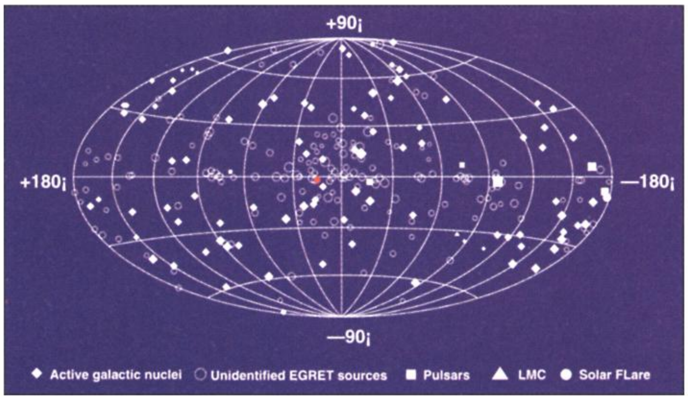
PERSPECTIVES: ASTRONOMY

A New Source of Gamma Rays

R. P. Fender

Relativistic outflows or "jets" are collimated streams of high-energy electrons that emit synchrotron radiation at radio wavelengths and have bulk velocities that are a substantial fraction of the speed of light. Jets have been known since Curtis observed a "curious straight ray" from the nucleus of the radio galaxy M87 in 1918. It is now clear that these jets trace the outflow of enormous amounts of energy and matter from a central supermassive black hole. The outflows are probably powered by the gravitational potential energy of the matter that crosses the event horizon and falls into the black hole; there may also be some contribution from the spin energy of the black hole if it is rapidly rotating.

It has become increasingly apparent in recent years that in addition to supermassive black holes at the centers of distant radio galaxies, there are many other sources of relativistic outflows on smaller scales, many of them within our own galaxy (*1*, *2*). Collimated structures from pulsars, supernova remnants, and gamma-ray bursts have all been attributed to powerful relativistic outflows.



Close association. The third EGRET catalog of high-energy (> 100 MeV) gamma-ray sources (*5*). The majority of the unidentified sources are clustered around the galactic plane and galactic center, indicating that they are located within our Milky Way. Indicated in red is the gamma-ray source that, according to Paredes *et al.* (*3*), is associated with a persistent, nearby x-ray binary.

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X-ray binaries offer the best opportunity for studying such jets at close range. In these systems, a neutron star or black hole captures mass from a more or less "normal" stellar binary companion. On page 2340 of this issue, Paredes *et al.* (*3*) report the discovery of a persistent relativistic outflow from a nearby, relatively faint x-ray binary and present a strong case for its association with a persistent high-energy gamma-ray source. The discovery that such persistent "microquasars" are common and may be associated with strong gamma-ray sources within our own galaxy is important for understanding the flow of material around collapsed relativistic objects such as neutron stars and black holes and the feedback of energy into the interstellar medium in the Milky Way and other galaxies.

The source investigated by Paredes *et al.*, LS 5039, is an x-ray binary system that probably lies at a distance of 2 to 3 kiloparsecs—closer than the galactic center and relatively nearby on an astronomical scale. Using very long baseline interferometry at a wavelength of 6 centimeters, the authors have resolved the radio emission into a jetlike outflow. Jet emission is likely to occur by a synchrotron mechanism, similar to particle accelerators on Earth. This means that the jet must contain a large number of hyper-relativistic electrons spiraling in a relatively strong magnetic field (compared with that in the ambient interstellar medium). Furthermore, simple arguments presented in the report show that the jet is likely to have a bulk outflow velocity greater than 20% of the speed of light. The accreting neutron star or black hole is thus accelerating electrons to extreme energies and then kicking them away from the system, probably in the form of collimated jets, at extremely high velocities. As the emitted synchoton radiation is dominated by the lighter, and hotter, electrons, it is only these particles that we can directly observe. However, we can assume that to maintain charge neutrality, strictly observed in the macroscopic universe, each electron has an associated proton (alternatively, the jet could be composed of electron:positron pairs and would ultimately be a source of annihilation radiation).

If there is indeed one proton for each electron, then the jet power, dominated by the kinetic energy of the flow, exceeds the observed x-ray luminosity by two to three orders of magnitude. This is reminiscent of the famous galactic source SS433 (*4*), which is a source of an enormous outpouring of energy in the form of continuous radio jets but only a relatively modest x-ray source. It has been generally accepted for more than 30 years that x-rays are the signature of high rates of accretion onto neutron stars and stellar mass black holes, but perhaps we are missing an entire population of accreting objects whose main power output channel is a relativistic jet.

It is perhaps even more intriguing that LS 5039 is the only x-ray source within this region of the sky that contains a persistent gamma-ray source, 3EG J1824-1514. The latter is one of 271 gamma-ray sources (see the figure) detected by the Energetic Gamma-Ray Experiment Telescope (EGRET) instrument onboard the recently deceased Compton Gamma-Ray Observatory (*5*) (the observatory was re-entered over the Pacific by NASA in the first week of June, after the loss of an onboard gyro). Most of these x-ray sources remain unidentified, but the overwhelming majority of those for which there are confident identifications are powerful distant radio galaxies called blazars (there are also a handful of pulsars and one solar flare). In blazars, the gamma rays are believed to originate in relativistic jets powered by a supermassive black hole. The probable association of one of these sources with a relatively nearby, apparently unspectacular x-ray binary system seems to open up the possibility that some of the unidentified EGRET sources may also be associated with relativistic jets, this time localized within our own galaxy.

The observations reported by Paredes *et al.* (*3*) demonstrate that strong x-ray emission is not the sole key signature of accretion at high rates onto black holes and neutron stars within our galaxy. The relatively unspectacular nature of the source at optical and x-ray wavelengths indicates that it may be just one of a large population of such objects that have previously been overlooked. The probable association with the gamma-ray source further demonstrates that a population of sources such as LS 5039 may well be a substantial, if not dominant, source of high-energy particles and photons produced within our galaxy.

References

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The author is in the Astronomical Institute 'Anton Pannekoek,' University of Amsterdam, Kruislaan 403, Amsterdam 1098 SJ, Netherlands. E-mail: rpf@astro.uva.nl