Expansion acceleration versus Dark Matter: additional comments

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Abstract: The Cosmic Expansion Acceleration Model has been proposed to avoid the Dark Matter hypothesis. This approach is unconventional and several questions have arised about its present assumptions. Additional comments are given here about those questions, in particular: the homogeneity or unhomogeneity hypothesis, the scale factor question, the need for a negative mass repartition. Comparative arguments are issued, versus the ΛCDM model and the MOND approach.

Résumé: Le modèle d'Accélération d'Expansion Cosmique a été proposé pour éviter l'hypothèse de Matière Noire. Cette approche est non conventionnelle et plusieurs questions ont été soulevées à propos de ses hypothèses actuelles. On donne ici des commentaires supplémentaires au sujet de ces questions, en particulier : l'hypothèse d'homogénéité, la question du facteur d'échelle, le besoin d'une répartition de matière négative. Des arguments comparatifs sont émis par rapport au modèle ΛCDM et à l'approche MOND.

I. Introduction

In preceding papers (Fleuret, 2014 to 2020), in order to avoid Dark Matter hypothesis, I proposed to introduce a cosmic expansion acceleration proportional to velocity, with the local expansion rate as a coefficient:

$$\vec{\Gamma} = \frac{\dot{r}}{r}\vec{V} \qquad (1)$$

This was applied to the problem of galactic flat rotation curves (Fleuret, 2014) and then, to a 3D (inhomogeneous) radially-symmetric expanding universe (Fleuret, 2019) with a mass density $\mu(r)$ and a cumulated mass:

$$M(r) = \int_0^r 4\pi\rho^2 \mu(\rho) d\rho \qquad (2)$$

It was found that negative masses should be considered by this theory.

Recently, I showed that this acceleration can be obtained as a solution of the Einstein's equation with a cosmological constant, for a particular metric with two different potentials ϕ and ψ for space and time (Fleuret, 2020):

$$ds^2 = [1 + 2\,\psi(r)]\,dt^2 - \frac{1}{1+2\,\phi(r)}\,dr^2 - r^2\,d\theta^2 - r^2\,sin^2\theta\,d\varphi^2 \qquad (3)$$

These first steps are encouraging for this approach to be considered as an alternative to the Dark Matter hypothesis or to the MOND proposals. When compared to the standard ΛCDM model, it is totally unconventional and several questions have arised about its present assumptions. Additional comments are given here to clarify these questions as far as possible. Conversely, I also emphasize the reasonable conditions which should be satisfied to really ascertain the Dark Matter's existence.

II. The question of the Universe homogeneity or unhomogeneity

It is commonly admitted that an isotropic universe is observed from where we are, and that it should be homogeneous everywhere, due to the idea that we should not have any particular position in this universe. Furthermore, the homogeneity hypothesis really simplifies our computations.

But can it be really stated for certain that the observed universe is isotropic?

And, is it certain that the anthropic principle necessarily implies a totally homogeneous universe or even a quasi-homogeneous universe as it is often proposed?

About the first question, it must be noticed that our present knowledge of the "universe" is extremely limited! In spite of all our efforts to draw star mapping databases, it will represent a so minute information when compared to the total number of stars to be observed! Furthermore, the degree of homogeneity obviously depends on the scale of observation. As instances, the common observation of a starry night on one side and the recent images of large structures in the universe on the other side reveal obvious and distinct anisotropies and unhomogeneities. At what scale should the universe be isotropic and homogeneous? In which spectral range? Could we only define an "isotropy or homogeneity degree" taking in consideration the spatial and spectral resolutions of our measurements, our error margins, the statistical validity of such measurements based on so minute observed samples? Not even to mention the unobservable part of the universe…

About the second question, the whole history of astronomical observations has revealed surprisingly diverse situations, deploying an exuberant richness, far away from a "like this everywhere" representation. **Is it not possible that – without having any privileged position – we could not force the universe to be seen the same everywhere?**

Shouldn't we be more careful in our assertions, avoiding to abuse our good intentions (the anthropic principle) to dictate to the universe what it should be? Just like this ("smart") animal that eats only bananas and - knowing that she is not privileged - necessarily concludes that all other species also exclusively feed on bananas?

Finally, the homogeneous hypothesis appears not to be so an obvious choice. And the unhomogeneous hypothesis, not to be an a priori forbidden one.

Concerning the radial symmetry assumption, I agree it is just a simplified theoretical situation, when compared to the probably more complex reality: it must be considered as a very first step towards a future more realistic representation.

III. The question of the scale factor

Up to now, my model does not include a time-dependent scale factor. Space is not supposed to "expand in time by himself". Nevertheless, the far-away galaxy redshifts are described by their "direct" movement with respect to the observer. The absence of a scale factor would not mean a comeback to "Newton-like" absolute space and time: as long as a solution of Einstein's equation is dealt with, spacetime does remain relative and not absolute.

Incidentally, gravitational waves could be produced without a scale factor: a sufficiently significant local movement will generate propagating disturbances, from close to close. Formulating this effect without a scale factor would perhaps offer an experimental test to distinguish the two approaches (with or without scale factor), depending on the shape of the received signal.

IV. The controversy about the measurements of the Hubble Constant

The present official cosmological model is based on two hypotheses: homogeneity and scale factor. It results into non coherent values for the Hubble "Constant". Does not it mean that the basic hypotheses should be reconsidered?

V. Expansion acceleration versus MOND

In MOND theory, the radial acceleration of a circular movement is supposed to be modified, through a threshold procedure. This radial modification is equivalent to an additional attractive acceleration: this can be thought of as due to a positive additional ("dark") matter.

Concerning the expansion acceleration theory, a positive (repulsive) radial acceleration is added. In this case, I have **demonstrated** that the **lateral part of the expansion acceleration** does imply a constant lateral velocity. This is not dependent on an arbitrary threshold and is not limited to a circular movement. Conversely, the radial (expansive) acceleration is equivalent to an additional **negative matter**.

VI. Expansion Acceleration and negative mass repartition

For the study of a 3D radially symmetric space with a mass density $\mu(r)$ in a Newtonian approach (Fleuret, 2019), the obtained dynamics was given by eq. *[18]*:

$$\dot{r}^2 = -{w_0}^2 + H^2 r^2 - 2Gr^2 \int \frac{M(\rho)}{\rho^4} d\rho \qquad [18]$$

where ${w_0}^2$ is the square magnitude of the constant transverse velocity.

(the notation *[number]* will indicate the eq. number, as numbered in ref. Fleuret, 2019)

This was applied to the two cases of exponential expansion and accelerated expansion, and the needed mass densities were computed in both cases.

It was found that the cosmic expansion acceleration was equivalent to a precise negative mass repartition, acting as a Newtonian (anti-) gravity; and the corresponding density $\widehat{\mu(\rho)}$ and cumulative mass $\widehat{M(r)}$ were computed.

For this purpose, the Laplace formulae was written to identify the Newtonian potential and the expansion potential.

But in fact, it is important to note that **only the radial part of the expansion acceleration can be thought of as generated by negative masses**.

In (Fleuret, 2019), the total potential was computed, giving:

$$d\Phi = \left[-\frac{w_0^2 + \dot{r}^2}{r} + \frac{GM(r)}{r^2} \right] dr \qquad [20]$$

But it was erroneous to deduce the negative masses from the complete first term on the right-hand side (which includes the ${w_0}^2$ term for the transverse work, which should not be there).

Incidentally, the negative masses can be directly and equivalently obtained by the following radial equation:

$$-\frac{G\widehat{M(r)}}{r^2} = \frac{\dot{r^2}}{r} \qquad (4)$$

Where the radial expansion acceleration (r. h. s.) is considered as a repulsive quasi-Newtonian acceleration (l. h. s.).

Here are the resulting consequences:

For the case of an exponentially expanding universe $where\ \dot{r} = Hr$
[32]

The negative density becomes: $\hat{\mu} = -\frac{3H^2}{4\pi G} = -2\mu_c$ *[38]*

And from *[18]* and *[32]*, the positive masses are in agreement with the paper:

$GM = w_0^2 r$ *[34]*

$4\pi G\mu = \frac{w_0^2}{r^2}$ (eq. *[31]* & *[35]*)

In this case, we still observe an **excess of negative masses for large r**. But for small r, there is an excess of positive masses, as observed in our surrounding.

In the case of an accelerated universe, characterized by $\dot{r^2} = w_1^2 + \gamma_1 r$ *[53]*

(with w_1^2 close to zero).

We now get from (4) the new equation *[61]*:

$$\hat{\mu} = \frac{-2\gamma_1}{4\pi G r} \qquad [61]$$

And from *[18]* and *[53]*, again the positive masses agree with the paper:

$$GM(r) = \frac{\gamma_1}{2} r^2 + (w_0^2 + w_1^2) r \qquad [56]$$

$$4\pi G\mu = \frac{\gamma_1}{r} + \frac{w_0^2 + w_1^2}{r^2} \qquad [57]$$

For large r, the same conclusion is obtained:

$$\hat{\mu} + \mu \simeq -\mu \qquad [62]$$

With an **excess of negative masses**.

But for small r where expansion is negligible, putting H≃0 and $\gamma_1 \# r_0 H^2 \simeq 0$ *[55]*, we obtain:

$\hat{\mu} \# 0$ and $4\pi G\mu = \frac{w_0^2}{r^2}$

i.e a large excess of positive masses.

To summarize: in both cases, there still is an **excess of negative masses for far-away regions**. **On the contrary, in our surroundings, positive masses predominate**.

In a first approach, negative masses can be considered as a purely mathematical trick, expressing another manner to take care of the radial part of the expansion acceleration (which is itself a consequence of Einstein's equation - Fleuret, 2020). In the present proposals, the positive and negative masses have been assumed "not to get in touch" since they have pushed them away from each other and are supposed to be seated in separate regions. But for the physical reality of negative masses to be admitted, a lot of work remains to be done: to better understand what can be the physical significance of a negative mass-energy, better know the negative masses behavior, particularly their interaction with positive ones and whether or not the run-away effect must be considered and – in the case it could be antimatter – whether or not antimatter will "anti-gravitate".

VII. Conclusion : conditions to be fulfilled by the expansion acceleration and conversely, by Dark Matter to really "exist"

The expansion acceleration model remains in its infancy, since it still must be confronted (probably by numerical simulations) to several pending astrophysical situations, such as the study of galaxy clusters, the simulation of large scale structures, gravitational lens effects, analysis of primordial galaxy formations... It could also be applied to new observational data obtained by the on-going systematic satellite observations of the star dynamics.
Conversely, what are the conditions for the Dark Matter model to be fully scientifically credible? Does Dark Matter physically "exist" or is it just another mathematical empirical trick? In my opinion, to admit this statement, it should be necessary to enlighten the real consistence of this matter: what it is made of, what type of particle(s) or what other kind of "matter" does-it consist in? How does its existence relate to the known table of ordinary particles? How is it sensitive or not to other forces of nature: electromagnetism, nuclear forces? How is it precisely distributed in the universe and why? What is its history? It will also be necessary to explain precisely why it does not interact with ordinary matter. And build experiences to concretely show how all these types of interactions (or non-interactions) do operate. Finally, set up an experimental device to isolate a piece of it...

As always in science, several models do compete to represent the real world. Which one will be finally emergent depends on the relative facilities offered by each approach to enlighten those difficult questions.

References:

J. Fleuret, Astrophys. et Space Sci., 350-2, 769 (2014)

J. Fleuret, Astrophys. et Space Sci., 357, 68 (2015)

J. Fleuret, Journ. Modern Physics, vol.07 No.16 (2016)

J. Fleuret, Physics Essays, 32, 2 (2019)

J. Fleuret, Gravity and dual gravity: proposals for an inhomogeneous expanding universe, https://www.fleuretjacques.com/scientific-works (2020)