

Fermi limits the intergalactic magnetic field

Astronomers have found evidence that the magnetic field between galaxies cannot be negligible. Otherwise, a blazar observed by the High Energy Stereoscopic System (HESS, *CERN Courier* January/February 2005 p30) at tera-electron-volt (TeV) energies should also have been detected by the Fermi Gamma-Ray Space Telescope in the giga-electron-volt (GeV) range (*CERN Courier* November 2008 p13). The non-detection by Fermi sets a lower limit of the order of 10^{-19} T on the magnetic field strength in intergalactic space, which is consistent with a cosmological origin of the field.

In the universe, the bigger the object, the weaker its magnetic field. The strongest fields are found around magnetars, neutron stars with a field of up to 10^{11} T (*CERN Courier* June 2005 p12). The Earth, being almost 1000 times larger than a neutron star has a modest field of 10^{-4} T, and the Milky Way's field is again about 20 000 times less, even at its centre. Measuring the extremely low magnetic field of intergalactic space – away from any galaxy – is very challenging. Until now, only upper-limits could be set, but thanks to Fermi's observations, the situation is changing. Two recent, independent papers give a lower-limit of the magnetic field based on very high-energy observations of the blazar 1ES 0229+200. Andrii Neronov and Ievgen Vovk from the ISDC data centre of the University of Geneva constrain the field to be higher than 3×10^{-20} T, while Fabrizio Tavecchio and colleagues from the Observatory of Brera, Italy, derive a lower



An artist's rendering of a blazar, a type of active galaxy where the powerful jet of plasma beams directly towards Earth. (Courtesy NASA/Goddard Space Flight Center Conceptual Image Lab.)

limit of 5×10^{-19} T. The difference comes from differing analyses and assumptions, but both studies are based on the same dataset and the same argument.

The blazar – a powerful jet source in a distant galaxy – emits gamma-rays at TeV energies in a narrow cone that happens to be pointing towards the Earth. Along their journey, some of the gamma-rays interact with the optical-infrared background light to produce electron-positron pairs (*CERN Courier* June 2006 p14). These pairs will then rapidly cool on photons of the cosmic microwave background and Compton scatter them to GeV energies. The strength of the intergalactic magnetic field can have an influence on the intensity of the GeV photons observed by Fermi. A weak

field will not significantly deflect electrons and positrons and hence the GeV photons will be predominantly emitted in the same direction as the primary TeV photons, whereas a strong field will result in an isotropically distributed GeV emission, which will then be undetectable by Fermi. The measurement of the TeV spectrum of the blazar by HESS, together with the upper limit on the GeV emission from the source direction set by Fermi, thus results in the determination of a lower limit on the magnetic field.

This very indirect determination is subject to many uncertainties, in particular on the opening angle of the jet emission, the intrinsic spectrum of the blazar and the intensity of the optical-infrared background light. Nevertheless, the estimated magnetic field is strong enough to favour a “top-down” scenario for its origin. The idea is that the accretion of matter within stars and galaxies amplifies a preexisting magnetic field that permeates the universe and would have been produced soon after the Big Bang. The alternative “bottom-up” scenario, where the magnetic fields are first produced in stars and then propagate outwards to galaxies and eventually intergalactic space, is disfavoured. This is good news for cosmologists because the field might help to identify and constrain processes at work in the very early universe.

Further reading:

A Neronov & I Vovk 2010 *Science* **328** 73.
F Tavecchio *et al.* 2010 *MNRAS* submitted
<http://arxiv.org/abs/1004.1329>.

Picture of the month



“Mystic mountains” is the name given to this spectacular cosmic landscape released to celebrate the 20th anniversary of Hubble's launch and deployment into orbit around Earth. The scene might look familiar to you because it was already shown in this column (*CERN Courier* June 2007 p12), but it looks even more dramatic with the new colour rendering. The pillar of gas and dust, three light-years tall, is eroded from outside by the brilliant light from nearby bright stars, as in the famous “pillars of creation” in the Eagle Nebula (*CERN Courier* June 2005 p12 and March 2007 p11). But here, the assault comes also from inside with infant stars firing off jets of gas that can be seen streaming from towering peaks. The turbulent cosmic pinnacle lies within the Carina Nebula, a stellar nursery some 7500 light-years away, where the giant star Eta Carinae came to birth (*CERN Courier* July/August 2008 p12). (Courtesy NASA/ESA/M Livio & Hubble 20th Anniversary Team (STScI).)