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Scientists Observe Super-Massive Black Holes Using Keck Observatory in Hawaii

An international team of scientists has observed four super-massive black holes at the center of galaxies, which may provide new information on how these central black hole systems operate. Their findings are published in December's first issue of the journal Astronomy and Astrophysics.

These super-massive black holes at the center of galaxies are called active galactic nuclei. For the first time, the team observed a quasar with an active galactic nucleus, as part of the group of four, which is located more than a billion light years from Earth. The scientists used the two Keck telescopes on top of Mauna Kea in Hawaii. These are the largest optical/infrared telescopes in the world.

The team also used the United Kingdom Infrared Telescope (UKIRT) to follow up the Keck observations, to obtain current near-infrared images of the target galaxies.

"Astronomers have been trying to see directly what exactly is going on in the vicinity of these accreting super-massive black holes," said co-author Robert Antonucci, a UC Santa Barbara astrophysicist.

He explained that the nuclei of many galaxies show intense radiation from X-ray to optical, infrared, and radio, where the nucleus may exhibit a strong jet

–– a linear feature carrying particles and magnetic energy out from a central super-massive black hole. Scientists believe these active nuclei are powered by accreting super-massive black holes. The accreting gas and dust are especially bright in the optical and infrared regions of the electromagnetic spectrum.

Scientists can now separate the emission from the regions outside the black hole from that in the very close vicinity of the black hole. This is the location of the most interesting physical process, the actual swallowing of matter by the black hole. "While not resolving this extremely small region directly, we can now better subtract the contribution from surrounding matter when we take a spectrum of the black hole and its surroundings, isolating the spectrum from the matter actually being consumed and lost forever by the hole," said Antonucci.

To observe such a distant object sharply enough in infrared wavelengths requires the use of a telescope having a diameter of about 100 meters or more. Instead of building such a large infrared telescope, which is currently impossible, a more practical way is to combine the beams from two or more telescopes that are roughly 100 meters apart. This method, used in radio astronomy for decades, is new for the infrared part of the spectrum. This type of instrument is called a long-baseline interferometer.

The Keck telescopes are separated by 85 meters and can be used as an interferometer. Combining the light from the telescopes allows astronomers to detect an interference pattern of the two beams and infer what the black hole vicinity looks like, explained first author Makoto Kishimoto, of the Max Planck Institute for Radio Astronomy in Bonn, Germany.

Kishimoto and Antonucci have a longstanding research collaboration, which began with Kishimoto's post-doctoral fellowship with Antonucci in the UCSB Department of Physics a decade ago. Antonucci points out that most of the credit for this current work goes to Kishimoto.

In 2003, astronomer Mark Swain at the Jet Propulsion Laboratory and his collaborators used the Keck Interferometer to observe the material accreting around one super-massive black hole, called NGC 4151. This is one of the brightest black holes in the optical and infrared wavelengths. The observations provided astronomers with the first direct clue about the inner region of a super-massive black hole system, said Antonucci.

"The results looked puzzling in 2003," said Kishimoto. "But with the new data and with more external information, we are quite sure of what we are seeing." According to the team's results, the Keck Interferometer has just begun to resolve the outer region of an active galactic nucleus's accreting gas, where co-existing dust grains are hot enough to evaporate, transitioning directly from a solid to a gas.

The W. M. Keck Observatory is a scientific partnership of the California Institute of Technology, the University of California, and NASA.

[RETURN TO TOP]

† Top photo: Robert Antonucci with photo of the Keck Observatory.

Credit: George Foulsham, Public Affairs, UCSB

†† Bottom photo: UKIRT infrared images of the four target galaxies show them in near-infrared color, where the images at different infrared wavelengths are assigned to represent red, green and blue colors. Observations with the Keck Interferometer have resolved the inner structure of the bright nucleus in all the four galaxies. The inferred ring-like structure obtained for NGC 4151 at the top-left is depicted in the top-right panel. The ring radius is 0.13 light years, corresponding to an extremely small ~0.5 milli-arcsecond angular size on the sky. The distance to each galaxy is indicated in million light-years, together with the redshift (z) of each galaxy.

Credit: M. Kishimoto, MPIfR

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