X-ray and Optical/UV Correlation Studies of Active Galactic Nuclei

H. Noda,*1 and T. Minezaki,*2 on behalf of the AGN Optical–X-ray Monitoring Collaboration

Almost all galaxies in the universe are considered to harbor, at their center, a supermassive Black Hole (BH) with a mass of $\sim 10^{5-10}$ $M_\odot$, where $M_\odot$ is Solar mass. In Active Galactic Nuclei (AGNs), a considerable amount gas accretes onto the BH, and multi wavelength signals, including optical, UV, and X-ray, are generated with bolometric luminosity of $\sim 10^{40-46}$ erg s^{-1}. The X-ray is presumably generated, via inverse comptonization in high-temperature electron clouds (coronae) formed near the BH, while the optical/UV emissions via black body processes of an optically thick and geometrically thin accretion disk extending out to farther radii from the BH. Although a combination of the accretion disk and coronae has been known as "the central engine" creating a large amount of energy in AGNs, its properties including geometries, physical conditions, and heating mechanisms are still unclear.

Applying a timing method[1)] to *Suzaku*[2)] data of an AGN called NGC 3227, we found that a Hard Primary Component (HPC) dominated X-ray emission in the faint phase, while a Broad-band Primary Component (BPC) appeared in addition to the HPC in the bright phase (Fig. 1a). This demonstrates that at least two X-ray emitting regions with distinct properties exist near a BH, and one emitting the HPC is always visible, while the other radiating the BPC shows up only when the amount of accreting gas is large[3)]. However, the geometries of the HPC and BPC creating regions can be hardly identified with only the X-ray information.

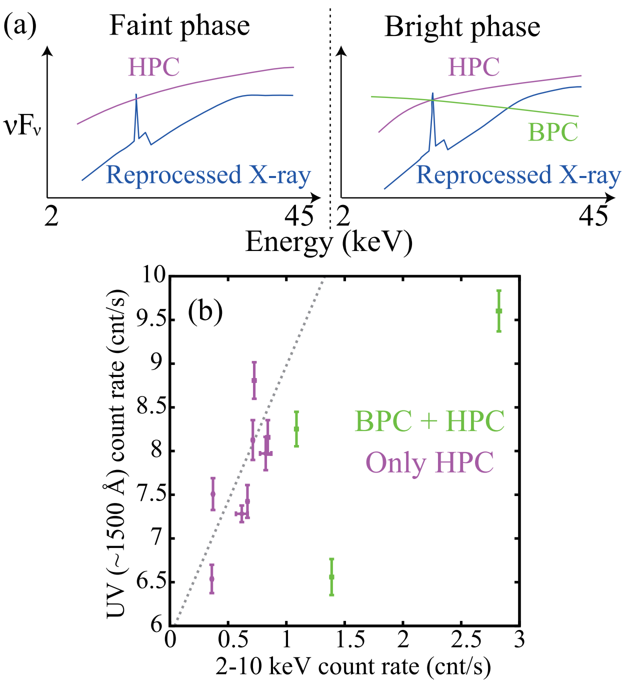

Fig. 1. (a) Spectral components of NGC 3227 in the faint (left) and bright (right) phase[3)]. (b) A plot between fluxes in the 2–10 keV and UV bands. Systematic errors of the *Swift* detectors were not included in the errors.

To study the geometries, we focus on correlations between the fluxes of primary X-ray and optical/UV, because a better correlation possibly reflects a stronger geometrical connection of an X-ray radiating region with the accretion disk. In 2013–2014, we performed optical and X-ray simultaneous monitoring on an AGN called NGC 3516 with *Suzaku* and five Japanese ground-based telescopes. As a result, a significant correlation was discovered between fluxes of HPC and the optical signals. The result will be discussed elsewhere.

Optical–UV data derived by *Swift*[4)] are useful as well. Almost all *Suzaku* observations of NGC 3227[3)] were simultaneously followed up by *Swift*; therefore X-ray flux in the faint and bright phase, identified by *Suzaku* (Fig. 1a), can be individually compared with those in optical/UV. First, we extracted UV count rates from a 5"-radius circle centering at the nucleus on UV images obtained with the UVW2 filter. Next, we extracted 2–10 keV count rates from the *Suzaku* and *Swift* datasets derived at the same time as the UV images. Figure 1(b) shows a count-count plot between the UV and X-ray count rates with different colors between the faint (purple) and bright (green) phases. When we fitted the faint-phase plots (Fig. 1b purple) with a linear function, including systematic errors of 3% into the UV count rates, the fit almost succeeded with $\chi^2/\nu = 13.4/6$. However, in fitting all the plots (Fig. 1b purple plus green) again with a linear function, after including the 3% systematic errors into the UV count rates, the result degraded giving $\chi^2/\nu = 61.5/9$. This might indicate that the HPC flux is strongly correlated with UV, while the BPC flux is little correlated.

Because the HPC was found to deeply relate with black body photons from the accretion disk, it may come from an hot accretion flow, and if so, the faint phase corresponds to the low/hard state[5)]. On the other hand, the origin of the BPC still remains unclear, because it did not appear for long enough in the previous observations of NGC 3516 and NGC 3227. To examine the bright phase in detail, we perform another X-ray and optical monitoring with *Suzaku*, and the systematic analyses of AGN data in the *Swift* archive.

*1 RIKEN Nishina Center
*2 Institute of Astronomy, School of Science, The University of Tokyo

References

1) H. Noda et al.: ApJ, 771, 100 (2013)
2) K. Mitsuda et al.: PASJ, 59, 1 (2007)
3) H. Noda et al.: ApJ, 794, 2 (2014)
4) N. Gehrels et al.: ApJ, 611, 1005 (2004)
5) F. Yuan & R. Narayan: ARAA, **52**, 529 (2014)