March 2, 2021

Earth & Space

Is dark matter lighting up the sky with X-rays?

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doi.org/10.25250/thescbr.brk484

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This Break was edited by Akira Ohkubo, Scientific Editor - TheScienceBreaker

We know little about dark matter beyond its existence. That would change dramatically if hints of dark matter decaying to X-rays were confirmed. Indeed, this signal could be the evidence that finally helps unravel one of the greatest mysteries in physics and astronomy. Yet when searching for that signal in our own Milky Way, we found only dark skies.

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Eighty-five percent of the mass in our Universe is the mysterious substance named dark matter. Besides giving it a name, however, we know little else about it. How can we claim we know dark matter exists if we can't even see it? Through gravity. Just as the Sun's pull on the Earth underlies our motion in the Solar System, so too dark matter pulls on the stars in our galaxy. While we can clearly see the Sun as it illuminates the world around us, there is no telescope we can look through to confirm dark matter's presence.

Or so we thought. In 2014, potentially revolutionary research suggested that dark matter is actually lighting up the sky, at least in X-rays, the higher energy of visible light. This discovery excited the scientific community. Is this a new portal through which we can finally unravel the dark matter mystery?

Today's leading hypothesis is that dark matter is a new subatomic particle, like an electron or neutron, that we have yet to discover. This may seem like a leap, but the atomic hypothesis — that conventional matter is made up of a zoo of particles at the smallest scales — has been wildly successful. If atomic theory extends to the dark side of the Universe, then the dark matter particles may undergo processes like the decay of the neutron. The idea that dark matter decays by emitting X-rays appears consistent with what researchers had seen. This X-ray decay hypothesis became the talk of the physics community.

This theory certainly got the attention of myself and colleagues Christopher Dessert (University of Michigan) and Benjamin Safdi (Lawrence Berkeley National Laboratory). We had previously been searching, without success, for hints that decaying dark matter might produce gamma-rays, photons of even higher energy than X-rays. In the process, we realised the importance of a largely overlooked reservoir of dark matter: our local Milky Way, the galaxy that contains our Solar System. The prevailing wisdom was that we should look at the largest collections of dark matter: the more matter, the more particles decaying, the brighter the signal (thus easier to detect!). This naturally led to galaxy clusters, monstrous objects like a version of the solar system where each planet is its own galaxy. The original X-ray signature was observed in these distant galaxy clusters. To put the discovery to the test, Christopher, Benjamin and I teamed to see if we could apply our gamma-ray findings — in particular, the insight that there should be a bright signal from the Milky Way — to the problem. If the dark matter in galaxy clusters was decaying to X-rays, we should be able to find an identical signal in our backyard.

While the Milky Way may have significantly less dark matter than where the line was first discovered, it is significantly closer, and exists all around us: in every direction we look there should be some hint of these X-rays. We quickly settled on using the European Space Agency's XMM-Newton to test the idea. This space-based X-ray telescope has been collecting publicly available data for over 20 years. Every observation involves looking out into the cosmos through the dark matter of the Milky Way, so we took the data and checked for a signature of dark matter. Nothing. Maybe we made a mistake, so we checked again, varying how we processed the data, where we looked on the sky, and how we accounted for the backgrounds. Again, we found nothing. How could it be that the dark matter in distant galaxies is decaying, but the particles closer to home weren't?

Our finding casts significant doubt on a dark matter interpretation of the signal — dark matter does not appear to be emitting X-rays. Not all researches were initially convinced by our finding. Did you forget to model nearby Argon lines? Are you sure you didn't overestimate the amount of dark matter in the Milky Way? We have checked each possibility, and finding again and again that the Milky Way is a much darker place in X-rays than it would need to be if dark matter was acting as claimed. Whatever is lighting up galaxy clusters in X-rays, it appears unlikely to be dark matter. So in one sense, we're back to the start when it comes to resolving the dark matter mystery. But we do so armed with new techniques, and a hope that a combination of these new ideas and experiments may have us on the verge of a discovery that is truly robust.