# On the Earth-Moon distance increment generated by the expansion of the universe

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**Abstract**

The Earth-Moon distance increment is generated by the expansion of the universe, Lunar Laser Ranging (LLR) experiment confirms that the Moon is spiraling away from Earth at a rate of 38 mm per year.

Dark matter gravity force is generated by the expansion of the universe, gravitational force is not strong enough and an extra centripetal force is needed due to this expansion, energy related to this new force is stored in the dark matter energy tensor D(4,0) related to the Riemann curvature.

The cosmological redshift energy loss due to the expansion of the universe is stored in the dark matter energy tensor D(4,0). The Cosmic Microwave Background energy loss has been stored in the dark matter energy tensor D(4,0)

Dark matter gravity is generated by D(4,0) energy related directly to the S(4,0) tensor, however this gravity is attributed to exotic particles never detected, galaxies in our universe are rotating with such speed that the gravity generated by their observable matter could not possibly hold them together

Total Energy T(4,0) and energy tensors are defined to complete the General Relativity field equations. The Ricci decomposition is a way of breaking up the Riemann curvature tensor into three orthogonal tensors, Z(4,0), Weyl tensor C(4,0) and S(4,0)

***Index terms***— Earth-Moon distance increment, dark matter, expansion of the universe, Riemann curvature, Ricci decomposition, Earth–Moon system, Cosmic Microwave Background redshift, General Relativity field equations

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## Earth-Moon distance increment generated by the expansion of the universe

The distance continually changes for a number of reasons, but averages $x_0 =$ 385000600 m between the center of the Earth and the center of the Moon, the Moon is spiraling away from Earth at a rate of $d_0 = 38$ mm per year, due to the expansion of the universe the final distance is

$x_f = bx_0, b > 1$

In the expansion of the universe angles remain invariant, so expansion must be proportional to the distance $x_0$

$x_f - x_0 = d_0$, $x_0(b-1) = d_0$

With $t_y =$ 31558150 seconds per year, the expansion rate per second $b_s$ is

$d_0 t_y^{-1} = x_0(b-1)t_y^{-1}$, $b_s = (b-1)t_y^{-1}$

$d_0 = x_0 b_s t_y$, $b_s = 3.12759603719903265776332121 61872\ 10^{-18}$

$d_1 = (x_0 + d_0)b_s t_y$, $d_1 = d_0(1 + b_s t_y)^1$

$d_n = d_0(1 + b_s t_y)^n$

$d_1 = d_0\ +\ d_0 b_s t_y$

$d_1 = d_0\ +\ 3.75064350549064079380655510666 75\ 10^{-12} m$

This quantity is too tiny to be confirmed by the LLR experiment.

# Dark matter gravity force is generated by the expansion of the universe

In an expanding universe a satellite is in a uniform circular orbit around a planet, satellite mass m << planet mass M, initial radius $r_0$, initial constant angular velocity $\omega_0$, initial velocity $v_0 << c$, c the speed of light, due to the expansion of the universe the final radius $r_f = ar_0, a > 1$, final constant angular velocity $\omega_f$, initial gravitational force $F_{0g}$ equals centripetal force

$$F_{0g} = G\frac{Mm}{r_0^2} = mr_0\omega_0^2,\; G\frac{Mm}{r_0} = m{r_0}^2\omega_0^2,\; V_0 = I_0\omega_0^2 = 2T_0$$

In the expansion of the universe angles remain invariant, so $\omega_0 = \omega_f$ and gravitational force $F_g$ equals centripetal force

$$F_g = G\frac{Mm}{r^2} = mr\omega^2,\; G\frac{Mm}{r_0} = m{r_0}^2\omega^2 a^3,\; \omega^2 a^3 = \omega_0^2$$

Since $\omega < \omega_0$, gravitational force $F_g$ is not strong enough and an extra centripetal force is needed, this extra force is attributed to exotic particles never detected

$$E_{dm} = E_f - E_0 = T_0a^2 - 2T_0a^{-1} + T_0$$

Dark Matter energy $E_{dm}$ has been stored in the dark matter energy tensor D(4,0) defined below, differentiating we get the dark matter force $F_{dm}$

$$F_{dm} = 2T_0a + 2T_0a^{-2}$$

The definition of the dark matter energy $E_{dm} = E_f - E_0 = T_0a^2 - 2T_0a^{-1} + T_0$ leads to think that dark matter effect is zero in a newborn galaxy (a = 1) and is increasing when it is becoming older while the universe is expanding (increasing a). I suggest comparing observational data of dark matter effect for similar galaxies nowadays and in the past in order to confirm this equation.

## Cosmological redshift energy loss due to the expansion of the universe

In an expanding closed universe, regardless our universe is closed or open, the final wave length of the photon when the closed universe reaches its maximum radius is [4]

$$\frac{\lambda_{now}}{r_{now}} = \frac{\lambda_f}{r_f}$$

$$\frac{\nu_f}{r_{now}} = \frac{\nu_{now}}{r_f}$$

$$E_l = h\nu_{now} - h\nu_f$$

where h is the Planck constant and $E_l$ is the energy loss, in a closed universe after reaching its maximum expansion the universe comes backwards and will reach $r_{now}$ again restoring the loss of energy to the photon, so this $E_l$ has been stored and was not definitely lost

The cosmological redshift energy loss due to the expansion of the universe is stored in the dark matter energy tensor D(4,0) related directly to the S(4,0) tensor, however this gravity is attributed to exotic particles never detected

The Cosmic Microwave Background energy loss has been stored in the dark matter energy tensor D(4,0), gravitational waves and other fields are subject to the same redshift phenomena

# Conformal energy U defined as a combination of C and the Hodge dual of C, dark matter energy D defined as a combination of S and the Hodge dual of S, similar definitions for V/Z and T/R

The Ricci decomposition is a way of breaking up the Riemann curvature tensor into three orthogonal tensors, **Z** , Weyl tensor **C** and **S**, **S** tensor generates the dark matter gravity

$$R_{ijkl} = Z_{ijkl} + C_{ijkl} + S_{ijkl}$$

$$S_{ijkl} = \frac{1}{12}R\left(g_{il}g_{jk} - g_{ik}g_{jl}\right)$$

$$Y_{jk} = R_{jk} - \frac{1}{4}Rg_{jk},\; Z_{ijkl} = \tfrac{1}{2}\big(Y_{il}g_{jk} - Y_{jl}g_{ik} - Y_{ik}g_{jl} + Y_{jk}g_{il}\big)$$

where $R_{abcd}$ is the Riemann tensor, $R_{ab}$ is the Ricci tensor, $R$ is the Ricci scalar (the scalar curvature)

The conformal energy tensor **U** can be defined as a combination of **C** and the Hodge dual of **C** [1]

$$U_{abcd} = 1/8\pi(C_{amcd}C^m_{bcd} + *C_{amcd}*C^m_{bcd} + C_{abcn}C^n_{abd} + *C_{abcn}*C^n_{abd})$$

The new dark matter energy tensor **D** can be defined as a combination of **S** and the Hodge dual of **S**

$$D_{abcd} = 1/8\pi(S_{amcd}S^m_{bcd} + *S_{amcd}*S^m_{bcd} + S_{abcn}S^n_{abd} + *S_{abcn}*S^n_{abd})$$

The new energy tensor **V** can be defined as a combination of **Z** and the Hodge dual of **Z**

$$V_{abcd} = 1/8\pi(Z_{amcd}Z^m_{bcd} + *Z_{amcd}*Z^m_{bcd} + Z_{abcn}Z^n_{abd} + *Z_{abcn}*Z^n_{abd})$$

The new Total Energy tensor **T** can be defined as a combination of the Riemann tensor **R** and the Hodge dual of **R**

$$T_{abcd} = 1/8\pi(R_{amcd}R^m_{bcd} + *R_{amcd}*R^m_{bcd} + R_{abcn}R^n_{abd} + *R_{abcn}*R^n_{abd})$$

## Hodge dual definitions

The Hodge dual definition for Electromagnetic tensor and Weyl tensor [2]

$*F_{ab} = \frac{1}{2}\varepsilon_{abln}F^{ln}$

$*C_{abcd} = \frac{1}{2}\varepsilon_{abln}C^{ln}_{cd}$

The Hodge dual definition for dark matter S tensor, Z and R tensors

$*S_{abcd} = \frac{1}{2}\varepsilon_{abln}S^{ln}_{cd}$ , $*Z_{abcd} = \frac{1}{2}\varepsilon_{abln}Z^{ln}_{cd}$ , $*R_{abcd} = \frac{1}{2}\varepsilon_{abln}R^{ln}_{cd}$

Weyl tensor C(4,0) is related to the new Conformal Energy tensor U(4,0). Dark matter tensor S(4,0) is related to the new dark matter energy tensor D(4,0). Z(4,0) tensor is related to the new energy tensor V(4,0). Riemann tensor R(4,0) is related to the new Total Energy tensor T(4,0)

## Complete General Relativity field equations

The complete field equations are described by a new T(4,0) tensor for Total Energy, the new conformal energy tensor U(4,0), the new energy tensor V(4,0) and the new dark matter energy tensor D(4,0)

$Z_{ab} - \frac{1}{2}Zg_{ab} + \Lambda_z g_{ab} = -k_z V_{ab}$

$C_{ab} - \frac{1}{2}Cg_{ab} + \Lambda_c g_{ab} = -k_c U_{ab}$

$S_{ab} - \frac{1}{2}Sg_{ab} + \Lambda_s g_{ab} = -k_s D_{ab}$

$R = Z + C + S$

$\kappa T = k_z V + k_c U + k_s D$

$\Lambda = \Lambda_z + \Lambda_c + \Lambda_s$

$\kappa T_{abcd} = k_z V_{abcd} + k_c U_{abcd} + k_s D_{abcd}$

In the general theory of relativity the Einstein field equations relate the geometry of spacetime to the distribution of matter. [3]

$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = -\kappa T_{\mu\nu}$

## References

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[4] Frank J. Tipler (1996) "La Física de la inmortalidad" Alianza Editorial, Madrid ISBN 84-206-2840-9, page 572.