Home » November » How to See the Invisible: 3 Approaches to Finding Dark Matter

FROM THE NOVEMBER 2011 ISSUE

# How to See the Invisible: 3 Approaches to Finding Dark Matter

Physicists scour heaven, Earth, and everywhere in between for the mysterious particles that hold together galaxies and sculpt the universe.

By Lisa Randall | Wednesday, February 22, 2012

RELATED TAGS: DARK MATTER



The 7,000-ton Atlas detector at the LHC will observe a billion proton collisions per second in its search for dark matter.

Claudia Marcelloni/CERN

**Dark Matter Detectors**

Current searches rely on a leap of faith that dark matter, despite its near invisibility, nonetheless interacts feebly with matter we know (and can build detectors out of). The only trace of a dark matter particle passing through a detector would be the consequences of its hitting nuclei in the detector and changing their energy by a minuscule amount. Dark matter detectors search for the tiny amounts of heat or recoil energy created when dark matter particles pass through. The detectors are designed to be either very cold or very sensitive in order to record the small heat or energy deposits from dark matter particles subtly ricocheting off.

The very cold devices, known as cryogenic detectors, are made with a crystalline absorber such as germanium. Experiments of this sort include the Cryogenic Dark Matter Search (CDMS), CRESST, and EDELWEISS. The other class of experiments involves detectors made of liquefied noble gases. Even though dark matter doesn't directly interact with light, the energy added to an atom of xenon or argon when a dark matter particle hits it can lead to a flash of characteristic scintillation. Experiments with xenon include XENON100 and LUX, and the other proposed noble liquid experiments include ZEPLIN and ArDM.

With these extraordinarily difficult dark matter experiments, the devil is in the details. CDMS has hockey-puck-size pieces of germanium or silicon topped by a delicate recording device, a phonon sensor. The detector operates at very low temperature—low enough to be just at the border between superconducting and nonsuperconducting. If even a small amount of energy from phonons (the sound units that carry the energy through the germanium or silicon, much as photons are the units of light) hit the detector, it can be enough to make the device lose superconductivity and register a potential dark matter event through a device called a superconducting quantum interference device, or SQUID. These devices are extraordinarily sensitive and measure the energy deposition extremely well.

But recording an event isn't the end of the story. The experimenters need to establish that the detector is recording dark matter—not just background radiation. The problem is that everything radiates. We radiate. The magazine (or electronic device) you're reading radiates. The sweat from a single experimenter's finger is enough to swamp any dark matter signal. And that doesn't even take into account all the primordial and man-made radioactive substances. The environment and the air as well as the detector itself carry radiation. Cosmic rays can hit the detector. Low-energy neutrons in rock can mimic dark matter. There are about 1,000 times as many background electromagnetic events as there are predicted signal events.

So the name of the game for dark matter experiments is shielding and discrimination. Shielding is accomplished in part by performing the experiments deep in mines. XENON100—as well as CRESST, a detector that uses tungsten—is set up in the Gran Sasso laboratory, situated in a tunnel in Italy about 1,400 meters underground. The CDMS experiment is in the Soudan mine in Minnesota, more than 700 meters underground. The experiments further shield the actual detectors in a variety of ways. CDMS has a layer of surrounding polyethylene that will light up if something too strongly interacting to be dark matter comes through from the outside. Even more memorable is the surrounding lead from an 18th-century sunken French galleon. Older lead that has been underwater for centuries has had time to shed its radioactivity. It is a dense absorbing material that is perfect for shielding the detector from incoming radiation.

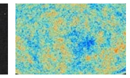
Impressive as CDMS is, though, noble gas experiments like XENON100 are currently the most sensitive detectors for dark matter. Liquid xenon is dense and homogenous, has a large mass per atom (enhancing the dark matter interaction rate), scintillates well, ionizes fairly readily when energy is deposited, and is relatively cheap. XENON100 uses special light-detecting phototubes that were designed to work in the low-temperature, high-pressure environment of the detector to measure the scintillation. Noble gas experiments have become a lot better as they have gotten bigger, and they should continue to do so. With more material, not only is detection more likely, but the outer part of the detector can shield the inner part of the detector more efficiently, helping assure a significant result.

The strange state of affairs today is that one scintillation experiment—DAMA, located at Gran Sasso—has actually seen a signal. DAMA, unlike the experiments described so far, has no internal discrimination between signal and background. Instead it relies on identifying dark matter signal events by their time dependence. Due to Earth's orbit around the sun, the speed of dark matter relative to us (and hence the energy deposited) depends on the time of year, making it easier to see a signal at some times of year (summer) than at others (winter). The DAMA experiment looks for an annual modulation in the event rate that accords with this prediction. The researchers' data indicate they have found such a signal. But people are skeptical because no other experiment has confirmed the result, although other experiments are beginning to see hints of a signal.

Although confusing, this is the sort of thing that makes science interesting. The result encourages us to think whether dark matter might have properties that make it easier for DAMA to see it than for other experiments to do so.

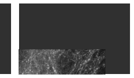
## You might also like


Astronomers Find a Galaxy Stuffed With Dark Matter

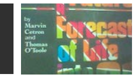

Baby Pictures of the Cosmos, Now in HD

Unknowns, From Matter to DNA to Brain Cells


Galaxies swarm and light bends under dark matter's sway


Dark matter, apparently, is midichlorians


It's full of stars!


Scientists Predict: The 2010s Will Be Freakin' Awesome—With Lasers

## Comment on this article

## NEW ON DISCOVER

**New Year's Day Asteroid Targets Earth, Hits the Bullseye**

**Data Mining Proves Darwin's Finches Weren't Really His**

**Dogs Align Themselves to Earth's Magnetic Field When Pooping**

**Why We Need to Move Beyond Facts in the GMO Debate**

**Science Needs Vigilantes**

## @DISCOVERMAG ON TWITTER

Today's top story: Data mining proves Darwin's finches weren't really his http://t.co/IFoIVAFXS9

RT @ramighandour: Everyone that hates the F-word should read "20 Things You Didn't Know About…Failure" http://t.co/vLNmXthD8p @DiscoverM…

Thanks in part to fracking, the US has now pulled ahead of Russia as top fuel producing country http://t.co/uPkY3HGjp1

Synthetic production of anti-malarial drugs finally kicked off in 2013 http://t.co/U8JFvtGZPv (sub req'd)

Data mining proves Darwin's finches weren't really his http://t.co/IFoIVAFXS9 http://t.co/ZjReutd7di

## POPULAR

**Where Did the Moon's Water Come From?**

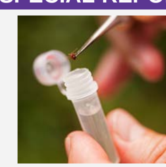
**A Paleo-Artist Reconstructs Long-Lost Human Ancestors**

**New Species of Dwarf Tapir Discovered in Amazon**

**Taking Vitamins? You Probably Shouldn't Be**

**Cats Became Pets Much Earlier Than Thought, According to Fossils**

## SPECIAL REPORT



**Investigating Lyme disease and tick-borne illness »**

## CITIZEN SCIENCE