

Astrowatch

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Gamma-ray observations constrain dark matter

Dark matter remains dark. The Fermi Gamma-ray Space Telescope could not detect an annihilation signal from dark-matter reservoirs in nearby dwarf galaxies. This nonetheless constrains the properties of candidate dark-matter particles. The results exclude for the first time weakly interacting massive particles (WIMPs) within a specific range of masses and interaction rates.

That 80 per cent of the matter content in the universe is invisible makes it one of the challenges of modern physics and astronomy. Looking at different wavelengths does not help because the elusive matter seems neither to emit nor absorb electromagnetic radiation. Yet, its gravitational influence is manifest in the orbital speeds of stars inside galaxies and in shaping the structure of clusters of galaxies. The mystery is compounded by the lack of clues as to what this dark matter actually is. It must be non-baryonic – that is, not made of ordinary matter, essentially protons and neutrons – which suggests a new kind of subatomic particle. A favoured class of dark-matter candidates consists of WIMPs, which are presumed not to interact with normal matter or radiation, except through gravitation, but which could mutually annihilate to produce gamma rays. Such a weak-scale annihilation has the advantage that it accounts naturally for the observed cosmological density of dark matter – and this is the prime motivation for favouring WIMP dark matter.

NASA's Fermi satellite is well suited to look for a WIMP-annihilation signal. Launched on 11 June 2008, its payload includes the Large Area Telescope (LAT), which scans the whole sky every three hours in the 100 MeV to 300 GeV energy range



This dwarf spheroidal galaxy, in the constellation Fornax, is a satellite of the Milky Way and one of those included in Fermi's dark-matter search. The presence of dark matter is inferred from the motion of the stars in the galaxy. (Image credit: ESO/Digital Sky Survey 2.)

(CERN Courier November 2008 p13). A prime target to look for signs of WIMP annihilation are dwarf spheroidal galaxies. These small galaxies orbit the Milky Way and are characterized by a high ratio of dark to normal matter. Their stellar population is old, making them unlikely to contain supernova remnants or pulsars emitting contaminating gamma rays; they can also be selected at locations in the sky that avoid the gamma-ray-bright Galactic plane.

The Fermi-LAT collaboration has made a study of the gamma-ray emission of dwarf spheroidal galaxies observed over two years and published results based on a joint likelihood analysis that evaluates all of the galaxies at once without merging the data (Ackermann *et al.* 2012). The study also accounts for uncertainties in the actual distribution of dark matter inside the galaxies. The results yield no evidence of a gamma-ray signal from dark matter and thus

can strongly constrain the cross-section for dark-matter particle annihilation.

Specifically, the study strongly disfavours the existence of WIMPs with the most generic velocity-averaged cross-section ($3 \times 10^{-26} \text{ cm}^3 \text{ s}^{-1}$ for a purely s-wave annihilation cross-section) and masses less than around 30 GeV. A lower cross-section would imply too high a cosmological density of dark matter, whereas a higher cross-section would result in a significant detection of gamma rays. The effective exclusion of the less massive WIMP candidates is confirmed by an independent study reported in the same issue of *Physical Review Letters*. Authored by Alex Geringer-Sameth and Savvas Koushiappas of Brown University, Rhode Island, the second analysis uses another set of Fermi-LAT data and a different statistical method and treatment of the background.

The limits presented in these two papers are among the strongest dark-matter limits obtained to date and suggest that Fermi-LAT has the potential either to discover the WIMP-annihilation signal from dwarf spheroidal galaxies or to rule out that dark matter is made of WIMPs. The next step is the inclusion of more recent gamma-ray measurements that extend to higher energies with an improved LAT sensitivity. It will be interesting to see whether the forthcoming study leads to a further decisive push towards higher energies of the allowed range of WIMP masses, or to a historic discovery.

● Further reading

M Ackermann *et al.* The Fermi-LAT collaboration 2011 *Phys. Rev. Lett.* **107** 241302.

A Geringer-Sameth and S M Koushiappas 2011 *Phys. Rev. Lett.* **107** 241303.

Picture of the month

This image from the NASA/ESA Hubble Space Telescope reveals the globular cluster Messier 9 (M9) in unprecedented detail. M9 is one out of 29 globular clusters included in the Messier catalogue of 110 nebulae and star clusters. The French astronomer Charles Messier could certainly not have even dreamt of such an image when he discovered and catalogued this “nebula without star” on 28 May 1764. It was only later in the 18th century that astronomers, notably William Herschel, began to spot stars within the cluster. Hubble's image now resolves about 250,000 stars, even right into the crowded centre of the cluster. The study of the brightness of the stars together with their colours – indicating different surface temperatures – allows astronomers to estimate their age. Stars in M9 have about twice the age of the Sun and are thus among the oldest stars in the Galaxy, born when the universe was only a small fraction of its current age. (Image credit: NASA/ESA.)

