Giant black holes revealed in the nuclei of merging galaxies

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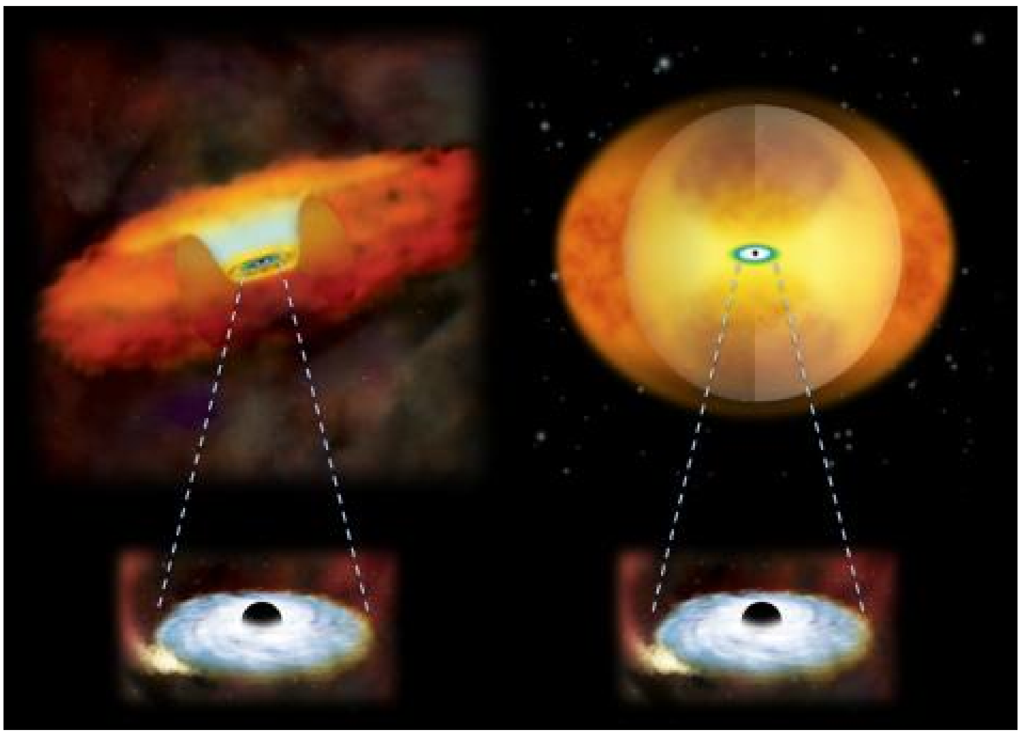

Figure 1: Schematic diagrams of obscured AGNs. left: A doughnut-shaped dusty medium hides an active mass-accreting SMBH. Photons from the central AGN (= a mass accreting SMBH) can escape along the doughnut axis and ionize the gas there. Since the emission pattern of such AGN-ionized gas clouds differs from those in star-forming regions, we can use optical spectroscopy to easily infer the presence of an AGN hidden behind the dusty medium. right: Dust in all lines-of-sight obscures and buries the active mass-accreting SMBH, which is very difficult to detect with conventional optical spectroscopy. Credits: NASA for the images of mass accreting SMBH (lower), and mass accreting SMBH surrounded by doughnut-shaped dusty medium (upper left). NAOJ, Naomi Ishikawa, for the upper-right image.

Subaru Telescope research team led by Dr. Masatoshi Imanishi at the National Astronomical Observatory of Japan sampled many infrared bright, merging galaxies and determined the presence of active supermassive black holes (SMBH) deeply buried in their centers.

The scientists used the 8.2 m Subaru Telescope atop Mauna Kea (4200 m in elevation) as well as the Gemini South telescope at Cerro Pachon, Chile (2700 m in elevation) to perform high-spatial-resolution infrared imaging observations of nearby infrared luminous merging galaxies. Observations with both telescopes revealed that some samples show characteristics of rapid star-formation, while others display the signature of active galactic nuclei (AGN) that draw their energy from SMBH.

According to prevailing galaxy formation theories, small gas-rich galaxies with central SMBHs collide and merge, and then grow into the matured galaxies of the current universe. This is why the investigation of nearby infrared luminous merging galaxies helps to clarify the process of galaxy formation. The collision and compression of gas clouds from the galaxy merger causes the rapid formation of new stars, a heating-up of the surrounding dust, and the consequent production of strong infrared radiation. Also the supply of material increases the accretion to the SMBHs.

Although the merging galaxies enhance star formation as well as accretion to SMBHs, they also hinder these processes. A large amount of gas and dust are supplied to their nuclear regions, a process that can easily bury the compact SMBHs and make them difficult to find. By chance some objects have a ring-shaped distribution of the dust and gas, allowing observers to peek into the effect of the active SMBHs (Figure 1).

To detect emission behind dust and gas, the current research team made observations at 18 micrometers, using Subaru Telescope's COMICS (Cooled Mid-Infrared Camera and Spectrometer) as well as Gemini South's T-ReCS (Thermal-Region Camera Spectrograph). By utilizing the time exchange program, the team could use both telescopes to survey objects all over the sky. Subaru's observations captured images in the northern hemisphere and Gemini South, in the southern hemisphere.

How, then, could they confirm the presence of active SMBHs? It was neither an easy nor a trivial task to discover active SMBHs in merging galaxies. The researchers had used their methodology and choice of instruments to overcome a number of challenges. First they needed to identify an object had a bright infrared emission but was compact in size. Both AGN activity (a mass accreting SMBH) and compact star formation region are spatially confined. Measuring the luminosity in the infrared was the key for the finally categorizing their source. If the emission surface brightness at the nucleus of a merging galaxy is substantially higher than the maximum brightness expected from star-formation, then one can infer that the emission comes from a luminous buried AGN, because an accreting SMBH can emit radiation much more efficiently than a star. Observations at infrared 18 micrometers with both the Subaru and Gemini South telescopes demonstrated that some infrared luminous merging galaxies show a star formation type of emission (spatially extended with modest surface brightness) while others had an emission typical of AGNs (spatially compact with high surface brightness) (Figure 2). Ten of the current sample of eighteen objects showed the characteristics of the AGNs.

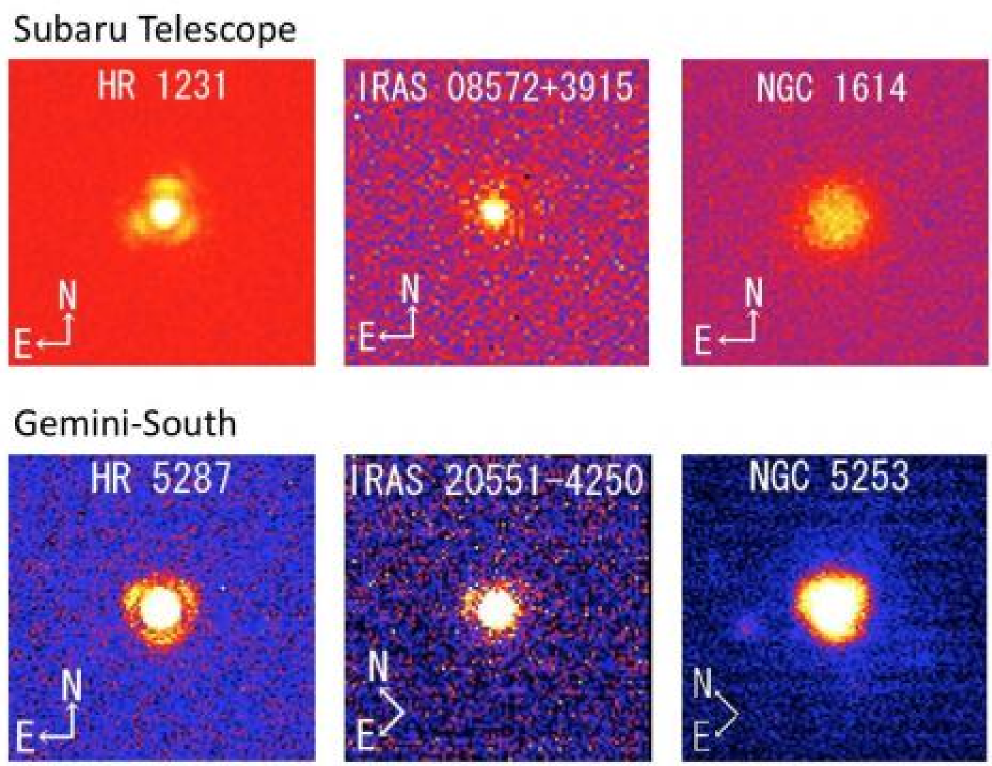

Figure 2: High-spatial-resolution infrared 18-micrometer images, obtained with the Subaru telescope (top) and the Gemini South telescope (bottom). The field of view (FOV) is 8 x 8 arcsec2. N and E indicate north and east directions, respectively. left: Image of a standard star. Three dots (top) or three dots with a ring pattern (bottom) demonstrate that the image has reached or is close to the limit for its highest possible resolution. middle: Image of an infrared luminous merging galaxy, with indication of a luminous AGN. The infrared emission is very compact, indistinguishable from the stellar image. The emission surface brightness is estimated to be significantly higher than the upper limit achieved by star-formation activity. right: Image of an infrared luminous merging galaxy, typical of a star-formation dominated source. The emission is spatially extended, and the emission surface brightness is within a range explained by star-formation activity.

The team's coherent, logical steps used to investigate the presence of supermassive black holes in merging galaxies yielded clear and important results, which were published in the *Astronomical Journal*: Imanishi et al. 2011 *Astronomical Journal*, 141, 156). Comparison of the results from high spatial resolution infrared observations with those from research using infrared spectroscopy to investigate deeply buried AGNs shows that both are reliable energy diagnostic tools and provide a consistent picture of the nature of hidden energy sources in merging galaxies.

Provided by Subaru Telescope

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