DARK MATTER AND VARIABLE COSMOLOGICAL CONSTANT

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ABSTRACT
In this paper we have investigated the astronomical evidences for Dark Matter which come from the wide variety of astrophysical measurements, its detection, along with study of Dark Matter candidates and importance of Robertson-Walker geometry.

Keywords: *Cosmological Constant, Dark Matter, Robertson-Walker metric.*
A.M.S. Subject Classification Number: *83F05*

1. INTRODUCTION
The present understanding of our universe is based upon the current cosmological observations at every scale and it is assumed that universe is made of (24 ± 0.02) percentage of matter [1] whereas only (4.171 ± 0.039) percentage consists of baryonic matter [2]. Evidences for the existence of an unseen 'dark' component in the energy density of the universe comes from several independent observations at different length scales, rotations of peripheral stars in the galaxies, cosmic microwave background anisotropies universe large scale structure, gravitational field in cluster of galaxies etc. The baryonic content is well known, both from element abundances produced in primordial nucleosynthesis roughly 100 seconds after the Big Bang and the measurement of anisotropies in the CMB. The evidence for the existence of Dark Matter is overwhelming and comes from a wide variety of astrophysical measurements.

In the present paper we have tried to highlight all the investigated astronomical evidences available for dark matter with the remark that Dark Matter in cosmology was observationally discovered, it was not predicted! However its nature is unknown, except that it is not baryonic. So, this is very hot topic in these days among cosmologists with much theoretical speculations about what it is?

2. DARK MATTER IN GALAXIES & CLUSTERS
From the peer research findings we can consider the fact that the 95% of the mass of the galaxies and clusters is made of some unknown component of Dark Matter (DM) which comes from:

a) Rotational curves
b) Gravitational lensing
c) Hot gas in clusters

2.1 Rotational Curves
In 1970, Ford & Rubin discovered that rotation curves of galaxies are flat and latter on it expressed as galaxies must have enormous dark halos made of unknown O dark matter. The baryonic matter which accounts for the gas & dust cannot alone explain the galactic rotation curve. The limitation is that one can see the beginning of dark matter halos, but cannot trace where most of the dark matter is.

2.2 Gravitational Lensing
Einstein's General theory of Relativity predicts that mass bends or lenses light. This effect can be used to gravitationally ascertain the existence of mass even when it emits no light. Gravitational lensing measurements confirm the existence of enormous quantities of dark matter both in galaxies and in clusters of galaxies. The main features of success of the lensing of dark matter to till date is the evidence that dark matter is seen out to much larger distances than could be established by rotational curves. The Dark Matter is seen in galaxies out of 200kpc from the centers of galaxies, in agreement with N-body simulations.

2.3 Hot gas in clusters

Another piece of gravitational evidence for Dark Matter is the hot gas in clusters. The existence of this gas in the clusters can only be explained by large Dark Matter components that provide the potential well to hold on to the gas. Hot gas is held in the cluster by gravity, but mass of the galaxies is not enough to explain the presence of this gas. Huge amounts of additional, invisible matter are needed for gravity to balance the pressure of the gas, which is at a very high temperature. This missing mass of unknown nature may be called as Dark Matter.

3. DETECTION OF DARK MATTER

3.1 Direct Detection

Many experimental efforts on a host of techniques have been made in the field of direct search of non-baryonic dark matter. Various detectors already reached sufficient sensitivity to begin to rest regions of SUSY (Super symmetric scenario) parameter space. On the basis of investigations, we can say that two classes of models are phenomenologically interesting and working as benchmarks:

a) The lightest neutralino in SUSY models when the R-parity is conserved.
b) Lightest Kaluza-Klein excitation predicted in models with universal extra dimensions.

3.2 Indirect Detection

Indirect detection of dark matter consists of observing and measuring the flux of standard particles $\upsilon, \gamma, e^{+} and \overline{p}$ issued from annihilations of neutralinos in the dark matter halo.

The main dependencies of these flux measured in earth can be expressed as:

a) For charged messengers

$$\left\langle \rho^{2} \right\rangle . \frac{\left\langle \sigma_{a} v \right\rangle}{m_{x}^{2}} \frac{d\phi}{dE} P(r) \tag{1}$$

b) For Gamma & neutrinos

$$\int \rho^{2} ds \frac{\left\langle \sigma_{a} v \right\rangle}{m_{x}^{2}} \frac{d\phi}{dE} \tag{2}$$

where, $\left\langle \sigma_{a} v \right\rangle$ is the annihilation cross-section σ_{a} .

m_{x} is the mass of dark matter depends upon the realized physics model [3].

v - the average velocity distribution of dark matter is 270km/sec.

$\frac{d\phi}{dE}$ is the energy spectrum of standard particles produced in annihilation.

ρ is the dark matter density in the region where the annihilation occur.

As per [4] the reasonable range lies between (0.2 to 0.8) $G_{e}v / m^{3}$.

$P(r)$ represents the propagation term between the production source and the detection.

4. WEAKLY INTERACTED MASSIVE PARTICLES (WIMPS)

One of the most important candidates for the invisible ‘dark matter’ is known as weakly interacted massive particles. These particles are also predicted by extensions of the standard model of particle physics, such as SUSY. If WIMPS exists, they are also the dominant mass in our own milky way and though they only very rarely interact with conventional matter should nonetheless be detectable by sufficiently sensitive detectors on earth.

In recent years, the application of cryogenic noble liquids in dark matter searches, has gained new momentum due to their promises for large target mass detectors with possibly as powerful background discriminations as cryogenic crystals. LX_e & LA_r are especially attractive s they are known to be good scintillators and ionizers as established by many researches.

5. IMPORTANCE OF ROBERTSON WALKER GEOMETRY

We can find inhomogeneous models to reproduce the observations without any exotic energy, as well as homogeneous models with some form of dark energy that explain the same observations. One natural query may arise that can we distinguish between the two? Is a Robertson Walker geometry is the correct metric for the observed universe region. Three kind of direct tests are possible:

i) CBR Based tests: CBR stands for cosmic Black body Radiation as pointed out by Goodman & Caldwell [5, 6]. This model is good for void models but misses stationary space times.

ii) Behaviour near origin: The universe must not have a geometric cusp at the origin, as this implies a singularity there. Thus there are essential conditions that must be fulfilled in the inhomogeneous models [7].

The distance modulus behaves as $\Delta dm(s) = -\left(\frac{5}{2}\right) q_0(s)$ in standard ΛCDM models, but if this were true in a LTB (Lemaitre–Tolman–Bondi) void model without Λ, this implies a singularity [8]. The observational tests of this requirement will be available from intermediate redshift supernovae.

iii) Constancy of Curvature: These are coupled in RW models as

$$d_i(z) = \frac{1+z}{H_0\sqrt{-\Omega_k}} sin\left(\sqrt{-\Omega_k}\int_0^z dz' \frac{H_0}{H(z')}\right) \tag{3}$$

These effects are strictly coupled in RW geometries; they are decoupled in LTB geometries.
In RW geometries we may combine the Hubble rate and distance data [9] to find the curvature today as:

$$\Omega_k = \frac{|H(z)D'(z)|^2 - 1}{[H_0 D(z)]^2} \tag{4}$$

The above relations are independent of all other cosmological parameters including dark matter model and theory of gravity. In the similar manner, one of the exciting results has been obtained by Clarkson [10].

6. CONCLUDING REMARKS

It may be concluded that 95% of the mass in galaxies and clusters of galaxies is in the form of an unknown type of Dark matter. We know this fact from various evidences of Dark Matter as rotation curves, Gravitational lensing & hot gas in clusters. If we analyse the direct or indirect observations of cosmologists involving the three fundamental independent aspects in cosmology, the expansion rate, the matter contents & large scale structure, all concluded that either the universe is open or the cosmological constant 'Λ' is non zero [11,12]. As we know that the Hubble constant 'H_0' gives an upper limit on the age of a matter dominated universe. Matter causes a deceleration of universal expansion over time. Thus, at earlier times the universe would have been expanding faster than it is at the present time. One can derive an upper limit on the age of the universe by considering the fact that all galaxies were once located together and using the relations for constant velocity to determine the length of time a galaxy at a given distance moving away at a constant velocity:

$$D = vt \tag{5}$$

$$\Rightarrow t = \frac{D}{t} = H_0^{-1} \tag{6}$$

where 'v' is the recession of a galaxy & 'D' is the proper distance.

In fact, we cannot stretch a measuring tape between the fundamental particles. Therefore, the proper distance 'D' is not a measureable quantity, however the great advantage of the realistic formulation is that it gives the relationship between quantities such as red-shifts, apparent magnitudes, number counts etc., which can be measured.
If we consider a fundamental particle at the origin $r = 0$ & another fundamental particle at 'r', then the proper distance 'D' between the two fundamental particles at a time 't' is given by:

$$D = R(t)\int_0^r \frac{dr}{\sqrt{1-kr^2}} = \begin{cases} R\sin^{-1} r & (k=1) \\ Rr & (k=0) \\ R\sinh^{-1} r & (k=-1) \end{cases} \quad (7)$$

therefore $D \propto R(t)$.

$$v = \dot{D} = \frac{\dot{R}}{R} D = HD \quad (8)$$

We can derive a specific relation between the Hubble constant 'H_0' & the age of the universe as:

i) For flat matter dominated universe

$$t = \left(\frac{2}{3}\right) H_0^{-1} = 9.7Gyr \quad (9)$$

ii) For open universe $(\Omega > 0.2)$

$$t < 0.85 H_0^{-1} \quad (10)$$
$$= 12.5Gyr \quad (11)$$

iii) For flat universe $(\Omega_\Lambda < 0.8)$

$$t < 1.08 H_0^{-1} \quad (12)$$
$$= 16Gyr \quad (13)$$

So, we have strong evidence that $\Lambda \neq 0$, it would allow a universal acceleration and hence it would allow an older universe for a fixed Hubble constant. Big Bang nucleosynthesis (BBN) has provided an upper limit on the total density of baryonic matter in the universe where $\Omega_B \leq 0.26$. As discussed in this paper Dark Matter observations are based on local scales while that Dark Energy behaviour at cosmological scales. More research regarding nature of baryonic matter is required & there is possibility to discuss the dual dark matter/dark energy properties in term of dark fluid. This need to be further investigated with chaotic behavior of universe.

7. REFERENCES

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