dark energy and zero active mass equation

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Abstract

For decades, the prevailing view in the scientific community has been that our universe is expanding at an accelerating rate. However, a recent experimental study (Junhjuk Son et al., 2025) seems to confirm that our universe shows no signs of acceleration; that is, we might be living in a non-accelerating universe. In this work, we present evidence that this result agrees with the predictions of relativistic theory. To this end, we present a proof of the zero active mass equation ($\rho + 3p = 0$) for a universe with FLRW metric and zero space curvature ($k = 0$). We study the expansion of the universe by analyzing two partial models: a classical energy model and a thermodynamic fluid dynamics model. The interrelation between these two models demonstrates that, for universes with zero space curvature and a Lapse function equal to one, the valid solutions to the Friedmann equations are only those that lead to a non-accelerating universe. It is important to note that this proof also provides a result on the energy needed for the expansion of the universe, concluding that for a non-accelerated expansion no additional energy is needed.

Keywords: large-scale structure of Universe, cosmology: theory, cosmology: miscellaneous, cosmological parameters

1.- Introduction

In 2022, Professor Fulvio Melia published an article in Astronimische Nachrichten entitled “Initial Energy of a Spatially Flat Universe: A Key to Its Possible Origin” (Melia, F. 2022). In it, he studies the expansion process of the universe from its beginnings and concludes that, according to the Friedmann equations, the spatial curvature of the universe, k, is proportional to the sum of the kinetic and potential energies involved in the expansion process. Therefore, for zero spatial curvature, as is the case with our universe, the total mechanical energy of the expansion process is zero.

Professor Fulvio Melia is also very optimistic about the results he is obtaining with his Rh = ct universe model (Melia F., 2021), which constitutes a valid alternative to the ΔCDM model according to the most recent experimental data (Hubble strain, uniformity of the cosmic microwave background radiation, age of the most distant galaxies, etc.), where the ΔCDM model falls short. The Rh = ct universe is a universe with FLRW metric and zero curvature, based on the study of the Rh gravitational horizon (Melia F, 2021) and two equations: the Rh = ct constraint equation and the zero active mass equation ($\rho + 3p = 0$). The latter conditions the scaling factor by setting $a'' = 0$, resulting in a non-accelerating universe.

In this work, we will demonstrate the zero active mass equation using a different method than the one currently employed to demonstrate it (Melia 2026). Here, we use the kinetic and potential energies involved in the expansion process (Melia F, 2022) and a thermodynamic universe, finding similarities between the expansion of the universe and the expansion of a gas in a piston. Therefore, we consider the thermodynamic principles related to the fluid model, applicable to all universes with FLRW metric. Finally, we establish a relationship between dark energy and non-accelerating universes. At all times, we assume a universe with zero spatial curvature, as deduced from Planck data (Planck, 2020)..

2.- Development of the zero active mass equation

2.1 Friedmann equations

Given the Friedmann equations, of the FLRW metric:

$$H^2 = \left(\frac{a'}{a}\right)^2 = \frac{8\pi G\rho}{3c^2} - \frac{kc^2}{a^2}$$

$$\left(\frac{a''}{a}\right) = -\frac{4\pi G}{3c^2}(\rho+3p)$$

ρ represents the total energy density in the cosmos, (ρ = Joules/m^3)

22 Model 1. Expansion of the universe according to a work by Fulvio Melia referenced here

Here is a brief summary of this model, according to the content of the cited paper (Melia F, 2022), we consider an isotropic, homogeneous and spatially spherical universe, which responds to the FLRW metric and which therefore expands. This universe has a certain energy density ρ at each instant of time. We are going to refer our calculations to an observer located in the center of it. We call R_h its gravitational horizon (Melia F, 2021) and M(r) the mass, which comes from its energy density ρ, contained in a sphere of radius "r" centered at the observer's point, $r < R_h$

We are going to calculate the kinetic energy and potential energy produced by the expansion of the universe for that observer considering that sphere. The increase in its kinetic energy, "ΔK", during the expansion process is given by:

$$\Delta K = (4\pi r^2\rho\Delta r)\,(\Delta r/\Delta t)^2/2$$

and the corresponding increase in its potential energy "ΔU", is given by:

$$\Delta U = -(4\pi r^2\rho\Delta r)\,GM(r)/r$$

In the expansion process, this potential energy will correspond to the work done by dark energy against gravitational forces.

According to the conclusions of the work of Fulvio Melia (Melia F, 2022), the spatial curvature of the universe k is proportional to the sum of the kinetic K and potential U energies involved in the process of expansion of the universe

$$k \sim K + U$$

Thus, in a universe of zero curvature k=0, the following holds true:

$$0 = K+U$$

$$0 = dK + dU$$

$$dK = -dU$$

2.3 Model 2. Expansion of the universe according to a gaseous fluid model inside a piston.

We will study thermodynamically the expansion of a gaseous fluid inside a piston, where the external pressure of the piston represents the forces that tend to compress it (i.e., gravitational forces, in relation to Model 1), and the pressure inside the piston represents the forces that tend to expand it (i.e., dark energy forces, in relation to Model 1). For this thermodynamic study of the expansion, we consider the approximation of an expanding ideal gas to be sufficient.

2.4. Similarity of magnitudes in both models

When studying the expansion between the two models, we must align several quantities:

The value of total energy in the model 1 and internal energy in the model 2, E_i, will be the same.

In Model 1, the change in potential energy during the expansion process corresponds in Model 2 to the work done by the gas inside the piston during the expansion process.

2.5 Derivation of the zero active mass equation

Taking into account the similarities made between the two models and the calculations to be performed, we consider the consideration of an ideal gas as a gaseous fluid inside the piston to be valid.

Given the ideal gas law:

$$PV = (n N_A) k_B T$$

where:

P is the pressure of the gas.

V is the volume of the gas.

n is the number of moles.

N_A is Avogadro's number.

k_B is the Boltzmann constant.

T is the absolute temperature of the gas.

In an ideal gas, the internal energy, E_i, is the same as its kinetic energy K, given by the equation:

$$E_i = K = (3/2)(n N_A) k_B T$$

Substituting into the ideal gas law equation, we have:

$$PV = (2/3) E = (2/3) K$$

Differentiating this equation, we get:

$$PdV + VdP = (2/3)\, dK \quad (1)$$

PdV is the work done by the gas during the adiabatic expansion process inside the piston, model 2. Based on the similarity we have established between the two models, this work against the piston walls during expansion corresponds in model 1 to the work done by dark energy against gravitational forces during the expansion process; that is, the potential energy with the opposite sign involved in model 1 during the expansion process. Thus:

$$-dU = PdV$$

Substituting in (1):

$$-dU + VdP = (2/3)\, dK$$

According to Model 1, and in a universe with zero spatial curvature, in the process of expansion of the universe it is true that:

$$0 = dK + dU$$

$$dK = -dU$$

Thus:

$$dK + VdP = (2//3)\, dK$$

$$VdP = (-1/3)\, dK$$

$$dP = (-1/3)\, dK/V$$

Since the energy in ideal gases is solely a function of temperature and the kinetic energy, K, coincides with its internal energy E_i, which we have in turn made coincide with the total energy, it follows that:

$$\int dP = P = \int \left(-\frac{1}{3}\right) dK/V =$$

$$= \left(-\frac{1}{3}\right) \int dE_i/V = (-1/3)\,\rho$$

$$p = (-1/3)\,\rho$$

$$(\rho + 3p) = 0$$

Substituting into Friedman's second equation:

$$a'' = 0$$

3. -Discussion

We have obtained a proof of the zero active mass equation based on cosmological and thermodynamic considerations. To do this, we have conducted a comparative study of two models that partially represent the expansion of the universe, interrelating them. The first, Model 1, is an energy model in which the energies involved—kinetic and potential—are analyzed, and in which we have taken into account a new equation that relates them, an equation obtained by Fulvio Melia and published in a work referenced here. (Melia F, 2022) The second model, Model 2, is a simple thermodynamic model, corresponding to the expansion of an ideal gas in a piston. In this model, the thermodynamic variables, pressure, volume, and temperature are analyzed through the ideal gas law and the work done by the gas in its expansion is related to the potential energy involved in the expansion process of the universe according to model 1. The application of the equation found by Fulvio Melia in his work relating kinetic and potential energy in the expansion for universes of zero spatial curvature leads immediately to the equation of zero active mass, as we wanted to demonstrate.

4. -Conclusions

Starting from a different approach than that found by Fulvio Melia to prove the equation (Melia, F, 2026), we have obtained a new proof of the zero active mass equation for universes with zero space curvature, k = 0. Through reasoning based on cosmology and thermodynamics, we have studied the expansion of the universe using two different energy models: one from classical mechanics and the other from thermodynamics. By interrelating these two models, we conclude that, according to the FLRW metric and for zero space curvature, k = 0, the only valid solutions to the Friedmann equations are those that lead to a non-accelerating universe, that is, a universe with a linear scale factor. It should be noted that we used a Lapse function $g_{00} = 1$. Accordingly, the universes to which this FLRW metric model leads are non-accelerating universes. Likewise, during the demonstration we used a result from a study by Fulvio Melia (Melia, F, 2022) which states that spatial curvature k is proportional to the mechanical energy (kinetic + potential) involved in the expansion. Therefore, zero curvature leads to zero mechanical energy, leading us to conclude that for a non-accelerating expanding universe, no energy input is necessary for its continued expansion, not even dark energy, thus minimizing its importance in the expansion process.

Recently (Junhjuk Son et al. 2025), after decades of opinions favoring an accelerating universe, it seems to be confirmed that our universe is not accelerating. To this end, the supernova data that led to the conclusion that the universe was accelerating have been re-analyzed, along with new discoveries regarding distance and age estimation based on the ages of host galaxies. This seems to confirm that the universe is in a non-accelerating expansion. This would bring the conclusions of our work closer to the most recent experimental data. We are on the right track.

Data availability:
No new data were generated or analyzed in support of this research.

Conflict of interest:
The author states that there is no conflict of interest

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