**ASTROPHYSICS** 

## A Hint of Dark Matter Sends Physicists Looking to the Skies After a search of neutron stars finds preliminary evidence for

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hypothetical dark matter particles called axions, astrophysicists are devising new ways to spot them.



proposed, from undiscovered particles to black holes. One idea in particular, however, is drawing renewed attention: the axion. And researchers are turning to the skies to track it down.

number of different explanations for this "dark matter" have been

The CAST axion telescope tracks the sun from inside a building at the CERN laboratory

pproximately 85% of the mass in the universe is missing — we

can infer its existence, we just can't see it. Over the years, a

near Geneva.

CERN / Madalin-Mihai Rosu

Axions are hypothetical lightweight particles whose existence would resolve two major problems. The first, fussed over since the 1960s, is the strong charge-parity (CP) problem, which asks why the quarks and gluons that make up protons and neutrons obey a certain symmetry. Axions would show that an unseen field is responsible. The second is dark matter. Axions "are excellent dark matter candidates," said Asimina Arvanitaki, a theoretical physicist at the

Perimeter Institute for Theoretical Physics in Waterloo, Canada.

Axions would clump together in exactly the ways we expect dark

matter to, and they have just the right properties to explain why they're so hard to find — namely, they're extremely light and reluctant to interact with regular matter. Earlier this year, a group of scientists reported that they might have spotted evidence of axions being produced by neutron stars — collapsed stars that are

Axions should be billions of times less massive than electrons, so they would be able to escape a dense neutron star's innards into space. Here they would encounter the extremely strong magnetic field of the neutron star. In the presence of such a strong magnetic field, axions are predicted to turn into ordinary photons, or particles of light. (This property forms the basis for earthbound axion searches such as the Axion Dark Matter Experiment, which uses powerful magnets to try and spot the transformation in action.) Axions flying through the neutron star's magnetic field would be transformed into X-ray photons.

so dense, a tiny sample little bigger than

a grain of sand would weigh as much as

an aircraft carrier. Ever since the 1980s,

physicists have thought that if axions do

exist, they should be produced inside the

neutrons and protons smash together at

hot cores of neutron stars, where

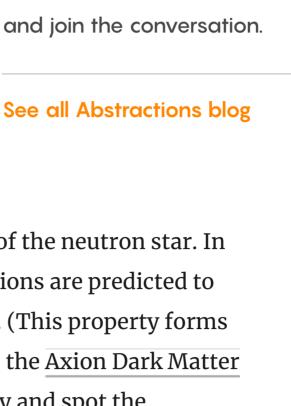
high energies.

sitting there."

investigation.

magnet.

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seven," so named because they are the only known neutron stars not

breaking discoveries is that unlike an ultra-clean laboratory on Earth, space has a lot of things going on. We could simply be observing some other astrophysical process, unrelated to axions, or the excess X-ray signal might not really be there at all. Safdi's team plans to investigate the matter further with additional instruments, like NASA's NuSTAR X-ray telescope, which can observe higher-energy X-rays than other space telescopes can see. "By observing these higher-energy X-rays, we could separate out a potential signal of axions," said Safdi.

Other axion searches use our sun, which is expected to produce axions

in its interior that then stream into space. A long-running experiment

at CERN in Switzerland called the CERN Axion Solar Telescope (CAST)

points a 10-meter-long superconducting magnet at the sun. The

magnet would turn any incoming axions into X-ray photons, which

would then get picked up by a detector placed at the back end of the

to rotate rapidly. "They are the most boring neutron stars you could

California, Berkeley, and a co-author on the study. "They're just

In the study, published in Physical Review Letters, Safdi and his

the existence of axions," Safdi said. The team does not claim a

colleagues suggest that all but one of these neutron stars show an

excess of higher-energy X-rays that "could possibly be explained by

definitive discovery, but rather highlights the discrepancy for further

Yet the trouble with looking into space for evidence of paradigm-

possibly imagine," said Benjamin Safdi, a physicist at the University of

These X-rays are hard to spot, however. Most known neutron stars are rapidly spinning pulsars, which release copious amounts of X-rays anyway — no axions needed. That's why the new research focused on a group of seven neutron stars in our galaxy known as the "magnificent

The NuSTAR telescope is sensitive to the high-energy X-rays that would provide stronger evidence for the existence of axions.

> energy from this star," said Irastorza. (A definitive link cannot yet be drawn, however.) Elsewhere, black holes have been touted as prime laboratories for probing the existence of axions by looking for signs of a process called superradiance, a phenomenon where lightweight

particles — such as axions — could slow the spin of a black hole

anywhere from 10% to 90% by causing it to lose energy and angular

momentum. "If you see a very quickly spinning black hole, you know

that this process did not happen," said Masha Baryakhtar, a particle

physicist at the University of Washington. But if we can measure the

masses and spins of enough black holes, such as with the LIGO and

Virgo gravitational wave detectors, we could begin to look for patterns

CAST hasn't found any axions, but its results, like those of other

has begun on CAST's successors, which will use bigger and more

characteristics, such as when axions might morph into photons. Work

powerful magnets. By 2024, the Baby International Axion Observatory

(BabyIAXO) will be switched on at a German accelerator center called

DESY. It will be 100 times more sensitive than CAST and will serve as

the precursor to the full IAXO experiment, which will be "yet another

factor of 100 better," said Igor Irastorza, one of the leaders of CAST.

Researchers are also exploring indirect ways to spot the influence of

axions out in space. Some white dwarfs — the remnant cores of stars

like our sun that have exhausted their fuel — appear to be cooling

down faster than expected. One possibility might be that axions are

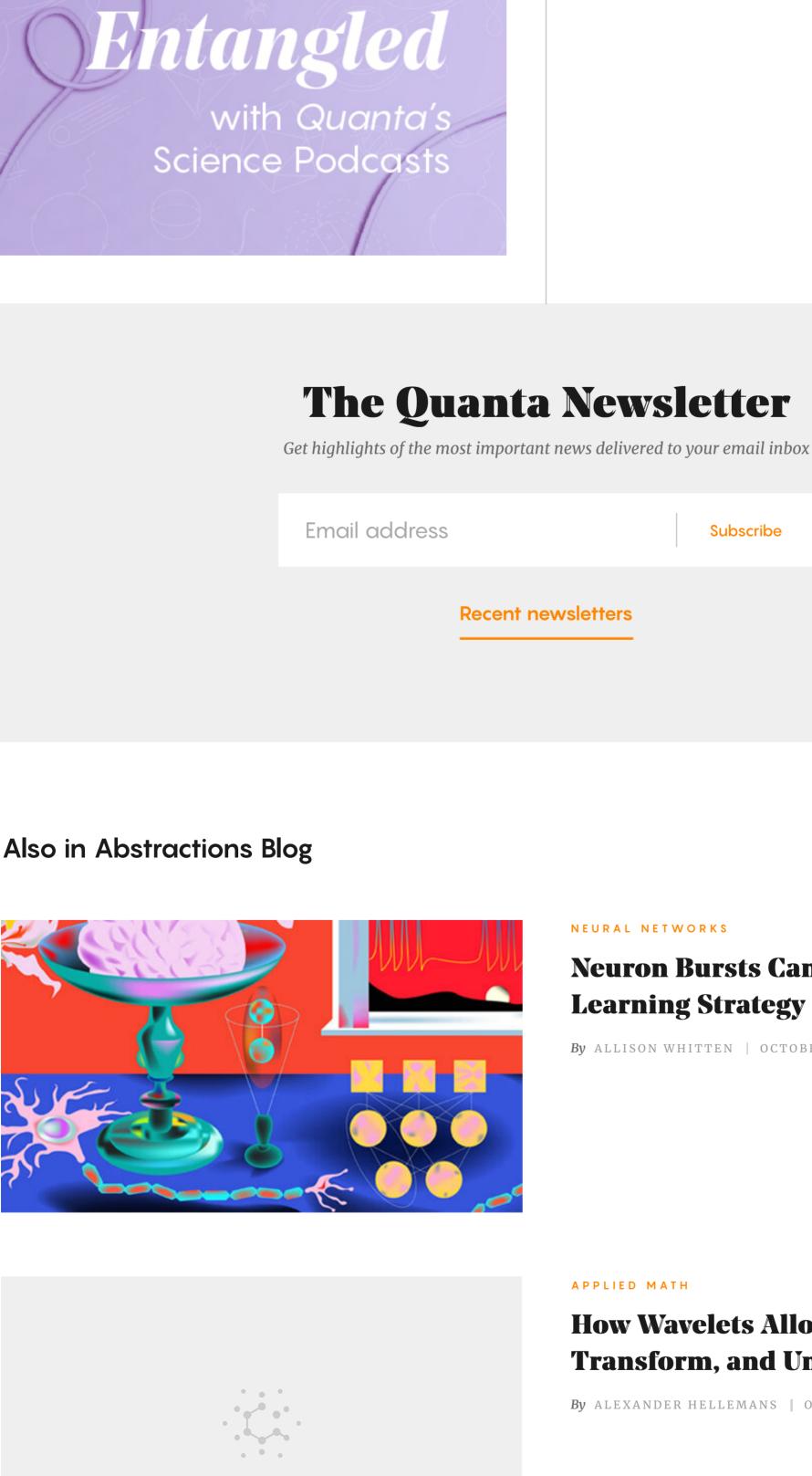
cooling is "exactly what one would expect if there are axions draining

escaping from the dead stars, taking energy with them. The rapid

searches taking place, provide useful constraints on axion

that might "match up with the calculations of what they should be if axions are there," said Baryakhtar. **RELATED:** Dark Matter Experiment Finds Unexplained Signal 2. Axions Would Solve Another Major Problem in Physics Top Dark Matter Candidate Loses Ground to Tiniest Competitor

As axions have slowly become one of the most tantalizing dark matter candidates, researchers have come up with ever more elaborate ways to find a wisp of a particle that may not even exist. "The field is just exploding," said Arvanitaki. And though earthbound searches "haven't seen anything of note," said Jesse Thaler, a particle physicist at the Massachusetts Institute of Technology, looking up might turn out to be the most promising way to track them down. "Because axions or other dark matter-like particles are so feebly interacting, you need a big number somewhere to ratchet it up to something you could see," said Thaler. "And one of the biggest numbers you can imagine would be [to] leverage the entirety of the universe as a detector." Jonathan O'Callaghan Contributing Writer



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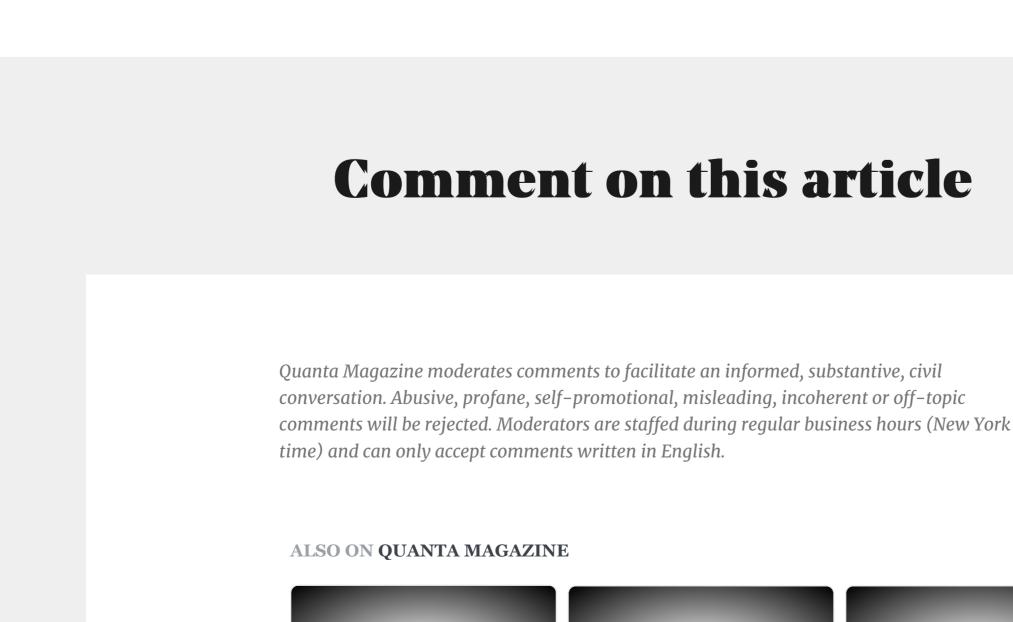
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