

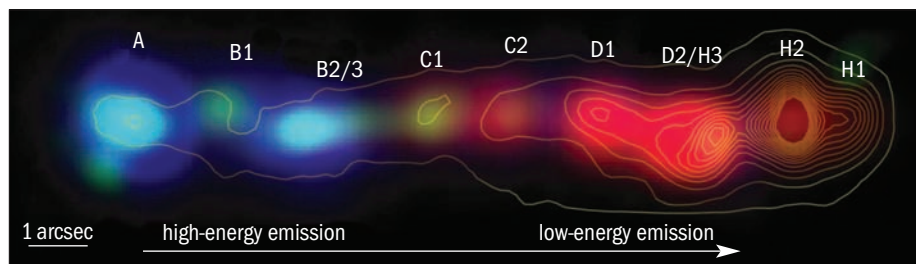
Quasar jets could be powerful accelerators

Infrared observations of the quasar 3C 273 by the Spitzer Space Telescope are giving new insight into the physics at play in its large-scale jet. The new images, combined with complementary radio, optical and X-ray observations, reveal two distinct spectral components. There is evidence that the component emitting X-rays is also producing synchrotron radiation, implying that ultra-energetic particles are continually accelerated all along the jet.

Back in 1963, 3C 273, an apparently faint star with associated radio emission, was found to be at a cosmological distance (redshift of 0.158). This implied that this “quasi-star” – the first identified quasar – was about 100 000 billion times more luminous than the Sun. It is also the brightest of this class of extreme active galactic nuclei, which completely outshine their host galaxies. At the time of discovery, deep optical images of 3C 273 revealed a faint jet with an extension of about 100 000 light-years ending at the exact position of a second radio source.

More than 40 years later, the detailed structure of this jet has been studied by NASA’s three great observatories: in visible and ultraviolet light by the Hubble Space Telescope, in X-rays by the Chandra Observatory and now also in the infrared by the Spitzer Space Telescope. This, together with radio observations by the Very Large Array (VLA), enables this powerful jet to be studied across the whole electromagnetic spectrum.

A team led by Y Uchiyama at Yale University has now shown that the overall spectrum of



Composite image of the jet of 3C 273 made from images in infrared (shown as red) and visible (green) obtained by the Spitzer and Hubble space telescopes, and in X-rays (blue) by the Chandra satellite. The superimposed radio-map contours are from the VLA. Letters label the main structures along the jet; knot A is closest to the quasar (Y Uchiyama et al.).

individual bright features in the jet contains two distinct spectral components. The first component extends from the radio to the infrared and the second becomes dominant in the visible up to the X-rays. While the low-energy component is undoubtedly of synchrotron origin (electron radiation in a magnetic field), the nature of the second component is uncertain.

The strong X-ray emission of quasar jets detected by Chandra was thought to be due to inverse-Compton radiation produced by electrons scattering off the cosmic microwave background (CMB) photons. This model requires a strong bulk velocity of the jet flow to enhance relativistically the CMB photon field as seen from the electrons. The new finding that the visible ultraviolet emission is apparently related to the X-ray spectral component adds additional constraints to this model, which conflicts with the observed radio and optical polarization.

It now seems more likely that the high-energy component is also of a synchrotron nature. This would require a distinct electron acceleration process all along the jet, which could occur in a region of velocity shear between a central spine of the jet flow and an outer sheath, as suggested by S Jester at Fermilab and collaborators. In such conditions, according to Uchiyama et al., ultra-high-energy protons could also be accelerated to energies up to 10^{19} eV enabling proton-synchrotron X-ray emission. This would mean that quasar jets are powerful particle accelerators producing extragalactic cosmic-ray protons with energies of 10^{16} – 10^{19} eV.

Further reading

S Jester et al. (in press) *Astrophysical Journal* <http://arxiv.org/abs/astro-ph/0605529>.

Y Uchiyama et al. (in press) *Astrophysical Journal* <http://arxiv.org/abs/astro-ph/0605530>.

Picture of the month



Several tens of globular clusters are orbiting our galaxy. The second in size and brightness is 47 Tucanae, visible to the naked eye in the southern sky near the Small Magellanic Cloud. This beautiful image from the Very Large Telescope (VLT) shows the central parts of this spherical cluster of several tens of thousands of stars held together by mutual gravity. The stars are all thought to be born at the same time from the same cloud of gas. 47 Tucanae is so dense that stars are less than 0.1 light-years apart, which is about the size of the solar system. (Courtesy ESO.)