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Time Dependence of Charged Dark Matter

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Abstract

We investigate a model of the universe where dark energy is replaced by electrically-charged extremely-massive dark matter. This was originally described only for the present cosmological time. The time dependence of the charged dark matter is different from that for dark energy and in the future the expansion will no longer accelerate and the scale factor $a(t)$ will revert to a matter-dominated behaviour $a(t) \sim t^{\frac{2}{3}}$. The consequences for the introverse and extroverse are discussed. Unlike in a ΛCDM model, many other galaxies will always remain visible.

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1 Introduction

A novel cosmological model was recently suggested [1, 2] in which dark energy is replaced by charged dark matter in the form of cPEMBHs or charged Primordial Extremely Massive Black Holes. That discussion focused on the present cosmological time $t = t_0 \simeq 13.8$ Gy and already provided some counterintuitive ideas such as that at the largest cosmological distances, *e.g.* greater than 1 Gpc, the dominant force is electromagnetism rather than gravitation.

The production mechanism for PBHs in general is not well understood, and for the cPEMBHs we shall make the simplifying assumption that they are first formed when the accelerated expansion begins at $t = t_{DE} \sim 9.8$ Gy, as in Table 1 in [3]. For the expansion before t_{DE} we shall assume that the ΛCDM model is approximately accurate.

The subsequent expansion in the charged dark matter cPEMBH model will in the future depart markedly from the ΛCDM case. We can regard this as advantageous because the future fate of the universe in the conventional picture does have certain distasteful features in terms of the extroverse, as we bieifly review.

In the ΛCDM model the introverse, or what is also called the visible universe, coincides with the extroverse at $t = t_{DE} \sim 9.8$ Gy with the common radius

$$R_{EV}(t_{DE}) = R_{IV}(t_{DE}) = 39Gly \tag{1}$$

according to Table 3 in [3]).

The introverse expansion is limited by the speed of light and its radius increases from Eq. (1) to 44 Gly at the present time $t = t_0$ and asymptotes to

$$R_{IV}(t \to \infty) = 58Gly \tag{2}$$

The extroverse expansion is exponential and superluminal. Its radius increases from its value 39 Gly in Eq. (1) to 52 Gly at the present time $t = t_0$ and grows without limit so that after a trillion years it attains the extremely large value

$$R_{EV}(t = 1Ty) = 9.7 \times 10^{32}Gly. \tag{3}$$

This future for the ΛCDM scenario seems distasteful because the introverse becomes of ever decreasing, and eventually vanishing, significance, relative to the extroverse.

2 The future of charged dark matter

A possible formation mechanism of cPEMBHs was provided in [4] where their common sign of electric charge, negative, arises from preferential accretion of electrons relative to protons. This formation mechanism is not well understood[†] [‡] [§] so to create a cosmological model we shall for simplicity assume that the cPEMBHs are all formed between $t = t_{DE} \sim 9.8$ Gy and $t_0 \sim 13.8$Gy. As discussed in [2], the Friedmann equation ignoring radiation, during this time window, is

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{\Lambda}{3} + \frac{8\pi G}{3}\rho_{matter} \tag{4}$$

where Λ is the cosmological constant generated by the Coulomb repulsion between the cPEMBHs. From Eq.(4), with $a(t_0) = 1$ and constant Λ, we would predict that

$$a(t \to \infty) \sim exp\left(\sqrt{\frac{\Lambda}{3}}(t - t_0)\right) \tag{5}$$

However, in the case of charged dark matter, with no dark energy, we must re-write Eq, (4) as

$$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho_{cPEMBHs} + \frac{8\pi G}{3}\rho_{matter} \tag{6}$$

in which

$$\rho_{matter}(t) = \frac{\rho_{matter}(t_0)}{a(t)^3} \tag{7}$$

where matter includes both normal matter and the uncharged dark matter.

Of special interest in the present discussion is the expected future behaviour of the charged dark matter

$$\rho_{cPEMBHs}(t) = \frac{\rho_{cPEMBHs}(t_0)}{a(t)^3} \tag{8}$$

so that comparison of Eq.(4) and Eq.(6) suggests that the cosmological constant is predicted to decrease from its present value. More specifically, we find that asymptotically the scale factor will behave as if matter-dominated and the cosmological constant will decrease at large future times as a power

$$a(t \to \infty) \sim t^{\frac{2}{3}} \qquad \Lambda(t \to \infty) \sim t^{-2}. \tag{9}$$

so that a trillion years in the future $\Lambda(t)$ will have decreased by some four orders of magnitude relative to $\Lambda(t_0)$.

[†] The cPEMBHs discussed in [4], while inspirational, do not experience long-range electromagnetic forces [5]. The cPEMBHs in the theory proposed by [3] therefore require a modified production mechanism.

[‡] A possible test for the presence of cPEMBHs was proposed in [6].

[§] Electrically neutral PEMBHS were first considered, with a different acronym SLABs, in [7].

3 Discussion

According to the ΛCDM model, we live at a special time in cosmic history because of the density coincidence between dark matter and dark energy. In the case of charged dark matter replacing dark energy, the present era is even more special because the striking accelerated expansion, discovered in 1998, is a temporary phenomenon centred around the present time. Acceleration began about 4 Gy ago at $t_{DE} = 9.8Gy = t_0 - 4Gy$. This unexpected behaviour will disappear in a few more billion years. The value of the cosmological constant is predicted to fall like $a(t)^{-2}$ so that, when $t \sim \sqrt{2}t_0 \sim 19.5Gy \sim t_0 + 4.7Gy$, the value of $\Lambda(t)$ will be one half of its present value, $\Lambda(t_0)$. As discussed in [2], the equation of state associated with Λ is predicted to be extremely close to $\omega = -1$, so close that measuring the difference seems impracticable.

Let us discuss the future time evolution of the introverse and extroverse in the case of charged dark matter. For the introverse, nothing changes from the ΛCDM case discussed in Table 3 of [3]. After a trillion years, the introverse radius will be at its asymptotic value $R_{IV} = 58Gly$, as stated in Eq.(2). By contrast, the future for the extroverse is very different for charged dark matter. WIth the growth $a(t) \propto t^{\frac{2}{3}}$ we find that the radius of the extroverse at $t = 1$ Ty is

$$R_{EV}(t = 1Ty) \sim 900Gly \tag{10}$$

to be compared with the corresponding huge value 9.7×10^{32} Gly predicted by the ΛCDM model, quoted in Eq.(3) above. Eq.(10) means that if there still exist humans in the Solar System, or at least in the Milky Way, their view of the distant universe will include many billions of galaxies.

In the ΛCDM case, a hypothetical observational cosmologist, one trillion years in the future, could observe only the Milky Way and objects such as the Magellanic Clouds which are gravitationally bound to it, so that cosmology could become an extinct science. In the case of charged dark matter, for comparison, the time dependence will allow about 180 billion out of a present trillion galaxies to remain observable at $t = 1Ty$ so that the view of the universe at that distant future time will look quite similar to the view at the present. .

The distinct physics advantage of charged dark matter is that it avoids the idea of an unknown repulsive gravity inherent in dark energy. Electromagnetism provides the only known long-range repulsion so it is more attractive to adopt it as the explanation for the accelerating universe. A second advantage of charged dark matter is that it provides a conducive environment for cosmology, a trillion years in the future.

References

[1] P.H. Frampton,
Electromagnetic Accelerating Universe.
Phys. Lett. **B835,** 137480 (2022).
`arXiv:2210.10632`.

[2] P.H. Frampton,
A Model of Dark Matter and Energy.
Mod. Phys. Lett. **A,** (2023 in press).
`arXiv:2301.10719`.

[3] P.H. Frampton,
Cyclic Entropy:An Alternative to Inflationary Cosmology.
Int. J.Mod. Phys. **A30,** 1550129 (2015).
`arXiv:1501.03054`.

[4] I.J. Araya, N.D. Padilla, M.E. Rubio, J. Sureda, J. Magana and L. Osorio,
Dark Matter from Primordial Black Holes Would Hold Charge.
JCAP **02:**030 (2023).
`arXiv:2207.05829`.

[5] I.J. Araya, private communication (2023).

[6] J. Wagner,
Observables for Moving, Extremely Charged Primordial Extremely Massive Black Holes.
`arXiv:2301.13210`. (2023).

[7] B. Carr, F. Kuhnel and L. Visinelli,
Constraints on Stupendously Large Black Holes.
MNRAS **501,** 2029 (2021).
`arXiv:2008.08077`.