Chapter 8
Dark Matter Anomaly

B. G. Sidharth and Abhishek Das

Abstract Latest observations by Riess and coworkers in 2017 have reconfirmed their earlier observation that the universe is accelerating some 8% faster than the currently accepted cosmological model described. In this chapter, we state again, in light of a recent paper, that this discrepancy can be eliminated by considering a universe consisting only of matter and dark energy.

8.1 Introduction

Very recently (Das and Sidharth 2019) Das and Sidharth have shown that the existence of dark matter is inconsistent with the observation of Riess et al. (2016). Now, Hubble's law is regarded as one of the major observational basis for the expansion of the universe. Later the existence of *dark matter* was hypothesized by Zwicky (1933, 1937) who inferred the existence some unseen matter based on his observations regarding the rotational velocity curves at the edge of galaxies. Although, Kapteyn (1922) and Oort (1932) had also had derived the same conclusions before Zwicky. Since then, various efforts have been made to prove the existence of *dark matter* (cf. ref. Bertone et al. (2005) for detailed review). Recently, after conducting experiments to detect weakly interacting massive particles (WIMPs) that interact only through gravity and the weak force and are hypothesized as the constituents of *dark matter*, it has been found that such hypotheses lead nowhere (Akerib et al. 2016).

Interestingly, authors such as Milgrom (1983), Bekenstein (2004) Sidharth (cf. Sect. 8.3) and Mannheim (2005) have endeavoured to find alternatives to the widely accepted *dark matter*. The author Sidharth (2000, 2006a, b) has also given a suitable alternative to the conventional *dark matter* paradigm.

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B. G. Sidharth · A. Das (✉)
B.M. Birla Science Centre, Hyderabad, India

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The generally accepted ideas may have to be revisited in view of latest observations of Riess et al. which point to the fact that cosmic acceleration is some 5–8% greater than what the current cosmological model suggests.

Before proceeding, it may be mentioned that in 1997, the accepted model of the universe was that of a dark matter dominated decelerating universe. That year the author Sidharth put forward his contra model—an accelerating universe (Sidharth 1998), dominated by not dark matter but rather what is today being called dark energy.

8.2 Theory

We are well acquainted with the fact that the Friedman equations govern the expansion of space in homogeneous and isotropic models of the universe within the context of general relativity. Let us begin with the following equation

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3}$$

where H is the Hubble parameter, a is the scale factor, G is the gravitational constant, k is the normalized spatial curvature of the universe and Λ is the cosmological constant. Considering $k = 0$ (a flat universe) with the domination of both matter and dark energy, one can derive the Hubble parameter as

$$H(z) = H_0\left[\Omega_{\mathrm{M}}(1+z)^3 + \Omega_{\mathrm{DE}}(1+z)^{3(1+w)}\right]^{\frac{1}{2}} \tag{8.1}$$

where, z is the redshift value or the recessional velocity and the dimensionless parameter w is given by

$$P = w\rho c^2$$

P being the pressure and ρ being the density. Now, we would like to expand the function $H(z)$ using the Taylor expansion about the point z_0. This yields

$$H(z) = H(z_0) + \frac{H'(z_0)}{1!}(z - z_0) + \cdots$$

Neglecting terms consisting second and higher order derivatives of the Hubble parameter and considering that $H(z_0) = H_0$ we have using (8.1)

$$H(z) = H_0 + \frac{H_0}{2}\frac{3\Omega_M(1+z_0)^2 + 3(1+w)\Omega_{DE}(1+z_0)^{3(1+w)-1}}{\left[\Omega_M(1+z_0)^3 + \Omega_{DE}(1+z_0)^{3(1+w)}\right]^{\frac{1}{2}}}(z - z_0) \quad (8.2)$$

Now, we know that if the dark energy derives from a cosmological constant then

$$w = -1$$

Therefore, in such a case we have

$$H(z) = H_0 + \frac{3H_0}{2}\frac{\Omega_M(1+z_0)^2}{\left[\Omega_M(1+z_0)^3 + \Omega_{DE}\right]^{\frac{1}{2}}}(z - z_0) \quad (8.3)$$

Now, since numerical values suggest that $\Omega_{DE} > \Omega_M$ we can use another series expansion for the denominator of the second term above to get

$$H(z) = H_0\left[1 + \frac{3}{2}\frac{1}{\sqrt{\Omega_{DE}}}\left\{\Omega_M(1+z_0)^2\right\}\left\{1 - \frac{\Omega_M(1+z_0)^3}{2\Omega_{DE}}\right\}\right](z - z_0) \quad (8.4)$$

Now, we would look at this equation at the point $z_0 = 0$ and for $z = 1$ to give

$$H = H_0\left[1 + \frac{3}{2}\frac{\Omega_M}{\sqrt{\Omega_{DE}}}\left\{1 - \frac{\Omega_M}{2\Omega_{DE}}\right\}\right] \quad (8.5)$$

Now, standard cosmological model suggests that the universe is comprised of baryonic matter, dark matter, dark energy and some other constituents. In a nutshell, we have (Knop et al. 2003).

$$\Omega_{Baryonic} \approx 0.04$$

$$\Omega_{Darkmatter} \approx 0.23$$

$$\Omega_{Darkenergy} \approx 0.73$$

and

$$\Omega_M = \Omega_{Baryonic} + \Omega_{Darkmatter}$$

Using all these values in (8.5) we have the Hubble parameter

$$H = H_0 + 0.39H_0$$

i.e. the acceleration of the universe should be approximately 39% greater than its value. But, due to recent observations it has been substantiated that the acceleration is about 5–8% greater than its value. So, in fact we should have

$$H = H_0 + 0.08H_0$$

If this is the case then doing some back calculations and using $\Omega_{\mathrm{DE}} \approx 0.73$, we have the following two values for Ω_{M}.

$$\Omega_{\mathrm{M}} \approx 1.41 \text{ or}, 0.044$$

Now, it is a fact that $\Omega_{\mathrm{M}} < 1$ and so $\Omega_{\mathrm{M}} \approx 1.41$ would be unphysical. Therefore we have the value of Ω_{M} as

$$\Omega_{\mathrm{M}} \approx 0.044 \tag{8.6}$$

But, this is very nearly equal to the value of Baryonic matter, i.e. $\Omega_{\mathrm{Baryonic}}$. This suggests ostensibly that

$$\Omega_{\mathrm{Darkmatter}} \approx 0 \tag{8.7}$$

In other words, the existence of dark matter is itself inconsistent according to the latest observations of Riess et al. In such a case, the total density of the universe is given by

$$\Omega = \Omega_{\mathrm{Baryonic}} + \Omega_{\mathrm{Darkenergy}} \approx 0.77 \tag{8.8}$$

which is less than the critical density. This suggests that the universe will be expanding in an accelerating manner.

8.3 Alternative to the *Dark Matter* Paradigm

Very recently the LUX detector in South Dakota has concluded (Akerib et al. 2016) that it has not found any traces of dark matter. So far this has been the most delicate detector. It will be recalled that dark matter was introduced in the 1930s by Zwicky to explain the flattening of the galactic rotational curves: With Newtonian gravity the speeds of these galactic curves at the edges should tend to zero according to the Keplerian law, $v \propto 1/\sqrt{r}$. Here r is the distance to the edge from the galactic centre. However velocity v remains more or less constant. Zwicky explained this by saying that there is a lot more of unseen matters concealed in the galaxies, causing this discrepancy. The fact is that even after nearly 90 years dark matter has not been detected.

The modified Newtonian dynamics approach of Milgrom (1983, 1986, 1989, 1994, 1997, 2001) was an interesting alternative to the *dark matter* paradigm. The objection of this fix has been that it is too ad hoc, without any underlying theory.

The author himself has been arguing over the years (Sidharth 2000, 2006a, b) (cf. ref. Sidharth (2008) for a summary) that the gravitational constant G is not fixed but varies slowly with time in a specific way. In fact this variation of the gravitational constant has been postulated by Dirac, Hoyle and others from a different point of view (cf. ref. Sidharth 2008; Narlikar 1993) which for various reasons including inconsistencies have in the author's scheme, exactly accounts for the galactic rotation anomaly without resorting to dark matter or without contradictions.

Our starting point is the rather well known relation (Narlikar 1993).

$$G = G_{\mathrm{o}}\left(1 - \frac{t}{t_{\mathrm{o}}}\right) \tag{8.9}$$

where G_{o} is the present value of G and t_{o} is the present age of the Universe, while t is the relatively small time elapsed from the present epoch. On this basis one could correctly explain the gravitational bending of light, the precession of the equinoxes of mercury, the shortening of the orbits of binary pulsars and even the anomalous acceleration of the pioneer spacecrafts (cf. references given above).

Returning to the problem of the rotational velocities at the edges of galaxies, one would expect these to fall off according to

$$v^2 \approx \frac{GM}{r} \tag{8.10}$$

However it is found that the velocities tend to a constant value,

$$v \sim 300\ \mathrm{km/s} \tag{8.11}$$

This, as noted, has led to the postulation of the as yet undetected additional matter alluded to, the so called dark matter.(However for an alternative view point cf. Sivaram and de Sabbata (1993).) We observe that from (8.9) it can be easily deduced that (Sidharth 2001).

$$a \equiv (\ddot{r}_o - \ddot{r}) \approx \frac{1}{t_o}(t\ddot{r}_o + 2\dot{r}_o) \approx -2\frac{r_o}{t_o^2} \tag{8.12}$$

as we are considering infinitesimal intervals t and nearly circular orbits. Equation (8.12) shows (cf. ref. Sidharth (2006a) also) that there is an anomalous inward acceleration, as if there is an extra attractive force, or an additional central mass, a la Zwicky's dark matter.

So,

$$\frac{GMm}{r^2} + \frac{2mr}{t_o^2} \approx \frac{mv^2}{r} \tag{8.13}$$

From (8.13) it follows that

$$v \approx \left(\frac{2r^2}{t_o^2} + \frac{GM}{r} \right)^{1/2} \tag{8.14}$$

From (8.14) it is easily seen that at distances within the edge of a typical galaxy, that is $r < 10^{23}$ cm, the Eq. (8.10) holds but as we reach the edge and beyond, that is for $r \geq 10^{24} cms$ we have $v{\sim}10^7$ cm per second, in agreement with (8.11). In fact as can be seen from (8.14), the first term in the square root has an extra contribution (due to the varying G) which is roughly some three to four times the second term, as if there is an extra mass, roughly that much more.

Thus the time variation of G explains observation without invoking dark matter.

8.4 Conclusion

We have seen that the discrepancy in the acceleration value of the universe, as reconfirmed multiple times by careful studies of Riess and coworkers can be removed by considering a universe consisting only of matter and dark energy.

Recently, Swinbank (2017) and Genzel et al. (2017) have concluded that nearly ten billion years ago dark matter concentration was very small and the universe was dominated by baryonic matter. It is possible that this negligible concentration of dark matter boiled down to zero in due course of evolution of the universe.

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