Search for dark matter moves one step closer to detecting elusive particle

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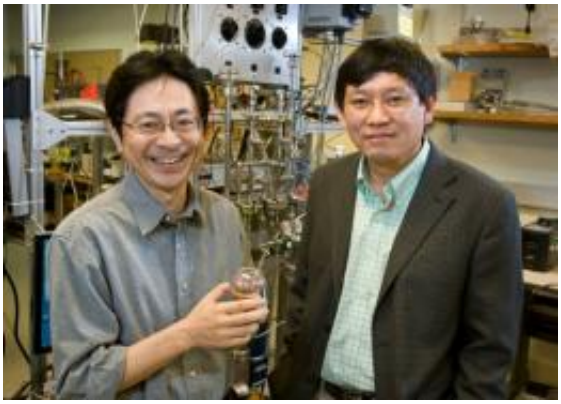


Katsushi Arisaka and Hanguo Wang

(PhysOrg.com) -- Dark matter, the mysterious substance that may account for nearly 25 percent of the universe, has so far evaded direct observation. But researchers from UCLA, Columbia University and other institutions participating in the international XENON collaboration say they are now closer than ever before.

Their new results, announced today at the Gran Sasso National Laboratory in Italy, where the XENON experiment is housed deep beneath a mountain 70 miles west of Rome, represent the highest-sensitivity search for dark matter yet, with background noise 100 times lower than competing efforts.

Dark matter is widely thought to be a kind of massive elementary particle that interacts weakly with ordinary matter. Physicists refer to these particles as WIMPS, for weakly interacting massive particles. The XENON researchers used a dark-matter detector known as XENON100 — an instrumented vat filled with over 100 pounds of liquid xenon — as a target for these WIMPs, which are thought to be streaming constantly through the solar system and the Earth.

And while the XENON100 experiment found no dark matter signal in 100 days of testing, the researchers' newly calculated upper limits on the mass of WIMPs and the probability of their interacting with other particles are the best in the world, said UCLA physics professor Katsushi Arisaka, a member of the international collaboration.

Seven QUPIDs (QUartz Photon Intensifying Detectors), a new photon-detector technology that emits no radiation and will greatly reduce background noise in future dark matter searches. (Credit: Katsushi Arisaka)

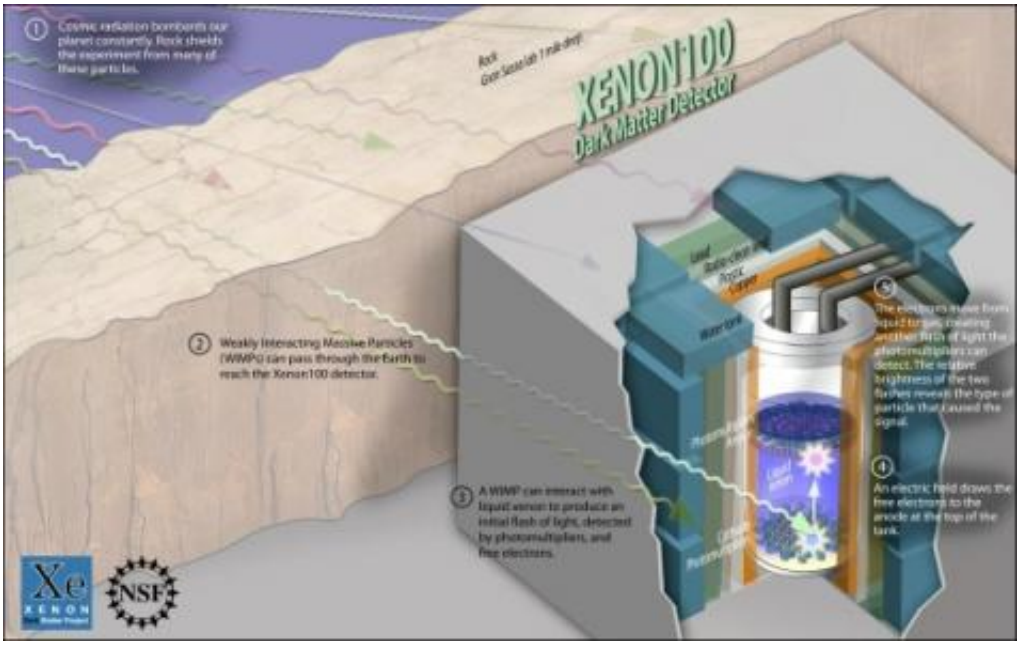
XENON100 looks for a primary flash of light that occurs when a particle bounces off a xenon atom inside the detector and a secondary flash when an electron knocked free from a xenon atom by a collision is accelerated toward the top of the device by an electric field, said UCLA physics researcher Hanguo Wang, who works closely with Arisaka. With this configuration, a WIMP will generate a signal fundamentally different from that of cosmic radiation or emission from the equipment itself, making it possible to identify background readings that could be mistaken for a positive detection, he said.

Even though the experiment did not detect a WIMP, the progress sets the stage for an ambitious next-generation project called XENON1T, which will use a much larger, one-ton liquid xenon instrument with highly specialized light-detectors developed at UCLA that make it 100 times more sensitive than XENON100, said David Cline, a UCLA professor of physics and founder of UCLA's dark matter group.

The search for dark matter

Ordinary matter, which makes up the stars, planets, gas and dust in our galaxy, emits or reflects light that can be observed using telescopes on Earth or in space. However, the effect of dark matter, according to several theories, can be observed only indirectly by the gravitational force exerted on the more visible portions of the galaxy around us, Cline said.

Despite the differences between ordinary and dark matter, cosmologists believe the two have been linked since the beginning of the universe, with dark matter playing a key role in the coalescing of particles into stars, galaxies and other large-scale structures after the Big Bang.



The XENON100 experiment is located deep underground at the Gran Sasso National Laboratory in Italy to reduce contaminating signals from cosmic radiation. (Credit: Zina Deretsky, National Science Foundation)

Though dark matter exerts a tangible force on the galaxy as a whole, individual WIMPs have proved far more difficult to detect. Because these particles interact only very weakly with normal matter, the small signal that might come from a WIMP detection above ground would be drowned out by the cosmic radiation that constantly bombards Earth's surface, Cline said.

To eliminate the majority of this background noise, the XENON100 experiment is buried beneath almost one mile of rock in the Gran Sasso lab, the largest underground facility of its kind in the world. While dark matter particles can travel easily through the vast expanse of stone and pass through the detector, only the most energetic particles from space are able to follow, Arisaka said.

Next steps

Because the XENON100 experiment is shielded by large amounts of rock, as well as by several tons of copper, lead and water, the largest source of background detections is actually the radiation coming from the instrument itself, Arisaka said.

In an effort to address this issue, Arisaka and Wang, working in collaboration with Hamamatsu Photonics in Japan, have developed the Quartz Photon Intensifying Detector (QUPID), a new light-detector technology that emits no radiation. The XENON group hopes to incorporate this breakthrough technology into the future XENON1T experiment.

"We have developed a detector to be used in future experiments based on new photon-detector technology," Wang said. "We invented, tested and demonstrated its operation in liquid xenon in our laboratory at UCLA."

In addition to Arisaka, Cline and Wang, UCLA's XENON group includes postdoctoral scholars Emilija Pantic and Paolo Beltrame and graduate students Artin Teymourian and Kevin Lung. Two students, Ethan Brown and Michael Lam, received doctorates last year through this experiment.

Elena Aprile, a professor of physics at Columbia University, is the XENON collaboration's principal investigator and spokesperson.

The XENON collaboration consists of 60 scientists from 14 institutions in the U.S. (UCLA, Columbia University, Rice University); China (Shanghai Jiao Tong University); France (Subatech Nantes); Germany (Max-Planck-Institut Heidelberg, Johannes Gutenberg University Mainz, Willhelms Universität Münster); Israel (Weizmann Institute of Science);

Italy (Laboratori Nazionali del Gran Sasso, INFN e Università di Bologna); the Netherlands (Nikhef Amsterdam); Portugal (Universidade de Coimbra); and Switzerland (Universität Zürich).

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