Throwing light on dark matter

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Bengaluru Apr 2, (Research Matters):

All the matter that we see around us is ultimately made up of atoms, which in turn is made up of protons and neutrons. Surprisingly, such ordinary matter constitutes less than 15% of the total matter in the Universe. Most of the Universe is made up of dark matter - matter that does not emit any light but interacts with other objects only through gravity. Although we know dark matter exists, we do not know what exactly it is. Now, a study by researchers from Bengaluru has tried to understand the dark matter better.

Dark matter has never been directly observed or created in a lab. Its existence and properties are inferred from its gravitational effects on objects that we can see. In this study, published in the *Journal of Cosmology and Astroparticle Physics*, researchers from the Raman Research Institute (RRI), Indian Institute of Science (IISc), and the Indian Institute of Astrophysics (IIA), have examined what future experiments can reveal about the nature of dark matter.

"The first partial evidence for dark matter was seen long ago, in the 1930s. But the main evidence came in the 1970s. It was observed that galaxies are rotating too fast to be held together by the gravity of the visible matter alone. Hence the existence of additional invisible, dark matter was postulated. By the late 1980s, additional lines of evidence had emerged from observations of clusters of galaxies, and from even larger cosmological scales", says Prof. Shiv Sethi from RRI, who is also an author of the study, talking about our quest to understand dark matter.

Although the exact nature of dark matter is unknown, there are several different models of what the dark matter particle could be, most of them motivated by different particle physics models. The most popular model is "cold dark matter", where cold refers to the velocity of the dark matter particles in the early Universe. If dark matter particles were 'hot', travelling at high speeds, they would rush from high density to low-density regions in the early Universe, thereby wiping out these density differences. In contrast, 'cold' dark matter, which moves slowly, would allow density differences in the early Universe to grow into galaxies. Since we can observe galaxies in the present Universe, hot dark matter model is now ruled out.

Scientists probe the nature of dark matter in several ways, including experiments that hope to detect dark matter particles directly. But in this study, the researchers focus on observations of the cosmic microwave background (CMB) -- relic radiation left over from the Big Bang. "CMB is the most precise measurement in almost all of astrophysics. Moreover, the physics that goes into it is extremely clean. So when we want to look for something in an experiment, we want to manage these two aspects," explains Prof. Sethi.

The cosmic microwave background is nearly uniform, but there are small differences in temperature and density. The pattern of variations in temperature and density depends on what particles are present in the early Universe, and their properties. Hence each type of particle leaves behind a distinct signature in the spectrum of temperature and density fluctuations in the CMB.

In this study, the researchers calculate the effects of different dark matter particle models on the CMB spectrum. "We have considered a whole range of models that exhaust nearly all possibilities that are still consistent with current experimental constraints," says Prof. Sethi. The researchers have tried to answer the question -- 'If dark matter changes its nature below a certain scale, how well can we probe it with future experiments? What kind of constraints can we put on these models?'

The study finds that previous and current observations of the CMB are not sensitive enough to distinguish between these dark matter particle models. However, many experiments are being proposed in the next decade to observe the CMB, such as the space-based PIXIE (Primordial Inflation Explorer) mission by NASA and the ground-based CMB S-4 (Stage 4) experiment at the South Pole. Based on the expected sensitivity of PIXIE, the researchers expect these experiments to be able to distinguish between at least some of the dark matter particle models, there by shedding light on the enduring mystery of what dark matter is.

Tags:
Dark matter, RRI, IISc, Cosmic microwave background, NASA