Columbia Researchers Lead Race to Find Dark Matter

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Some of the light sensors that make up the lower detector on the XENON experiment. Image credit: Guillaume Plante

(PhysOrg.com) -- Inside a mountain range in central Italy, Columbia researchers are trying to solve one of the most pressing questions in modern physics: What is dark matter? The riddle has obsessed astronomers and physicists since the 1930s, when Caltech professor Fritz Zwicky first predicted its existence. Because dark matter neither emits nor reflects light and cannot be directly observed, no one has ever proven that it exists; yet theories show it makes up as much as a quarter of the universe. Columbia physics professor Elena Aprile, with collaborators from universities around the world, including Rice University and UCLA, is leading the race to find and identify dark matter for the first time.

“Sometimes I think of dark matter as a mysterious woman with her face covered by one of those beautiful Venetian masks,” said Aprile, who is also co-director of Columbia’s Astrophysics Lab. “All of us experimentalists are driven by one desire: to uncover that face.”

Scientists first developed the theory of dark matter to explain how galaxies keep from breaking apart as they spin. Like merry-go-rounds, galaxies generate centripetal force as they rotate. Gravity is the glue that counteracts that force and holds stars and planets together, but there isn’t enough visible matter in the universe to generate the amount of gravity needed to keep galaxies from being torn to shreds. That’s why scientists believe there must be additional, unseen matter out there. Finding it will give them a deeper understanding of the laws of nature.

Aprile and many other physicists believe that dark matter is made up of WIMPS, or weakly interacting massive particles. As their name suggests, WIMPS very rarely bump into each other or into anything else; otherwise, scientists would have discovered them a long time ago.

Aprile and her colleagues are looking for WIMPS beneath 5,000 feet of rock in Italy’s Gran Sasso mountains in an experiment known as XENON. The project, which recently won $2.5 million of additional funding from the National Science Foundation, consists of a hatbox-sized container of liquid xenon—an element that occurs naturally in the atmosphere as a gas—sandwiched between two detectors. Should a dark matter particle come into contact with a xenon atom, it will trigger a flash of bluish light that the detectors will pick up. The particle is also expected to generate a small electrical charge—weaker than that of any other known radioactive particle. If one of the cameras registers such a charge, it will be a strong indication that Aprile’s team has found dark matter.

The Columbia researchers use xenon because it is one of the heaviest elements in the periodic table; at three times the density of water, it has many atoms per square kilogram, maximizing the chances that a WIMP will collide with it. “It’s like a densely woven fishing net,” said Rafael Lang, a postdoctoral research scientist in Aprile’s lab.

The experiment was set up underground to shield it from as many known atoms and particles as possible, including cosmic rays in the atmosphere. “The number of these cosmic rays keeps going down as you get deeper and deeper in the ground,” said Aprile, who travels frequently between New York and Gran Sasso. A coating of lead around the xenon vat keeps out X-rays and gamma rays; rock inside the mountain acts as a shield against muons, a type of heavy electron. “Gran Sasso is the best place in the world for doing this science,” she says.

The region is home to Italy’s Laboratori Nazionali del Gran Sasso, one of the world’s largest underground physics labs, which hosts a handful of dark matter experiments. Aprile’s experiment is recognized as a leader in the field because it is one of the largest and most sensitive, and it's expanding at the fastest rate. The new funding will allow her team to begin gathering data later this year and, soon, to expand the amount of xenon they use tenfold, to one ton. The experiment will run in phases through 2012.

Provided by The Earth Institute at Columbia University (news : web)

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