Dissipation of Modified Entropic Gravitational Energy Through Gravitational Waves

Clovis Jacinto de Matos

1 European Space Agency, 8-10 rue Mario Nikis, 75015 Paris, France
(Dated: 22 September 2011)

The phenomenological nature of a new gravitational type interaction between two different bodies derived from Verlinde’s entropic approach to gravitation in combination with Sorkin’s definition of Universe’s quantum information content, is investigated. Assuming that the energy stored in this entropic gravitational field is dissipated under the form of gravitational waves and that the Heisenberg principle holds for this system, one calculates a possible value for an absolute minimum time scale in nature \( \tau = \frac{15}{16} \frac{\Lambda^{1/2} \bar{h} \bar{G}}{c^3} \sim 9.27 \times 10^{-105} \) seconds, which is much smaller than the Planck time \( \tau_P = (\bar{h}G/c^5)^{1/2} \sim 5.38 \times 10^{-44} \) seconds. This appears together with an absolute possible maximum value for Newtonian gravitational forces generated by matter \( F_e = \frac{G M_0^2}{R^3} \sim 3.84 \times 10^{165} \) Newtons, which is much higher than the gravitational field between two Planck masses separated by the Planck length \( F_{gP} = c^4/G \sim 1.21 \times 10^{74} \) Newtons.

MODIFIED ENTROPIC GRAVITATION BETWEEN TWO BODIES

In a recent paper [1], the author derived a new gravitational type force law, Equ.(1), starting from Verlinde’s entropic approach to gravitation, and assuming Sorkin’s hypothesis that the total amount of information in the Universe is directly proportional to the Universe four-Volume.

\[
F = \frac{3 \Lambda^{1/2} G^2 \bar{h} M_0 m_0}{c^3} \sim 5.93 \times 10^{-106} \frac{M_0 m_0}{R^3} \tag{1}
\]

Where \( G \) is Newton’s universal gravitational constant, \( \bar{h} \) is the Planck constant divided by \( 2\pi \), \( \Lambda = 1.29 \times 10^{-52}[m^{-2}] \) is the cosmological constant [2], and \( M_0, m_0 \) are the respective masses of the interacting bodies whose center of mass are separated by the distance \( R \). Since this force contains a proportionality constant \( \Lambda^{1/2} G^2 \bar{h}/c^3 \sim 5.93 \times 10^{-106} \) which is extremely small (to say the least), It is easy to conceive that this new type of gravitational force has never been experimentally detected in the context of the gravitational interaction between massive bodies. From the force law Equ.(1) one deduces that the total mechanical energy stored in a gravitating binary system orbiting under the single influence of this force is:

\[
E = \pm \frac{3 \Lambda^{1/2} G^2 \bar{h} M_0 m_0}{2c^3} \frac{R}{R^2} \tag{2}
\]

For the moment one does not make any assumption with respect to the attractive or repulsive character of the force \( F \). This explains why we consider two possible signs for the total mechanical energy of the system (negative if the force is attractive, positive if the force is repulsive).

GRAVITATIONAL RADIATION EMITTED BY A BINARY SYSTEM UNDER THE SINGLE INFLUENCE OF A MODIFIED ENTROPIC GRAVITATIONAL FORCE

Let one consider that the two bodies have identical masses, \( M_0 = m_0 \), and that they are spinning with angular velocity \( \omega \) about the center of mass of the binary system. Thus they form a kind of spinning dumbbell. General relativity predicts that this system will emit gravitational waves, with radiating power \( \varphi \) [3].

\[
\varphi = \frac{8}{5} \frac{G}{c^5} m_0^2 R^4 \omega^6 \tag{3}
\]

Where \( R \) is the distance between the respective centers of mass of the two bodies.

Dividing Equ.(2) by Equ.(3) one deduces the interval of time \( \tau \) required to dissipate entirely the total mechanical energy of the system under the form of gravitational radiation:

\[
\tau = \frac{E}{\varphi} = \frac{15}{16} \Lambda^{1/2} c^2 \bar{h} G (R \omega)^{-6} \tag{4}
\]

Since \( \omega = v/R \) (\( v \) being the tangential velocity of rotation), and assuming the asymptotic limit \( v = c \), one deduces from Equ.(1) a dissipating time \( \tau \) which does not depend on the relative distance \( R \) between the two bodies.

\[
\tau = \frac{E}{\varphi} = \frac{15}{16} \frac{\Lambda^{1/2} \bar{h} G}{c^4} \sim 9.27 \times 10^{-105}[\text{Seconds}] \tag{5}
\]

Note that the masses of the bodies \( m_0 \) have disappeared from Equ.(4) and Equ.(5) due to the principle of equivalence.

DISCUSSION AND CONCLUSIONS

Assuming that the the time required to dissipate the mechanical energy of the binary system, Equ.(2), should
also comply with the Heisenberg uncertainty principle, one calculates an alternative dissipation time \( \tau' \)

\[
\tau' \sim \frac{\hbar}{E} = \frac{2}{3} \frac{c^3}{\Lambda^{1/2} G^2 m_0^2} \tag{6}
\]

Imposing that both decay times must be equal to each other, \( \tau = \tau' \), one deduces a maximum Newtonian binding gravitational force for the binary system.

\[
F_g = G \frac{m_0^2}{R^2} = \frac{32}{30} \frac{c^7}{\Lambda \hbar G^2} \sim 3.84 \times 10^{165}\text{[Newtons]} \tag{7}
\]

Neither the time interval \( \tau \), and the gravitational Newtonian force \( F_g \) depend on the radius \( R \) of the system or on the angular frequency \( \omega \) at which the two bodies rotate around their commune center of mass. Instead both \( \tau \) and \( F_g \) depend only on the fundamental constants \( G, \hbar, c, \Lambda \). Since the value of \( \tau \) is much smaller than the Planck time, \( t_P = (\hbar G/c^5)^{1/2} \sim 5.38 \times 10^{-44} \) seconds, it is tempting to consider this interval of time as an absolute minimum time in nature. A similar argument could also hold for the gravitational Newtonian force \( F_g \), which could be understood as a maximum scale value (for this type of force) since it is much higher than the Newtonian gravitational force between two Planck masses separated by the planck length \( F_{gP} = c^4/G \sim 1.21 \times 10^{44} \) Newtons.

It is also instructive to note that the Planck time \( t_P \) corresponds to a good approximation (within 85% agreement) to the geometric mean between the Universe age \( T_U \) and the decay time \( \tau \)

\[
t_p \sim \sqrt{\tau T_U} \tag{8}
\]

where \( T_U \sim 1/H_0 = 4.348 \times 10^{17} \) s (\( H_0 \) being the Hubble constant). This encourages one interpreting the time \( \tau \) as the minimum possible time in nature and the Universe age \( T_u \) as the maximum possible time with physical meaning.

ACKNOWLEDGEMENTS

I would like to thank the referee who reviewed my paper on ”modified entropic gravitation in superconductors” [1], for outlining that the numerical value of the fundamental constant appearing in the force law between two different universes: \( 3\Lambda^{1/2} G^2 \hbar/c^3 \sim 5.93 \times 10^{-106} \) [\( m^4 s^{-2} Kg^{-1} \)] is extremely close to the square of the proportionality constant appearing in the relativistic law determining the power radiated by an accelerated physical system: \( (G/c^5)^2 = 7.58 \times 10^{-106} \) [\( s^3 m^{-2} Kg^{-1} \)]. The author would like also to thank the referee of the present paper for precious guidance in the physical interpretation of the physical phenomena presented in this paper.

[1] de Matos, C. J., 2011, Physica C, DOI: 10.1016/j.physc.2011.09.011, (2011)
[2] Spergel, D. N., 1984, Astro.J.Suppl., 148, 175
[3] Forward, R. 1961, Proceedings of the IRE, 49, pp. 892-904