Astronomy & Astrophysics : An Introductory Survey

A lecture series by Prof. G. Srinivasan

A ‘Golden Jubilee Celebration’ Event of the Astronomical Society of India

Lecture 8 : Rotation of our Galaxy

Dark matter is a component of our universe whose presence is discerned from its gravitational attraction rather than its luminosity. Originally known as the “missing mass”, the concept of dark matter originated in the 1930s when Swiss-American astronomer Fritz Zwicky considered the velocities of a large number of galaxies in the Coma cluster and observed that the gravitational pull from visible matter alone was not sufficient to keep the cluster bound. He inferred that there must exist certain form of ‘invisible’ matter - dark matter - which provides most of the gravitational pull responsible for holding the cluster galaxies together. Forty years later, Vera Rubin and Kent Ford found more evidence for dark matter by studying the motion of stars within spiral galaxies. But ‘dark matter’ made its presence felt earlier and much closer to home, when the study of the rotation of our Galaxy first began.

All spiral galaxies rotate, and so does our Milky Way Galaxy. Around 1920, it was discovered that our galaxy rotates ‘differentially’, like the planets in the solar system. But in order to determine the precise law of rotation how the angular velocity depends on the distance from the galactic centre one had to wait for the discovery of the 21 cm radiation from neutral hydrogen atoms in the interstellar medium. When the ‘rotation curves’ of galaxies were finally measured using the 21 cm radiation, it threw up a shocking result, namely, all galaxies are embedded in a giant halo of “Dark Matter” whose nature is still unclear. This lecture is devoted to these exciting developments.

Searching for Dark Matter (ongoing experiments) -

The LZ Dark Matter Experiment	https://lz.lbl.gov
Super Cryogenic Dark Matter Search	https://supercdms.slac.stanford.edu
The XENON Experiment	http://xenon1t.org/
The Axion Dark Matter eXperiment	https://depts.washington.edu/admx/

For the curious -

V. Rubin & W. K. Ford, 1970, Astrophysical Journal, **159**, 379

24 June 2022

Lecture Series Website : https://astron-soc.in/srini-ana

ASI on Facebook : https://www.facebook.com/asi.poec
ASI on Instagram : https://www.instagram.com/publicastronomy
ASI on Twitter : https://twitter.com/asipoec

Prepared by Dr. Sushan Konar : ***sushan.konar@gmail.com***

Astronomy & Astrophysics : An Introductory Survey

A lecture series by Prof. G. Srinivasan

A 'Golden Jubilee Celebration' Event of the Astronomical Society of India

Lecture 7 : Rotation of our Galaxy

[Supplementary Material : Dr. Sushan Konar]

Suggested Problems

1. How can one obtain the rotation curve of an external galaxy? It was noted in the lecture that, for Milky Way, we we use 21 cm spectral line of neutral hydrogen to obtain the rotational velocity of the regions far away from the galactic centre. Is it possible to use the same probe for distant galaxies?

2. A spiral galaxy has a rotation curve which rises linearly from zero at the center to 200 km/s at 5 kpc from the center. The rotation curve then remains flat at a constant value of 200 km/s out to 15 kpc, beyond which it can not be measured.

   (a) Make a plot of M(r), the total mass enclosed within radius r, as a function of radius. Assume that the mass distribution in the galaxy is spherically symmetric.

   (b) Assume that the form of the rotation curve is dominated by dark matter. Plot the density of the dark matter versus radius.

   (c) If this model is applied to our own Galaxy, what would be the estimated mass in dark matter interior to the Earth's orbit in the Solar System (i.e. within 1 AU of the Sun)?

3. A galaxy has a flat rotation curve, $v(r) = v_c$, with v_c a constant, out to some radius R. Interior to R the dominant contribution to the potential is dark matter, with a spherically symmetric distribution. Outside R, the density is zero. Show that the escape velocity from the galaxy for $r < R$ is given by,

$$v_e^2 = 2v_c^2 \left(1 \ln\left(\frac{R}{r}\right)\right) . \qquad (1)$$

4. Discuss why 'hot' but weakly interacting particles, like neutrinos, can not be considered to be the main constituent of the 'Dark Matter'.

24 June 2022