The New York Times: -Can Axions Save The Universe?- [C2]

I laboratori più all'avanguardia del mondo sono alla costante ricerca della materia oscura, il maggior enigma dell'astrofisica. Potrebbe aiutarci a rispondere a molte domande sull'origine dell'universo.

The search is on for some of **the flimsiest** **lumps of matter** and energy ever dreamed up by physicists. They are darker than night, **barely** more substantial than a thought, and named after a **laundry** detergent. But axions, as they are called, could constitute most of the matter in our universe, forming the unseen skeletons of galaxies and chains of light that adorn the skies of astronomers. Confirmation of their existence would **upset** some of the deepest theories of nature. “For nearly ten years we've been operating in a search mode, and any day we could make a discovery,” said Gray Rybka, a physicist at the University of Washington who is a **spokesperson** for the Axion Dark Matter eXperiment, or ADMX, in Seattle, which is trying to **conjure** axions with powerful magnetic fields. Astronomers, too, are hunting for hints that axions exist, by analyzing how black holes **spin** and the shapes of infant galaxies that the James Webb Space Telescope has brought to light. But so far, nobody has found them. Success would provide a big clue to one of the grandest mysteries in the cosmos: What is the universe made of?

SIGNS FROM THE SKY

Astronomers tracking the motions of stars and galaxies have **reluctantly** concluded that there is much more to the universe than can be seen directly with telescopes. The ordinary matter that composes the stars, planets, galaxies and us **accounts for** only one-sixth of the matter in the universe. The rest is so-called ‘dark matter’, invisible and **aloof** but with sufficient gravity to hold the visible universe together. Countless particles have been hypothesized as candidates for dark matter. But the most popular are those that fill gaps in the Standard Model, humanity's best, **if** imperfect, model of nature and the forces that drive it. For decades, scientists have bet their dark-matter hopes and dreams on weakly interacting massive particles, known cheekily as WIMPs . These gained favour in the 1970s as a prominent feature of a theory called supersymmetry, devised to solve deep problems in the Standard Model. WIMPs were invisible, interacted with the universe mostly through gravity and weighed hundreds or even thousands of times as much as protons. Being heavy by subatomic scales, they were also slow compared with the speed of light. Such particles were just what cosmologists needed to fill in their universe. "The WIMP was the default assumption because the WIMP was a miracle," said Luna Zagorac, a particle cosmologist at the Perimeter Institute for Theoretical Physics in Waterloo. "Everybody wants the miracle to be true." Millions of dollars have been spent building ever-larger, ever-more precise detectors deep underground or in the sides of mountains in hopes of finding a WIMP. But searches by the LZ Dark Matter Experiment, the mighty Large Hadron Collider at CERN and other detectors continue to turn up short, suggesting that the elusive particles are out of experimental reach, at least for the foreseeable future. Maybe it's time for a Plan B, some scientists say. "Given that we have come up empty after decades of looking," Priyamvada Natarajan, an astrophysicist at Yale University, wrote in an email, "it seems pretty natural to start looking further afield." The axion, she added, "is a candidate I find compelling."

A CASE FOR THE AXION

The nature of dark matter has come under closer scrutiny as scientists have learned more about the very early universe, when the first stars were emerging from the detritus of the Big Bang. It seems that the earliest galaxies were too big, too bright and more numerous than predicted by WIMP-based theories. Axions, if they exist, could offer an explanation. Current theories do not predict their mass, only that axions barely interact with matter and are hard to catch in action. Axions were first conjured in 1977, when Roberto Peccei, a theoretical physicist at UCLA and Helen Quinn, a particle physicist then at Stanford University, suggested a slight modif ication to the theory that governs strong nuclear forces. Among other things, the tweakica") would explain why neutrons, the neutrally charged building blocks of the atomic nucleus, are not electrically **lopsided**, as they should be according to the Standard Model. “We get excited anytime a theory predicts something and it’s wrong,” Rybka said. “That’s a great place to go looking for new physics.” Frank Wilczek, a theoretical physicist at the Massachusetts Institute of Technology, and Steven Weinberg at the University of Texas at Austin independently realized that the Peccei-Quinn modification implied the existence of a new particle. Wilczek named it the ‘axion’. Wilczek and others also realized that, like **WIMPs**, axions of a certain mass had many of the properties required for dark matter. These would have to weigh as little as a few millionths of an electron volt, the units of mass and energy preferred by particle physicists. (By comparison, the electrons that dance around in your smartphone weigh about a half-million electron volts **apiece**.) In theory, however, axions and axion-like particles could be any size or mass, with drastic consequences for the universe. Different species could play the role of the dark matter that **binds** galaxies, distort the cosmic microwave background that fills space with radiation left over from the Big Bang, or even contribute to the so-called dark energy causing the universe to expand at an ever-faster rate. String theory — the **vaunted** and **heretofore** untestable theory of everything — is full of axion-like particles. The discovery of more than one kind of axion could constitute the first experimental evidence of string theory, said Savas Dimopoulos, a theoretical physicist at Stanford University, who refers to this panoply of possibility as “the axiverse.”

HUNTING IN THE DARK

The goal is just to figure out how to catch one. The search takes physicists into the subatomic realm, where the weird laws of quantum mechanics dictate that everything, including dark matter, exists as both a particle and a wave. **WIMPs** are heavy and so behave like **ungainly** particles, **bouncing off** atoms like bowling balls slamming into ping-pong balls. Axions come in many varieties; those that could fulfill the role of dark matter are lightweight and fundamentally act like waves. With so little mass, axions were long considered beyond experimental reach. But advancements in quantum computing and cryogenics have made the search for axions more **feasible**.

In 1983, Pierre Sikivie, a physicist at the University of Florida, suggested that in a strong magnetic field, an axion could turn into a photon, the particle that transmits light. That insight laid the foundation for experiments like ADMX. Today, the most established way to look for axions is by using "the biggest, baddest magnet you can find," Rybka said. ADMX is built around a superconducting electromagnet that is 100,000 times stronger than Earth's magnetic field, surrounded by a large copper canister cooled to one-tenth of a degree above absolute zero. When an axion of the right size penetrates this magnetized cavity, it generates a cascade of microwaves that causes the chamber to resonate. Rybka compared the experiment to an AM radio: slowly tune the knob, shifting the resonant frequency of the can, and listen through the static until you find the station — or particle — you're looking for. The frequency of the microwaves, he said, depends on the mass of the axion. Experiments like ADMX have already determined that axions of certain masses don't exist. But there is a vast range left to explore. "If you're playing in that sandbox , it's a very fun box to play in," Zagorac said, referring to the lack of constraints that she and other theorists have in proposing new types of axions. "But if you're trying to find a needle buried in that sandbox, good luck." It wasn't until 2018, after more than twenty years of operation, that the ADMX team announced that its experiment had finally gotten good enough to begin probing the most theoretically promising masses for dark matter axions. "Any day we could make a discovery, because we're just slowing-tuning that frequency," Rybka said recently.

TUNING IN THE COSMOS

For now, the hunt for axions may be limited to laboratories. But scientists think that they could one day be detectable in outer space. "There is a way in which astrophysics can produce this particle, and can produce it even if it's not the dark matter," Dimopoulos said. Axions of a certain size could suck energy from spinning black holes, in a process called 'superradiance'. That could lead to a deficit of certain sizes of black holes observed by detectors like the Laser Interferometer Gravitational-Wave Observatory. A recent study suggests that clouds of axions in the magnetospheres of pulsating stars could convert into microwaves, like a natural, outer-space version of ADMX.

Signals emitted from the phenomenon could then be measured by radio telescopes on the ground. Axions could even be produced by the Sun, and are being sought by experiments like the **CERN** Axion Solar Telescope in Switzerland. “We wouldn’t know **if** they are dark matter,” Aaron Manalaysay, a WIMP researcher at Lawrence Berkeley National Laboratory, said of solar axions. “But we would know that the universe allows for this particle.” Another **alluring** possibility, called ‘**fuzzy dark matter**’, has **seized the imaginations** of some cosmologists. In a galaxy, ultralight axions — with wavelengths up to hundreds of light-years long — could interfere with one another, leaving tiny filaments and **knots** in the visible part of the galaxy. Stars passing through this **bumpy** space-time would **pump** energy into the galaxy, leading to oscillations in its brightness, said Jeremiah Ostriker, an astrophysicist at Columbia University. “I like axions because they heat the stars up,” he said. But so far, ultralight axions have not **reciprocated** Ostriker’s love. They remain missing, their fuzzy features too small to resolve with today’s optical telescopes. A **flaw**etto”) in all of these models is the assumption that there is only one kind of dark matter in the universe. After all, why should the dark side of the universe be any less interesting or complicated than the one we see? So for now, **the jury is still out**, and the universe is wide open. Zagorac isn’t certain that axions — or any type of dark matter — will be discovered in her l**if**etime. “We might get lucky,” she said. “But until then, it’s my **sandbox** to play in.”

Glossary

- **canister** = contenitore
- **probing** = indagare, investigare
- **the flimsiest** = i più delicati
- **laundry** = bucato
- **WIMPs** = debole
- **compelling** = convincente, valido
- **binds** = legare
- **copper** = rame
- **bumpy** = turbolento, irregolare
- **conjure** = far apparire
- **further afield** = più lontano
- **apiece** = ciascuno, a testa
- **vaunted** = acclamata
- **ungainly** = sgraziate, goffe
- **bouncing off** = rimbalzare
- **reluctantly** = con riluttanza
- **accounts for** = rappresentare
- **drive** = manovrare, pilotare
- **CERN** = Organizzazione Europea per la Ricerca Nucleare (sigla di Conseil Européen pour la Recherche Nucléaire)
- **knots** = nodi
- **upset** = turbare, sconvolgere
- **cheekily** = ironicamente
- **come up empty** = non trovare niente, non ottenere nulla
- **spokesperson** = portavoce, rappresentante
- **spin** = girare, ruotare
- **laid the foundation** = gettare le basi
- **pump** = pompare
- **the jury is still out** = il verdetto è ancora incerto, la giuria non si è ancora espressa
- **flaw** = difetto
- **barely** = a malapena
- **aloof** = distante

- **turn up short** = risultare insufficiente
- **for the foreseeable future** = nell’immediato futuro
- **insight** = intuizione
- **seized the imaginations** = catturare l’immaginazione
- **alluring** = affascinante, allettante
- **fuzzy dark matter** = materia oscura sfocata
- **lumps of matter** = frammenti di materia
- **tweak** = modifica
- **lopsided** = sbilanciati
- **cooled** = raffreddare
- **constraints** = vincoli
- **suck** = succhiare
- **sandbox** = sabbiera, recinto con la sabbia
- **needle** = ago
- **if** = anche se
- **default** = predefinita
- **mighty** = potente
- **heretofore** = finora
- **feasible** = fattibile, possibile
- **tune the knob** = ruotare la manopola
- **reciprocated** = ricambiare