10 UNANSWERED QUESTIONS ABOUT DARK MATTER THAT WILL LEAVE YOU INTRIGUED

Primary Keyword:- Dark Matter
# of images:- 10

Ever since the 'lone-wolf' astronomer Fritz Zwicky coined the term 'Dark Matter', there has been an element of mystery associated with it. Be it its nature, or its properties or even doubts pertaining to its existence, Dark Matter has intrigued many astrophysicists and cosmologists alike over multiple decades. Although by now we pretty much have a broad understanding of how it influences standard objects in our universe (like galaxies), there are some serious questions that need to be addressed with more advanced scientific technologies.

1. What exactly is Dark Matter?

You might wonder whether we know absolutely nothing about Dark Matter. Although the situation is not that bad, we really do not know much about what it is. Let us elaborate.

A brief history of Dark Matter:

To understand the status quo, we should talk a bit about the history of Dark Matter. When Zwicky first proposed the idea, he was observing the Coma Cluster (a cluster of galaxies) and noted that the speed at which the galaxies were revolving around each other was significantly more than what laws of gravity predicted. One might think of claiming the laws of gravity to be wrong, but by the time of this observation, these laws were so well established, it was too radical to make such a claim. *(This however did not stop physicists from pursuing such a claim. More on this below.)*

Figure 1: Coma Cluster. Credits: NASA, ESA and the Hubble Heritage Team (STScI/AURA). Licensed under CC BY 4.0

The other, more sensible option that Zwicky considered was that if somehow, there was some ‘heavy hidden matter’ at the heart of the Coma Cluster that our instruments (mainly telescopes) weren’t able to observe, then the high velocities of the revolution can be explained. This ‘heavy hidden matter’ must therefore not emit any light signal as otherwise our telescopes would have clearly detected it. Instead, it was considered ‘heavy’, allowing it to interact with all matter gravitationally - hence, the name “Dark Matter”.

The Question:

This was a wonderful prediction, and decades of data from new galaxy clusters further confirmed this hypothesis. However, what remained a puzzle since its inception was the fact that - any kind of matter that does not emit light can be categorized under “Dark

Matter”. It then became quite natural to ask - “What constituent particles is Dark Matter made up of? Is it a single species or a collection of many? How do they interact with each other?”

2. What makes up Dark Matter?

One immediate question that follows is what constitutes Dark Matter? Throughout the past decades there have been many candidates.

Subsequent observations in potential Dark Matter hotspots - for instance in a Dark Matter ‘halo’ surrounding a galaxy which is essential for galaxy formation - have ruled many of them out. We mention some of the famous candidates here and the reasons for ruling them out.

Disqualified Candidates:

- **MaCHOs**: The name stands for Massive Compact Halo Objects. The following astrophysical objects fall under MaCHOs,

    - *Massive Stars* – ruled out for obvious reasons. Stars emit light that can always be detected in some form or the other. (Interested in knowing the classification of all stars, then click here to know more!)

    - *Neutron Stars* – ruled out because a neutron star is formed when a dying star explodes in a supernova, leaving behind heavy elements like carbon, neon, iron in the surrounding gas. Such heavy elements are not found in the gas surrounding Dark Matter hotspots. (Do all stellar objects undergo supernovae and end up as neutron stars? Check this out!)

    - *Stellar Black Holes* – ruled out for the same reason as neutron stars. (Curious to know everything about black holes? Then this is the right place for you!)

    - *Brown-Dwarfs* – ruled out by gravitational microlensing experiments, because brown-dwarfs are planets that are more massive than Jupiter but not massive enough to form a star and would have been detected by gravitational lensing due to their large masses.

- **Fundamental Particles**: Electrons, protons and neutrons are also ruled out
  - *Electrons and Protons* – ruled out because they emit X-rays (Bremsstrahlung) that are not always observed in Dark Matter hotspots.
  - *Neutrons* – ruled out because free neutrons decay into protons and electrons (and neutrinos) and they are already ruled out.

    Note:- Although neutron decay ruled it out as a potential candidate, ironically though, a neutron might itself decay into a Dark Matter. More on this below!

  - *Hot Neutrinos* – ruled out since present understanding of galaxy formation requires the Dark Matter to be cold (non-relativistic) so as to concentrate near the center of every galaxy. Hot (relativistic) neutrinos might be weakly interacting enough to qualify as Dark Matter, but at such high speeds, the Dark Matter would not settle for the center and will instead fly away.

- **Gas and Dust**: ruled out since gas and dust radiates in the infrared, and will also obscure the background galaxies, none of which is observed in the Dark Matter hotspots.

Potential Candidates:

- **Primordial Black Holes**: Black Holes that were formed in the early universe could also be potential candidates for Dark Matter. They are heavy, and at the same time small and 'dark' enough to be hidden. They are not formed by stars that have undergone supernovae, so they cannot be ruled out using the arguments used against stellar black holes.

- **WIMPs**: An embarrassingly creative acronym for Weakly Interacting Massive Particles, since anything that interacts weakly (that is, through gravitational forces only) with all other matter particles and with themselves can be called a WIMP, this candidate will almost certainly be never ruled out. Some of the WIMPs are
  - *Sterile Neutrinos* – A hypothesized neutrino that interacts only gravitationally with the other generations of neutrinos (normal neutrinos can also interact via another Weak Nuclear force).

- ➢ *Axions* – A hypothesized type of particle that is currently the leading candidate.

3. Can Axions make up Dark Matter?

One of the leading candidates is a hypothetical particle known as an axion, which would be extremely light, perhaps as light as 10^{31} times less massive than a proton. At present, one possibility is that these axions could form star-like objects, which might produce detectable radiation that would be quite similar to mysterious phenomena known as fast-radio bursts. Experiments are designed to look for axions or axion-like particles.

4. Is there a 'Dark Sector' of particles?

We have been talking about Dark Matter as if it is a single species. However, there is no reason to believe that there could not be a whole zoo of 'Dark' particles that have a set of laws of their own, interacting amongst themselves through some mysterious 'Dark' force. Just like ordinary (often called Standard Model) particles like protons, neutrons, electrons, neutrinos, muons and pions, there could be dark protons, dark neutrons, dark electrons, dark neutrinos. Even a "dark hydrogen atom" made by one dark proton and dark electron combining could exist. However, no straightforward experimental designs have yet been constructed that can detect any of these particles in the 'Dark' sector directly or indirectly.

5. Is Dark Matter Influenced by some 'Dark Force'?

Along with the possible zoo of dark matter, there is the possibility that dark matter experiences forces analogous to those felt by regular matter. For instance "Dark photons" could play the role of normal photons exchanged between normal particles that give rise to the electromagnetic force, except they would be felt only by dark matter particles. One theoretical proposal put forward in favor of dark photon detection is the annihilation of normal electron and positron pairs to produce a photon and a dark photon which would in turn produce some changes that can be detected experimentally.

6. What if Dark Matter is not that dark after all?

Dark Matter is ‘Dark’ owing to the fact that it does not emit any kind of light signal. Not just visible light, Dark Matter does not emit any electromagnetic radiation - Infrared, Ultraviolet, Radio, X-rays, Gamma rays - nothing. Any matter that can emit light signals is actually capable of interacting with light, so absence of light emission indicates that Dark Matter cannot interact with electromagnetic radiation.

In the physics parlance, in order to be able to emit/interact with electromagnetic radiation, the physical object must have electric charge. You might have heard of how antennas work. The radio waves that are incident on the antenna rods actually oscillate the electrons inside it. These oscillating electrons inside create an alternating current which the receiver uses to convert the waves into digital signals. So, the leading principle behind a working antenna is electron oscillation. Why does the electron oscillate? It is because electrons are charged particles, without which it would not be able to respond to the radio waves.

Absence of any kind of interaction with light suggests that Dark Matter might actually have no charge.

Electrically Charged Dark Matter:

Absence of any kind of interaction with light might also suggest that the value of charge that a Dark Matter has is significantly less compared to the charge of an electron (the charge of an electron is yet considered to be the most basic unit of charge). Maybe the charge is so weak that for all practical instruments yet designed, the interaction with light is undetectable.

At first glance, this seems ad hoc and unnecessary. Why would someone want to deliberately introduce charges into Dark Matter when there seems to be no a priori reason or need for so? Well there is some unexplained observation, that might be explained by attributing charge to the Dark Matter.

Cosmic Microwave Background and the 21 cm photon:

We will digress a bit here and briefly introduce the concepts of Cosmic Microwave Background (CMB) and hydrogen 21 cm wavelength. If you are familiar, you can just skip to the main topic.

Enter the EDGES (Experiment to Detect the Global Epoch of Reionization Signature) experiment. Do not be bothered if the name sounds gibberish, we will not be using the name elsewhere. This experiment is primarily designed to look for the very first stars of our universe.

If you look at the history of our universe, there was a time when the universe was filled with protons, electrons and photons with a small amount of neutrons (if Dark Matter existed back then, then it was there too, but only as a passive audience) . The universe was so hot that photons of all wavelengths constantly bombarded the electrons, not letting it bind with the proton to form a hydrogen atom. As a result, the photons themselves were trapped in a hot 'soup' of protons and electrons. As the universe slowly cooled, most of the photons lost their energy, unable to prevent the electrons from binding. This was the first time in the history of our universe that neutral hydrogen atoms formed. Consequently, photons no longer remain trapped inside this 'soup', instead it streamed freely throughout the cosmos. This free-streaming radiation is available all around us even at this moment as you read. It is constantly hitting you and your surroundings in the form of microwaves. This radiation is aptly named - Cosmic Microwave Background (CMB).

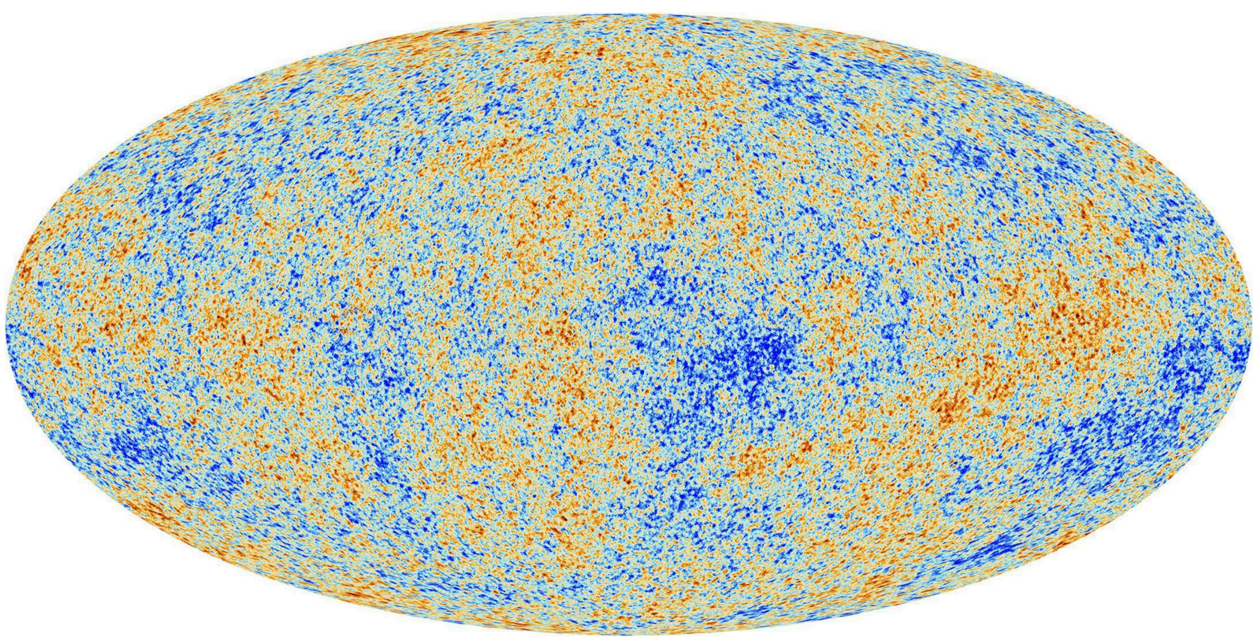

Figure 2: Cosmic Microwave Background map showing the regions that are hotter (red) and colder (blue) compared to the average temperature of the radiation. Credits: ESA and the Planck Collaboration. Licensed under ESA Standard Licence.

Soon after this, neutral hydrogen combined to form enormous clouds of hydrogen gas (H_2), while the CMB freely streamed around in the background. Eventually these clouds collapsed in multiple places under their own weight to form stars and galaxies (more on this below). Once these stars lit up, they emitted light signals that can now be detected using sophisticated telescopes. The period in between the free-streaming CMB and the first stars lighting up, however, is very difficult to detect. The only feasible method available is to resort to the hydrogen 21 cm photon.

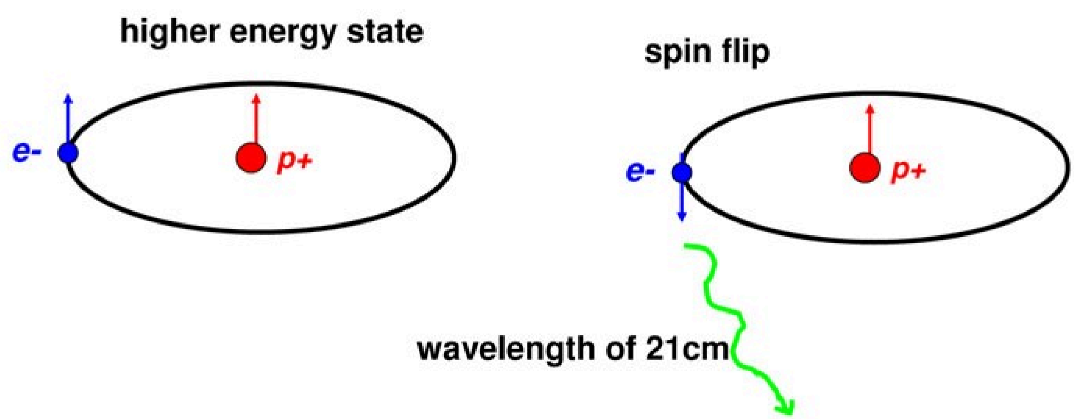

Figure 3: 21 cm wavelength of hydrogen. Credits: Abraham Loeb. (Public Domain).

The hydrogen 21 cm photon is a special wavelength of light (21 cm) that can be absorbed by and only by hydrogen molecules **at rest** (we highlight the word ‘at rest’ because this will be important soon) . The free streaming CMB on the other hand had photons of all wavelengths available. Thus, while roaming around, the gas cloud specifically absorbed this 21 cm wavelength, while leaving out the rest.

Need for Charged Dark Matter?

When physicists make observations of the CMB, they do find this missing 21 cm photon as expected. However, something unexpected happened as well. The intensity drop in the missing 21 cm photon directly accounts for the number of photons that have been absorbed. At any given temperature, the average number of hydrogen molecules that will be nearly at rest is fixed. However, as the temperature rises, the number of molecules at rest decreases. Hence, the number of 21 cm photons absorbed also decreases and correspondingly, the intensity drop decreases. (This is exactly the reason why after the first stars formed, no intensity drop in the 21 cm photon is found since the stars heat up the surrounding gas).

On the contrary, a significant drop in the intensity that was observed was much deeper than predicted from standard cosmology, implying that the hydrogen gas was much cooler.

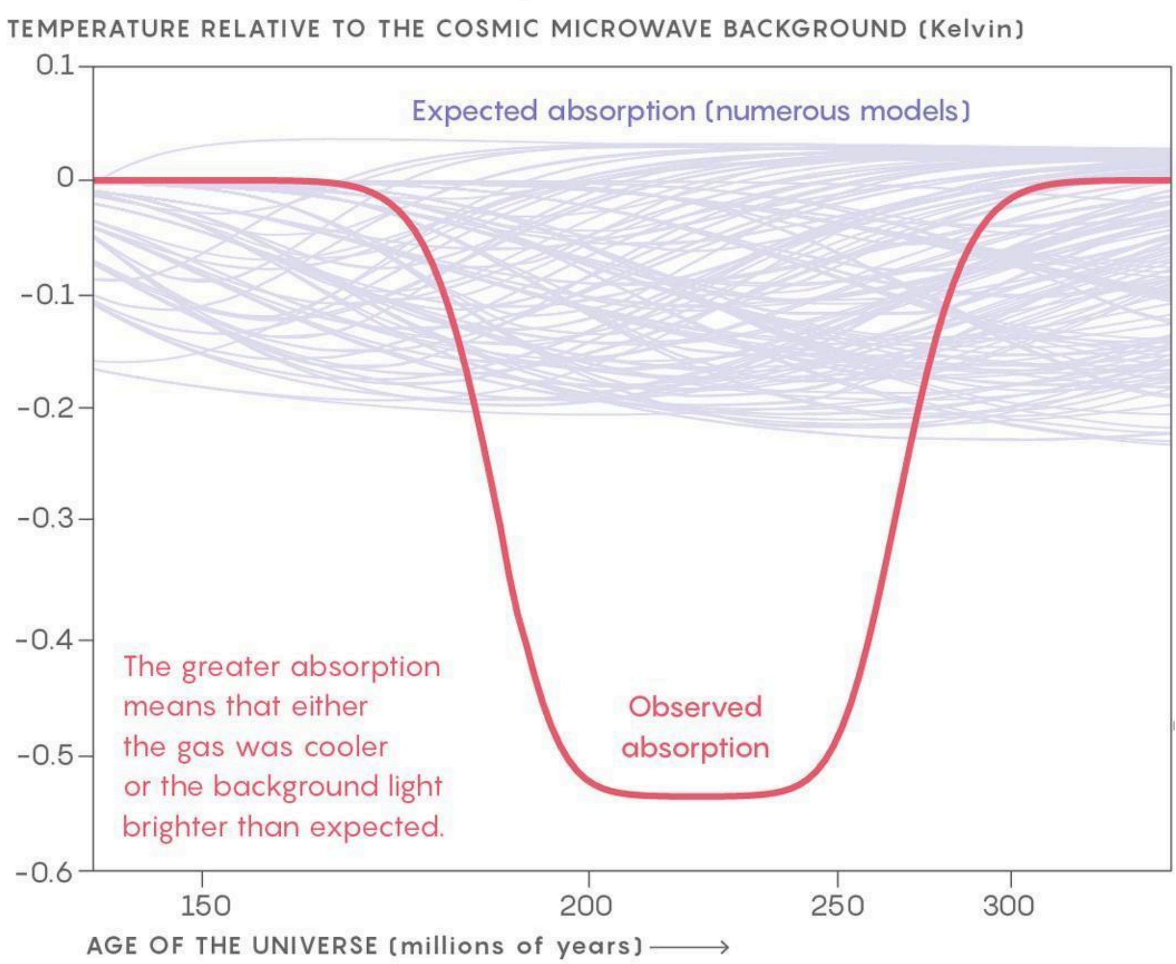

Figure 4: 21 cm intensity drop. Credits: Quanta Magazine. Source: arXiv:1609.02312v3 Figure 1 (expected); doi:10.1038/nature25792 Figure 2 (observed)

This led some into considering the possibility that maybe, a few of the CMB photons (including the 21 cm) might have interacted with the Dark Matter which should already be abundant by that time and dumped its energy to the Dark Matter instead of the hydrogen gas. Since the number of photons decreases in this case as well, it looked like the hydrogen gas was colder, while in reality some of the energy was actually lost to Dark Matter.

This is an interesting idea, however the only problem is that Dark Matter is considered to not have any charge. But to interact with photons, it must have charge.
The proposal was then as follows - maybe Dark Matter is indeed charged, but the charge is so small compared to the electron that in daily life, there is no significant observation of its interaction with light. One could then hold to this idea and constrain the value of the charge sufficient to reproduce the intensity drop. As it turns out, the value of charge must be less than a 1000th of the charge of an electron - hence resulting in the term "Millicharged Dark Matter". Experiments are conducted to observe them but the results still stand null and void.

7. Is Dark Matter at the heart of every galaxy?

Einstein's General theory of Relativity (which is the most accurate theory of gravity till date) can be used to predict how galaxies formed in the early days of our universe. In simple terms it can be explained as follows.

Galaxy formation:

You might have heard the quote "Matter tells space how to curve; space tells matter how to move". The first part of the quote indicates that one can think of space as a rubber sheet and matter as solid balls. When matter is kept in space, it curves the space just like balls kept on a rubber sheet bends it below. The second part implies that any other ball when thrown in this bent sheet will be attracted near the 'pit', just like the Earth goes around the Sun and the Moon goes around the Earth.

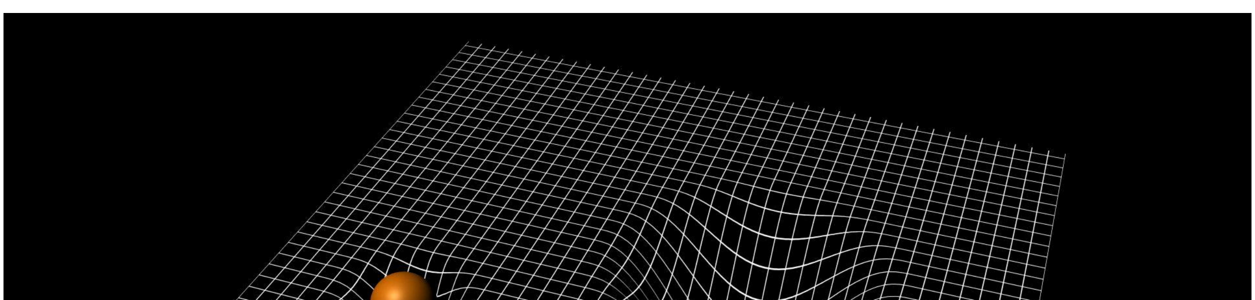

Figure 5: Matter bends the space (shown as a gray mesh) forming 'pits'. These 'pits' then further attract more matter. Credits: ESA-C.Carreau. Licensed under ESA Standard Licence.

Now imagine the early universe to be a vast rubber sheet that is filled with nothing but uniform gas clouds. At some places, the gas clouds are a bit more dense while at other places, it is a bit less. These slightly overdense regions bend the rubber sheet more than others, which will in turn attract more clouds into the 'pit', which in turn will make the 'pit' grow even deeper and so on, going on and on in a feedback cycle until hindered by the outward gas pressure. This 'pit' will later become the nucleus of a galaxy that will hold all of its contents (and the matter that was falling becomes the stars and other interstellar medium of that galaxy). This was once the accepted theory of galaxy formation.

Note:- For the science nerds, the accurate quote will be "Matter tells space-time how to curve; space-time tells matter how to move"!

Dark Matter Halo:

However great an idea this was, calculations showed that the 'pit' cannot grow deep enough to run an entire galaxy. Something else was needed to make the 'pit' grow large. The proposal went in the favor of Dark Matter once again. Current models of galaxy formation dictate that before any sensibly large galaxy had started forming, the Dark Matter content of our universe kept these 'pits' ready for them. Hence, every galaxy that we observe is actually encased in a 'halo' of Dark Matter around them.

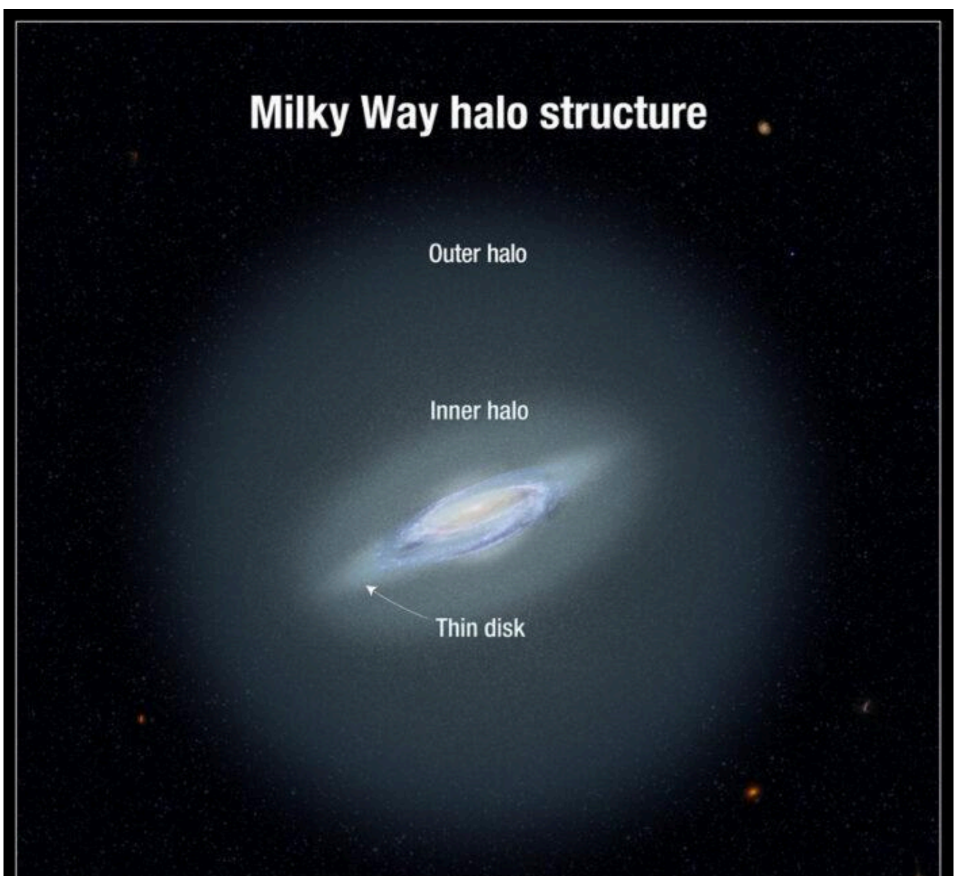

Figure 6: Dark Matter halo surrounding Milky Way Galaxy. Credits: NASA, ESA and A. Feild (STScI). Licensed under CC BY 4.0

For a short while, physicists were enlightened with Dark Matter halo but the enlightenment soon faded away when a cluster of galaxies by the name Bullet Cluster was discovered to be evolving without a Dark Matter core. You might wonder that this cluster answers our question but it does not.

What happens is that the Bullet cluster was once a group of two separate galaxy clusters - each probably with a Dark Matter core, which upon collision separated away from the rest of the contents. Thus, we are yet to discover galaxies forming without a Dark Matter from scratch in order to provide an unambiguous answer.

The Bullet Cluster offers many more insights into Dark Matter, especially since it provides strong evidence against many alternative theories.

8. Is Dark Matter the only game in town?

A digression into the story of Vulcan - a hypothetical planet thought to be existing in between the orbit of Mercury and Sun - will be an appropriate starting point of this discussion. It might seem never ending but bear with us, it will be worthline.

The orbit of Mercury around the Sun shows a kind of peculiarity. Every other planet in our solar system also shows peculiarities of the same kind but Mercury’s peculiarity is more prominent than others and cannot be explained simply invoking Newton’s laws of gravity. Let’s explain what we mean.

Story of Vulcan:

If our solar system contained only one planet and the Sun (with no other external disturbances like comets), Newton’s laws of gravity tells us that this planet will go around the Sun in an elliptical orbit forever. However, the moment we introduce another planet, both the trajectories of these planets will deviate from ellipses. Precisely speaking, they will slowly ‘precess’.

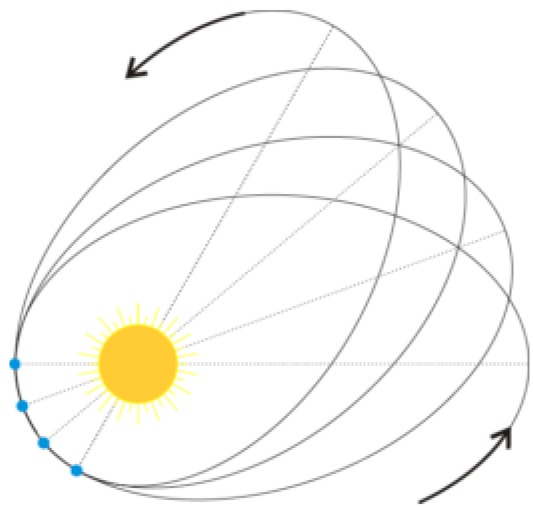

Figure 7: Orbital precession of a planet around the Sun. Credits: Mpfiz (Public Domain).

Precession happens because besides the attraction of the Sun, the second planet slightly pulls the first, nudging its orbit towards the second. However, since the second planet is also revolving around the Sun, it constantly pulls the orbit of the first in its direction, leading to precession of its orbit. The rate at which the orbit precesses can be computed from the amount of force with which the second planet is tugging the first. The vice versa is equally true.

Now why are we talking about Mercury? As it turns out, the peculiarity we were talking about is orbital precession. The rate at which Mercury's orbit precesses could not be explained just by considering the combined pull of all other planets of our solar system (external disturbances like comets are so far away that they were not worth considering). The only feasible solution seemed to be considering an yet unknown planet which lies inside of Mercury's orbit - close enough to provide the pull necessary for the precession rate. This planet was named - 'Vulcan'.

Obviously, everyone still assumed Newton's laws to be the ultimate theory of gravity.

General Relativity to the Rescue:

Quite a fascinating story, is it not? Indeed, it was along the same lines of reasoning that the planet Neptune was predicted and discovered subsequently through telescopic observations. Unfortunately, such a discovery could not be made about the planet Vulcan despite multiple efforts and false detection claims.

Years later, when General Relativity was postulated as the more accurate theory of gravity, calculations performed for Mercury's precession rate precisely matched with that of observations, thus eliminating the need for another hypothetical planet inside Mercury's orbit. General Relativity triumphed over Newton's laws of gravity.

Like Dark Planets like Dark Matter:

What was thought to be a hidden 'Dark' planet causing the peculiarity of Mercury's orbit turned out to be a fundamental flaw in the theory of gravity itself!

What if physicists nowadays are committing the same mistake? Maybe, there is no Dark Matter after all! Maybe at galactic scales, gravity does indeed behave differently than predicted using General Relativity, just like we discussed above!

This is the premise of Modified Newtonian Dynamics (MOND). MOND is an attempt to empirically describe the observation Zwicky made without invoking any 'dark' stuff.

While Dark Matter proponents suggest that it is the hidden mass of the Dark Matter at the center that causes the galaxies to speed up, MOND suggests that it could be erroneous to think the laws of gravity to hold at galactic scales, and so the expectation that these galaxies should revolve slowly could be our mistake. Instead, one should doubt the established laws and modify it so as to fit the observations. Once the data fits, one can then use MOND to make predictions about other galaxies and clusters and verify its validity. MOND technically belongs to the general class of "Modified Gravity" theories.

The simplest approach MOND takes is to model Newton's second law (F = ma) in such a way that galaxies that are closer to the center of the cluster will be interacting exactly via standard Newtonian gravity, while for the galaxies that are far away, the second law is precisely modified such that the velocities do not decrease as much as standard laws predict.

Bullet Cluster to the Rescue?

When two galaxy clusters collide, the stars and the gasses present in the cluster pull each other, slowing down their motion. The gasses slow down much more than stars mostly because of the electromagnetic interaction between these hot ionized gasses. Dark Matter content present in these clusters on the other hand barely slows down since they do not interact electromagnetically at all. If there ever happens to be a head-on collision, the Dark Matter content of both clusters will pass through each other, moving poles apart, but the hot gasses will lag behind them.

This is exactly what gravitational lensing and X-ray observations of the bullet cluster have shown.

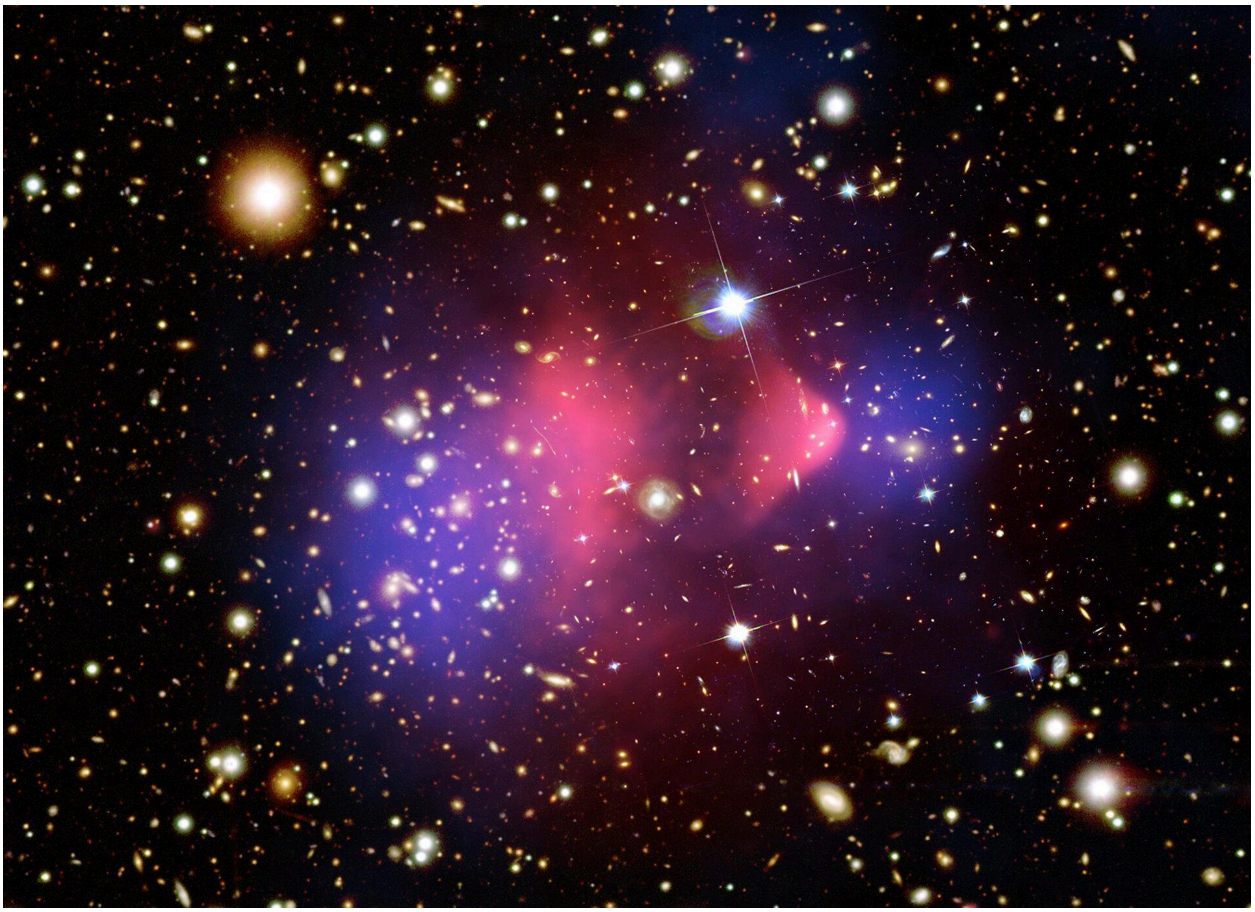

Figure 8: Bullet Cluster. The pink regions are observations made in the X-ray showing the distribution of hot intergalactic gasses. The blue regions are gravitational lensing observations showing where most of the mass of the combined cluster lies. This is where most of the Dark Matter of the combined cluster is distributed. Credits: X-ray: NASA/CXC/CfA/M.Markevitch, Optical and lensing map: NASA/STScI, Magellan/U.Arizona/D.Clowe, Lensing map: ESO WFI. Licensed under ESA Standard Licence.

MOND on the other hand does not invoke any Dark Matter. Hence, it predicts that the gravitationally lensed regions (blue) should overlap with the intergalactic gaseous region (pink), since according to MOND, there is no Dark Matter and all of the mass of a galaxy is concentrated near the regions where the intergalactic gasses are predominant.

As of now, Bullet Cluster provides wonderful evidence to the existence of Dark Matter. However, the possibility of other Modified Gravity theories are still not ruled out.

9. Can ordinary particles decay into Dark Matter?

Take a jar and fill it up with apples. Assume that each apple in this jar will magically ‘convert’ itself into a banana, but randomly. You cannot predict when a particular apple will convert, but you can estimate on an average how long an apple takes to convert - based on counting how many apples remain ‘unconverted’ after a certain time. This is known as the ‘lifetime’ of the apple, and is **roughly the time it takes for half the number of apples to remain unconverted into bananas**.

The other way you can compute this ‘lifetime’ is by counting how many bananas have formed inside the bottle after a certain time.

Quite intuitively we can understand that these two methods of computations should yield the same value. Yet one thing that nature offers us without change are surprises.

These two methods of computations have precisely been performed in experiments, except instead of apples and bananas, physicists observed the decay of neutrons into protons. The first method - called the “bottle” method - involves counting the left over neutrons that are kept in a jar. While the second method - called the “beam” method - involves allowing a beam of neutrons to pass through a cylinder and count the number of emerging protons (a single neutron decays into a proton, electron and an antineutrino).

Even with ever increasing precision measurements, a discrepancy of 9 seconds of the neutron lifetime has remained between these two counting strategies. The first method predicted a lifetime of 14 minutes 39 seconds for the neutron while the second method predicted 14 minutes 48 seconds.

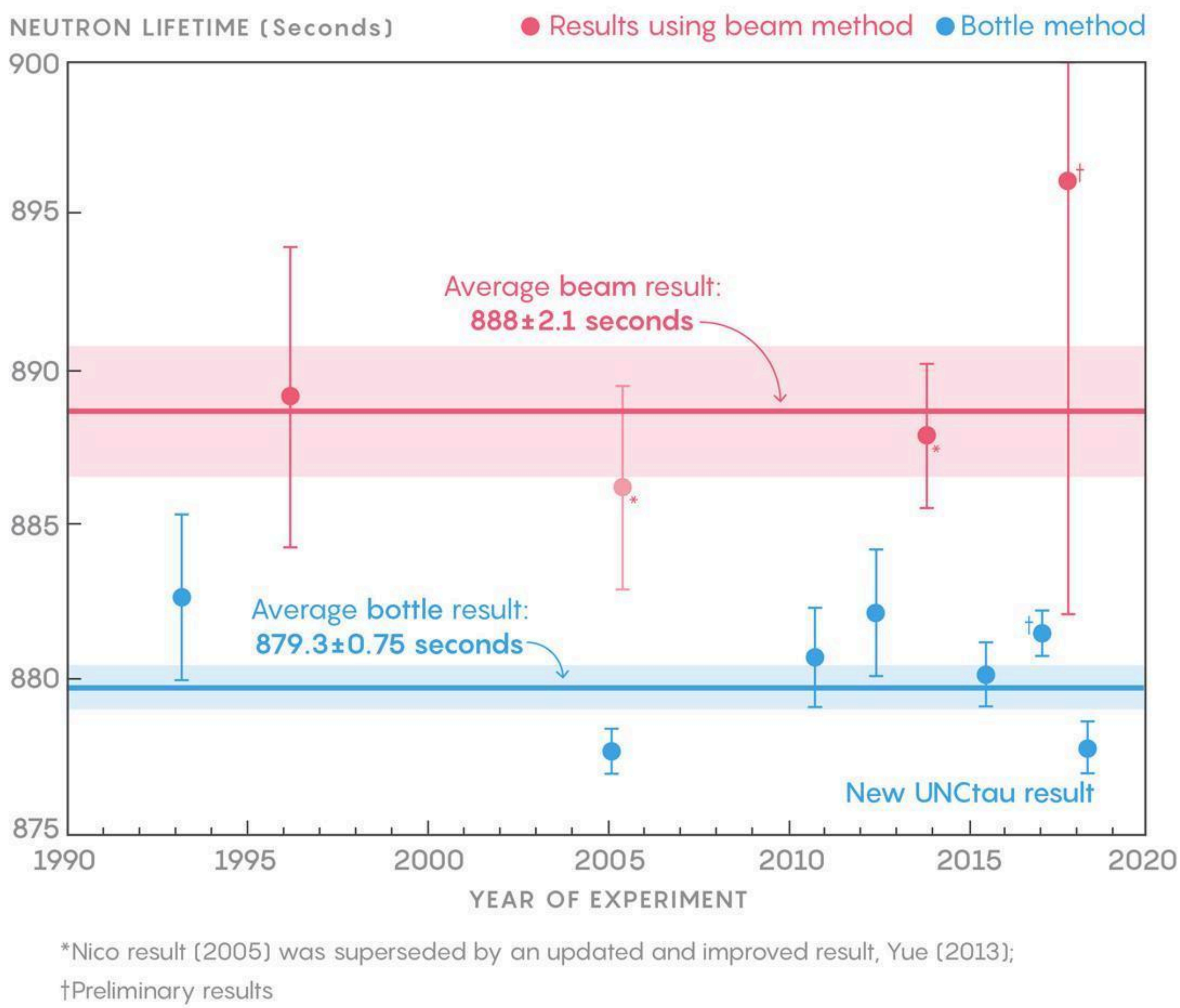

Figure 9: Neutron Lifetime discrepancy. Credits: Quanta Magazine. Source: pre-2017, Particle Data Group; Serebrov 2017, arxiv:1712.05663; Pattie, 2018, arxiv:1707.01817

One possible and very interesting explanation that was posed as a solution to this conundrum was the decay of neutrons into Dark Matter.

Returning to our example of apples and bananas, let us say normally out of 100 apples, 37 of them are left unconverted after 10 seconds. So the usual ‘lifetime’ of the apple is 10 seconds. In a new scenario, suppose now instead of always decaying into a banana, maybe 2 out of every 100 apples decay into black grapes. If one is unable to observe these grapes, one would think that after 10 seconds the number of apples left over is 35 therefore concluding that more apples have converted to bananas in the same 10 seconds, implying falsely that the ‘lifetime’ of apples is slightly less than 10 seconds. While on the other hand, if one counts the number of bananas, one will still count 63 instead of 65, concluding that the ‘lifetime’ of the apple remains 10 seconds. Thus the problem of discrepancy could be evaded by designing experiments to detect those hidden black grapes.

A similar strategy follows for our actual neutron decay experiment. Unfortunately, no such Dark Matter has been found yet!

10. Is Dark Matter blowing in the Wind?

On a humid evening, you feel very sweaty. Your room feels stagnant and neither your ceiling nor your table fan perform any better. What do you do? If you know how to ride you may start driving your bike, without a helmet, just to feel the air. Unfortunately though when you return back and stop driving, the soothing wind stops blowing at all.

This is a day-to-day phenomena, and it's so basic that nobody needs an explanation for it. It is not the wind that is blowing, rather it is the bike that moves forward. Hence, relative to the bike, it looks like the wind is blowing at your face.

However, such a simple picture has a very interesting potential for Dark Matter detection. The situation is similar to the bike riding experiment.

Our Sun is traveling at some 220 kilometers per second around the center of our Milky Way Galaxy. Assuming that, like every other galaxy, our Milky Way is also encased in a Dark Matter halo, our Sun is constantly gushing through this halo at very high speeds. Just like relative to the bike, the air seems to slam into your face, with respect to the solar system, the Dark Matter in the halo blows throughout the system - this is known as the Dark Matter “wind”.

Now that we already have this wind blowing, think about the Earth. Almost half of the year, Earth travels in one direction, while during the other half, it travels the opposite direction. Given that the wind is constantly flowing in one direction, it seems as if the

Earth travels ‘upstream’ against the wind, and during the other half it travels ‘downstream’ along the direction of the wind. Experience tells us that while moving upstream, one feels more resistance. It feels as if the wind is flowing even faster than when at rest. While traveling downstream, the wind feels slower than normal. More wind means more Dark Matter passing through the Earth and hence increase in the number of detections, while less wind means less detections. One can hope to detect this small change in this rate of detection as evidence for Dark Matter (and consequently the presence of the halo).

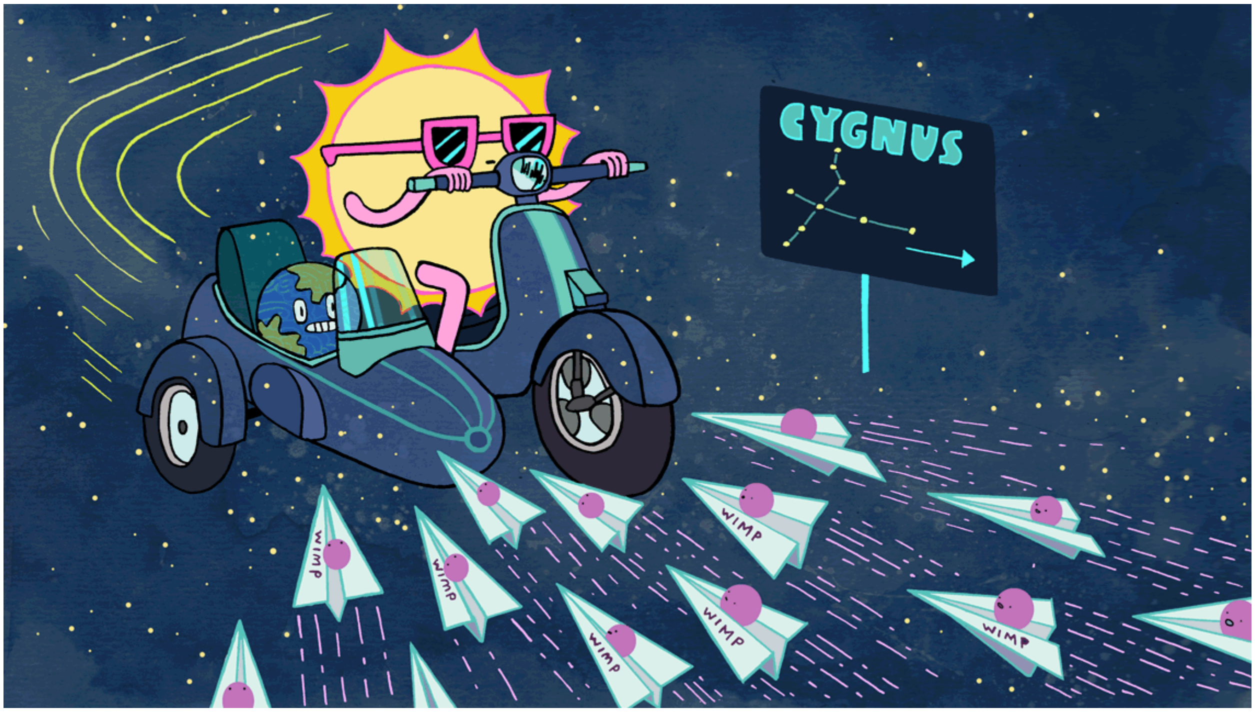

Figure 10: Artist’s expression of Dark Matter Wind. Credits: Symmetry Magazine. Source: Artwork by Sandbox Studio, Chicago with Corinne Mucha. (Public Domain)

The best part is that this change in the rate of detection is “model independent”, meaning that no assumption needs to be made about the nature and property of Dark Matter other than that it interacts very weakly. In addition, one can show that this rate of detection cannot be affected by any other astrophysical objects like solar neutrinos or cosmic rays. This seems to be the cleanest method of Dark Matter detection.

Unfortunately, except the claim by the DAMA/LIBRA team, no further groups have been able to observe or reproduce DAMA/LIBRA’s results, rendering this possibility of detection still to be a mystery.

Conclusion

We know Dark Matter is elusive and has evaded detection for a long time. Regardless, physicists and engineers alike are in a constant pursuit to look out for more and more hints lurking around some corner of this vastly unknown universe. Perhaps one of the readers of this blog will be excited enough to put an end to all of these puzzles holding a place in the universe, for Dark Matter and for themselves.

May the Force be with you!

Join our Discord channel to stay updated on all the latest astronomical events and discussions! Feel free to ask any queries related to astronomy—we're here to help you explore the wonders of the cosmos.

Do you know that many of the topics introduced in this blog had some fascinating history? Or that black holes can also be destroyed? What about recent discoveries of our own galaxy? If yes, then consider reading:

- Friedmann's best work: Not just a WW1 Russian pilot
- The death of Black Holes: No monster is invincible
- How to Escape from the Black Hole
- Milky Way's Cosmic Spark: Revealing the Marvels of 2 star streams Shiva and Shakti
- The Great Attractor