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The Universal Gravitational Constant(G) in an Expanding Universe

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I. Introduction

Theoretical cosmology has been traditionally underpinned by two universal constants, the speed of light (c) and the universal gravitational constant (G). A recent investigation of dark matter (Bye 2021) has found that there is a third universal constant, which is the density of dark matter (ρ_D). This note assumes that c and ρ_D are absolute constants, i.e. they are independent of the evolutionary state of the Universe, from which an expression for the universal gravitational constant (G) is derived.

II. The Key Relations

(i) The azimuthal velocity at the edge of the Universe is,

$$c = (G\,M/R)^{1/2} \qquad (1)$$

where c is the velocity of light, and M and R are respectively the mass and the radius of the Universe. From (1),

$$2\,\pi\,R\,/\,T = c \qquad (2)$$

where T is the orbital period of the dark matter. On substituting (2) in (1) we obtain
Newton's Law for the mass (M),

$$GM=4\pi^2R^3/T^2 \qquad (3)$$

in which
(ii) The mass of the universe (M) is,

$$M= 4/3\,\pi\,\rho_D\,R^3 \qquad (4)$$

where ρ_D is the density of the dark matter, which the planetary data indicate is a universal quantity [1].

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III. The Universal Gravitational Constant

On eliminating M between (3) and (4), we find that the universal gravitational constant (G) is,

$$G = 3\,\pi\,/(\rho_D\,T^2) \qquad (5)$$

Eq. (5) is a general expression for G, which, on using (2) yields,

$$G = [3c^2/4\pi\rho_D]/R^2 \qquad (6)$$

Hence the universal gravitational constant (G)is inversely proportional to the square of R. At the birth of the Universe ($R \to 0$), $M \to 0$ and $T \to 0$, and $G \to\infty$, whereas at the death of the Universe ($R \to\infty$), $M\to \infty$ and $T\to \infty$ and $G \to 0$. The intermediate phase between these two limits may be regarded as the mature Universe, of which we are a part.

Planetary data indicate that $\rho_D = 2.1\ \ 10^{-6}$ kg m^{-3} and also that $R = R_o$ where $R_o = 1.25\ 10^{16}$ m (Bye 2021). On substituting in (6) we obtain $G = 6.54\ 10^{-11}$ kg^{-1} m^3 s^{-2}, which is very similar to the observed value of $6.674\ 10^{-11}$ kg^{-1} m^3 s^{-2}(Wikipedia 2022)and well within the likely error bounds for ρ_D and R_o. On evaluating (6) for an arbitrary R, we obtain,

$$G = A\,R^{-2} \qquad (7)$$

in which for $\rho_D = 2.1\ 10^{-6}$ kg m^{-3}, $A=1.02\ 10^{22}$ kg^{-1} m^5 s^{-2}. We suggest that (6) should be used for G in cosmic models in which R is evolving, rather than the traditional relation in which $G = 6.674\ 10^{-11}$ kg^{-1} m^3 s^{-2}.

IV. The Expanding Universe

Eq.(6) shows that the universal gravitational constant is a function of the size of the Universe (R) as might have been expected a priori, and the properties of the present Universe predict a value for G($6.54\ 10^{-11}$ kg^{-1} m^3 s^{-2}), which is similar to the observed experimental value of $G = 6.674\ 10^{-11}$ kg^{-1} m^3 s^{-2}. This gives confidence in the use of (6). Eq. (6) has already been incorporated implicitly in the universal energy balance expressions due to dark matter in Bye (2021) through Eq. (15).Here it is shown to be a seminal expression for the evolving Universe, which in particular, relates the time variability of G to that of R.

V. Conclusion

The most important conclusion is that as the Universe ages, the universal gravitational constant reduces according to (6). We propose that this reduction of G must be fully included in cosmological modelling.

In broad brush terms the decrease of the universal gravitational constant (G) with time is 'a secular relativity' in which, (1) shows that as the Universe ages, in order to maintain an azimuthal velocity which is equal to the velocity of light (c), the reduction in the universal gravitational constant (G) is compensated by an increase in mass density (M/R). Within the Universe, however, as the universal gravitational constant (G) decreases, the orbital velocity about a principal mass (M_o = M) at a radius (R) slows, arguably promoting planetary formation.

References Références Referencias

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