Black hole 'batteries' keep blazars going and going (w/ Video)

June 3 2014, by Francis Reddy

(Phys.org) —Astronomers studying two classes of black-hole-powered galaxies monitored by NASA's Fermi Gamma-ray Space Telescope have found evidence that they represent different sides of the same cosmic coin. By unraveling how these objects, called blazars, are distributed throughout the universe, the scientists suggest that apparently distinctive properties defining each class more likely reflect a change in the way the galaxies extract energy from their central black holes.

"We can think of one blazar class as a gas-guzzling car and the other as an energy-efficient electric vehicle," said lead researcher Marco Ajello, an astrophysicist at Clemson University in South Carolina. "Our results suggest that we're actually seeing hybrids, which tap into the energy of their black holes in different ways as they age."

Active galaxies possess extraordinarily luminous cores powered by black holes containing millions or even billions of times the mass of the sun. As gas falls toward these supermassive black holes, it settles into an accretion disk and heats up. Near the brink of the black hole, through processes not yet well understood, some of the gas blasts out of the disk in jets moving in opposite directions at nearly the speed of light.

Blazars are the highest-energy type of active galaxy and emit light across the spectrum, from radio to gamma rays. They make up more than half of the discrete gamma-ray sources cataloged by Fermi's Large Area Telescope, which has detected more than 1,000 to date. Astronomers think blazars appear so intense because they happen to tip our way, bringing one jet nearly into our line of sight. Looking almost directly down the barrel of a particle jet moving near the speed of light, emissions from the jet and the region producing it dominate our view.

To be considered a blazar, an active galaxy must show either rapid changes in visible light on timescales as short as a few days, strong optical polarization, or glow brightly at radio wavelengths with a "flat spectrum"—that is, one exhibiting relatively little change in brightness among neighboring frequencies.

Astronomers have identified two models in the blazar line. One, known as flat-spectrum radio quasars (FSRQs), show strong emission from an active accretion disk, much higher luminosities, smaller black hole masses and lower particle acceleration in the jets. The other, called BL Lacs, are totally dominated by the jet emission, with the jet particles reaching much higher energy and the accretion disk emission either weak or absent.

Speaking at the American Astronomical Society meeting in Boston on Tuesday, Ajello said he and his team wanted to probe how the distribution of these objects changed over the course of cosmic history, but solid distance information for large numbers of gamma-ray-producing BL Lac objects was hard to come by.

"One of our most important tools for determining distance is the movement of spectral lines toward redder wavelengths as we look deeper into the cosmos," explained team member Dario Gasparrini, an astronomer at the Italian Space Agency's Science Data Center in Rome. "The weak disk emission from BL Lacs makes it extremely difficult to measure their redshift and therefore to establish a distance."

So the team undertook an extensive program of optical observations to measure the redshifts of BL Lac objects detected by Fermi.

"This project has taken several years and simply wouldn't have been possible without the extensive use of many ground-based observatories by our colleagues," said team member Roger Romani, an astrophysicist at the Kavli Institute for Particle Astrophysics and Cosmology, a facility run jointly by Stanford University and the SLAC National Accelerator Laboratory in Menlo Park, California.

The redshift survey included 25 nights on the Hobby-Eberly Telescope at McDonald Observatory in Texas, led by Romani; eight nights on the 200-inch telescope at Palomar Observatory and nine nights on the 10-meter Keck Telescope in Hawaii, led by Anthony Readhead at Caltech in Pasadena, California; and nine nights on telescopes at the European Southern Observatory in Chile, led by Garret Cotter at the University of Oxford in England. In addition, important observations were provided by the Chile-based GROND camera, led by Jochen Greiner at the Max Planck Institute for Extraterrestrial Physics in Garching, Germany, and the Ultraviolet/Optical Telescope on NASA's Swift satellite, led by Neil Gehrels at Goddard Space Flight Center in Greenbelt, Maryland.

With distances for about 200 BL Lacs in hand—the largest and most comprehensive sample available to date—the astronomers could compare their distribution across cosmic time with a similar sample of FSRQs. What emerged suggests that, starting around 5.6 billion years ago, FSRQs began to decline while BL Lacs underwent a steady increase in numbers. The rise is particularly noticeable among BL Lacs with the most extreme energies, which are known as high-synchrotron-peaked blazars based on a particular type of emission.

"What we think we're seeing here is a changeover from one style of extracting energy from the central black hole to another," adds Romani.

Large galaxies grew out of collisions and mergers with many smaller galaxies, and this process occurs with greater frequency as we look back in time. These collisions provided plentiful gas to the growing galaxy and kept the gas stirred up so it could more easily reach the central black hole, where it piled up into a vast, hot, and bright accretion disk like those seen in "gas-guzzling" FSRQs. Some of the gas near the hole powers a jet while the rest falls in and gradually increases the black hole's spin.

As the universe expands and the density of galaxies decreases, so do galaxy collisions and the fresh supply of gas they provide to the black hole. The accretion disk becomes depleted over time, but what's left is orbiting a faster-spinning and more massive black hole. These properties allow BL Lac objects to maintain a powerful jet even though relatively meager amounts of material are spiraling toward the black hole.

In effect, the energy of accretion from the galaxy's days as an FSRQ becomes stored in the increasing rotation and mass of its black hole, which acts much like a battery. When the gas-rich accretion disk all but disappears, the blazar taps into the black hole's stored energy that, despite a lower accretion rate, allows it to continue operating its particle jet and producing high-energy emissions as a BL Lac object.

One observational consequence of the hybrid blazar notion is that the luminosity of BL Lacs should decrease over time as the black hole loses energy and spins down.

The astronomers say they are eager to test this idea with larger blazar samples provided in part by Fermi's continuing all-sky survey. Understanding the details of this transition also will require better knowledge of the jet, the black hole mass and the galaxy environment for both blazar classes.

More information: Paper: "The Cosmic Evolution of Fermi BL Lacertae Objects" iopscience.iop.org/0004-637X/780/1/73

Provided by NASA