Chiba University
e-mail (speaker): igarashi.taichi@rikkyo.ac.jp

Active galactic nuclei (AGNs) show various activities, including intense radiation comparable to that of entire galaxies. Such activities are driven by the accretion flow formed around the central supermassive black hole. In addition to UV emission from the thermal emission of the accretion disk and hard X-ray emission from inverse Compton scattering in the hot accretion flow, soft X-ray emission is also observed in the radiation spectrum from bright active galactic nuclei. The soft X-ray emission is explained either by the reflection of the hard X-ray emission irradiating the optically thick cool disk or by radiation from a warm Compton region with temperature 10^6-10^7K optically thick for the electron scattering. Recent observations prefer the warm Compton model but the geometry of the warm Comptonization region is still unknown.

In this study, we perform radiation magnetohydrodynamic simulations of the accretion flow around a super-massive black hole when the accretion rate exceeds the upper limit for the radiatively inefficient accretion flows (RIAF). We report numerical results when the accretion rate is 10-30% of the Eddington accretion rate L_{Edd}/c^2, where L_{Edd} is the maximum luminosity of the spherical accretion flow called Eddington luminosity. Bremsstrahlung emission and Compton scattering are considered.

In the region near the black hole ($r < 20r_s$, where r_s is the Schwarzschild radius), since the accretion time scale is shorter than the cooling time, accretion flow stays hot ($T \sim 10^{10}$K), The hot, optically thin accretion flow co-exists with the outer Thomson -thick warm ($T \sim 10^6$-10^7K) region. Soft X-rays are emitted from this region. The temperature of the warm Compton region is higher than that of the optically thick, cool ($T \sim 10^5$K) standard disk around a super-massive black hole. Numerical results indicate that the warm Compton region exists for a time scale longer than the thermal time scale of the region. It indicates that the warm Compton region is nearly in thermal equilibrium. Furthermore, the warm Compton region is supported by azimuthal magnetic fields enhanced by vertical contraction of the disk due to radiative cooling. Numerical results are compared with steady models of the magnetic pressure dominant disk studied by Oda et al. (2009, 2012). Magnetic heating by the release of magnetic energy enables the disk to stay in a soft X-ray emitting warm state.

References

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