A Stressed Universe Can Make Our Universe Stop Expanding

R. F. Favreau[1]
[1]Department of Physics and Space Science, Royal Military College, Kingston, ON, Canada

Abstract:

The critical density ρ_c required by general relativity to stop the universe expansion is $1x10^{-26}$ kg/m^3 [1]. But the average density of the universe due to the cosmic bodies was evaluated as 3 $x10^{-28}$ kg/m^3 [1], which is smaller than ρ_c. Many scientists had expected that sufficient cosmic body mass would eventually be found to exceed ρ_c, and thus stop the expansion of the universe. However, sufficient mass, even with dark matter, has not been found. The dominant opinion has become that the universe will expand forever, especially as recent measurements indicate that the expansion is accelerating [2]. This article proposes a universe of compressed stressed dark matter that does not expand forever. Rather, the expansion will stop and contract, and the universe will oscillate forever. This conclusion is based on the universe being a large body of approximate radius R_u, mass M_u, which is comprised mostly of ambient uniform density ρ_{dm} of compressive stressed dark matter that has permanently existed since matter became dominant over radiation. This article demonstrates that this stressed dark matter oscillates because all its radial elements oscillate in unison with the same period $T_{SHM} = 6.47x10^{10}$ years but variable amplitude R A which increases with R, where A = 0.14 x 10^{26} m. This article shows that the mass associated with the stressed dark matter together with the kinetic energy of the oscillations is such that the bulk of the mass of this stressed universe is this very density ρ_{dm} of stressed dark matter itself, and ρ_{dm} far exceeds ρ_c. This article demonstrates that the Hubble formula V = H R is the natural behavior of such a stressed universe, and that the expansion of such a universe presently accelerates but will eventually stop expanding and will begin to oscillate with a period $T_{SHM} = 6.47x10^{10}$ years. Thus, this article offers a very new approach to study the universe, an approach which challenges conventional understanding with a totally new stressed model of the universe.

Introduction:

General relativity demonstrates that if the average density of the universe is below the critical value $\rho_c = 1x10^{-26}$ kg/m^3 then the universe will expand forever, while if it is above ρ_c then it will stop expanding. Hence, since Hubble's discovery that the universe is expanding with velocity V = H R [3, 4], some astrophysicists have sought adequate dark matter to stop the expansion, but insufficient additional mass was found to stop the expansion [ref 1]. This article proposes that there exists everywhere in the whole of space a density ρ_p of compressive dark matter stressed to a level P, which is kept in place by the combined gravitational and stress forces, and which has permanently existed since matter became dominant over radiation, and whose total mass far exceeds that of the cosmic bodies. This article investigates if the existence of such stressed dark matter can stop the expansion of the universe and cause it to oscillate [6, 7]. The calculations of the properties of such a stressed universe [8, 9] turn out to demonstrate that they do stop the expansion and do cause oscillations. The stressed universe is treated as a large body of approximate radius R_u and mass M_u [10, 11] involving compressive stress of level P. The total density $\rho_t = \rho_p + \rho_k + \rho_{cb} = \rho_{dm} + \rho_{cb}$ is small, so that calculations may use solely gravitation to obtain a first approximation of a universe model. Here ρ_p is the density of stressed mass and it causes the expansion to decrease, ρ_k is the density of kinetic energy associated with the oscillations and it causes the expansion to increase, ρ_{cb} is the density of the cosmic bodies that make up the galaxies, while $\rho_{dm} = \rho_p + \rho_k$. Each of these densities is assumed to be uniform and independent of R, and the total mass/energy density of the universe is uniform and constant due to the equivalence of mass and energy ($E = mc^2$).

I. Mass density associated with stress P:

Any matter that is stressed to a compressive level P inherently possesses mass of density P/c^2, as will now be demonstrated. The energy/mass of a stressed body is evaluated by calculating the work required to assemble it from infinity. For example, consider a spherical shell of radius R, thickness dR, which is in a state of compressive stress P. Suppose that it has been assembled from infinity by slowly shrinking its radius R f under the push of an inward radial pressure P acting on the outer area $4\pi\,(R+dR)^2 f^2$ against the resistance of an outward radial pressure P acting on the inner area $4\pi\, R^2 f^2$. Then for a series of inward radial steps R(- df) an external source had to do an amount of work W as follows: $W = \int ((P/f^5)\, 4\pi\, (R+dR)^2 f^2) - ((P/f^5)\, 4\pi\, R^2 f^2)) \times (- R\, df)$

which had to be supplied by the external force. Hence the total external work W to bring the shell from infinity to R is:

$W = 4\pi P\, (2\, R\, dR)\, R \int - (f^2 / f^5)\, df = 4\pi\, P\, (2\, R\, dR)\, R \int - (df / f^3)$

$= 4\pi\, P\, (2\, R\, dR)\, R\, (1 / (2\, f^2)$ evaluated from ∞ to $1 = 4\pi\, P\, (2\, R\, dR)\, R / 2$

Hence: $\rho\, c^2 = W / (4\, \pi\, R^2\, dR) = 4\pi\, P\, (R\, dR)\, R / (4\pi\, R^2\, dR) = P$

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

is the density of mass in the shell because it is in a state of stress P. The dependence P/f^5 of P on f is necessary to obtain this result, as will be further discussed in this article.

II. Calculation of the distribution P(R) of the compressive stress in the ambient dark matter of the proposed stressed universe model:

Consider a cone $R^2\, d\theta^2$ of ambient stressed dark matter of density ρ_{dm}; the forces acting on a mass element of stressed dark matter δM_{dm} are those in equation (1), where the gravitational and stress forces are balanced.

$$- G\, M(R)\, \delta M(R) / R^2 - dP(R)\, (R\, d\theta)^2 = 0 \qquad (1)$$

where M includes only the mass of the stressed dark matter itself, including the mass P / c^2 added by the presence of the stress P as explained in Section I. It also could include the mass ρ_{cb} of the cosmic bodies; however, it will be shown below that the density ρ_{dm} of the mass associated with the stressed dark matter is so very much greater than the average density ρ_{cb} of the cosmic bodies that the inclusion of their mass at this stage is not of much consequence, and so the calculations will be simplified by assuming that the total density $\rho_t = \rho_{dm} + \rho_{cb} \approx \rho_{dm}$. Of course, the cosmic bodies do exist; nevertheless, their presence will be neglected in the calculations, because it will be demonstrated that the mechanics of solely the stressed dark matter suffice to stop the expansion and start the oscillations. The presence of the cosmic bodies plays no essential role in the mechanics that lead to oscillations rather than everlasting expansion; the solar bodies are simply carried along by the oscillating stressed dark matter. For densities that are independent of R, then M(R) and δM(R) in equation (1) can be written as:

$M(R) = \int \rho_{dm} 4\pi R^2 dR = \rho_{dm} (4\pi/3) R^3$; $\delta M(R) = \rho_{dm} R^2 d\theta^2 dR$

Use of these in (1) gives:

$$- G (\rho_{dm} (4\pi/3) R^3) (\rho_{dm} (R d\theta)^2 dR) / R^2 - dP(R) (R d\theta)^2 = 0$$

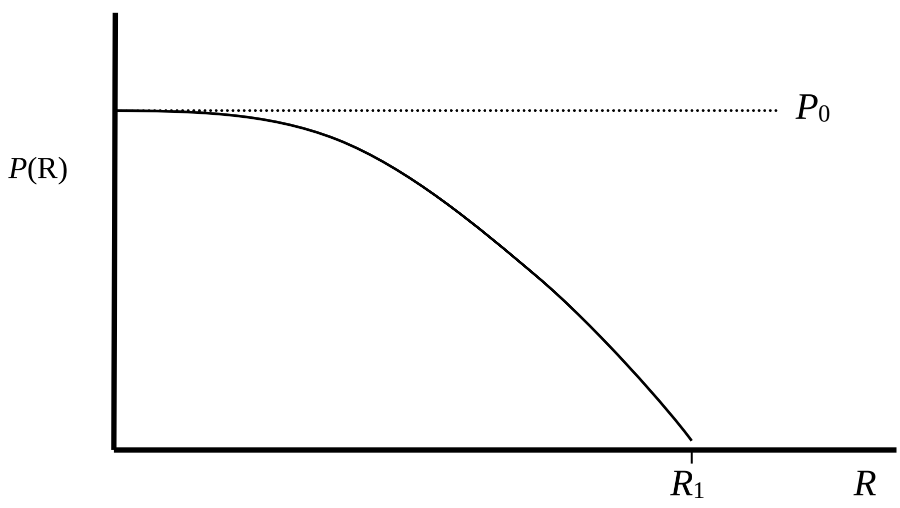
which can be integrated:

$$dP(R) = - G \rho_{dm}^2 (4\pi/3) R dR$$

$$P(R) = P_0 - G \rho_{dm}^2 (4\pi/3) R^2/2 = P_0 - G \rho_{dm}^2 (2\pi/3) R^2 \qquad (2)$$

Thus, while the ambient density ρ_{dm} of the stressed dark matter is uniform and independent of R, on the contrary the distribution P(R) of the stress level according to equation (2) is a function of R, as shown in figure 1.

Figure 1 – Distribution of the ambient pressure P(R) versus distance R:



P(R) goes to zero at distance $R_1 = R_u$, the size of the universe, indicating that such a stressed universe is finite, its finite size being given by equation (2):

$$R_u = (3 P_0/(2\pi G \rho_{dm}^2))^{1/2} \qquad (3)$$

A finite size is a reasonable opinion for a mechanical model of the universe. In figure 1 the solid curve is at time $t = t_1$, the majority of matter having since $t = t_0$ become compressive stressed dark matter, t=0 being the start of the Big Bang (see figure 2).

III. Oscillations of the ambient stressed dark matter:

For mathematical convenience, in order to consider a systematic displacement of all the mass elements $\delta M(R)$ at time t, let them at time t be at R f, where f is a useful multiplier with value f = 1 at time t_1 and value $f = 1+ \delta$ greater or smaller than 1 at time $t > t_0$. The article next investigates if each such element $\delta M(R)$ can stop expanding and undergo oscillations.

The Newtonian equation of motion for the mass element δM of equation (1) when at time t it is at a value of f other than 1, is:

$$- G\, M(R)\, \delta M(R) / (R f)^2 - dP(R, f)\, (R f\, d\theta)^2$$
$$= \delta M(R) \text{ x acceleration} = \delta M(R)\, R\, df^2 / dt^2$$

$$= \delta M(R)\, R\, d^2 (1+ \delta) / dt^2 = \delta M(R)\, R d^2 \delta / dt^2 \qquad (4)$$

Newtonian mechanics alone suffice for a first demonstration that the stressed universe ceases to expand and oscillates. Equation (4) applies only after t_0. The density ρ_{dm} used for calculating the movement of the sole ambient stressed dark matter is expected to be small, so that as is often done in research a first study based only on gravitation can be expected to give results which are approximate but nevertheless are useful as guidelines for further work. In equation (4), δM is indicated as $\delta M(R)$ and not $\delta M(R, t)$ because in the absence of action by external forces during the movement of a mass δM, there are no reasons for the magnitude of $\delta M(R)$ to change, nor that of M(R). The objective of the article is to seek properties for dP(R, f) such that equation (4) will be of a form indicating oscillations for small values of δ. In equation (4), as δ in $f = 1+ \delta$ increases, then the gravitational force decreases as f^{-2}. Similarly, dP(R, f) can be expected to decrease as a function of f. Following the reasoning in Section I, it will next be shown that if dP(R, f) decreases according to $dP(R, f) = dP(R)\, f^{-5}$, then the proposed stressed dark matter does oscillate in SHM. To demonstrate this, with δ small compared to 1, let equation (4) be rewritten with f^{-2} in the gravitational term approximated by $(1 - 2\delta)$ and with f^{-3} in the dP term approximated by $(1 - 3\delta)$, where the f^2 multiplying R^2 is combined with f^{-5} multiplying dP(R) according to $dP(R, f) = dP(R)\, f^{-5}$; (4) then becomes:

$$(- G\, M(R)\, \delta M(R) / R^2)(1 - 2\delta) - dP(R)\, R^2\, d\theta^{\,2}\, (1 - 3\delta)$$
$$= (- G\, M(R)\, \delta M(R) / R^2) - dP(R)\, R^2\, d\theta^{\,2}$$
$$+ (- G\, M(R)\, \delta M(R) / R^2)(-2\delta) - dP(R)\, R^2\, d\theta^{\,2}\, (-3\, \delta)$$

$$= \delta\, M(R)\, R\, d^2\, \delta / dt^2 \qquad (5)$$

But according to the f=1 equation (1) above:

$$- G M(R) \delta M(R) / R^2 = + dP(R) R^2 d\theta^2 \qquad (6)$$

Introducing (6) into (5) gives: $(dP(R) R^2 d\theta^2) (- 2 + 3) \delta = dP(R) R^2 d\theta^2 \delta$

$$= - (- dP(R) R^2 d\theta^2) \delta = \delta M(R) R d^2 \delta / dt^2 \qquad (7)$$

Divide equation (7) by R $\delta M(R)$:

$$(- (-dP(R) R^2 d\theta^2) / (R \delta M(R)) \delta = d^2 \delta / dt^2 \qquad (8)$$

Let it be required that:

$$((- dP(R) R^2 d\theta^2) / (R\delta M(R)) = k \qquad (9)$$

where k is a constant. hen equation (9) implies SHM for δ:

$$d^2 \delta / dt^2 = - k\delta \qquad (10)$$

whose solution for $t > t_0$ is $\delta = A \sin Wt$, where A is the amplitude and $W = 2 \pi v$ are the angular velocity W and frequency *v*, which apply to the oscillations of every mass element δ M. Equation (10) is the usual equation for the oscillations of a spring and a mass M; k serves as K in the force equation F = - K X for a spring. This article demonstrates that all elements δM_{dm} oscillate with the same frequency *v* but variable amplitude RA which increases with R. The assumption that dP(R, f) decreases according to $dP(R, f) = dP(R) f^{-5}$ is justified because it is needed in Section I and because it meets the objective of demonstrating that the proposed stressed dark matter does oscillate. Introducing $\delta = A \sin Wt$ into equation (10) gives:

$$-AW^2 \sin Wt = - k A \sin Wt ; \qquad k = W^2 \qquad (11)$$

IV. Mechanical behavior of the stressed universe:

The velocity is given by:

$$V(R, t) = d(R f)/dt = R df/dt =R d(1+ \delta)/dt$$

$$= R d \delta /dt = R d(A \sin Wt)/dt = RWA \cos Wt \qquad (12)$$

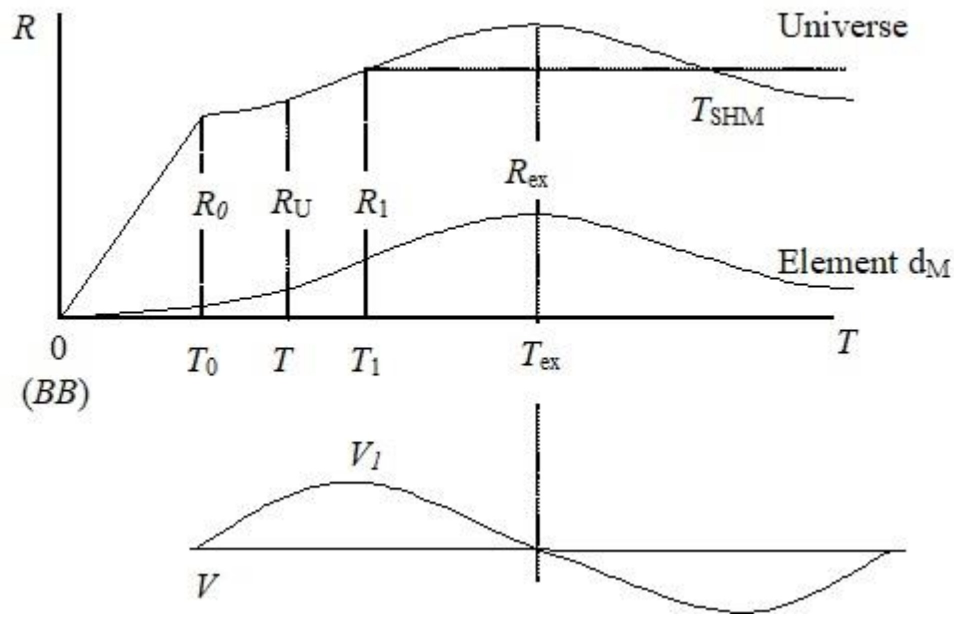
The solution $\delta = A \sin Wt$ of equation (10) is acceptable only if equations (9) and (2) are compatible; which is easy to prove by integrating (9) to show that $P(R)=P_0 (1-(k/2c^2) R^2)$ which is compatible with equation (2) provided that $k = W^2 = ((4 \pi /3)GP_0)/c^2$.

Again in this Section IV, ρ_{dm} has been used to approximate the total density $\rho_t = \rho_{cb} + \rho_{dm} = \rho_{cb} + (\rho_{k} + \rho_p)$. ρ_{dm} can be replaced by P_0/c^2, as the velocity given by V= R A W cosWt must at R=0 be V=0, so that the kinetic energy mass must also be 0 at R=0, and thus $\rho_{dm} = \rho_k + \rho_p$ must at R=0 be equal to ρ_p alone; hence $\rho_{dm} = P_0/c^2$ at R=0. But since ρ_{dm} is uniform independent of R, hence the density P_0/c^2 also must be uniform independent of R, which is the situation indicated for the solid curve in figure 1.

Thus, the proposal of the existence of ambient stressed dark matter of density ρ_{dm} leads to the conclusion that all mass elements δM associated with this stressed dark matter simply oscillate back and forth as a spring in SHM, rather than expanding forever.

Figure 2 shows the growth of the size of the universe and of an element δM_{dm} as calculated with the stressed universe model.

Figure 2 – Growth of the size of the universe following the Big Bang at T=0:



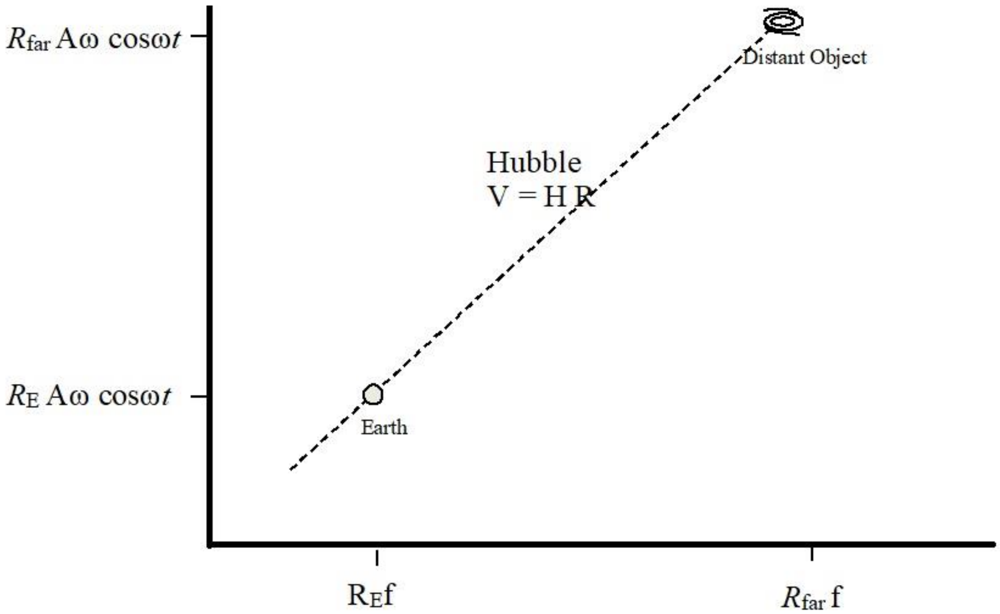
At the present time T = approximately $H^{-1} = 1.38 \times 10^{10}$ years [3], the universe of size R_u= approximately 1.28×10^{26} m [4] and density ρ_{dm} = approximately 3.4×10^{-26} kg/m^3, expands with accelerating expansion [2, 15], but will reach a maximum size R_{ex} = about 1.51×10^{26} m at time T_{ex} = approximately 3.81×10^{10} years, following which it will contract and oscillate with a period estimated at $T_{SHM} = 6.47 \times 10^{10}$ years. In figure 2: BB is the Big Bang at time 0; To is the time when matter of density ρ_{dm} has become dominant over radiation, size of the universe R_0; T_1 starts the next full oscillation period, size R_1= approximately 1.38 $\times 10^{26}$ m, where $R_u = R_1$(1-A sinWt) and Wt = about -45 degrees measured from time T_1; V is the variable velocity of the size R of the universe, maximum V_1; the expansion and contraction of the stressed universe is shown as a sine curve in SHM around an average dimension R_1, oscillating with plus and minus velocity V. The oscillations started at time T_0 when the Big Bang radiation changed to matter. The

expansion is currently at about time $T = H^{-1} = 1.38x10^{10}$ years, size R_u, which is on the concave portion of the sine curve indicating that the rate of expansion is currently increasing [2]. At T_1 the expansion will have reached its maximum velocity V_1 and the rate of expansion will begin to decrease on the convex portion of the sine curve. At T_{ex}, the expansion will have reached its maximum and the universe will begin to contract; the oscillation velocity will then begin to change direction, following the SHM sine curve. Overall, the universe will not expand forever and will not contract back to a big crunch, but will continue to oscillate with a period of about $6.47 x10^{10}$ years. During the oscillations there is a constant exchange between stress density ρ_p and kinetic energy density ρ_k, which results from the work done by the resultant force $k\delta$ acting on a constant mass element δM. The expansion is presently accelerating; nevertheless figure 2 demonstrates that at the present time the rate of acceleration is diminishing.
The approximate values of the parameters in figure 2 are estimated via the description of the stressed universe as explained in Sections I to IV, which also gives the constant value of the universe mass M_u=$371x10^{51}$ kg, the value of P_0 = approximately $3.06x10^{-9}$ N/m^2 at time T_1 which is extremely minute, the value of ρ_{dm} = approximately $4.22x10^{-26}$ kg/m^3 at the present which is almost a vacuum but is much larger than the critical ρ_c =$1x10^{-26}$ kg/m^3. The present value of Wt is estimated at the end of Section V below as Wt=-45 degrees. The amplitude $A = R_{ex} - R_1$ = approximately $0.14x10^{26}$m. Details on these estimates can be supplied on demand.

V. Explanation of the Hubble V=H x R slope according to the stressed universe model:

According to Hubble the cosmic bodies are moving away with velocity V that increases with distance R according to V = H R [3], the slope of which is $H = 0.244x10^{-17}$ $sec.^{-1}$. The stressed universe model proposes that the universe is essentially constituted of the oscillating stressed dark matter; but the cosmic bodies are carried along with the stressed dark matter so that at time t the locations and velocities of the Earth and a Far Cosmic Body are those in figure 3, whose slope corresponding to H in equation (13):

Figure 3- Explanation of the Hubble expansion:



$$(R_{far} \; A \; W \cos Wt - R_E \; A \; W \cos Wt) \,/\, (R_{far} - R_E) \; f = H \tag{13}$$

$$(A \; W \cos Wt) \,/\, f = H \tag{14}$$

Thus, it can be seen that the behavior of the cosmic bodies according to Hubble is a normal activity according to the proposed stressed universe model.

It is pertinent that according to equation (14) the value of H varies with time. Recent evidence indicates that indeed H varies with time. References [16, 17, 18] propose that a new theory of the universe is needed to explain this variation with time; the stressed universe model is just such a new theory.

Equation (14), together with some reasonable assumptions, can help to estimate the phase angle Wt of the oscillations at the present time t as sinWt = approximately - 0.70, Wt = - 45 degrees.

Conclusions:

At first the Big Bang universe was radiation dominated; then it converted to matter dominated. This article proposes that a very large majority of this matter is ambient stressed dark matter of uniform density ρ_{dm}, and pressure P. This article calculates the mechanical behavior of this stressed dark matter and demonstrates that it presently is accelerated expansion, but will later stop expanding, contract, and begin to oscillate. All the radial elements $\delta \; M_{dm}$ of the universe oscillate with the same period $T_{SHM} = 6.47 \times 10^{10}$ years but amplitude R A which increases with R. The universe is essentially constituted of the oscillating stressed dark matter; the cosmic bodies are simply carried along with the stressed dark matter. The model also demonstrates that the Hubble formula V=HR occurs as a normal behavior of such a stressed universe. The level of stress $P = 3.06 \times 10^{-9}$ N/m^2 is so minute that it cannot be measured. These results neglect general relativity calculations. The stressed universe has a constant mass of $371 x 10^{51}$ kg which according to relativity is adequate to stop and reverse the expansion, so that the stressed model is compatible with the general relativity condition required for the expansion to stop. Incorporating further general relativity considerations is expected to slightly improve the accuracy of the calculations but is not expected to alter the main characteristics and behavior of the proposed stressed universe model. There are no reasons why stressed dark matter should not have been created after the Big Bang, so that the proposal of compressive stressed dark matter of uniform density ρ_{dm} is conceptually reasonable, especially as such a stressed universe does not continue to expand forever. Therefore, this article offers a very new approach to study the universe, an approach which challenges conventional understanding with a totally new stressed model of the universe. It offers much scope for further publications.

References:

1) Kenneth Krane, *Modern Physics*, John Wiley and Sons, New York, 1987, ISBN0-471-07963-4. Chapters 15 and 16 review cosmology in a very well-organized manner.

2) Adam G. Reiss, etc., ‘Observational evidence from supernovae for an accelerating universe and a cosmological constant’, Astronomical Journal, 116 (3):1009-38, 1998.

3) M. Rowan-Robinson, *Cosmology*, Clarendon Press, Oxford, 1977.

4) C. Raifeartaigh, M. O`Keefe, N. and S. Mitlon, `Einstein`s 1917 static model of the universe: a centennial review`, Eur. Phys. J. (H) 42: 431-474.

5) ‘Dark energy’, 11/28/2019, https://en.wikipedia.org/wiki/Dark_energy, summarizes 85 articles which deal with a universe that expands forever.

6) F. Packner, `An oscillating isotropic universe without singularity`, Mon. Not. R. Astr Society (1965) 131, 173-176.

7) K. Malda, Y. Minsonoh, T. Kobayaski, `Oscillating universe in Horava-Lifshitz gravity`, Physical Review D82, 064024 (2010).

8) M. Seracie, K. Prabhu, M. Roberts, `Physical stress, mass and energy for non-relativistic matter`, arXiv: 1609, 0629 v2 [hep-th] 25 March 2017.

9) Dimitar Valev, `Estimate of the total mass and energy of the universe`, arXiv: 1004.1035 v 1 [Physics.gen-ph] 7 April 2010.

10) C. Mercier, `Calculation of the mass of the universe, the radius of the universe, the age of the universe and the quantum of speed`, Journal of Modern Physics, 2019, 10, 980-1001.

11) C. Cataldo, `From the oscillating universe to relativistic energy: a review`, Journal of High Energy Physics, gravitation and cosmology, 2017, 3, 68-77.

12) Plank Collaboration, `Planck 2015 results. XII Cosmological parameters`, Astronomy plus Astrophysics- 594: A13, Table plus arXiv: 1502.0589 (2016).

13) P. Gupta, `Mass of the universe and the redshift`, International Journal of Astronomy and Astrophysics, 2018, 8, 68-78.

14) K. Zhang, P. Wu, H. Yu, `Oscillating universe in massive gravity`, Physical Review D87, 063513 (2013).

15) M. Sumi, R. Myryakulov, `Late time cosmic acceleration: ABCD of dark energy and modified theory of gravity`, International Journal of Modern Physics D.25(12), (2015).

16) M. G. Dainotti et al, `On the Hubble Constant tension in the SNe la Pantheon sample`, Astrophysical Journal, May 17, 2021.

17) Webmaster, `Charting the expansion history of the universe with supernovae`, nao.ac.jp/en/news/science/2021 0514-dos.html.

18) Karoline Loeve, Kristine Simone Nielsen, Steen H. Hansen, `Consistency analysis of a dark matter velocity dependent force as an alternative to the Cosmological Constant`, arXiv: 2102.07792v[astro-phys.CO] 15 Feb. 2021.

Acknowledgements:

Thanks are given to the staff of the Department of Physics and Space Science of the Royal Military College, Kingston ON, Canada for their sustained encouragement, and particularly to LCol (retired) P. Somers who made significant suggestions, and P. Snell and M. Lavoie who kindly helped with the publication of the article.