

Astrowatch

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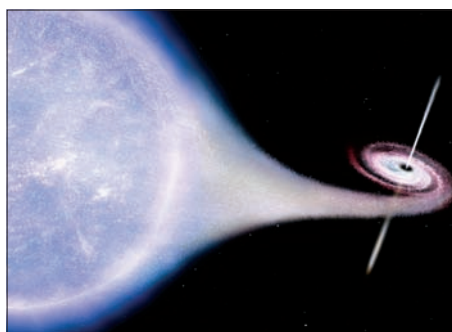
INTEGRAL sees gamma rays from black-hole jets

A detailed analysis of observations of Cygnus X-1 by ESA's International Gamma-ray Astronomical Laboratory (INTEGRAL) has found strongly polarized gamma-ray emission. The polarization suggests that the highest-energy emission from this famous galactic binary is emitted by the jets ejected by the black hole.

Discovered in 1964 with an X-ray sensitive rocket, Cygnus X-1 is the first Galactic binary system for which strong evidence for a black hole was found in the early 1970s. About 7000 light-years away in the Cygnus constellation, the black hole of about 10 solar-masses orbits a blue supergiant star of 35 times the mass of the Sun. This heavy stellar couple is tightly bound. Its separation is five times smaller than the Sun–Earth distance – close enough for the black hole to strip away some of the gas from the outer layers of the star.

The stolen gas falls onto the black hole and forms an accretion disc. Swirling up to relativistic velocities, the plasma in the inner disc is frictionally heated to millions of degrees, thus emitting X-rays. While some of the material will fall inside the event horizon of the black hole, a significant part may escape by following the lines of magnetic field generated by the accretion disc. Evidence of this process comes from the observation of two opposite radio jets, which are presumably ejected on both sides of the disc. This property makes Cygnus X-1 a “microquasar”, which is a Galactic scaled-down version of the massive black holes that power the nuclei of active galaxies.

Cygnus X-1 was the target of



An artist's impression of the Cygnus X-1 binary system. Gas from the blue giant star spirals into the black hole but a small fraction is diverted by magnetic fields into two opposite jets. (Image credit: ESA.)

INTEGRAL's first-light observation in November 2002. It has since been the subject of several studies, adding up to about two months of exposure time. Philippe Laurent of the Astroparticles and Cosmology (APC) centre in Paris and colleagues from Europe and the US searched for a polarized signal in this huge dataset.

The study of gamma-ray polarization requires non-standard analysis of the data. A successful technique was developed for the spectrometer of INTEGRAL, allowing the polarized radiation from the Crab Nebula to be measured (*CERN Courier* November 2008 p11). The current study instead uses the main imaging instrument and selects photons that happen to interact with both of its detector layers. Indeed, gamma rays with energies above around 250 keV can Compton-scatter on electrons in the upper

layer and be deflected towards the second layer below. Because the Compton scattering angle depends on the polarization direction of the incident photon, it is therefore possible to measure the polarization properties of the incoming radiation.

Laurent and his team found a strong polarization fraction of $67 \pm 30\%$ for gamma rays at the highest detected energies in the 400–2000 keV range. The polarization is much lower in the 250–400 keV band, with an upper-limit of 20%. Spectroscopically, the polarized signal can be attributed to a power-law emission that starts to dominate a thermal-emission component just around 400 keV. A coherent magnetic field is needed to account for the observed polarization and this suggests a jet origin for the high-energy gamma rays.

The authors of the paper published by *Science* cannot distinguish between a synchrotron or an inverse-Compton origin for this polarized emission component. Synchrotron emission would imply electrons with energies around a few tera-electronvolts, which could then also account – via inverse-Compton scattering – for the tera-electron-volt photons detected from Cygnus X-1 by the MAGIC Cherenkov telescope in September 2006. An alternative, inverse-Compton scenario would correspond to the gamma-ray emission process in the neighbouring microquasar, Cygnus X-3 (*CERN Courier* January/February 2010 p11).

● Further reading

P Laurent *et al.* 2011 *Science Express*, doi: 10.1126/science.1200848.

Picture of the month

No, this is not a virus or a jellyfish. Instead it is an amazing image of Tycho's supernova remnant (SNR). The very deep view by NASA's Chandra X-ray Telescope shows the detailed structure of gas, glowing in X-rays, from the supernova witnessed in 1572 by the famous Danish astronomer Tycho Brahe. This explosion of a white-dwarf star was so bright that it could even be seen during the day. In this image, lower- and higher-energy X-rays are colour coded in red and blue, respectively, and are shown on a starry background from the Digital Sky Survey. The blue-coded image contains a pattern of stripes never seen before in other SNRs (*CERN Courier* October 2004 p19, December 2004 p15 and January/February 2011 p11). The spacing of two stripes was found to correspond to a gyromagnetic-radius of a proton of 10^{15} eV, the “knee” energy of the cosmic-ray spectrum. (Image credit: X-ray, NASA/CXC/Rutgers/K Eriksen *et al.*; optical, DSS.)

