How does it look when Earth is bombarded with dark matter?

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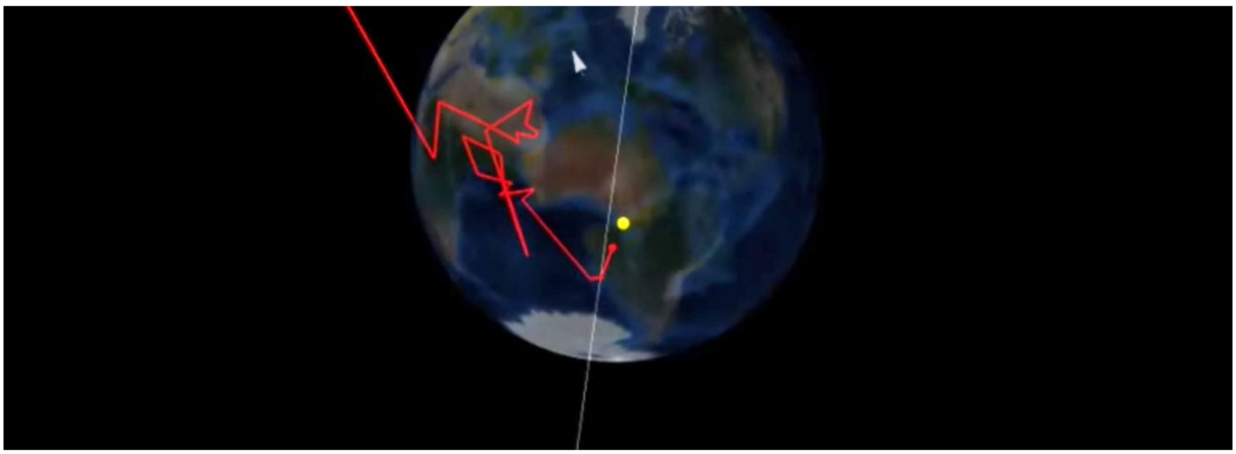

Credit: University of Southern Denmark

University of Southern Denmark researchers have conducted simulations of dark matter particles hitting the Earth. Physicists believe that Earth collides with uncountable dark matter particles as it hurtles through space. Although no one has ever seen these mysterious particles, there is no question among physicists about their existence. Researchers have installed detectors around the globe in the hope of detecting them.

Dark matter particles can penetrate all other forms of matter, which means that they may even be able to traverse through Earth without losing any energy whatsoever. On the other hand, their impact with ordinary may hamper them slightly, resulting in a loss of energy.

"We just don't know, and that definitely doesn't make it any easier looking for them," said Timon Emken, a Ph.D. student at the Centre for Cosmology and Particle Physics Phenomenology (CP3) at the University of Southern Denmark. In order to learn more about how dark matter particles react with normal matter, Emken enlisted the aid of a supercomputer. The result was a program that can simulate the collision of dark matter particles with the Earth.

"Now, I can ask the computer to show me on the screen what happens when a dark matter particle hits Earth. For example, I can see on the screen which trajectory the particle would take from when it hits the surface of our planet until it leaves again," he explained.

The simulation is called DaMaSCUS, and it gives physicists the world over a new opportunity to test out various theories. The program is freely available, and the work that went into it has been published in the journal *JCAP*.

In the standard paradigm, dark matter particles transverse the Earth with a very low probability of interacting with atoms comprising the planet. However, underground detectors are tuned to do just that, i.e., to capture rare events of dark matter particle collisions with an atom inside a detector.

"But what if dark matter particles do not follow the standard paradigm? What if they actually interact strongly enough with ordinary atoms, that, as they cross the surface of the Earth and travel underground, they lose enough energy to become undetectable? In that case, we will never spot them using standard techniques," said Associate Professor Chris Kouvaris from CP3.

One of the things he is currently investigating is the possibility that dark matter particles scatter significantly as they transverse the Earth. Kouvaris and Emken used DaMaSCUS to demonstrate how such a scenario would play out. DaMaSCUS simulates billions of dark matter particles penetrating the Earth and scattering significantly with underground atoms, zig-zagging after every single collision.

"If this is the case, underground scatterings of dark matter particles with atoms might make the dark matter particles lose enough energy to be detectable in the underground detectors that we deploy today."

Kouvaris' proposal is therefore to take a different approach to looking for the elusive particles. Today, there are a number of detectors situated around two kilometres below the Earth's surface. If dark matter interacts weakly with ordinary matter as neutrinos do, only these two particles can penetrate kilometres of the Earth's crust without being stopped. Thus, deep site detectors evade contamination of the signal from unwanted cosmic and terrestrial radiation and background noise.

However, according to Chris Kouvaris, if dark matter is light, it could actually interact strongly with ordinary atoms, losing energy on the way to the detector, and this can make deep site detectors unable to catch it.

"In that case, it would make more sense to search for dark matter signals using detectors on the Earth's surface," he said.

To overcome the problem of background noise, he suggests that instead of trying to distinguish dark matter from background noise, researchers should look for a daily varying signal in surface or low depth detectors.

Because the Earth is moving with respect to the center of the galaxy, dark matter hits the Earth predominantly from one direction. However, due to the rotation of the Earth around its own axis, dark matter particles that come from the direction of the dark matter wind travel different distances during the 24-hour period of a day.

The larger the distance travelled underground, the higher the probability of underground scattering. This is what creates the daily variation of the signal. The optimal location to exploit this effect is in the southern hemisphere at approximately 40 degrees latitude, i.e. in countries such as Argentina, Chile and New Zealand.

Using DaMaSCUS, Kouvaris and Emken can determine precisely the amplitude and phase of this daily varying signal, which could lead to the discovery of dark matter, if this scenario turns out to be true. Kouvaris is now collaborating with the dark matter experiment DAMIC, which has a portable detector that could potentially be used to test Kouvaris' theories. In the new phase of DAMIC, the portable detector will weigh 1 kg. It is made of silicon manufactured by the Danish company, TOPSIL.

It is thought that 27 percent of the universe consists of dark matter. Scientists believe it binds galaxies together. However, no one really knows yet what dark matter is.

More information: Timon Emken et al. DaMaSCUS: the impact of underground scatterings on direct detection of light dark matter, *Journal of Cosmology and Astroparticle Physics* (2017). DOI: 10.1088/1475-7516/2017/10/031

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