New data from XENON100 narrows the possible range for dark matter

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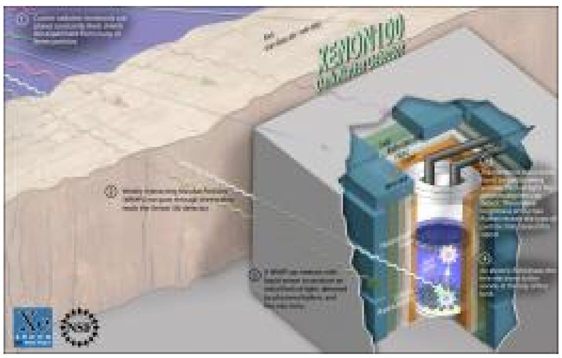

1) The surface of the Earth is constantly bombarded by cosmic radiation. Only the most energetic particles penetrate the rock, so detectors aiming to "see" the rare signal from cosmic Dark Matter are placed beneath the Earth. 2) Dark Matter in the form of Weakly Interacting Massive Particles (WIMPs) can traverse the Earth without interacting with it to reach XENON100, a detector filled with liquid xenon that is designed to be sensitive to such rare encounters. 3) A WIMP interaction in the liquid xenon will excite atoms and free electrons, which will be picked up again swiftly by the atoms. Both processes produce a flash of light that can be detected by photomultipliers, which act as extremely sensitive cameras, at each end of the tank. 4) An electric field running through the detector prevents some of the electrons from recombining with the xenon atoms. These free electrons are pushed upwards towards the anode, an electrode through which electric current flows, until they reach the liquid-to-gas interface. 5) At the interface, a stronger electric field pulls the electrons out of the liquid into the gas, where they create another flash of light that is detected by the same photomultipliers. The brightness of this second flash compared with the first one reveals the type of particle that caused the signal.Credit: Zina Deretsky, National Science Foundation

(PhysOrg.com) -- An International team of scientists in the XENON collaboration, including several from the Weizmann Institute, announced on Thursday the results of their search for the elusive component of our universe known as dark matter. This search was conducted with greater sensitivity than ever before. After one hundred days of data collection in the XENON100 experiment, carried out deep underground at the Gran Sasso National Laboratory of the INFN, in Italy, they found no evidence for the existence of Weakly Interacting Massive Particles – or WIMPs – the leading candidates for the mysterious dark matter. The three candidate events they observed were consistent with two they expected to see from background radiation. These new results reveal the highest sensitivity reported as yet by any dark matter experiment, while placing the strongest constraints on new physics models for particles of dark matter. Weizmann Institute professors Eilam Gross, Ehud Duchovni and Amos Breskin, and the research student Ofer Vitells, made significant contributions to the findings by introducing a new statistical method that both increases the search sensitivity and enables new discovery.

Any direct observation of WIMP activity would link the largest observed structures in the Universe with the world of subatomic particle physics. While such detection cannot be claimed as yet, the level of sensitivity achieved by the XENON100 experiment could be high enough to allow an actual detection in the near future. What sets XENON100 apart from competing experiments is its significantly lower background radiation The XENON100 detector, which uses 62 kg of liquid xenon as its WIMP target, and which measures tiny charges and light signals produced by predicted rare collisions between WIMPs and xenon atoms, continues its search for WIMPs. New data from the 2011 run, as well as the plan to build a much larger experiment in the coming years, promise an exciting decade in the search for the solution to one of nature's most fundamental mysteries.

Dark matter has so far foiled most means of detection, but researchers are *continuing to pursue its mysteries. They're using the most sensitive detector yet, called Xenon100, to try to glimpse the particles. See how it works in this video. Credit: National Science Foundation*

Cosmological observations consistently point to a picture of our universe in which the ordinary matter we know makes up only 17% of all matter; the rest – 83% – is in an as yet unobserved form – so-called dark matter. This complies with predictions of the smallest scales; necessary extensions of the Standard Model of particle physics suggest that exotic new particles exist, and these are perfect dark matter candidates. Weakly Interacting Massive Particles (WIMPs) are thus implied in both cosmology and particle physics. An additional hint for their existence lies in the fact that the calculated abundance of such particles arising from the Big Bang matches the required amount of dark matter. The search for WIMPs is thus well-founded; a direct detection of such particles would provide the central missing piece needed to confirm this new picture of our Universe.

The properties of dark matter have been addressed through a variety of approaches and methods; these have provided the scientists with indirect hints of what to search for. WIMPs are expected to have a mass comparable to that of atomic nuclei, with a very low probability of interacting with normal matter. Such particles are thought be distributed in an enormous cloud surrounding the visible disk of the Milky Way. Earth is moving through this cloud, along with the Sun, on its journey around the Galaxy center. This movement results in a 'WIMP wind,' which may occasionally scatter off atomic nuclei in an Earth-bound detector, releasing a tiny amount of energy, which can then be detected with ultra- sensitive devices.

In the XENON100 experiment, 62 kg of liquid xenon acts as a WIMP target. The liquid, at a temperature of about -90° C, is contained in a stainless steel cryostat equipped with a cryo-cooler to maintain highly stable operating conditions. The experiment is located in the Gran Sasso Underground Laboratory (LNGS) in Italy where it is shielded from cosmic radiation by 1400 meters of rock. Further shielding from radioactivity in the detector itself and its surroundings is provided by layers of active and passive absorbers surrounding the target. These include 100 kg of active liquid xenon scintillator, 2 tons of ultra-pure copper, 1.6 tons of polyethylene and 34 tons of lead and water. The radio-pure materials used to produce the detector components assure an ultra-low background radiation environment.

Particles interacting within the active liquid xenon space excite and ionize atoms. This results in light emission in the deep ultraviolet. As electrons drift across the liquid xenon, they create a delayed, luminescent signal on the top of the detector, due to the experiment's strong electric field. Both primary and secondary scintillation light signals are detected via two arrays of photosensors – one located in the liquid xenon at the bottom, and one in the gas above the liquid (Figure 1). The simultaneous measurement of these two light signals enables the researchers to infer both the energy and the spatial coordinates of the particles' interaction, while providing information on their nature. This analysis of ratio of the two light signals and their precise localization in space is an extremely accurate method of distinguishing WIMP signals from background events.

Many of technologies and methods used in the XENON100 experiment have been built on the research and development efforts of the XENON Dark Matter Search program, which produced, in 2006, the XENON10 prototype. For XENON100, a ten-fold increase in fiducial target mass, combined with 100-fold reduction in background, translates into a substantial improvement in sensitivity to WIMP-nucleon elastic scattering. An extensive calibration using various sources of gammas and neutrons was performed to demonstrate that XENON100 reached its goals for sensitivity and for low background radiation.

Results from a preliminary analysis from11.2 days worth of data, taken during the experiment's commissioning phase in October and November 2009, have already set new upper limits on the interaction rate of WIMPs – the world's best for WIMP masses below about 80 times the mass of a proton (Physical Review Letters 105 (2010) 131302).

A new dark matter search was performed between January and June, 2010, and 100 days worth of data from this run have been analyzed. Three candidate events were found within the pre-defined parameters in which the WIMP signal is expected to appear. However, these events, while coming from true particle interactions in the detector, are consistent with predictions of two such events resulting from radioactive backgrounds. Thus evidence for dark matter cannot be claimed, but a new upper limit for the strength of its interaction with normal matter could be calculated. These results represent the best limits to date. They narrow the possibilities open to supersymmetric particle physics theories that predict the nature of dark matter.

XENON100 has achieved the lowest background among all dark matter experiments worldwide (Physical Review D (2011), arXiv:1101.3866). Since the data presented here were collected, the intrinsic background from radioactive krypton in the xenon filling XENON100 has been reduced to an unprecedented low level and the detectors' performance has been improved as well. Even as new data are being collected in these improved conditions, the scientific team is preparing a next-generation dark-matter search experiment featuring a detector that will contain more than 1000 kg of liquid xenon as a fiducial WIMP target. With further reduction in overall background radiation, XENON1T promises to be a hundred times more sensitive than XENON100.

Provided by Weizmann Institute of Science

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