Subaru High-Spatial-Resolution Infrared Imaging of Gas-Rich Merging Galaxies

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According to the widely-accepted cold-dark-matter based galaxy formation scenario, small gas-rich galaxies collide and merge, and evolve into massive galaxies. Recent observations of nearby galaxies have shown that supermassive blackholes (SMBHs) with $>10^6$ solar mass are ubiquitously present at the center of galaxies, and that the masses of central SMBHs and galaxy stellar components are correlated. When gas-rich galaxies collide and merge, a large amount of gas is quickly transported to the nuclear regions, and active starburst activity occurs. At the same time, such gas can accrete onto the pre-existing SMBHs, and such accreting SMBHs can become luminous and be observed as active galactic nucleus (AGN) activity. Investigating these kinds of activity is crucial to understand the galaxy formation process in the universe, but such activity is deeply obscured by gas and dust, so that observations at the wavelength of low dust extinction are necessary.

We have developed a unique method to clearly distinguish between AGN and starburst activity, based on high-spatial-resolution, infrared K-band (2.2μm) and L'-band (3.8μm) imaging observations, assisted with the adaptive optics system of the Subaru Telescope, because the effects of dust extinction are small in these infrared K- and L'-bands. Since a mass-accreting SMBH has much higher radiative energy generation efficiency than nuclear fusion reaction inside stars, an AGN can produce a larger amount of hot (several 100K) dust in the close vicinity. Such hot dust produces strong infrared L'-band emission, so that K−L' colors become distinctly different between AGNs and starbursts, making the colors an excellent indicator to distinguish between these kinds of activity.

We have observed 29 infrared-luminous gas-rich merging galaxies, and detected at least one active SMBH in 28 sources, demonstrating that our infrared method is very powerful to detect deeply buried AGNs in merging galaxy nuclei. However, multiple AGNs have been found only in 4 sources (~15%) (Figure 1). Since multiple SMBHs are expected in merging galaxies, the small detectable fraction of multiple AGNs (=active SMBHs) indicates that not all SMBHs are actively mass-accreting and become luminous AGNs. AGN luminosity is proportional to the mass accretion rate onto a SMBH. The AGN luminosity, divided by SMBH mass, is widely used to measure how active a SMBH is. We found that the SMBH-mass normalized AGN luminosity is higher in more massive SMBHs than less massive SMBHs in merging galaxies [1].

Since the gravitational force of a SMBH increases, in proportion to the SMBH mass, more massive SMBH can attract a larger amount of surrounding material than less massive SMBH. However, our result means that activity of SMBH is higher for more massive SMBH, even after the normalization by SMBH mass. Namely, the amount of accreting material onto SMBH increases more rapidly than the increase of SMBH mass. Given the above-mentioned relation between SMBH mass and galaxy stellar mass, our result is interpreted that SMBHs are more active in more massive galaxies. Recently, the so-called galaxy-downsizing phenomenon has widely been discussed, where more massive galaxies are generally redder in colors, and have finished major star-formation in an earlier cosmic age than less massive galaxies. This phenomenon apparently contradicts to the cold-dark-matter based galaxy formation scenario which postulates that small galaxies are formed first. It is theoretically proposed that if SMBHs are more active and AGN radiation effects are stronger in more massive galaxies, then this galaxy-downsizing phenomenon could be reproduced. Our result may support this scenario.

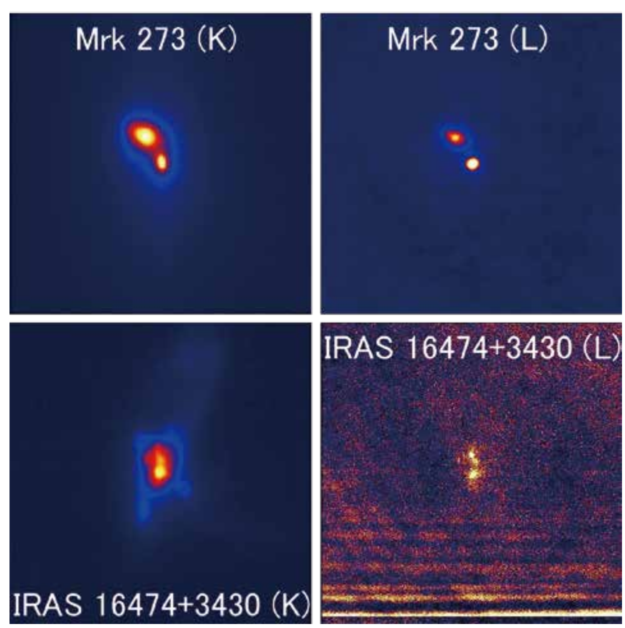

Figure 1: Examples of infrared K- and L'-band images of merging galaxies with detected multiple active SMBHs [1].

Reference

[1] Imanishi, M., Saito, Y.: 2014, *ApJ*, **780**, 106.