# Expansion force as a consequence of Bohmian Quantum Mechanics

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## Abstract

I proposed a new expansion force to explain Universe expansion without Dark Matter.

In this paper, it is shown that this force can be deduced from Bohmian Quantum Mechanics, introducing a bridge between QM and Astrophysics.

This approach could clarify the present questions about the Hubble « Constant » measurements and give information about the real mass content of the Universe and its repartition.

## Résumé

J'ai proposé une force d'expansion nouvelle pour expliquer l'expansion de l'Univers.

Dans cet article, il est démontré que cette force peut se déduire de la Mécanique Quantique Bohmienne, ce qui établit un pont entre la Mécanique Quantique et l'Astrophysique.

Cette approche pourrait éclaircir les présentes questions posées à propos des mesures de la « Constante » de Hubble et fournir des informations sur le contenu massique réel de l'Univers et sa répartition.

## Introduction

As is well known, the two fundamental theories of physics are based on quite different postulates: continuity and determinism for Relativity, quantification and Hazard for Quantum Mechanics. It is also known that De Broglie and Bohm (Bohm, D., 1952; De Broglie, L., 1987) developed the pilot wave theory, which has the advantage to avoid intrinsic hazard in science (Bacciagaluppi and Valentini, 2009; Durr & Teufel, 2009; Oriols, & Mompart, 2019). It is surprising in my opinion that this approach is only considered by a small part of the scientific community (Valentini, A. 2010; Gondran, M. & A., 2014).

Anyway, both theories have developed an impressive amount of results. In particular, cosmology – mostly based on Relativity – has produced a lot of knowledge about the universe, with the ΛCDM model. But this "knowledge" is based on the quasi totally unknown Dark Matter in particular. I have proposed a new approach to avoid the Dark Matter hypothesis (Fleuret, J., 2014): a new expansion acceleration should be added to the Newtonian attraction. I have shown that it can be considered as a solution of the Einstein equation for a particular metric (Fleuret, J., 2020) and applied it to the study of a non necessarily homogeneous universe. According to this theory (Fleuret, J., 2021), the universe should not be "expanding by himself" (with a scale factor), but the expansion force would act on each particle, "expanding" its movement, in a new dynamics principle.

For our present point of view, it will be sufficient to restrict our attention to a radial movement. In this case, the expansion acceleration has the form:

$$\gamma_{exp} = \frac{\dot{r}^2}{r}. \qquad (1)$$

In this paper, I propose that **this acceleration could be due to a Bohmian Quantum effect**. For this purpose, the differential equation is first established for a particle moving with its pilot wave in a Newtonian potential. Then, this is applied to the radial movement of a far-away galaxy submitted to the Newton's attraction from all other masses. It is then shown that **the additional expansion force is a consequence of quantum Bohmian Mechanics**. Then are examined the cases of a uniform Universe and a non homogeneous one. In this case, a possible validation test can be envisioned by the analysis of the present Hubble "Constant" measurements.

## Bohmian particle dynamics in a Newtonian potential

Let-us consider a particle of mass m, with its pilot wave $\psi$ (supposed to be Gaussian).

It is supposed to be in the outskirt of the universe, in such a way that the influence of all other masses can be considered as if they were concentrated in a total mass M(r), where r is the distance measured from the observer.

[In Bohmian dynamics, this mass M should have a pilot wave, and the global pilot wave should be the sum of the two. But the "particle" is so small when compared to the total mass of the universe - even if it is a far-away galaxy - and it is so far away that its global influence to all other masses can be reasonably neglected, in such a way that the pilot wave of the central mass M disappears in the total pilot wave to be considered.]

The problem is thus reduced to the behavior of the "particle" with its pilot wave in an "empty" space with a central attractor M(r). Let-us focus our attention to radial movements. It is then a 1D problem. Let-us call r the position of the particle. Since, according to the Gauss theorem, the Newton's acceleration is the same as produced by the total concentrated mass M(r), the acting potential can be written as:

$$V(r) = -\int -\frac{M(r)G}{r^2}dr \tag{2}$$

Let-us assume that the initial pilot wave of the “particule” is described by the following (normalized) gaussian expression:

$$\psi(r,t=0) = \frac{1}{(2\pi Д^2)^{\frac{1}{4}}} e^{-\frac{r^2}{4Д^2}} \tag{3}$$

The Fourier components of the initial wave are given by:

$$\varphi(p,0) \sim \int e^{-\frac{r^2}{4Д^2}} e^{-\frac{ipr}{\hbar}} dr \tag{4}$$

Each plane wave $e^{-i(\frac{pr}{\hbar}-\omega t)}$ (5)

evolves with time and satisfies the Schrodinger equation, leading to:

$$E = \hbar\omega = \frac{p^2}{2m} + V \tag{6}$$

From (5) the time evolution of the wave can be computed as:

$$\psi(r,t) = \int \varphi(p)\, e^{\frac{ipr}{\hbar} - i\frac{p^2 t}{2m\hbar} - i\frac{Vt}{\hbar}} dp \tag{7}$$

This can be integrated and normalized (Dabin, 2009) to give:

$$\psi(r,t) = \frac{1}{\left[2\pi Д^2\left(1+i\frac{t}{\tau}\right)\right]^{\frac{1}{4}}} e^{-\frac{r^2}{4Д^2\left(1+i\frac{t}{\tau}\right)} - i\frac{Vt}{\hbar}} \tag{8}$$

where the time parameter τ has been introduced: $\tau = \frac{2mД^2}{\hbar}$ (9)

Finally, the Bohmian solution for the particle dynamics is given by:

$$\frac{dr}{dt} = \frac{1}{m}\frac{\partial S}{\partial r} - \frac{MG}{r^2}t \tag{10}$$

Where $\frac{S}{\hbar}$ represents the phase of the wave.

Or, from (2) and (8):

$$\frac{dr}{dt} = \frac{rt}{t^2+\tau^2} - \frac{MG}{r^2}t \tag{11}$$

## Application to the far-away galaxy dynamics

If we consider the motion of a far-away galaxy, taken as “particle”, the time parameter τ is very large. For $m \cong 10^{42}$ and Д about the size of our galaxy ($10^{21}m$), τ is around $10^{118}$. Consequently, the first term of eq. (11) can be neglected, leading to:

$$\frac{dr}{dt} = -\frac{MG}{r^2}t \tag{12}$$

Let-us consider a homogeneous space with mass density $\rho_0$:

$$M(r) = \frac{4}{3}\pi\rho_0 r^3 \tag{13}$$

Eq. (12) becomes:

$$\frac{dr}{dt} = -Krt \tag{14}$$

Where $$K = \frac{4}{3}\pi G\rho_0 \tag{15}$$

And $$MG = Kr^3 \tag{16}$$

The solution of (14) is a gaussian curve:

$$r = Re^{-K\frac{t^2}{2}} \tag{17}$$

How can this be identified with the present observations of a far-away galaxy motion?

These observations are commonly expressed within the second order parameters:

$$H = \frac{\dot{r}}{r} \tag{18}$$

$$q = \frac{r\ddot{r}}{\dot{r}^2} \tag{19}$$

For the eq (17) dynamics, it is easily found that:

$$H = -Kt \tag{20}$$

$$q = 1 - \frac{1}{Kt^2} \tag{21}$$

Clearly, for the expansion to be positive, our present time $t_0$ on the curve (17) must be negative, with the present parameters:

$$H_0 = -Kt_0 \tag{22}$$

$$q_0 = 1 - \frac{1}{K{t_0}^2} \tag{23}$$

$H_0$ is the Hubble Constant value at the present time. Since $q_0$ is presently estimated to be equal to ½, it allows to determine our present position on the curve (17):

$$t_0^2 = \frac{2}{K} = \frac{3}{2\pi G\rho_0} \qquad\qquad r = r_0 = \frac{R}{e} \tag{24}$$

And finally, from (22) and (24): $$H_0^2 = 2K = \frac{4}{t_0^2} = \frac{8\pi G\rho_0}{3} \tag{25}$$

This means that, in fact, **$\rho_0$ must be the critical density: it is the necessary density to ensure a ½ acceleration parameter.**

Incidentally, our initial proposal to neglect the first term in (11) reveals to be totally valid, since:

$$\frac{\left(\frac{MG}{r^2}\right)}{\left(\frac{r}{\tau^2}\right)} = K\tau^2 = \frac{H_0^2\tau^2}{2} \gg 1 \tag{26}$$

## An infinitely expanding and contracting dynamics, and the forces in action

What are the forces in action to generate the eq. (17) dynamics? To answer the question, let-us compute the acceleration, from (14) and (16). It can be easily written as:

$$\ddot{r} = -\frac{MG}{r^2} + \frac{\dot{r}^2}{r} \tag{27}$$

where **the second term is nothing else than the radial expansion acceleration (1)**.

This important result tends to show that **the expansion force can be considered as a consequence of Quantum Bohmian Mechanics**.

Furthermore, it is notable that the mass repartition (13) of a simple homogeneous universe is the only one to produce the precise extra-acceleration term $\frac{\dot{r}^2}{r}$ in eq (27).

Eq (17) represents the possible trajectory of a galaxy. It describes an infinite evolution in time (no Big-Bang), made of an expansion phase followed by a contraction phase, as illustrated figure 1.

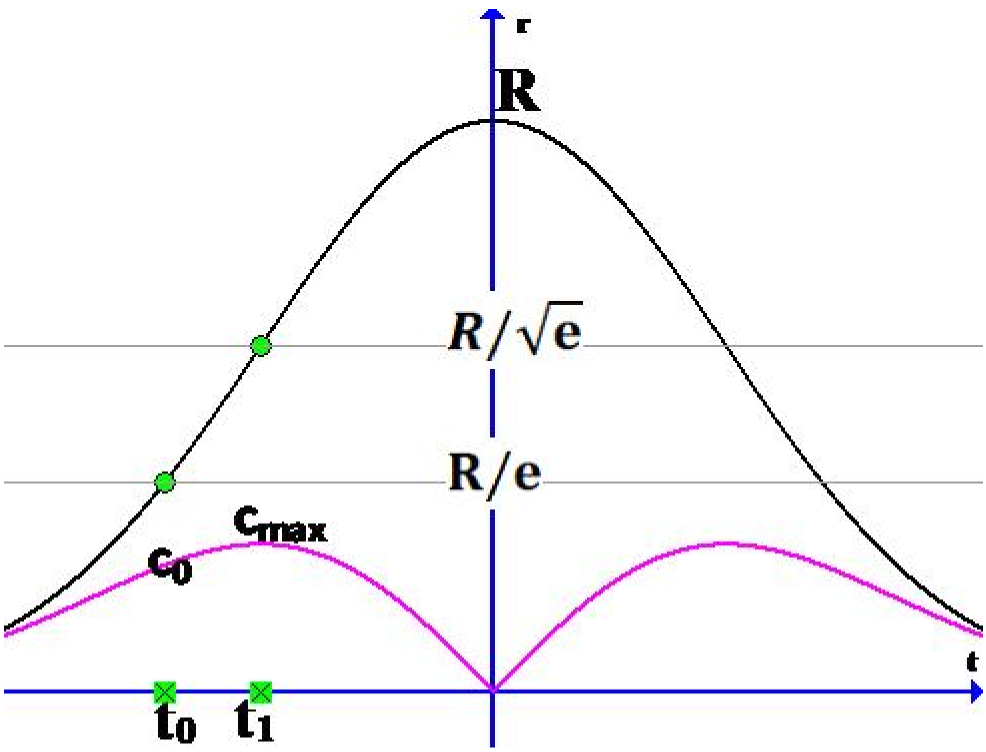


**Figure 1: Eq (17) dynamics for $r$ and $|\dot{r}|$**

At the present time ( $t_0 < 0, r = r_0 = \frac{R}{e}$), expansion is governed by $H_0$ and $q_0 = \frac{1}{2}$.

$t_0$ is anterior to time $t_1$ of the inflection point, where :

$$t_1^2 = \frac{1}{K} \qquad r = r_1 = \frac{R}{\sqrt{e}} \tag{28}$$

So, from our present time, expansion will accelerate till time $t_1$ $(< 0)$, then it will decelerate, up to time 0, from which an infinite contraction period will succeed.

This dynamics is ruled by the two dual forces: the Newtons'force ($-\frac{MG}{r^2}$) and the expansion force ($\frac{\dot{r}^2}{r}$). The first one dominates for $|t| < |t_1|$, and the second above $|t_1|$. Their relative amplitudes vary as:

$$\frac{\left(\frac{\dot{r}^2}{r}\right)}{\left(\frac{MG}{r^2}\right)} = Kt^2 = \begin{cases} \infty & t = \pm\infty \\ \\ 2 & t = t_0 \\ 1 & t = t_1 \\ 0 & t = 0 \end{cases} \tag{29}$$

## What if Newton's force was alone?

In this case, we should have to solve:

$$\ddot{r} = \frac{MG}{r^2} = -Kr \tag{30}$$

Whose solution:

$$r = r_0 \, sin\left(\sqrt{K}t\right) \tag{31}$$

Leads to:

$$H = \sqrt{K} \tag{32}$$

$$q = \frac{-Kr^2}{\dot{r}^2} < 0 \tag{33}$$

Unless to admit that the universe could be made of a uniform negative mass density (which is not the case), $q = \frac{1}{2}$ cannot be obtained. Without expansion force, expansion phases could happen, but they should be decelerated, due to the obvious inward attraction by all other masses. The Universe is not a harmonic oscillator.

**This fact tends to validate Bohmian Mechanics on one side, and the expansion force on the other side.**

## Time evolution of H and q

Let-us go back to the eq (17) dynamics.

From (20) to (26), the Hubble and the acceleration parameter depend on t, and their evolutions are given by:

$$\frac{H^2}{H_0^2} = \frac{t^2}{t_0^2} \tag{34}$$

$$q = 1 - \frac{t_0^2}{2t^2} \tag{35}$$

As illustrated figure 1, we see that $|H|$ is proportional to $|t|$. It is well defined at each time and does not depend on the distance of observation at that time. The Hubble Constant (25) is really a constant.

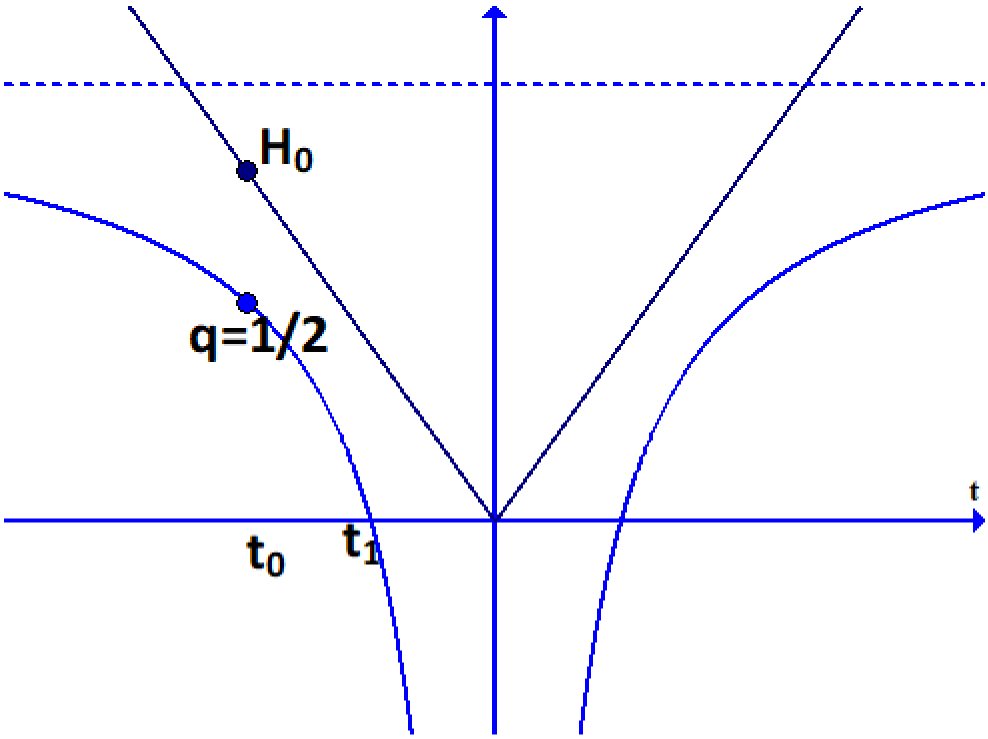


**Figure 2: Temporal evolution of H and q**

The acceleration/deceleration parameter q is symmetrical in t and changes its sign at $\pm\, t_1$. Its absolute value decreases in the expansion phase and increases in the contraction phase.

As illustrated on figure 1, the dynamics evolution follows four ranges ($t_1 < 0$):

- Accelerated expansion for $t < t_1$
- Decelerated expansion for $t_1 < t < 0$
- Accelerated contraction for $0 < t < -t_1$
- Decelerated contraction for $t > -t_1$

[When t will tend to 0, q will tend to infinity. t=0 is a singular point for our theory, which will have to be improved. It remains a lot of time to do this: 27 Gyears.]

## Light velocity and radius of the Universe

Let-us recall that a-priori, for a given galaxy, R is a free parameter. Any other galaxy will have another homothetic trajectory with another R parameter. However, it is notable that H and q do depend on t only.

Let-us consider, at a given time, the most remote galaxy among all trajectories with various R coefficients. At this time and for this galaxy, $|\dot{r}| = |H|r = c$ can be assimilated to light velocity. Here, r represents the maximum possible distance in the Universe at that time, due to the maximum possible velocity at that time.

This suggests that light velocity should also vary – according to eq. (17) and (24) – as:

$$c = ec_0 \left|\frac{t}{t_0}\right| e^{-\frac{t^2}{t_0^2}} \qquad (36)$$

Where $c_0$ is the present light velocity:

$$c_0 = H_0 \frac{R}{e} \tag{37}$$

Since c varies as $|\dot{r}|$, it is null for r=0 and $r = R$ and it is maximum for the inflation points where:

$$c = c_{max} = c_0 \sqrt{\frac{e}{2}} \tag{38}$$

It means that light velocity should increase very slowly from now on, and reach its maximum (1,17 $c_0$ ) in the time delay:

$$|t_1 - t_0| = \frac{2-\sqrt{2}}{H_0} \sim 8 \text{ Gyears} \tag{39}$$

It means also that light velocity should have been much smaller in the past, for $t < t_0$. As an instance, according to (36) it was a tenth less than its present value around 2,7 Gyears ago.

This "radius" of the Universe will also vary with time according to the gaussian curve and attain its maximum value at t=0: it will be e-times larger than our present Universe radius.

## Non homogeneous Universe and variation of the Hubble "Constant"

Let-us consider now a more complex Universe made of a non homogeneous mass density such as:

$$\rho = \rho_0 + \rho_1 \frac{r_1}{r} + \rho_2 \frac{r_2^2}{r^2} \tag{40}$$

as an instance of an inhomogeneous model defined by some unknown density parameters $\rho_n$.

($r_1$ not to be confused with eq (28))

The total mass repartition is now the sum of 3 terms, in $r^3$, $r^2$ and $r$ respectively, and the Newton's acceleration can be written as:

$$\frac{MG}{r^2} = Kr + \Gamma + \frac{W}{r} \tag{41}$$

with $$K = \frac{4\pi G \rho_0}{3} \qquad \Gamma = 2\pi G \rho_1 r_1 \qquad W = 4\pi G \rho_2 r_2^2 \tag{42}$$

As above, let-us compute the acceleration from eq (12):

$$\dot{r} = -\left(Kr + \Gamma + \frac{W}{r}\right) t \tag{14 bis}$$

It can be found easily that:

$$\ddot{r} = -\frac{MG}{r^2} + \left[\frac{K - \frac{W}{r^2}}{K + \frac{\Gamma}{r} + \frac{W}{r^2}}\right] \frac{\dot{r}^2}{r} \tag{27 bis}$$

The $\frac{\dot{r}^2}{r}$ term is not exactly found again as in (27), but it tends to it for large radius r. So it can be considered that the same far-away dynamics is again ruled by the same two forces as above.

From (14 bis), the Hubble "Constant" can be derived easily:

$$H_0 = \frac{\dot{r}}{r}(t_0) = -\left(K + \frac{\Gamma}{r_0} + \frac{W}{r_0^2}\right) t \tag{43}$$

**It now varies with the distance of observation as:**

$$H_0 \sim \frac{M(r_0)G}{r_0^3} = 4\pi G\left(\frac{\rho_0}{3} + \rho_1\frac{r_1}{2r} + \rho_2\frac{r_2^2}{r_0^2}\right) \quad (44)$$

And this depends on the density parameters $\rho_n$ of our model.

I propose to compare his result to all measured values of the Hubble Constant, with different methods (Planck, 2018 ; Riess & al., 2019 ; Verde & al., 2019 ; Wong, 2019 ; Friedmann & al., 2019 ; Friedmann &al ., 2020). Beyond potential "theoretical biases" in these measurements (whose expressions more or less depend on accepted theories), it may be questioned whether these various employed methods do not consist in **measuring $H_0$ at different observation distances?** In this case, it may be envisioned that the comparison with (44) makes it possible to calibrate the various results and estimate the corresponding density parameters. This could provide answers to the question of the degree of homogeneity of the Universe and of what kind of real matter it is made of.

In addition, several theoretical attempts have been made to consider potential negative masses (Hossenfelder, 2008; Petit & d'Agostini, 2014; Chardin & Manfredi, 2018; Manfredi, 2018; Fleuret, 2019; Konstantinov, 2020; Fleuret, 2020; Fleuret, 2021).It can then be suggested not to exclude negative signs for the density parameters, which will tell us if the presence of negative matter must be considered or not, and under what repartition.

## Conclusion

I have shown that the observed dynamics of far-away galaxies can be explained by an additional expansion force, which happens to be a consequence of Quantum Bohmian Mechanics.

This proposal tends to build a bridge between Quantum Mechanics and Astrophysics.

The combined action of the two dual forces (Newton's one and expansion force) produces an infinitely evolving Universe (no Big Bang), with an expansion phase followed by a contraction phase. It agres with the observations of our time, in particular the fact that the expansion is presently accelerated with a ½ acceleration parameter.

Furthermore, the study of a non homogeneous Universe has given us a means to better analyse the present Hubble "Constant" measurements and approach a better understanding of what our Universe is really made of. As far as this process is carried out in an open-minded way, considering what Nature can teach us, instead of being disturbed by what we believe we know.

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