WHAT'S HOT IN... PHYSICS, march/april 2010

Gran Sasso Search for WIMPs Draws a Blank

by Simon Mitton

PDF

It is rare for a negative result in a physics experiment to produce a high-flying paper for the Top Ten, but that's precisely what has happened this period, with #9, reporting no contact in a dark matter search conducted at Italy's Gran Sasso National Laboratory (LNGS). This paper is of great importance to both particle physics and cosmology because it constrains the assumed particle physics properties of the dark matter candidates required for cosmology.

Dark matter in the universe has been a problem for decades. In 1937 Fritz Zwicky, an astronomer at Caltech, published a paper about the masses of galaxies. He asserted that invisible dark matter (cool stars, cold dust) outweighed visible matter (stars) by a factor of up to 100. His paper had zero impact, possibly because Zwicky was a cantankerous maverick. His paper received just one citation in the 20 years following publication, yet in 2009 it scored 29 hits. Clearly, research on dark matter has changed a lot in 70 years. The citation rate of Zwicky's classic shows how interest has exploded.

A big change in how dark matter is perceived can be tracked by looking at answers to the following question: What is dark matter? Zwicky speculated that it was ordinary matter that was too cold to emit of light. In the 1970s cosmologists still clung onto baryonic matter, in the shape of neutron stars and stellar-mass black holes. The consensus today, however, is that dark matter must be non-baryonic material, and this takes particle physics beyond the standard model into the realm of supersymmetry.

Right now, dark matter candidates include weakly interacting massive particles, or WIMPs, exotic relics of the Big Bang. The hypothesis is that WIMPs engage with ordinary matter through the weak interaction (one of the four forces of physics), which would enable them to transfer kinetic energy to baryonic matter in nuclear recoils from atomic nuclei. The principle underlying the search described in #9 is to detect such recoils. Clearly such an experiment can only be expected to work if the detector is shielded from cosmic rays. That's where Gran Sasso, or LNGS, comes into play.

LNGS is the largest underground laboratory in the world for experiments in particle astrophysics. The facility has three experimental halls, hacked out of the Gran Sasso Mountain, 120 km from Rome. Above these chambers, 1400 m of dolomite rock reduces the cosmic ray flux to 10-6 of the surface flux. Currently the facility houses 15 experiments, one being XENON10, which is dedicated to the direct detection of dark matter by looking at the low energy recoils of Xe nuclei when zapped by WIMPs.

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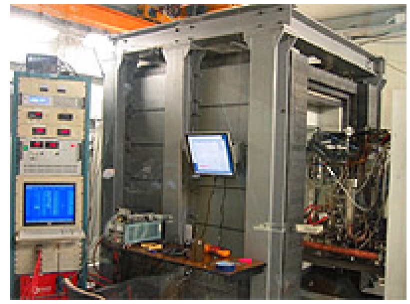

The XENON10 detector in operation, with some of the control displays, July 2006.

View the XENON10 Picture Gallery from the XENON Dark Matter Project.

In paper #9, lead author Jesse Angle and colleagues from the XENON10 consortium describe their experimental set-up: liquid Xe at –93 degrees C provides the target. Detection of a collision between dark matter and Xe nuclei is achieved by photomultiplier tubes, which are sensitive to scintillation in the liquid Xe. Their technique is long established in particle physics: detect and measure by scintillation the energy released in collision, using a protocol to eliminate background events due to cosmic rays and radioactive decay from local sources (dolomite rock contains very little U and Th, which helps). The Nevis Laboratory at Columbia University designed and built the detector.

An analysis of 58.6 live days of WIMP search data from XENON10 produced only 10 events in the WIMP-search window. However a careful analysis of these candidate events led the team to the conclusion that they had detected no WIMP interactions. This negative result has a positive outcome: it impacts on the parameter space for the minimal supersymmetric models of particle physics. That’s because previously unexplored parameter space is eliminated, setting new limits on the cross-section for WIMP-nucleon interaction.

The situation in consensus cosmology is unchanged by this LNGS result. Around 23% of the universe is non-baryonic dark matter, about which we know nothing apart from the effect of its mass on the dynamics of the universe. Paper #9, which describes just one of many ongoing direct detection attempts, is highly cited partly because it shows that detectors based on liquid Xe are improving rapidly, and they are catching up on the cryogenic experiments. But another underground facility will soon be on the case: the Large Hadron Collider…

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Physics Top 10 Papers

Rank	Paper	Citations This Period (Sep-Oct 09)	Rank Last Period (Jul-Aug 09)
1	E. Komatsu, *et al.*, **" Five-year *Wilkinson Microwave Anisotropy Probe* observations: Cosmological interpretation,"** *Astrophys. J. Suppl. Ser.*, 180(2): 330-76, February 2009. [14 institutions worldwide] *406EI	156	1

2	J. Dunkley, *et al.*, **"Five-year *Wilkinson Microwave Anisotropy Probe* observations: Likelihoods and parameters from the *WMAP* data,"** *Astrophys. J. Suppl. Ser.*, 180(2): 306-29, February 2009. [14 U.S. and Canadian institutions] *406EI	75	4
3	O. Adriani, *et al.*, **"An anomalous positron abundance in cosmic rays with energies 1.5-100 GeV,"** *Nature*, 458(7238): 607-9, 2 April 2009. [17 institutions worldwide] *427RK	68	8
4	X.H. Chen, *et al.*, **"Superconductivity at 43K in $SmFeAsO_{1-x}F_x$,"** *Nature*, 453(7196): 761-2, 5 June 2008. [U. Sci. & Tech., Hefei, China] *308UK	51	2
5	Z.A. Ren, *et al.*, **"Superconductivity at 55 K in iron-based F-doped layered quaternary compound $Sm[O_{1-x}F_x]FeAs$,"** *Chinese Phys. Lett.*, 25(6): 2215-6, June 2008. [Chinese Acad. Sci, Beijing] *306MN	37	3
6	J.K. Adelman-McCarthy, *et al.*, **"The Sixth Data Release of the Sloan Digital Sky Survey,"** *Astrophys. J. Suppl. Ser.*, 175(2): 297-313, April 2008. [84 institutions worldwide] *327WN	35	†
7	O. Aharony, *et al.*, **"N = 6 superconformal Chern-Simons-matter theories, M2-branes and their gravity duals,"** *J. High Energy Phys.*, 10: no. 091, October 2008. [Weizmann Inst., Rehovot, Israel; Inst. Adv. Study, Princeton, NJ; Technion, Haifa, Israel; Rutgers U., Piscataway, NJ] *370JT	34	†
8	M. Kowalski, *et al.*, **"Improved cosmological constraints from new, old, and combined supernova data sets,"** *Astrophys. J.*, 686(2): 749-78, 20 October 2008. [41 institutions worldwide] *364YB	32	9
9	J. Angle, *et al.*, **"First results of the XENON10 dark matter experiment at the Gran Sasso National Laboratory,"** *Phys. Rev. Lett.*, 1(2): no. 021303, 18 January 2008. [11 U.S. and European institutions] *252UD	31	†
10	F.-C. Hsu, *et al.*, **"Superconductivity in the PbO-type structure alpha-FeSe,"** *PNAS*, 105(38): 14262-4, 23 September 2008. [Acad. Sinica, Taipei, Taiwan; Natl. Tsing Hua U., Hsinchu, Taiwan; Duke U., Durham, NC] *353TY	29	5

SOURCE: Thomson Reuters Hot Papers Database. Read the Legend.

KEYWORDS: Dark matter, cosmology, weakly interacting massive particles, WIMPs, XENON10, Gran Sasso National Laboratory, Fritz Zwicky.