Constraints on Janus Cosmological model from recent observations of supernovae type Ia

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Constraints on Janus Cosmological model from recent observations of supernovae type Ia

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From our exact solution of the Janus Cosmological equation we derive the relation of the predicted magnitude of distant sources versus their red shift. The comparison, through this one free parameter model, to the available data from 740 distant supernovae shows an excellent fit.

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INTRODUCTION

Modern cosmology is facing quizzical observational data. One of them is the acceleration of expansion of the universe [1–3]. Scientists are then facing two choices:

- They either limit their interpretation of the phenomenon within the geometrical frame issued from the complete Einstein's field equation, including the so-called cosmological constant Λ. Therefore the price to pay for it, is to add the concept of dark energy, whose physical nature remains a complete mystery. On top of that, this creates a model with a lot of free parameters giving it the nature of ad hoc model.

- Or they have to deal with a drastic geometric and paradigmatic change which extends General Relativity to a wider model. This very model includes negative mass and negative energy particles whose physical nature can be described through the dynamic groups theory. These particles are simple copies of our classical matter and antimatter, with negative mass. Moreover, such a model, inspired by Andrei Sakharov's ideas, does explain why we do not observe any primeval antimatter.

THE JANUS COSMOLOGICAL MODEL, A NECESSARY NEW GEOMETRICAL FRAMEWORK

The JCM is based on the introduction of negative mass and negative energy in the cosmological model. As shown in 1957 by Hermann Bondi[4] and confirmed later by W.Bonnor[5], the introduction of negative masses in the GR model produced an unmanageable runaway effect.
This effect comes from the usual way we deal with a particle embedded in a gravitational field where particles follow the same geodesic whatever positive or negative their mass would be. As a conclusion, from Einstein's equation:

- A positive mass object does attract any positive or negative mass.

- A negative mass object does repel any positive or negative mass.

If, as an example, we are taking two opposite masses : the positive one is escaping from the following chasing negative one. Both are experiencing a uniform acceleration. But the energy is conserved because the negative mass carries a negative energy.
This unmanageable feature banished negative mass concept during 60 years. But this effect vanishes when we consider that positive and negative masses follow different geodesic systems, which both derived from both distinct metric tensor fields $g^{(+)}_{\mu\nu}$ and $g^{(-)}_{\mu\nu}$. These two are meant to be solution of a coupled field equations system and the JCM brings the solution[6–9]. See S.Hossenfelder[10, 11] for corresponding Langrangian derivation of such bimetric system.

$$\begin{aligned} R^{(+)}_{\mu\nu} - \frac{1}{2}\,R^{(+)}\,g^{(+)}_{\mu\nu} &= +\chi\left(T^{(+)}_{\mu\nu} + \frac{a^{(-)\,3}}{a^{(+)\,3}}\,T^{(-)}_{\mu\nu}\right) \\ R^{(-)}_{\mu\nu} - \frac{1}{2}\,R^{(-)}\,g^{(-)}_{\mu\nu} &= -\chi\left(T^{(-)}_{\mu\nu} + \frac{a^{(+)\,3}}{a^{(-)\,3}}\,T^{(+)}_{\mu\nu}\right) \end{aligned} \tag{1}$$

The corresponding interaction scheme is the following:

- Positive masses do attract each other, though Newton's law.

- Negative masses do attract each other, though Newton's law.

- Opposed masses do repel each other, through anti-Newton's law.

This interaction scheme fits the action-reaction principle.

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THE BENEFIT OF THE JCM MODEL

JCM is not another extra model with a lot of puzzling components, associated with a subsequent set of free parameters. It's a model without unknown components.
Indeed, it is nothing else but an extension of Andrei Sakaraov's ideas [12–14].
In 1967 Andrei Sakharov gave an explanation of the observational absence of primeval antimatter (nowadays there still is no other challenging theory). At the time, he thought the universe to be composed by two "twin universes", both only linked together via one singularity "origin". Inspired from a CPT symmetry scheme, Sakharov suggested that :

- The arrow of time would be antiparallel to ours (T-symmetry).
- It would be enantiomorphic (P-symmetry).
- It would contain antimatter (C-symmetry).

JCM globally follows this above general scheme, but, instead of two distinct universes, we suggest to consider one single universe corresponding to a manifold M4 with two metrics. This corresponds to a new, but clear, geometrical framework.
As shown by J.M.Souriau in 1970 [15] T-symmetry goes with energy and mass inversion, so that the "twin universes content" only corresponds to a copy of our particles (photon, proton, neutron, electron, up to quarks and their anti), but with negative energy and negative mass if any.
Negative masses emit negative energy photons, therefore this matter is invisible to us. It only reveals its presence through (anti) gravitational effects.
Following A.Sakharov, we can assume that the ratio of the rate of production of baryon versus antibaryons would be inverse for the negative population.
So that :

- JCM explains the absence of observation of the so-called primeval antimatter, opposite to the mainstream ΛCDM model.
- JCM describes precisely the nature of the invisible components of the universe, opposite to the mainstream ΛCDM model.
- In addition, JCM predicts that the antimatter produced in laboratory will react as the matter with respect to the gravitational field of the Earth (it will fall).
- Because positive and negative matter are repelling each other, the negative matter content in the solar system is almost zero. So, JCM fits the classical relativistic observations, as presented in former papers[7–9].
- JCM suggests a clear scheme for VLS formation [17] when the mainstream ΛCDM model seems to struggle more to give one.
- JCM explains the observed repellent effect due to "the Great Repeller" [18]. The measured escape velocities of galaxies are due to the presence of an invisible repellent cluster made of negative mass in the centre of a big void. The mainstream model's supporters suggest that such a repellent effect could be due to some kind of hole in the dark matter field of the universe (positive masses). But, if the gravitational instability leads to the setting up of massive clusters, it does not provide any scheme for such void formations. So that the mainstream ΛCDM model does not provide any explanation for this observation.
- JCM explains the confinement of galaxies and the shape of their rotation curves. As we showed in Petit et al. (2001), if one introduces a surrounding repellent negative matter environment, it gives larger rotation velocities at distance, see fig. 1 Mysterious dark matter is no longer required, while the mainstream ΛCDM model does.

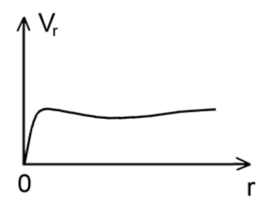

FIG. 1. Circular velocity, after Petit et al. (2001). This can be compared with results from numerical simulations by Farnes (2017)[16]

- After JCM, the intensity of the observed gravitational lensing effect is mainly due to the negative matter that surrounds galaxies and clusters of galaxies. Mysterious dark matter is no longer required, while the ΛCDM model does.
- JCM suggests an explanation of the low magnitude of very young galaxies: this would be due to negative lensing weakening, when their light are crossing the negative mass clusters located at the center of the big void. Mysterious dark matter is no longer required, while the ΛCDM model does.
- JCM explains the spiral structure of galaxies[19], see fig.2, due to dynamical friction with the surrounding negative mass. The ΛCDM model don't give any model explaining the spiral structure.

As a conclusion JCM is definitively not a simple or pure speculative product of theoretical mathematics. It had been compared with many observations and happened

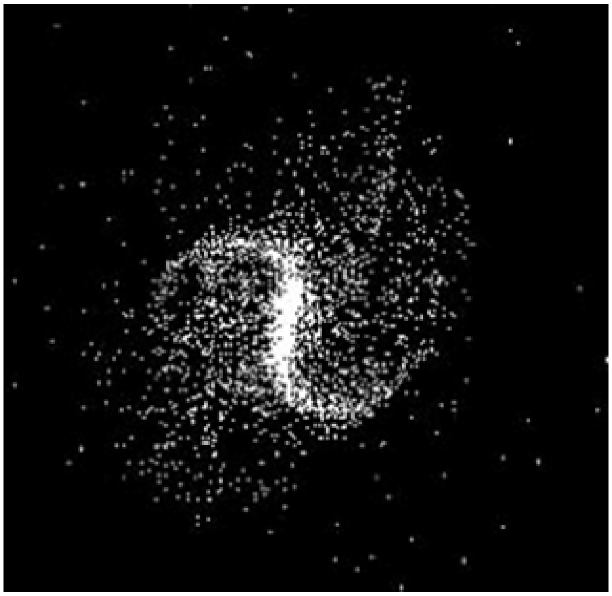

FIG. 2. Spiral structure in numerical simulation

to fit with them. Opposite to the today's mainstream ΛCDM model, JCM does not carry unknown and mystery like dark matter or dark energy.

JCM EXPLAINS THE ACCELERATION OF THE UNIVERSE

An exact solution of the system (1) for the dust era of the universe, was presented in Astrophysics and Space Science journal in 2014[8], which gives, for positive species :

$$\begin{aligned} a^{(+)}(u) &= \alpha^2\, ch^2(u) \\ t^{(+)}(u) &= \frac{\alpha^2}{c}\left(1 + \frac{1}{2}\, sh(2u) + u\right) \end{aligned} \tag{2}$$

In the following,we will show that the predicted values of the bolometric magnitude versus redshift fits pretty well the available data.
For sake of simplicity, we will now write $a^{(+)} \equiv a$.
The deceleration parameter q is :

$$q \equiv -\frac{a\,\ddot{a}}{\dot{a}^2} = -\frac{1}{2\, sh^2(u)} < 0 \tag{3}$$

And the 'Hubble constant' is :

$$H \equiv \frac{\dot{a}}{a} \tag{4}$$

We can derive (see annex A) the relation for the bolometric magnitude with respect to the redshift z :

$$m_{bol} = 5\, log_{10}\left[z + \frac{z^2(1-q_0)}{1 + q_0 z + \sqrt{1+2q_0 z}}\right] + cst \tag{5}$$

where $q_0 < 0$ and $1 + 2q_0 z > 0$. Fitting q_0 and cst to available observational data [20], gives :

$$q_0 = -0.087 \pm 0.015 \tag{6}$$

Results presented below, show the standardized distance modulus, linked to experimental parameters through the relation :

$$\mu = m_B^* - M_B + \alpha X_1 - \beta C \tag{7}$$

where m_B^* is the observed peak magnitude in rest frame B band, X_1 is the time stretching of the light curve and C the supernova color at maximum brightness.
Both M_B , α and β are nuisance parameters in the distance estimate.
We took the values given in ref.[20] corresponding to the best fit of the whole set of combined data (740 supernovae) with ΛCDM model.

With our best fit, we have :$\chi^2/d.o.f. = 657/738$ (740 points and 2 parameters).
The corresponding curves are shown in fig. 3, 4, 5, 6, in excellent agreement with the experimental data. The comparison with both model best fits are shown in fig. 7.

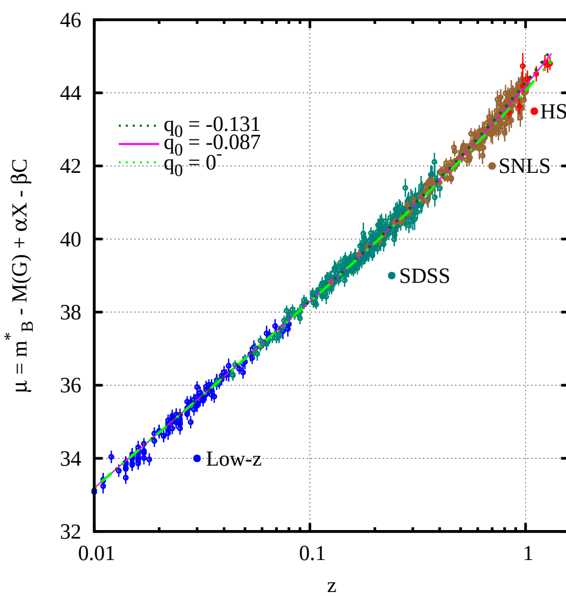

FIG. 3. Hubble diagram of the combined sample (log scale)

We can derive the age of the universe (see annex B) with respect to q_0 and H_0 and some numerical values are given in table I, for different (q_0, H_0) values. For our best fit, we get :

$$T_0 = \frac{1.07}{H_0} = 15.0 Gyr \tag{8}$$

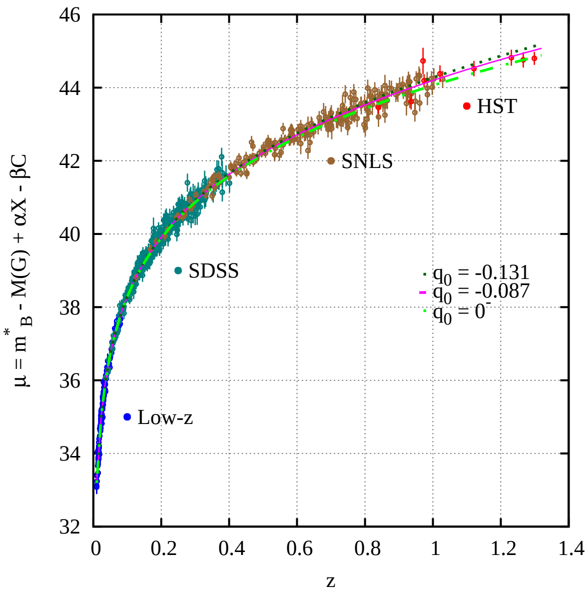

FIG. 4. Hubble diagram of the combined sample (linear scale)

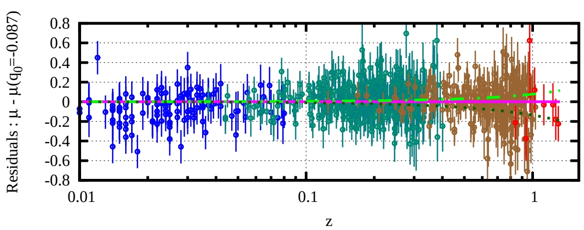

FIG. 5. Residuals from the best fit versus redshift (log scale)

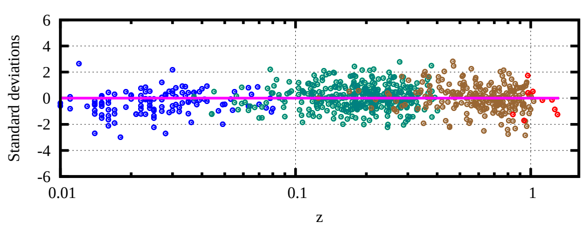

FIG. 6. Standard deviation versus redshift

TABLE I. T_0 values with respect to q_0 and H_0

T_0 (Gyr)		q_0 = ***0.00***	***-0.045***	***-0.087***	***-0.102***	***-0.117***	***-0.132***
H_0	***70***	14.0	15.0	15.0	14.9	14.9	14.8
	73	13.4	14.4	14.4	14.3	14.3	14.2

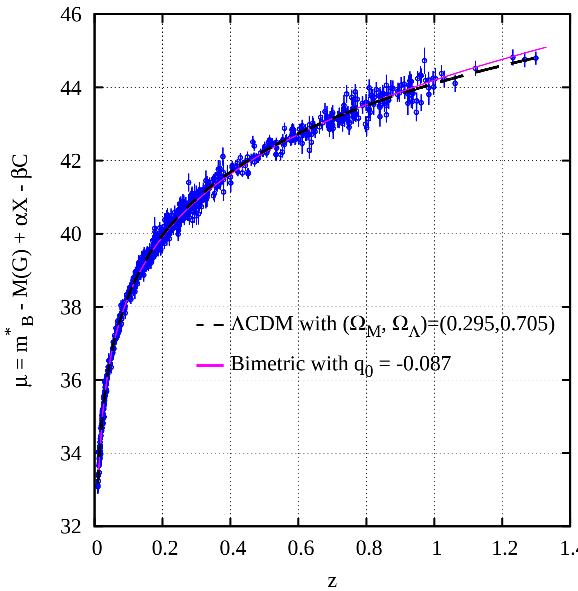

FIG. 7. Hubble diagram of the combined sample and compraison with the 2 models (linear scale)

WHAT IS MISSING

Let's figure out that, when extended to the early age of the universe, the JCM proposes an alternative to the inflation theory, in order to justify the great homogeneity of the primeval universe. This was introduced first in 1988[21], extended in 1995[7], and implies a variable constants system which preserves all equations of physics. As a basis of the interpretation of the very large structure of the universe we supposed that the mass density of the negative species (negative mass 'twin' matter) is much higher that the one of the positive species.
In JCM, we have to take into account two systems, each owing their own sets of "variable constants" plus space and time scale factors :

$$[c^{(+)}, G^{(+)}, h^{(+)}, m^{(+)}, e^{(+)}, a^{(+)}, t^{(+)}]$$
$$[c^{(-)}, G^{(-)}, h^{(-)}, m^{(-)}, e^{(-)}, a^{(-)}, t^{(-)}]$$

A future work will show how, the system of coupled field equations (1) including a variable constants process, starting from a fully symmetrical initial situation can explain density instabilities.
Moreover, when the densities get weaker, the sets :

$$[c^{(+)}, G^{(+)}, h^{(+)}, m^{(+)}, e^{(+)}]$$
$$[c^{(-)}, G^{(-)}, h^{(-)}, m^{(-)}, e^{(-)}]$$

behave as absolute constants, in each sector, with $a^{(+)}c^{(+)2} = a^{(-)}c^{(-)2}$.
The ΛCDM model provides an interpretation of the fluctuations of the CMB. If the JCM wants to pretend to challenge the ΛCDM it must provide an alternative interpretation of such observational data.
This is out of the scope of the present paper and will the subject of future works.

CONCLUSION

Based on a new geometrical framework the JCM modelis taking into account many observational data. It precisely defines the nature of the invisible components of the universe, as a copy of ordinary components, with negative energy and negative mass, if any. By developping former Sakharov's theory, it explains the lack of primeval antimatter observation. The negative sector is then composed with negative mass protons, neutrons, electrons and so on. Through such a negative energy, photons make all negative sectors species invisible to us.
JCM model is explaining the strong gravitational lensing effects around galaxies and clusters of galaxies, due to the surrounding and confining negative mass environment. It brings a model for VLS formation, spiral structure and gives an explanation to the repellent phenomena recently observed in a very large size mapping. It also explains the flatness of the rotation curves of galaxies.
The extension of JCM to a variable constants regime, applying to the early stage, explains the homogeneity of the early universe.
It brings an exact solution in the dust era, which takes takes into account the acceleration of the universe. This paper is willing to demonstrate the good agreement of this solution with a single free parameter, with the experimental data on supernovae. The deceleration parameter q_0, allways negative, happened to be small and there is no need in JCM to introduce a non zero cosmological constant to fit the so far available data.
It is also pointed out that the model must now provide its own interpretation of additional features like the CMB fluctuations.

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Annex A : Bolometric magnitude

Starting from the cosmological equations corresponding to positive species and neglectible pressure (dust universe) establish in ref.[8] :

$$a^{(+)\,2}\,\ddot{a}^{(+)} + \frac{8\pi G}{3}E = 0 \tag{9}$$

with $E \equiv a^{(+)\,3}\rho^{(+)} + a^{(-)\,3}\rho^{(-)} = constant < 0$. For the sake of simplicity we will write $a \equiv a^{(+)}$ in the following. A parametric solution of Eq. (9) can be written as :

$$a(u) = \alpha^2\,ch^2(u) \qquad t(u) = \frac{\alpha^2}{c}\left(1 + \frac{sh(2u)}{2} + u\right) \tag{10}$$

with

$$\alpha^2 = -\frac{8\pi G}{3\,c^2}E \tag{11}$$

This solution imposes $k = -1$. Writing the usual definitions:

$$q \equiv -\frac{a\ddot{a}}{\dot{a}^2} \qquad and \qquad H \equiv \frac{\dot{a}}{a} \tag{12}$$

we can write :

$$q = -\frac{1}{2\,sh^2(u)} = -\frac{4\pi G}{3}\,\frac{|E|}{a^3\,H^2} \tag{13}$$

and also

$$(1-2\,q) \;=\; \frac{c^2}{a^2\,H^2} \qquad (14)$$

In terms of the time t used in the FRLW metric, the light emitted by G_e at time t_e is observed on G_0 at a time t_0 ($t_e > t_0$) and the distance l travelled by photons ($ds^2 = 0$) is related to the time difference t and then to the u parameter through the relation :

$$l = \int_{t_e}^{t_0} \frac{c\,dt}{a(t)} \;=\; \int_{u_e}^{u_0} \frac{(1+ch(2\,u)}{ch^2(u)} du \;=2\,u_0 \;-\; 2\,u_e \qquad (15)$$

We can also relate the distance l to the distance marker r by (using Friedman s metric with $k = -1$) :

$$l = \int_{t_e}^{t_0} \frac{c\,dt}{a(t)} \;=\; \int_{0}^{r} \frac{dr'}{\sqrt{1+r'^2}} = argsh(r) \qquad (16)$$

So we can write :

$$r \;=\; sh(2\,u_0 - 2\,u_e) \;=\; 2\,sh(u_0 - u_e)\,ch(u_0 - u_e) \quad (17)$$

We need now to link u_e and u_0 to observable quantities q_0, H_0, and z. From Eq. (10) we get :

$$u \;=\; argch\left(\sqrt{\frac{a}{\alpha^2}}\right) \qquad (18)$$

Eq. (15) gives the usual redshift expression :

$$a_e = \frac{a_0}{1+z} \qquad (19)$$

From Eq. (13) and (18) we get :

$$u_0 \;=\; argch\sqrt{\frac{2q_0-1}{2q_0}} \;=\; argsh\sqrt{-\frac{1}{2q_0}} \qquad (20)$$

From Eq. (13), (18)) and (19)) we get :

$$u_e \;=\; argch\sqrt{\frac{2q_0-1}{2q_0(1+z)}} \;=\; argsh\sqrt{-\frac{1+2q_0z}{2q_0(1+z)}} \quad (21)$$

Inserting Eq. (20) and (21) into Eq. (17), after a few technical manipulations, using at the end Eq.(14) and considering the constraint that $1 + 2q_0z > 0$, we get :

$$r = \frac{c}{a_0H_0}\,\frac{q_0z + (1-q_0)\left(1-\sqrt{1+2q_0z}\right)}{q_0^2(1+z)} \qquad (22)$$

Which is similar to Mattig's work [22] with usual Friedmann solutions where $q_0 > 0$, here we have always $q_0 < 0$.

The total energy received per unit area and unit time interval measured by bolometers is related to the luminosity :

$$E_{bol} \;=\; \frac{L}{4\pi a_0^2 r^2 (1+z)^2} \qquad (23)$$

Using Eq. (22), the bolometric magnitude can therefore be written as :

$$m_{bol} = 5Log_{10}\left[\frac{q_0z + (1-q_0)\left(1-\sqrt{1+2q_0z}\right)}{q_0^2}\right] + cte \qquad (24)$$

This relation rewrites as [23]:

$$m_{bol} = 5Log_{10}\left[z + \frac{z^2(1-q_0)}{1+q_0z+\sqrt{1+2q_0z}}\right] + cst \qquad (25)$$

which is valid for $q_0 = 0$.

Annex B : Age of the universe

Below we will establish the relation between the age of the universe T_0 with q_0 and H_0. This age is defined by :

$$T_0 \;=\; \frac{\alpha^2}{c}\left(\frac{sh(2u_0)}{2} + u_0\right) \qquad (26)$$

From Eq. (11), (13), (14) we get :

$$\frac{\alpha^2}{c} \;=\; -\frac{2q}{H}\,(1-2q)^{-\frac{3}{2}} \;=\; \frac{2q_0}{H_0}\,(1-2q_0)^{-\frac{3}{2}} \qquad (27)$$

and so :

$$T_0. = -2q_0\,(1-2q_0)^{-\frac{3}{2}}\left(\frac{sh(2u_0)}{2} + u_0\right)\frac{1}{H_0} \qquad (28)$$

Inserting Eq. (20) in Eq. (28) we finally get :

$$T_0.H_0 = 2q_0\,(1-2q_0)^{-\frac{3}{2}}\left(argsh\sqrt{\frac{-1}{2q_0}} - \frac{\sqrt{1-2q_0}}{2q_0}\right) \qquad (29)$$

This relation is shown in fig. 8.

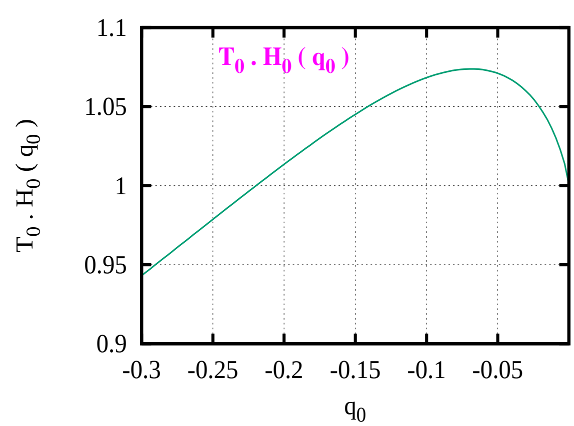

FIG. 8. Age of the universe time Hubble's constant versus q_0