# *Expansion as a consequence of a rest-mass erosion theory*

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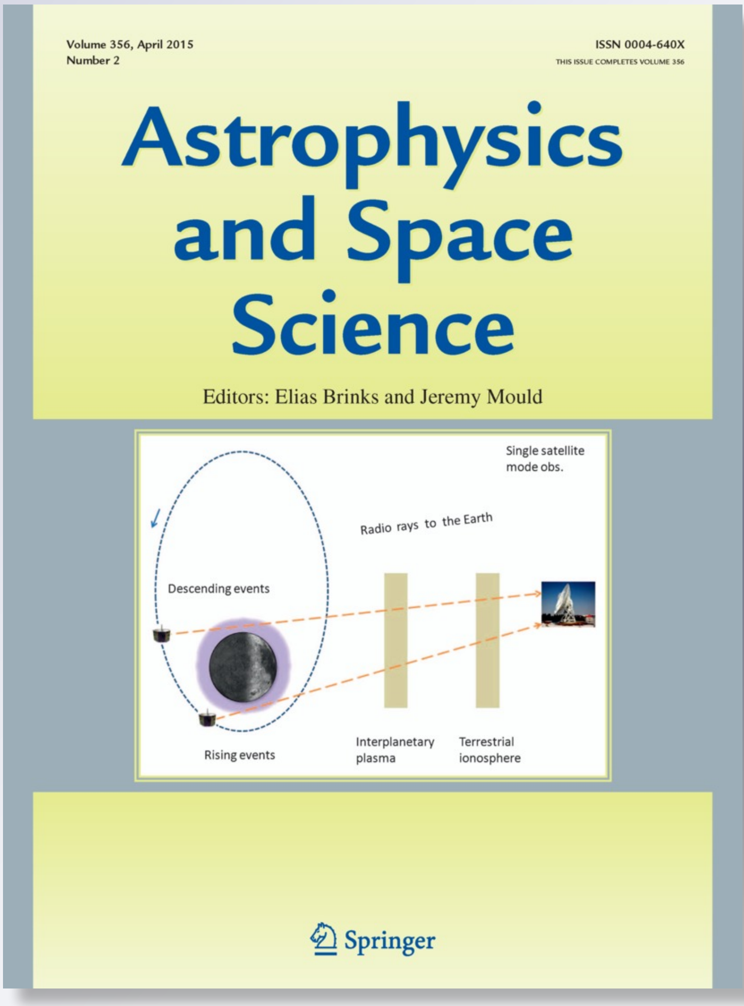

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LETTER

# Expansion as a consequence of a rest-mass erosion theory

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**Abstract** I propose a new paradigm to understand expansion. In a non-preserving mass theory, space expansion is driven by a slow continuous mass (or energy) erosion process. I show that this proposal is formally equivalent to an additional cosmic "evolution" force, which was suggested previously to explain the flat rotation curves of spiral galaxies.

The energy equation shows how expansion is related to gravitation and mass erosion.

According to this theory, the fundamental rectilinear movement is exponential in time. More generally, it is also shown how space, time *and* mass are inter-dependent. A cosmological equation is then obtained, similar to the FRW equation. This proposal confirms Masreliez's SEC theory and is a candidate to replace dark matter and dark energy hypotheses.

**Keywords** Expansion · Galaxy · Flat rotation curves · Cosmology · Dark matter · Dark energy

## 1 Introduction

The hypothesis of dark matter was firstly introduced to answer the problem of flat rotation curves of spiral galaxies, by J. Oort in 1932 and later studied by Rubin (Rubin and Ford 1970). It was also extended to the study of clusters of galaxies, gravitational lenses, cosmic background anisotropies, etc. Today, the constitution of non-baryonic matter remains controversial: will it be made of neutrinos, axions, super symmetric particles, WHIMPS, MACHOS, or even some new recent Higgs bosons?... (Aprile and Profumo 2009; Bertone et al. 2005; Bergstrom 2000).

The search for dark energy followed a comparable quest, since Einstein introduced his famous cosmological constant. Theoretical explanations and experimental processes were boosted by the discovery of the accelerated expansion of the universe (Riess et al. 1998; Perlmutter et al. 1997). Will this missing energy come from the vacuum energy (despite the enormous gap in the numerical values), variable energy fields, antimatter, dark matter collisions?... (Uzan 2010).

Until now and in spite of many theoretical and experimental efforts (Matarrese et al. 2011), the certitudes remain very weak and the various observational results are controversial and not fully convincing. Some observations establish limits on the exotic matter proportions and some recent experiments fail to find it as predicted.

With 28 % of black matter and 68 % of black energy, these "food of thought" seem to bring a lot of problems with their proposed solutions.

A few alternatives have been proposed.

For the flat rotation curves, galaxy models have been attempted, by a retro-calculation of the mass density to fit the observed curve (Cooperstock and Tieu 2007; Mizony 2003).

More generally, two different theories were developed. The MOND theory (Milgrom 1983), consists to modify gravitation for low accelerations. It was applied with success to recover the flat rotation curves (Cardone et al. 2011; Sanders and McGaugh 2002), extended to other problems and to a relativistic approach (Moffat 2008; Brownstein and Moffat 2006; Bekenstein 2004). Similarly, a more recent proposal consists to add an expansion term to the gravitation potential (Hamaji 2014).

Based on the general hypothesis of space *and* time expansion, the Masreliez Scale Expansion Cosmos (SEC) theory

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is also able to derive flat rotation curves (Masreliez 2012, 2004a, 2004b) and explain other physics anomalies.

My proposals are among the outsider essays to potentially find a simple theoretical paradigm to solve those questions, without extraneous matter or energy having exotic properties.

## 2 A new cosmic force, equivalent to a mass erosion process

In a preceding paper (Fleuret 2014) I proposed to introduce an additional cosmic force to explain the flat rotation curves of spiral galaxies, without dark matter. This force was expressed as:

$$\vec{f} = m\frac{\dot{r}}{r}\vec{u} \tag{1}$$

where $m$ is the mass of the considered star, $r$ its radial distance from the galactic center, and $\vec{u}$ its velocity.

I showed that this "extraneous" force could also explain the Tully-Fisher law (Fleuret 2014; McGaugh 2011), and derived some cosmological consequences.

But I did not really give a direct causal explanation for this new force, except that it could be a consequence of the SEC theory.

I show here that this hypothetical force can be considered as the expression of a non rest-mass preserving theory.

This unique principle—that each rest-mass (or rest-energy) in the Universe could slowly decrease with time—leads to simple explanations of complex phenomena such as the flat rotation curves of spiral galaxies, and also the accelerated expansion of the universe.

## 3 Mass erosion and universe expansion

Assuming that the rest mass could not be preserved (Rindler 2009), the gravitation force $\vec{F}$ should satisfy the dynamics equation:

$$\vec{F} = -\frac{GmM}{r^2}\hat{r} = \frac{d}{dt}(m\vec{u}) = m\frac{d\vec{u}}{dt} + \vec{u}\frac{dm}{dt} \tag{2}$$

where $M$ is the cumulative galactic mass (up to $r$). $G$ is the gravitation constant and $\hat{r}$ the unit radial vector.

In polar coordinates, this leads to the two equations for the two components of $m\frac{d\vec{u}}{dt}$:

$$m(2\dot{r}\dot{\theta} + r\ddot{\theta}) = -r\dot{\theta}\frac{dm}{dt} \tag{3}$$

$$m(\ddot{r} - r\dot{\theta}^2) = -\frac{GmM}{r^2} - \dot{r}\frac{dm}{dt} \tag{4}$$

Since in spiral galaxies, according to experience, the transverse velocity of rotating stars turns out to be a constant:

$$\dot{r}\dot{\theta} + r\ddot{\theta} = 0 \quad \Leftrightarrow \quad r\dot{\theta} = v_0$$

This can only be obtained from Eq. (3) if the following condition is satisfied:

$$-r\dot{\theta}\frac{dm}{dt} = m\dot{r}\dot{\theta} \tag{5}$$

Or—except the rectilinear radial movement ($\dot{\theta} = 0$):

$$\frac{\dot{m}}{m} = -\frac{\dot{r}}{r} \tag{6}$$

Which means that $m$ should be inversely proportional to $r$. In this case, the angular momentum remains constant (since both $v_0$ and $mr$ are constants).

Another way to derive Eq. (6) is to consider that the gravitation force has no torque. Therefore, the angular momentum must be constant, which implies Eq. (6) if $v_0$ is constant.

Incidentally, it must be noted that any modified gravitation theory using a central potential will not take care of the needed transverse modification (Eq. (3)).

Under condition (6), it becomes clear that the variable mass contribution appears to be equivalent of the proposed force (Eq. (1)):

$$-r\dot{\theta}\frac{dm}{dt} = -r\dot{\theta}\left(-\frac{\dot{r}}{r}m\right) = m\frac{\dot{r}}{r}r\dot{\theta} \tag{7}$$

$$-\dot{r}\frac{dm}{dt} = -\dot{r}\left(-\frac{\dot{r}}{r}m\right) = m\frac{\dot{r}}{r}\dot{r} \tag{8}$$

Finally after some calculation, the longitudinal equation (4) leads to:

$$u^2 = v_0^2 + \dot{r}^2 = r\ddot{r} + \frac{GM}{r} \tag{9}$$

## 4 The energy balance

From (2), the energy equation is:

$$\vec{F}\cdot\vec{u} = \frac{1}{2}m\frac{du^2}{dt} + u^2\frac{dm}{dt} \tag{10}$$

with:

$$u^2 = v_0^2 + \dot{r}^2 \tag{11}$$

Then, from (6), (10) and (11):

$$-m\frac{GM}{r^2}\dot{r} = m\dot{r}\ddot{r} - mu^2\frac{\dot{r}}{r} \tag{12}$$

Which (excluding the trivial $\dot{r} = 0$ solution), comes up to Eq. (9).

In this relationship, three terms are balanced: the gravitation potential, the kinetic energy and the mass variation energy.

Equivalently, from (1), (6) and (10), the energy equation can also be written as:

$$(\vec{F}+\vec{f})\cdot\vec{u}=\frac{1}{2}m\frac{du^2}{dt} \tag{13}$$

where gravitation and our "equivalent cosmic force" (which represents mass erosion) do contribute to the kinetic energy.

## 5 Case of the rectilinear "free" movement

It is significant to examine the case $M=0$ and $v_0=0$ (straight line movement without external force and no rotation).

In this case, we have, from Eq. (2):

$$\frac{\dot{u}}{u}=\frac{\ddot{r}}{\dot{r}}=-\frac{\dot{m}}{m} \tag{14}$$

and from (9):

$$\dot{r}^2=r\ddot{r} \tag{15}$$

which represents an exponential law:

$$r=r_0e^{ht} \quad \leftrightarrow \quad \frac{\dot{r}}{r}=\frac{\ddot{r}}{\dot{r}}=h \tag{16}$$

with:

$$m=m_0e^{-ht} \tag{17}$$

We verify that $m$ is inversely proportional to $r$, and also to $\dot{r}$, as predicted by Eq. (2) or (14).

From these results, we are tempted to consider that the natural "free" movement is not linear in time, but exponential, the expansion being fed by mass erosion. This has not been observed up to now because $h$ is extremely small.

Theoretically, it can be envisioned that, in certain circumstances, $h$ could be negative: a (locally) contracted universe could contribute to a mass increase!

## 6 Space, time and mass (or energy) are inter-dependent

Equation (9) can be solved to obtain the expansion rate $\frac{\dot{r}}{r}$ as a function of $r$:

$$\frac{\dot{r}}{r}=h(r) \tag{18}$$

Then, from (6), the following equation is locally satisfied:

$$\frac{\dot{m}}{m}=-\frac{\dot{r}}{r}=-h(r) \tag{19}$$

Or, equivalently:

$$\frac{dm}{m}=-\frac{dr}{r}=-h(r)dt \tag{20}$$

And (under a choice of units to take care of the integration constants):

$$Ln(m)=-Ln(r)=-h(r)t \tag{21}$$

We are then leaded to conclude that space, time *and* mass (or energy) are not independent. In fact, time appears to be the measurement of mass erosion or (simultaneously) of space expansion.

## 7 Cosmological consequences

Let us now consider the trajectory of a remote galaxy of mass $m$.

$M$ is now the mass of the Universe, up to distance $r$.

Assuming that the expansion rate does not explicitly depend on time, Eq. (9) can be rewritten as:

$$\frac{\dot{r}}{r}\frac{\partial}{\partial r}\left(\frac{\dot{r}}{r}\right)=\frac{v_0^2}{r^3}-\frac{GM}{r^4} \tag{22}$$

It can be integrated, leading to:

$$\frac{\dot{r}}{r}=h(r)=\pm\sqrt{\lambda-\frac{v_0^2}{r^2}+\frac{2}{3}\frac{GM}{r^3}} \tag{23}$$

Or:

$$\dot{r}^2=\lambda r^2-v_0^2+\frac{2}{3}\frac{GM}{r} \tag{24}$$

where $\lambda$ is an integration constant...[1]

For a homogeneous universe, the mass (or energy) density $\rho_m(t)$ is inversely proportional to $r^3$. Introducing the usual notations (Hartle 2007):

$$\rho_m(t)=\rho_m(t_0)\frac{r_0^3}{r^3} \tag{25}$$

$$\Omega_m=\frac{\rho_m(t_0)}{\rho_c} \tag{26}$$

where $t_0$ is the present time, $r_0$ the present distance and $\rho_c$ the critical density:

$$\rho_c=\frac{3H_0^2}{8\pi G} \tag{27}$$

[1] This parameter $\lambda$ has been abusively noted $h^2$ in my last paper (Fleuret 2014), presupposing that it should be positive, which is not necessarily the case. Furthermore, the $\pm$sign in Eq. (23) is also significant: it can be applied both to expanding or contracting parts of the universe, and modelize cosmic flows.

($H_0$ is the Hubble constant).

It is then obtained:

$$GM = \frac{1}{2} H_0^2 r_0^3 \Omega_m \tag{28}$$

Let us also introduce:

$$\Omega_v = \frac{\lambda}{H_0^2} \tag{29}$$

and

$$\Omega_c = \frac{-v_0^2}{H_0^2 r_0^2} \tag{30}$$

After the variable changes $u = \frac{r}{r_0}$ and $\tilde{t} = H_0 t$, Eq. (24) can be rewritten as:

$$u'^2 = \Omega_v u^2 + \Omega_c + \frac{\Omega_m}{3u} \tag{24b}$$

where the derivative is taken with respect to $\tilde{t}$.

Since $\left[(\frac{\dot{r}}{r})\right]_{r=r_0} = H_0$, an additional constraint must be satisfied. From (24):

$$H_0^2 \left(1 - \frac{\Omega_m}{3}\right) = \lambda - \omega_0^2 \tag{31}$$

with

$$\omega_0 = \frac{v_0}{r_0}. \tag{32}$$

Or, equivalently, from (24b):

$$\Omega_v + \Omega_c + \frac{\Omega_m}{3} = 1 \tag{31b}$$

The obtained universe evolution is formally identical[2] to the FRW model results (Hartle 2007) for a closed or flat universe ($\Omega_c$ is negative or null). Incidentally, Eq. (24b) is the same as the initial Lemaître result (Lemaître 1927) where he had $\Omega_c = -1$.

Most of the characteristics of universe evolution can be derived from (24) or (24b).

Let us recall that this result has been derived from a simple Newtonian approach, as the 1934 Milne approach (Dunning-Davies 2004; Milne 1934). The novelty is the introduction of the additional cosmic force (Eq. (1)), an "evolution force", which is nothing else than the expression of the mass erosion process.

The most important point is that the "cosmological constant" $\lambda$ is a logical consequence of our theory, and has nothing to do with hidden extraneous matter or energy.

[2]The radiation contribution—which we know is small—has not been considered here.

The universe evolution is driven by only two principles, as clearly illustrated by the computation of the second derivative, from (24) or (24b), which, after some calculation, leads to:

$$\ddot{r} - \frac{v_0^2}{r} = \frac{\dot{r}^2}{r} - \frac{H_0^2 r_0^3 \Omega_m}{3r^2} \tag{33}$$

$$u'' = \Omega_v u - \frac{\Omega_m}{6u^2} \tag{33b}$$

where the first contribution comes from the evolution force (or mass erosion, or space expansion) and the second one is gravity.

Further developments will be needed to find out the deep meaning of the 3 terms of Eq. (24), in comparison with the existing cosmological theories and the observation results.

## 8 Conclusion

I have shown—in the context of the rotation curves of spiral galaxies—that the proposed cosmic force (1) is equivalent to the hypothesis of a slow continuous mass erosion process. According to this new paradigm, the mass variation appears to be the source of energy for space expansion. This novel idea is much simpler than most existing postulates about a modified gravitation or extraneous dark matter or energy.

Furthermore, these results do confirm the SEC theory, as stated by Eq. (21) where space expansion, mass erosion and "time expansion" are intrinsically related. This can also be illustrated by the qualitative following argument. Since energy is mass, and also frequency ($E = mc^2 = h\upsilon$), mass erosion is equivalent to frequency decrease, which is due—according to Masreliez' SEC theory—to expansion of time itself.

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