NASA's IXPE helps researchers maximize 'microquasar' findings

January 17 2024, by Beth Ridgeway

This composite image of the Manatee Nebula captures the jet emanating from SS 433, a black hole devouring material embedded in the supernova remnant which spawned it. Radio emissions from the remnant are blue-green, whereas X-rays combined from IXPE, XMM-Newton, and Chandra are highlighted in bright blue-purple and pinkish-white against a backdrop of infrared data in red. The black hole emits twin jets of matter traveling in opposite directions at nearly the speed of light, distorting the remnant's shape. The jets become bright about

100 light years away from the black hole, where particles are accelerated to very high energies by shocks within the jet. The IXPE data shows that the magnetic field, which plays a key role in how particles are accelerated, is aligned parallel to the jet—aiding our understanding of how astrophysical jets accelerate these particles to high energies. Credit: X-ray: (IXPE): NASA/MSFC/IXPE; (Chandra): NASA/CXC/SAO; (XMM): ESA/XMM-Newton; IR: NASA/JPL/Caltech/WISE; Radio: NRAO/AUI/NSF/VLA/B. Saxton. (IR/Radio image created with data from M. Goss, et al.); Image Processing: NASA/CXC/SAO/N. Wolk & K.Arcand

The powerful gravity fields of black holes can devour whole planets' worth of matter—often so violently that they expel streams of particles traveling near the speed of light in formations known as jets. Scientists understand that these high-speed jets can accelerate these particles, called cosmic rays, but little is definitively known about that process.

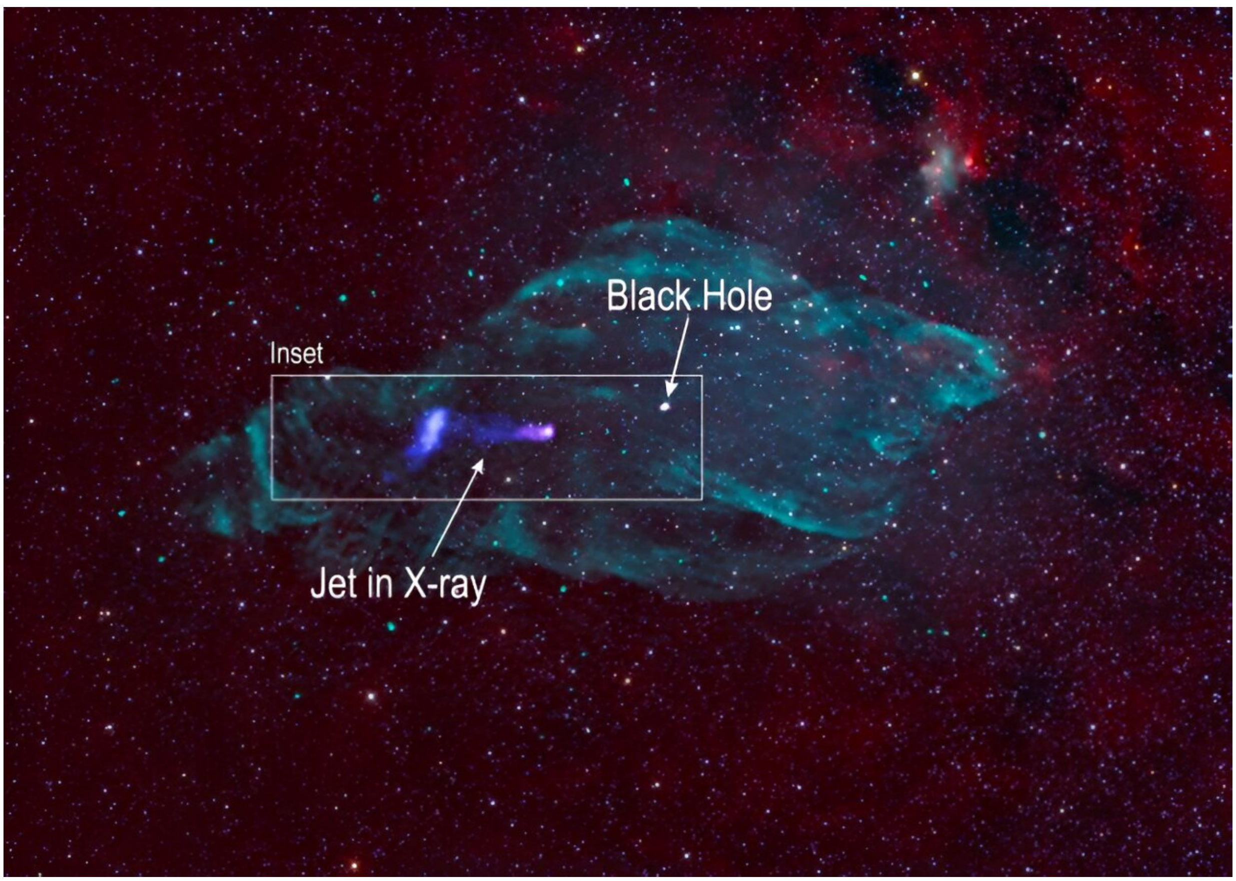
Recent findings by researchers using data from NASA's IXPE (Imaging X-ray Polarimetry Explorer) spacecraft give scientists new clues as to how particle acceleration happens in this extreme environment. The observations came from a "microquasar," a system comprised of a black hole siphoning off material from a companion star.

The new paper, detailing IXPE's observations at SS 433, is available in the latest edition of *The Astrophysical Journal*.

The microquasar in question—Stephenson and Sanduleak 433, or SS 433—sits in the center of the supernova remnant W50 in the constellation Aquila, some 18,000 light-years from Earth. SS 433's powerful jets, which distort the remnant's shape and earned it the nickname the "Manatee Nebula," have been clocked at roughly 26% of the speed of light, or more than 48,000 miles per second. Identified in the late 1970s, SS 433 is the first microquasar ever discovered.

IXPE's three onboard telescopes measure a special property of X-ray light called polarization, which tells scientists about the organization and alignment of electromagnetic waves at X-ray frequencies. X-ray polarization helps researchers understand the physical processes taking place within extreme regions of our universe such as the environment around black holes, and how particles get accelerated in these regions.

IXPE spent 18 days in April and May of 2023 studying one such acceleration site in the eastern lobe of SS 433, where emissions are made by energetic electrons spiraling in a magnetic field—a process called synchrotron radiation.



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"The IXPE data show that the magnetic field near the acceleration region points in the direction the jets are moving," said astrophysicist Philip Kaaret of NASA's Marshall Space Flight Center in Huntsville, Alabama, and principal investigator of the IXPE mission, along with lead author of a new paper about the findings at SS 433.

"The high level of polarization seen with IXPE shows that the magnetic field is well ordered, with at least half of the field aligned in the same direction," Kaaret said.

That finding was unexpected, he said. Researchers have long theorized that the interaction between the jet and the interstellar medium—the environment of gas and dust between stars—likely creates a shock, leading to disordered magnetic fields.

The data suggest a new possibility, Kaaret said—that the magnetic fields within the powerful jets may be "trapped" and stretched when they collide with interstellar matter, directly impacting their alignment in the region of particle acceleration.

Since the 1980s, researchers have surmised that SS 433's jets act as particle accelerators. In 2018, observers at the High-Altitude Water Cherenkov Observatory in Puebla, Mexico, verified the jets' acceleration effect, and scientists used NASA's NuSTAR (Nuclear Spectroscopic Telescope Array) and the European Space Agency's XMM-Newton observatories to pinpoint the region of acceleration.

As researchers continue to assess IXPE findings and study new targets in space, its data also could help determine whether the same mechanism acts to align magnetic fields in outflows expelled by a variety of phenomena—from black hole jets streaming away from supernova remnants to debris ejected from exploded stars such as blazars.

"This very delicate measurement was made possible by the imaging capabilities of IXPE's X-ray polarimeters, making possible the detection of the tenuous signal in a small region of the jet 95 light-years from the central black hole," said Paolo Soffitta, Italian principal investigator for the IXPE mission.

More information: Philip Kaaret et al, X-Ray Polarization of the Eastern Lobe of SS 433, *The Astrophysical Journal Letters* (2024). DOI: 10.3847/2041-8213/ad103b

Provided by NASA