WIMP STARS AS DARK MATTER IN THE UNIVERSE

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It is suggested that the dark matter in the Universe may be made of stars and black holes made up of WIMP matter.

The existence of "dark matter" in the Universe is by now established\(^1\). Brown Dwarfs, Black Holes, neutrinos, weakly interacting massive particles (WIMP) and other Super Symmetric particles have been suggested as candidates for dark matter\(^1\). So far the nature of the dark matter is not known. It is generally assumed that if dark matter is made up of particles, it exists as diffuse matter. It is likely, however, that primordial dark matter also condenses due to gravitational force. Here we consider the possibility that dark matter exists in the form of WIMP stars.

Primordial WIMP matter, which is presumably intermixed with baryonic matter, should also condense along with baryonic matter due to gravitational force. Starting with density fluctuations, the intermixed material should condense to form proto-galaxies. When galaxies are formed from the proto-galaxies, in order to condense, the baryonic matter gets rid of its angular momentum via various viscosities. The WIMP matter, however, will find it hard to get rid of the angular momentum due to its weak interaction. This may result in the WIMP matter getting separated from the baryonic matter, and will stay in the outer regions of galaxies. The WIMP matter then may further condense into WIMP stars.

The formation of neutrino stars has been suggested\(^2\). The Chandrasekhar limit for such stars is given as\(^2\),

\[
M_\star = 1.016 \times 10^{30} M_\odot \left( \frac{17.2\text{keV}}{m_\nu c^2} \right)^2 g^{-1/2} \ldots \ldots (1)
\]

where \(M_\odot\) is the mass of the sun, \(m_\nu\) is the mass of the neutrino, \(c\) is the velocity of light and \(g\) the degeneracy factor. This corresponds
to a Schwarzschild radius of

\[ R_s = 1.16 \left( \frac{17.2 \text{keV}}{m_\nu c^2} \right)^2 g^{-1/2} \] ....................(2)

where \( R_s \) is given in light days. The radius of the neutrino star is given by,

\[ R_0 = 6.8631 \left( \frac{M_\odot}{M_S} \right)^{1/3} g^{-2/3} \left( \frac{17.2 \text{keV}}{m_\nu c^2} \right)^{8/3} \] .....................(3)

where \( R_0 \) is given in light years. The neutrino stars are suggested to be at the centres of galaxies.

The above equations should also hold for stars made of the weakly interacting WIMP particles. The mass of a WIMP is predicted to be in the range of 10-1000 GeV. The mass limit for a WIMP star, if the mass of the WIMP is taken as 10 GeV, using (3) is \( M_w \sim 3 \times 10^{-2} M_\odot \). The radius of a WIMP star at the mass limit, using (2), is \( R_w = 8.9 \times 10^3 \) cm, while the Schwarzschild radius is \( R_s = 2.8 \times 10^3 \) cm. Since \( R_w \) is greater than \( R_s \), the star can be stable. The density of such stars is \( \rho_w \sim 2 \times 10^{19} \text{ gm cm}^{-3} \). At such densities even with weak interaction cross-sections, WIMPs will annihilate if they are Majorana particles. Even if they are Dirac particles, WIMPs and anti-WIMPs cannot coexist at such high densities. One has to assume that they are made up of only one kind of WIMPs, by appealing to processes similar to those that separated baryonic matter and anti-matter, or processes which resulted in only one kind of baryonic matter in the Universe.

It was mentioned earlier that WIMP matter, while condensing, may find it difficult to get rid of its angular momentum. It is therefore possible that WIMP stars with masses greater than the limit given above may exist as ellipsoidal stars or disks. If the mass of the WIMP condensate exceeds the limit given above, it may also form a WIMP black hole.

Attempts have been made to detect compact objects that make up the dark matter in the halo of our galaxy. In these attempts, gravitational lensing of the stars in the Large Magellanic Cloud by compact objects that make up the dark matter in the galactic halo (MACHO) was detected. The conclusion of these studies is that such objects make up a small fraction of the dark matter required in the
halo. The Large Magellanic Cloud is at a high galactic latitude, and if the compact objects like WIMP stars are located closer to the galactic plane, as are normal stars, and in the outer regions (due to angular momentum considerations suggested earlier), the observations cited above\textsuperscript{5,6} may not detect them. Observations using lensing of supernova in external galaxies\textsuperscript{7} may be able to detect WIMP stars.

It will be interesting to study accretion of gas on to WIMP stars. If one of them is captured by an ordinary star to form a close binary, then such accretion is possible. It may allow identification of WIMP stars or WIMP black holes.

In conclusion, dark matter in the Universe may exist in the form of WIMP stars and WIMP black holes.

References

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