.Dark Matter, The Invisible Glue of the Universe

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When you look at the sky on a clear, cloudless night, you see thousands of bright stars twinkling in the blackness of space. If you have a telescope, you can also observe planets, colorful nebulae, and even distant galaxies. Seeing this amazing view, you might think you are looking at the entire universe. But the truth is much stranger. Everything we see, know, and are made of (including stars, planets, trees, the human body, and even the smartphone in your hand), makes .up only about 5 percent of the total content of the universe

So what is the rest of the universe made of? Cosmologists believe that about 27 percent of the universe is made up of a mysterious, invisible, and unknown substance called "Dark Matter" (the remaining 68 percent belongs to an even stranger phenomenon called "Dark Energy," which is responsible for the accelerated expansion of the universe). Dark Matter does not interact with .light or ordinary matter, but without it, the universe as we know it today would never have formed

The Galactic Merry-Go-Round and a Strange Discovery To understand how scientists realized the existence of something that cannot be seen at all, we have to go back to the 1970s. A prominent astronomer named Vera Rubin was studying the rotation of spiral galaxies (similar to .(our own Milky Way

The laws of Newtonian physics that we know on Earth dictate that the further you get from the center of a rotating system (like the solar system), the slower the rotation speed of objects should be. For example, the planet Mercury, which is close to the sun, rotates at a very high speed, while the distant planet Neptune has a much slower movement. Vera Rubin expected to see the same law in galaxies: stars at the outer edges of the galaxy should rotate much slower than stars near the center of the galaxy.

But what she observed shocked the world of physics. The stars at the edge of the galaxy were rotating at the same breakneck speed as the central stars. At such a speed, the gravitational force from visible matter (stars and gases within the galaxy) was not enough to hold these stars together. The galaxies should have flown apart like a merry-go-round spinning too fast, flinging their stars into endless space. But this did not happen. Something invisible, with its immensely powerful gravitational pull, was holding these galaxies together. This "invisible glue" is what we call Dark Matter today.

What is Dark Matter NOT? Sometimes, to understand a grand mystery, it is better to first state what that thing is not. Through decades of research, scientists have crossed many options off the list:

- **It is not ordinary (baryonic) matter:** Dark matter is not made of the protons, neutrons, and electrons that make up us and the world around us. If it were ordinary matter, its clouds and masses should have absorbed the light of the stars behind them, and we would be able to see their shadows.
- **It is not Antimatter:** When antimatter collides with ordinary matter, both are annihilated, producing powerful gamma rays. We do not see such massive gamma-ray bursts in the cosmos that would indicate the presence of huge amounts of antimatter.
- **It is not supermassive black holes:** If dark matter were made up of countless black holes, we should see their intense, point-like gravitational effects on the light of stars passing by them (in a phenomenon called gravitational microlensing), but our observations have recorded very few of these events.

If it is invisible, how do we know it exists? You might wonder, when we cannot see something with any telescope (optical, infrared, X-ray, or radio), why are scientists so sure of its existence? The answer lies in Albert Einstein's masterpiece, the "Theory of General Relativity".

Einstein proved that mass can bend space-time. When light passes by a very massive object, its path is curved. This phenomenon is called "gravitational lensing." When observing distant galaxy clusters, astronomers noticed that the light from galaxies behind these clusters was severely

.(bent, stretched, and distorted (like looking at your surroundings through a glass of water

By calculating the amount of this curvature, scientists could calculate exactly how much mass must exist in that galaxy cluster to create such a powerful lens. The result was stunning! The actual mass of the galaxy cluster was dozens of times greater than the mass calculated from its ".stars and glowing gases. This massive and invisible mass is "Dark Matter

The importance of Dark Matter is not just limited to holding galaxies together; dark matter actually shaped the architecture of the entire universe. Shortly after the Big Bang, the universe was a very hot and relatively uniform soup of particles. But within this uniformity, there were small quantum fluctuations. Here, dark matter played the role of the hero. Since dark matter did not interact with light and the intense radiation of that era, it was able to condense much earlier than ordinary .matter

With its gravity, dark matter formed massive clumps that acted like a scaffold or skeleton for the universe. This scaffold created a massive network called the "Cosmic Web." Then, the gravity of these invisible skeletons pulled ordinary matter (hydrogen and helium gases) toward themselves. These gases condensed, heated up, and gave birth to the first stars and, ultimately, galaxies. If dark matter did not exist, our universe today would just be a space full of thin, scattered gas, and .there would be no stars, planets, or humans in it

Particles that science has yet to find. If dark matter exists, then what particle is it made of? Particle physicists have proposed several potential candidates for it, two of which have the best :chances

- **WIMPs:** This acronym stands for "Weakly Interacting Massive Particles." WIMPs are hypothetical particles that have a large mass but rarely interact with ordinary matter. Currently, advanced laboratories deep underground (to stay safe from cosmic rays) are using massive tanks of liquid xenon trying to record the collision of a WIMP particle .with atoms of ordinary matter, but nothing has been found to this day
- **Axions:** These particles are much, much lighter than WIMPs and were initially proposed to solve a complex problem in quantum physics, but it later became clear that .they could also be a suitable candidate for dark matter

Of course, a small group of scientists also believes that there might be no new particle at all. They propose a theory called MOND (Modified Newtonian Dynamics), which says that perhaps on very large galactic scales, Newton's and Einstein's laws of gravity need to be changed and modified. However, to date, the MOND theory has not been able to explain all cosmic phenomena (especially the pattern of the cosmic microwave background radiation) as well as the

.dark matter theory can

You might ask yourself, what good does it do us on Earth to understand a substance that is ?invisible and located in distant galaxies? And why does this matter to humanity

Keep in mind that science has always sought to discover the truth. One hundred years before this article was written, when scientists were discovering the structure of the atom and quantum mechanics, no one imagined that this research would one day lead to the invention of transistors, computers, the internet, and smartphones. Dark matter is the greatest scientific mystery of the 21st century. Discovering the nature of this substance will most likely require the formulation of entirely new laws in physics; laws that could change our understanding of the reality of existence and perhaps, in the distant future, bring about technologies that today we cannot even imagine in .science fiction stories

Dark matter reminds us how mysterious and vast our universe is and that we are still at the beginning of understanding our cosmic home. We revolve around an ordinary star on a small rocky planet and have just realized that 95 percent of the play of existence is performed by actors .whose faces we have not yet seen