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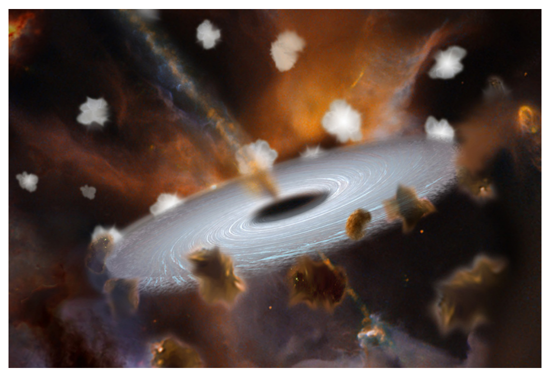
Astronomers Take a Closer Look at the Centers of Galaxies

Study sheds light on how matter around the vicinity of supermassive black holes is distributed

A recent study, published in The Astrophysical Journal by a team of astronomers from UC San Diego's Center for Astrophysics and Space Sciences (CASS), NASA Goddard Space Flight Center (GSFC), the University of Maryland and Leibniz Institute for Astrophysics Potsdam, has provided a glimpse of what is going on in the centers of "active galaxies."

Nearly every galaxy has a giant black hole at its center, and some are voracious eaters that gobble up nearby gas and dust. All of this moving material heats up and emits a huge amount of light from the accretion disk—the blurry halo of flowing gas and dust that surrounds a black hole. Such systems are called active galactic nuclei (AGN).



Artist's illustration of gas and dust as it swirls toward the supermassive black hole—some matter forms a flat "accretion disk" that feeds the black hole directly, while other matter forms numerous compact clouds that can orbit the black hole farther out. Image by Jay Friedlander (NASA/GSFC) and Sibasish Laha (NASA/GSFC), et. al (2020).

The regions around these central black holes appear so small and far away that they can't be seen directly. So astronomers like Alex Markowitz (CASS) and former UC San Diego postdoctoral scholars Sibasish Laha (assistant research scientist with NASA/GSFC and University of Maryland) and Mirko Krumpe (Leibniz Institute for Astrophysics Potsdam) look for signatures in their light as a way to understand what kind of matter is present. By examining how the signatures change over time, scientists can trace gas as it moves across the line of sight, and thereby learn where different structures are near the black hole.

Using European Space Agency's XMM-Newton, NASA's Chandra, and JAXA's Suzaku telescopes, the researchers found three distinct regions where the X-rays get absorbed by matter: (1) compact clumpy clouds very close to the black hole that drift across the line of sight,

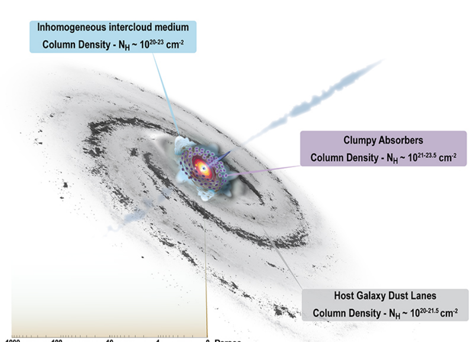
(2) variable-density diffuse streams of matter that also drift across the line of sight and (3) dust lanes in the host galaxy.

“Half of the sources show partial covering absorbers along the line of sight, implying very high-density gas sitting right next to the black hole,” said Laha, first-author of the published paper.

Markowitz explained that previous papers (including his and Krumpe’s 2014 publication in *Monthly Notices of the Royal Astronomical Society*) confirmed that gaseous and dusty structures near accreting black holes can exist in various forms, such as discrete clouds—as opposed to a smooth-density distribution previously hypothesized. “However, we wanted to map out these structures in more detail by studying a sample of the most-absorbed accreting black holes,” said the CASS research scientist and affiliate of the Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences. “The (new) study reveals a diverse range of types and locations of clouds across various AGNs and their host galaxies.”

The study also confirmed that gas and dust in the host galaxy itself plays a critical role in how scientists study these AGN systems. “Our ability to measure the properties of gas and dust near the black hole has to be disentangled from the role of the host galaxy’s gas and dust at large distance scales,” Markowitz noted.

According to Laha, the significance of this finding is how it helps scientists better understand how the matter around the vicinity of the supermassive black hole is distributed, which is otherwise not observable to current generation telescopes due to the lack of spatial resolution. “This matter, in the form of high-density clumps and continuous media, is responsible for feeding the ‘monster’ black hole and thereby keeping the AGN ‘active’ and bright,” he said.



Artist’s illustration of the multiple locations where X-ray-absorbing gas resides in an "active" galaxy—including compact high-density clumps close to the black hole and large-scale dusty structures in the host galaxy, very far from the black hole. Image courtesy Laha (NASA/GSFC), et. al (2020).

Laha said that the most surprising result of the study was the finding that not all AGN show signatures of moving clouds along the line of sight on timescales of days – years, implying that the clouds may be distant or continuous, hence no variability. This means that the feeding nature of the giant black holes is not the same across different AGN.

As for their methodology, Markowitz said that compared to the X-ray telescope used in the 2014 study, the three X-ray telescopes in the 2020 study are more sensitive to smaller variations in density, allowing the scientists to detect smaller-density clouds.

“X-ray emission comes from some of the most energetic events very near the black holes and hence X-rays are the best probes of the ‘situation’ near the black hole. The accretion disk and the ‘corona’ emit in UV and X-rays, respectively, which comes to us directly,” explained Laha. “If there are clouds in the line of sight, then we see ‘dips’ in the incoming X-rays. These dips are measured carefully in the ‘spectra’ and then we investigate if these dips vary with time. If it varies with time, it means it’s moving across our line of sight. The variability timescale tells us the location of the clouds as they orbit the black hole.”

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