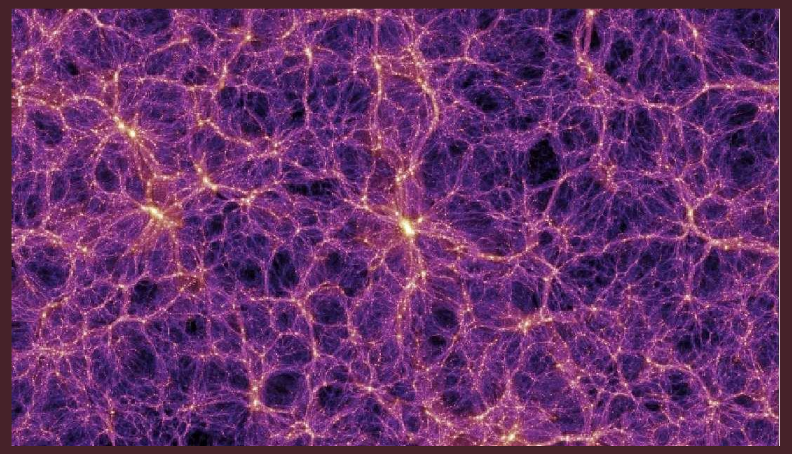

Dark Matter

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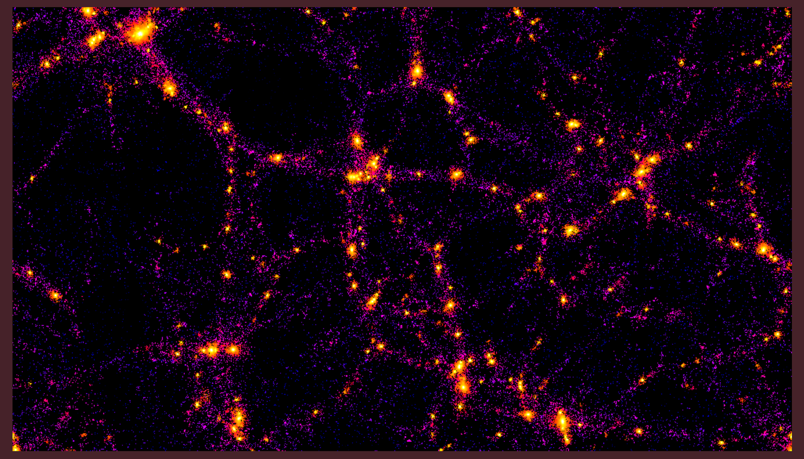


Introduction

Our world is not only made from everything we see. It is also made by the unseen. Since the 1930s, astronomers have observed that the velocities of orbiting galaxies does not match the relationship between mass and orbital velocity. Physicists proposed that in order for the galaxies to travel at such a high speed at large distance from the galaxy clusters, there has to be invisible matter that is exerting the needed gravitational pull.

One of our purposes during the 2013 Quarknet Summer Research Program is to study the three frontiers of particle physics. Dark matter research falls under both the Energy Frontier and the Cosmic Frontier. During these few weeks, we studied the history of dark matter research, the present methods of dark matter detection, and the various effects dark matter have on our universe.

We have included some important discoveries in the field of dark matter research, along with information about several ongoing experiments in this poster.

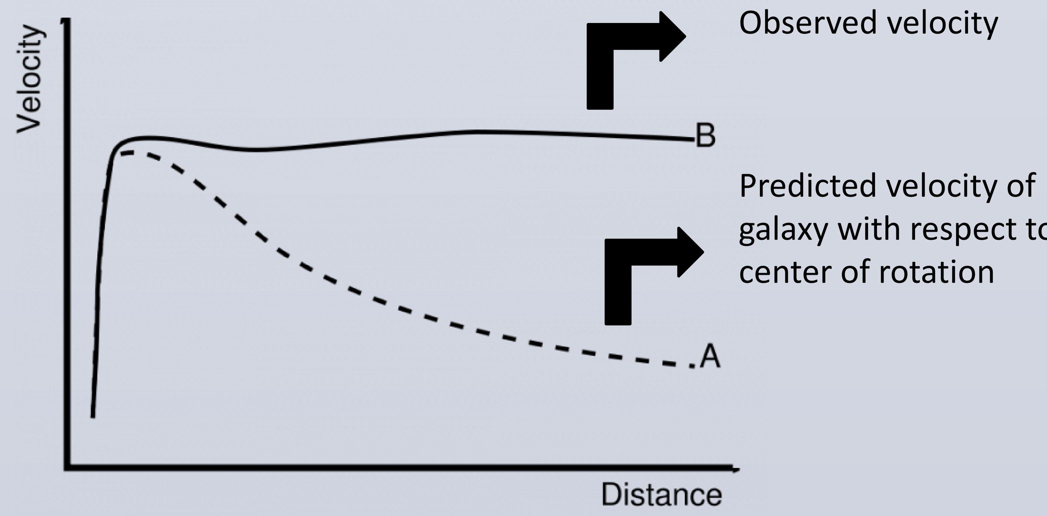
The Early Days

- In 1932, Dutch astronomer Jan Oort was conducting studies on the velocity of stars. The resulting velocities did not correspond to the estimated mass of the galaxies.
- Swiss astronomer Fritz Zwicky had similar findings a year later while examining the Coma Galaxy Cluster.
- A hypothesis was drawn from this finding, that there was unseen matter causing this higher velocity of the stars.

$$v = \sqrt{\mu\left(\frac{2}{r} - \frac{1}{a}\right)}$$

The equation for elliptical orbit velocity, the velocity of orbiting objects increases as the μ (denoting the gravitational constant x the mass of the center object) increases.

Vera Rubin discovered a discrepancy between the predicted angular motion of galaxies and the actual motion(1960s-1970s). According to her calculations, the galaxies should fly apart at the speed they are traveling. However, they don't fly apart, and it was theorized that this was due to a massive amount of unseen matter that was holding the galaxies together.



Current Theories

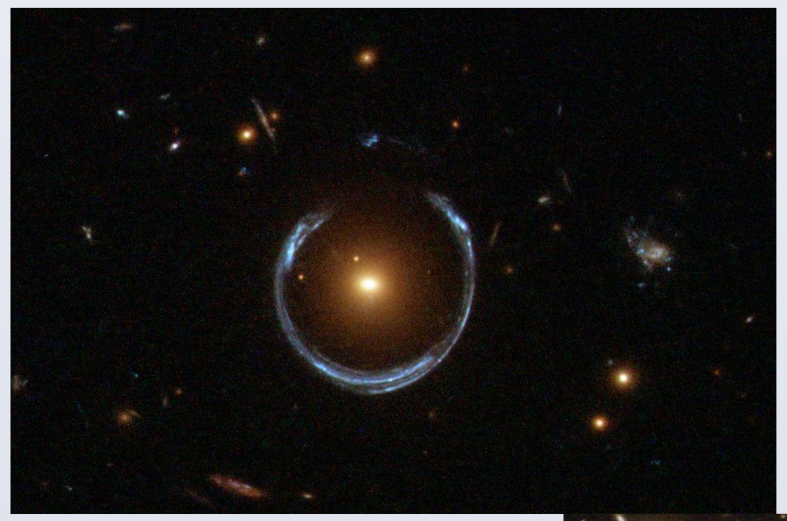
Currently, dark matter is categorized into different classes:

1. Hot dark matter: characterized by very fast speed.
   - Neutrino
2. Warm dark matter: sharing the characteristics of both the hot and cold dark matter.
   - Sterile neutrinos
3. Cold dark matter: characterized by relatively slow speed.
   - massive astrophysical compact halo object
   - robust associations of massive baryonic objects
   - weakly interacting massive particles
   - Axions

Gravitational Lensing

Another evidence of dark matter stems from the gravitational lensing of galaxy clusters.

Gravitational lensing occurs when light is bent around an object that has great mass.



Horse Shoe Einstein Ring

These observable mass of these galaxies cannot account for how much the light is bent, there has to be unseen matter contributing to the gravitational force on the surrounding space.

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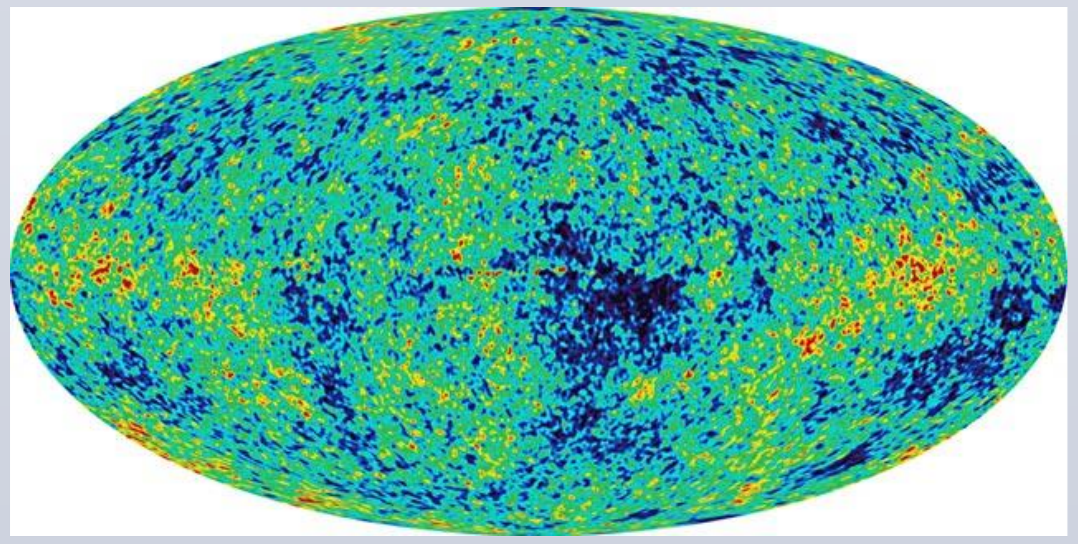
Cosmic Background Radiation

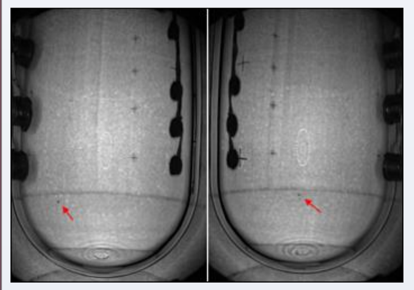
After the big bang, the temperature of the universe gradually cools as it expands. High energy photons in the gamma ray range experience a drop in energy and frequency, some of those photons drops down to microwave frequencies, causing the background noise.

Dark matter's presence is further substantiated because the cosmic background radiation pictures from WMAP also seem to be affected by gravitational lensing



Experiments

Coupp-60 Experiment



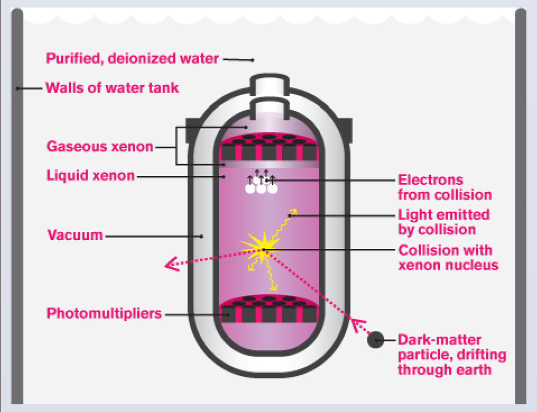
The Coupp-60 experiment is designed to detect dark matter particles as they pass through ordinary matter and interact weakly. The hope is that dark matter particles will collide and weakly interact with the liquid for long enough to create a single bubble

This can be differentiated from regular neutron collisions because other collisions interact more, and therefore create a trail of bubbles

CDMS at Soudan Mine

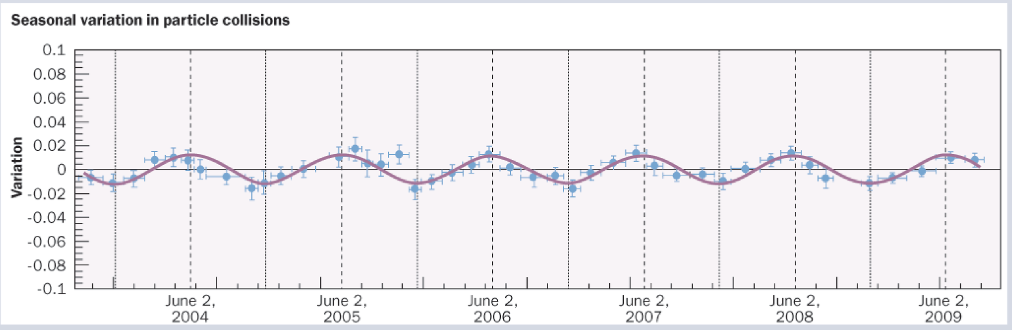
Helium-cooled cryogenic detectors(Made from germanium and silicon) are used to detect wimps. WIMPS and Neutrons produce nuclear recoils. To differentiate between WIMP hits and Neutrons, the rate of interaction on the Ge and Si are compared. WIMPs should interact with Ge more because Ge has more nucleons, whereas neutrons interact with Ge and Si with similar probability.

LUX Detector



Xenon detectors scintillate and ionize when particles such as photons, neutrons, and dark matter possibly interact. WIMPs can be identified by the different ratio of scintillation with ionization compared to particle interactions. WIMPs are differentiated from neutrons because WIMPs have an extremely small chance of a double interaction, whereas, a neutron has a likely chance

DAMA/LIBRA



Observations of the data taken show an annual cycle. During this time, the sun could be moving through the theoretical dark matter fields.

A three level sealing system prevents environmental air from interfering with the radiopure scintillating thallium-doped sodium iodide crystal detector.

Summary

The exploration of dark matter started with Jan Oort when he conducted experiments on galaxy rotation. This discovery fueled Vera Rubin to do further studies on the angular motion of galaxies. She found that the observed velocity has stayed constant at any distance away from the galaxy, while the predicted velocity should have decreased.

Current theories include hot dark matter, warm dark matter, and cold dark matter. Cold dark matter includes MACHOs, RAMBOs, and WIMPs.

Evidence for dark matter includes Gravitational Lensing and the Cosmic Background Radiation. Future evidence will be provided through experiments such as Coupp-60, CDMS, LUX, and DAMA/LIBRA.

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Acknowledgements and contact

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