Title :DARK MATTER-PHYSICAL INTERPRETATION OF THE CMB REST FRAME

Author:Thierry DELORT
INRIA-SACLAYS
Date:8^{th} June 2015
Email :tdelort@yahoo.fr

Abstract:

In this article, we propose a new model of dark matter. According to this new model, dark matter is a substance, that is a new physical element not constituted of classical particles, called *dark substance* and filling the Universe. Assuming some very simple physical properties to this dark substance, we theoretically justify the flat rotation curve of galaxies and the baryonic Tully-Fisher's law. Then we give a Physical Interpretation of the CMB Rest Frame (CRF). This new Interpretation of the CRF permits also a new interpretation of the Cosmological time. Moreover it is in agreement with the Standard Cosmological Model (SCM) on many points. For instance it assumes the validity of the Special and General Relativity. Then using these new interpretations of dark matter and of the CRF, we are led to propose a new model of Universe, flat and finite, that is not predicted by the SCM. Despite of this we will see that a first mathematical model of our Physical Interpretation of the CRF, that is based on the equations of the General Relativity as the SCM, leads to an observable Universe with the same theoretical astrophysical predictions as the SCM. We will see that a 2^{nd} mathematical model, much simpler, has nonetheless theoretical astrophysical predictions that are in agreement with astronomical observations.

We will then study the theoretical consequences of those 2 models.

Key words: Tully-Fisher's law, dark matter, dark substance, CMB, CMB rest frame.

1.INTRODUCTION

In this article, we propose that a new physical element, called *dark substance*, constitutes the dark matter. According to our model, this dark substance fills all the Universe and has physical properties close to the physical properties of an ideal gas. We then show that it is possible, using those properties, to justify theoretically the flat rotation curve that is observed for some galaxies. If moreover we assume simple thermal properties to this dark substance, we see that we can justify theoretically the baryonic Tully-Fisher's law, despite the great specificity of this law. We recall that up to date, neither the flat rotation curve of galaxies nor the baryonic Tully-Fisher law have been justified theoretically in a satisfying way. It is true that a simple density of dark matter (in $1/r^2$) permitting to obtain this flat rotation curve has already been proposed, but this expression of density (in $1/r^2$) has not been theoretically justified. A theory called MOND theory (1) proposes also a theoretical justification of the flat rotation curve, but it is contrary to Newton's attraction law (which is difficultly acceptable) and moreover it is contradicted by some astronomical observations.

We also know that the CMB (Cosmic Microwave Background) Rest Frame (CRF), has not physical interpretation, concerning its nature and its main physical properties, in the Standard Cosmological Model (SCM). In this article, we are going to give a Physical Interpretation of the CRF, which permits new definitions of Cosmological variables (in particular the Cosmological time and Cosmological distances), that are in agreement with their definitions in the SCM. This will lead to propose a new model of Universe, flat and finite, that is not predicted by the SCM. Nonetheless, our Physical Interpretation of the CRF assumes the validity of Special and General Relativity as the SCM. This Physical Interpretation of the CRF proposes 2 mathematical models of expansion of the Universe. The

1st model is as the SCM based on the equations of General Relativity. We then show that in this 1st model the observable Universe is identical to the observable Universe predicted by the SCM (Provided that some conditions be verfied). Indeed in this 1st mathematical model, Cosmological distances and Hubble's constant , have the same mathematical expression as in the SCM.

The 2nd mathematical model of our Interpretation of the CRF is not based on the equations of the SCM but is much simpler. Despite of this, its theoretical astrophysical predictions (In particular Hubble's law and Cosmological distances) are in agreement with astronomical observations. Moreover this 2nd model solves the enigma of the dark energy.

We remind that for many astrophysicists and physicists, the enigmas in the SCM, in particular the enigmas concerning dark matter and dark energy, make necessary a new paradigm for the SCM [(2)]. Our article proposes such a new paradigm.

In this article we will express the main physical properties of the dark substance and the CRF in some Postulates, divided in points a),b)..

In our model of dark substance and in our Physical Interpretation of the CRF, we will keep all the points of the SCM, except the points of the SCM that are not compatible with our Postulates or that become useless because of them.

2. DARK SUBSTANCE-CMB REST FRAME

2.1 Physical properties of the dark substance.

As we have seen in 1.INTRODUCTION, we admit the Postulate 1 expressing the physical properties of the dark substance:

Postulate 1:

a)A substance, called *dark substance*, fills all the Universe.

b)This substance does not interact with photons crossing it.

c)This substance has a mass and verifies the law of ideal gas:

An element of dark substance with a mass m, a volume V, a pressure P and a temperature T verifies, k_0 being a constant:

$PV=k_0mT$

We have 2 remarks consequences of this Postulate1:

-Firstly despite of its name, the dark substance is not really dark but transparent. Indeed, because of the preceding Postulate 1b) it does not interact with photons crossing it.

-Secondly because of the Postulate 1a), what is usually called "vacuum" is not empty in reality: It is full of dark substance.

2.2 Flat rotation curves of galaxies.

Using the fact that the dark substance behaves as an ideal gas (Postulate 1c), we are going to show that a spherical concentration of dark substance in thermodynamic and gravitational equilibrium can constitute the dark matter in a galaxy with a flat rotation curve.

According to Postulate 1c) an element of dark substance with a mass m, a volume V, a pressure P and a temperature T verifies the law, k_0 being a constant:

$$PV=k_0mT \qquad (1)$$

Which means, setting $k_1=k_0T$:

$PV=k_1m$ (2)

Or equivalently, ρ being the mass density of the element:

$P=k_1\rho$ (3a)

We then emit the natural hypothesis that a galaxy can be modeled as a concentration of dark substance with a spherical symmetry, at an homogeneous temperature T.

We then consider the spherical surface S(r) (resp. the spherical surface S(r+dr)) that is the spherical surface with a radius r (resp. r+dr) and whose the center is the center O of the galaxy. S(O,r) is the sphere full of dark substance with a radius r and the center O.

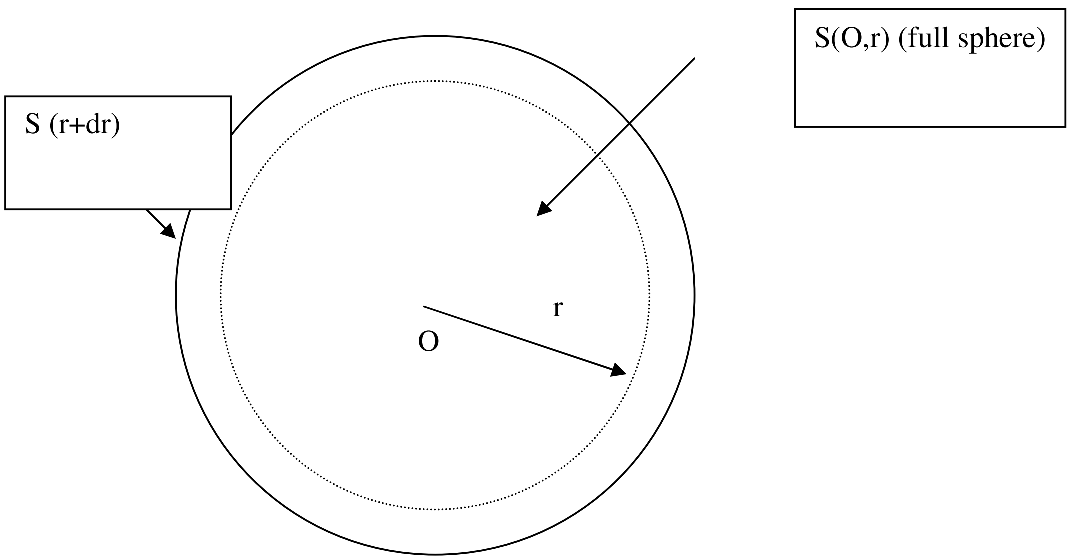

Figure 1:The spherical concentration of dark substance

The mass M(r) of the sphere S(O,r)is given by:

$$M(r)=\int_0^r \rho(x)4\pi x^2 dx \qquad (3b)$$

We then consider the following equation (4) of equilibrium of forces on an element dark substance with a surface dS, a width dr, situated between the 2 spheres S(O,r) and S(r+dr):

$$dSP(r+dr)+\frac{G}{r^2}(\rho(r)dSdr)(\int_0^r \rho(x)4\pi x^2 dx)-dSP(r)=0 \qquad (4)$$

Eliminating dS, we obtain the equation:

$$\frac{dP}{dr}=-\frac{G}{r^2}(\rho(r))(\int_0^r \rho(x)4\pi x^2 dx) \qquad (5)$$

And using the equation (3), we obtain the equation:

$$k_1 \frac{d\rho}{dr} = -\frac{G}{r^2}(\rho(r))(\int_0^r \rho(x) 4\pi x^2 dx) \qquad (6)$$

We then verify that the density of the dark substance ρ(r) satisfying the preceding equation of equilibrium is:

$$\rho(r) = \frac{k_2}{4\pi r^2} \qquad (7)$$

(A density of dark matter expressed as in Equation (7) has already been proposed in order to explain the flat rotation curve of spiral galaxies, but it has not been justified theoretically. Here we a theoretical justification of this expression (7), consequence of the model of dark substance as an ideal gas, Postulate 1)

The constant k_2 is given by, G being the Universal attraction gravitational constant:

$$k_2 = \frac{2k_1}{G} = \frac{2k_0 T}{G} \qquad (8)$$

Using the preceding equation (7), we obtain that the mass M(r) of the sphere S(O,r) is given by the equation:

$$M(r) = \int_0^r 4\pi x^2 \rho(x) dx = k_2 r \quad (9)$$

We then obtain, neglecting the mass of stars in the galaxy, that the velocity v(r) of a star of a galaxy situated at a distance r from the center O of the galaxy is given by $v(r)^2/r=GM(r)/r^2$ and consequently :

$$v(r)^2=Gk_2=2k_1=2k_0T \qquad (10)$$

So we obtain in the previous equation (10) that the velocity of a star in a galaxy is independent of its distance to the center O of the galaxy.

2.3 Baryonic Tully-Fisher's law.

2.3.1 Recall.

Tully and Fisher realized some observations on spiral galaxies with a flat rotation curve. They obtained that the luminosity L of such a spiral galaxy is proportional to the 4^{th} power of the velocity v of stars in this galaxy. So we have the Tully-Fisher's law for spiral galaxies, K_1 being a constant:

$$L=K_1v^4 \qquad (11)$$

But in the case studied by Tully and Fisher, the baryonic mass M of a spiral galaxy is usually proportional to its luminosity L. So we have also the law for such a spiral galaxy, K_2 being a constant:

$M=K_2v^4$ (12)

This 2nd form of Tully-Fisher's law is known as the *baryonic Tully-Fisher's law*.

The more recent observations of Mc Gaugh [3] show that the baryonic Tully-Fisher's law (equation (12)) seems to be true for all galaxies with a flat rotation curve, including the galaxies with a luminosity not proportional to their baryonic mass.

We are going to show that using the Postulate 1 and a Postulate 2 expressing very simple thermal properties of the dark substance, (in particular its thermal interaction with baryonic particles), we can justify this baryonic law of Tully-Fisher despite of its great specificity.

2.3.2 Theory of quantified loss of calorific energy (by nuclei).

We saw in the previous equation (10) that according to our model of dark substance the square of the velocity of stars in a galaxy with a flat rotation curve is proportional to the temperature of the concentration of dark substance constituting this galaxy. So we need to determinate T:

-A first possible idea is that the temperature T is the temperature of the CMB. But this is impossible because it would imply that all stars of all galaxies with a flat rotation curve be driven with the same velocity and we know that it is not the case.

-A second possible idea is that in the considered galaxy, each baryon interacts with the dark substance constituting the galaxy, transmitting to it a calorific energy. We can expect that this thermal energy is then very low, but because of the expected very low density of the dark substance and of the considered times (we remind that the diameter of galaxies is if the order of 100000 light-years), it can lead to appreciable temperatures of dark substance. A priori we could expect that this loss of calorific energy for each baryon (transmitted to the dark substance) depends on the temperature of this baryon and of the temperature T of the dark substance in which the baryon is immerged, but if it was the case, the total calorific loss for all baryons would be extremely difficult to calculate and moreover it should be very probable that we would then be unable to obtain the very simple baryonic Tully-Fisher's law.

We are then led to make the simplest hypothesis defining the thermal transfer between dark substance and baryons, expressed in the following Postulate 2a) (Postulate 2 gives the thermal properties of the dark substance):

Postulate 2a):

-Each nucleus of atom in a galaxy is submitted to a loss of calorific energy, transmitted to the dark substance in which it is immerged.

-This thermal transfer depends only on the number n of nucleons constituting the nucleus (So it is independent of the temperature of the nucleus). So if p is the thermal power dissipated by the nucleus, it exists a constant p_0 (thermal power dissipated by nucleon) such that:

$p=np_0$ (13)

According to the equation (13), the total thermal power transmitted by all the atoms of a galaxy towards the spherical concentration of dark matter constituting the galaxy is proportional to the total number of nucleons of the galaxy and consequently to the baryonic mass of this galaxy. So if m_0 is the mass of one nucleon, M being the baryonic mass of the galaxy, we obtain according to the equation (13) that the total thermal power P_r received by the spherical concentration of dark substance constituting the galaxy from all the atoms is given by the following equation, K_3 being the constant p_0/m_0:

$$P_r=(M/m_0)p_0=K_3M \qquad (14)$$

Concerning the preceding Postulate 2a):
-It is possible (but not compulsory) that it be true only for atoms whose temperature is superior to the temperature T of the concentration of dark substance.
-It permits to obtain the very simple Equation (14). We will see that this equation is essential in order to obtain the baryonic Tully-Fisher's law.

2.3.3 Obtainment of the baryonic Tully-Fisher's law.

In agreement with the previous model of galaxy (Section 2.2), we model a galaxy with a flat rotation curve as a spherical concentration of dark substance, at a temperature T and surrounded itself by a medium constituted of dark substance (called "intergalactic dark substance") at a temperature T_0 and with a density ρ_0.

In order to obtain the radius R of the concentration of dark substance constituting the galaxy, it is natural to make the hypothesis of the continuity of $\rho(r)$: R is the radius for which the density $\rho(r)$ of the concentration of dark substance is equal to ρ_0. So we have the equation:

$$\rho(R)=\rho_0 \qquad (15)$$

Consequently we have according to the equations (7) and (8):

$$\frac{k_2}{4\pi R^2}=\rho_0 \qquad (16)$$

$$\frac{2k_0T}{G}\times\frac{1}{4\pi R^2}=\rho_0 \qquad (17)$$

So we obtain that the radius R of the concentration of dark substance constituting the galaxy is given approximately by the equation:

$$R=(\frac{2k_0T}{4\pi G\rho_0})^{1/2}=K_4T^{1/2} \qquad (18)$$

The constant K_4 being given by :

$$K_4=(\frac{2k_0}{4\pi G\rho_0})^{1/2} \qquad (19)$$

We can then consider that the sphere with a radius R of dark substance constituting the galaxy at the temperature T is in thermal interaction with the medium constituted of intergalactic dark substance at the temperature T_0 surrounding it. The simplest and more natural thermal transfer is the classical convective transfer. We admit this in the Postulate 2b):

Postulate 2b):

The thermal interaction between the spherical concentration of dark substance constituting the galaxy (at the temperature T) and the surrounding intergalactic dark substance (at the temperature T_0) can be modeled as a classical convective thermal transfer.

We know that if φ is the thermal flow of thermal energy on the borders of the spherical concentration of dark substance with a radius R, P_l being the total power lost by the spherical concentration of dark substance constituting the galaxy is given by the equation:

$$P_l=4\pi R^2\varphi \qquad (20)$$

But we know that according to the definition a convective thermal transfer between a medium at a temperature T and a medium at a temperature T_0 and according to the previous Postulate 2b) the flow φ between the 2 media is given by the expression, h being a constant depending only on ρ_0:

$$\varphi=h(T-T_0) \qquad (21)$$

Consequently the total power lost by the concentration of dark substance is:

$$P_l=4\pi R^2h(T-T_0) \qquad (22)$$

We can consider that at the equilibrium, the total thermal power P_r received by the spherical concentration of dark substance constituting the galaxy is equal to the thermal power P_l lost by this spherical concentration. Consequently according to the equations (14) and (22), (M being the baryonic mass of the galaxy), we have:

$$K_3M=4\pi R^2h(T-T_0) \qquad (23)$$

Using then the equation (18) :

$$K_3M=4\pi K_4^2hT(T-T_0) \qquad (24)$$

Making the approximation $T_0<<T$:

$$M = 4\pi \frac{K_4^2}{K_3} hT^2 \qquad (25)$$

Consequently we obtain the expression of T, defining the constant K_5 :

$$T = (\frac{K_3}{4\pi K_4^2 h})^{1/2} M^{1/2} = K_5 M^{1/2} \qquad (26)$$

And then according to the equation (10) :

$$v^2=2k_0T=2k_0K_5M^{1/2} \qquad (27)$$

So :

$$M = \left(\frac{1}{2k_0 K_5}\right)^2 v^4 \qquad (28a)$$

So we finally obtain :

$$M=K_6 v^4 \qquad (28b)$$

The constant K_6 being defined by:

$$K_6 = \left(\frac{1}{2k_0 K_5}\right)^2 = \frac{4\pi K_4^2 h}{4k_0^2 K_3}$$

$$K_6 = \frac{4\pi h}{4k_0^2 K_3} \times \frac{2k_0}{4\pi G \rho_0}$$

$$K_6 = \frac{m_0 h}{2k_0 G \rho_0 p_0} \qquad (28c)$$

So we obtain the baryonic Tully-Fisher's law (12), with $K_2=K_6$. It is natural to assume that h depends on ρ_0. The simplest expression of h is $h=C_1\rho_0$, C_1 being a constant. With this relation, K_6 is independent of ρ_0, and we can use the baryonic Tully-Fisher's law in order to define candles used to evaluate distances in the Universe.

2.4 Temperature of the intergalactic dark substance.

We introduced the temperature T_0 of the intergalactic dark substance. We could make the hypothesis that this temperature is the temperature of the CMB but we remind that in order to get the baryonic Tully-Fisher's law we supposed $T_0 << T$ (T temperature of the spherical concentration of dark substance constituting galaxy). Consequently the previous hypothesis would lead to very high temperatures of spherical concentrations of dark substance constituting galaxies.

So we can be in the following cases:

a)The temperature T_0 of the intergalactic dark substance (equation (21) is far less than the temperature of the CMB.

b)Baryons can emit thermal power towards dark substance as assumed in the Postulate 2a) even if their temperature is inferior to the one of dark substance.

We remind that according to the Postulate 1b), the dark substance does not interact with photons and in particular with the photons of the CMB. Consequently dark substance does not receive radiated energy.

2.5 Form of the Universe

If the Universe was completely isotropic, we could expect by symmetry that the thermal flow through a great surface be nil. Consequently the temperature of the dark substance inside a great sphere S of the Universe (For instance with a radius of 1 billion years) should increase and probably tend to a uniform temperature of dark substance inside the sphere S, because the thermal flow on S would be nil. We know that it is not possible in our model of dark substance because in this model spherical concentrations of dark substance constituting galaxies have not the same temperature (Because the velocity of stars is not always the same in all galaxies and we know that the temperature of the spherical concentration of dark substance is proportional to she squared velocities of stars inside this concentration (Equation (10)) and moreover because we admitted that the temperature T_0 of the intergalactic dark substance is by far inferior to the temperature of the spherical concentrations of dark substance constituting galaxies. So an infinite or finite isotropic Universe would contradict our model of dark substance.

Nonetheless with our model of dark substance, it is much easier to define a finite Universe than in the SCM. Indeed we can consider that the Universe is a sphere (We could have chosen any other finite convex volume, but the spherical volume is by far the most attractive) constituted of dark substance surrounded by a medium called “nothingness” that is not constituted of dark substance. This was not possible in the SCM that admitted the Cosmological Principle according to which the Universe was isotropic observed from any point and also that did not interpreted dark matter as the dark substance that we introduced. Nonetheless we will see that according to our Physical Interpretation of the CRF, the observable Universe remains isotropic if it is observed sufficiently far from its borders (Not compulsory from its center).

In the case in which Universe is a sphere (or any finite convex volume with a finite surface) constituted of dark substance, we avoid the previous problem concerning the temperature of the intergalactic dark substance. Indeed, we can assume, generalizing the Postulate 2b), that at the borders of the Universe, there is a convective thermal transfer. This new kind of thermal transfer is modeled as a convective transfer between a medium constituted of intergalactic dark substance at a temperature T_0 and a medium at a temperature equal to 0 (The nothingness). Then the thermal flow lost by the Universe is, h_n being a variable or a constant:

$$\varphi=h_n(T_0-0)=h_nT_0 \qquad (28d)$$

M being the baryonic mass of the Universe assumed to remain approximately constant, we obtain from equation (14) that the equation of thermal equilibrium is:

$$K_3M = 4\pi R_E(t)^2\ \varphi = 4\pi R_E(t)^2\ h_nT_0(t) \qquad (29a)$$

So we see that if the Universe increases from a factor f, according to the equation (29a), if h_n is a constant (independent of the density of the intergalactic dark substance), the temperature $T_0(t)$ of the intergalactic dark substance diminishes from a factor f^2. If we had supposed that $h_n=C_2\rho_0$, ρ_0 being the mass density of the intergalactic dark substance and C_2 being a constant, it is very easy to obtain that if the Universe increases from a factor f, then T also increases by a factor f which is impossible.

We also remark that the hypothesis of an infinite Universe, or a finite Universe without borders, that are models proposed by the SCM, seems to be impossible to be conceived by the human spirit, which is not the case with the previous finite spherical Universe, full of dark substance (or any finite convex volume with a finite surface).

2.6 Physical Interpretation of the CRF.

2.6.1 The 2 models of the Physical Interpretation of the CRF.

We remind that the CMB presents a Doppler effect that is canceled in a frame called for this reason the CMB Rest Frame (CRF). But this CRF has none physical interpretation in the SCM. We are going to give here a Physical Interpretation of the CRF, which permits to obtain a new model of Universe, that is spherical as in the preceding section 2.5. This new Physical Interpretation of the CRF is in agreement with the SCM in many points, in particular it admits Special and General Relativity. Also it permits to define *Cosmological variables* (Cosmological time, Cosmological distances, Hubble Constant) in a more precise way than in the SCM but nonetheless in a way that is in agreement with their definition in the SCM. Our Physical Interpretation of the CRF proposes 2 mathematical models of expansion of the Universe. (Because we will see that the Universe is in expansion in our Physical Interpretation of the CRF as it is in the SCM). The 1st mathematical model is based on General Relativity as the SCM. We will see that according to this 1st model the mathematical expressions of Cosmological variables are identical to their expression in the SCM. The 2nd mathematical model is incomparably simpler, but nonetheless its theoretical predictions are in agreement with observation.

Concerning the physical properties of the CRF:

-Firstly it is natural that in each point of the Universe (and not only on the earth), we can define a CRF. We then can suppose that all CRF have parallel corresponding axis.

-Secondly we can think that the CRF permits to define very easily the Cosmological time, identified to the age of the Universe. The simplest definition of the Cosmological time would be that the time of the CRF (meaning the time given by the clocks at rest in the CRF) be precisely the Cosmological time. And we will see that this hypothesis is in agreement with observations. For instance we will see that its validity is illustrated by a very simple observation concerning the inertial frame linked to the sun.

-Thirdly we know that according to Special Relativity (We remind that we admit it as in the SCM) the velocity of a photon relative to the CRF in which it is situated is equal to c in norm. Moreover according to Special Relativity its velocity considered as a vector **c** keeps itself in this CRF. We will call *local velocity* this velocity **c**. An attractive hypothesis would be that the local velocity of the photon keeps itself the photon traveling in all the Universe. We will see that this hypothesis involves theoretical predictions that are in agreement with observation. In particular we will see that it permits to justify very simply the effect of the expansion of the Universe on the lengths of wave of photons and on the distances between 2 photons following one another. (This effect is also predicted by the SCM) .

So we express the preceding hypothesis in the following Postulate 3:

Postulate 3:

a)At each point of the Universe, we can define a CRF. We will assume that all CRF have parallel corresponding axis.

b)The Cosmological time (identified with the age of the Universe) is the time of all the CRF.

c)The *local velocity* of a photon, meaning measured in the CRF in which it is situated, keeps itself, the photon traveling in all the Universe.

We could think that the CRF are defined only after the apparition of the CMB, meaning at a very low Cosmological time but not at a Cosmological time equal to 0. In reality we will see in the Postulate 4 that in reality the RRC are defined since the beginning of the Universe. But CMB is presently the only way for detecting the CRF. This can be considered as a consequence of Special Relativity.

Because of the Postulate 3b), and since we know that the inertial frame R_S linked to the sun is driven with a velocity $v_S<<c$ relative to the local CRF, the time of this frame R_S is very close to the time of the CRF, that is the Cosmological time, which is an agreement with observation. So the Postulate 3b) justifies that the time of R_S can be identified to the Cosmological time which was not at all evident. In fact we can assume that all galaxies of the

Universe have a local velocity negligible (relative to c) relative to the local CRF and that consequently the time given by the inertial frame linked to any star of any galaxy is very close to the Cosmological time.

We know need to define all the CRF. Each CRF has an origin and by analogy with the SCM, we can expect that if A(t) and B(t) are 2 origins of any 2 CRF (t Cosmological time), then the distance A(t)B(t) increases by the factor of expansion of the Universe 1+z. Moreover this factor 1+z must also exist, as in the SCM in our Physical Interpretation of the CRF.

We saw in the previous section 2.5 that we could expect that the Universe had a finite convex volume with a finite surface, and we will assume in what follows that the Universe is a sphere (centre O), full of dark substance, surrounded but what we called "nothingness". We remind nonetheless that what follows can be generalized if the Universe is a finite convex volume with a finite surface filled of dark substance and surrounded by what we called "the nothingness".

In order to define completely the CRF, we introduce a new kind of frame, called *Cosmological frame*, having its origin in O, centre of the sphere. This Cosmological frame R_C will be used in order to define Cosmological variables. In particular the time of this Referential R_C is the Cosmological time of the CRF. Moreover we will assume that the axis of R_C are parallel to the corresponding axis of the CRF and that locally they give the same distances as the CRF. Nonetheless, the Cosmological frame R_C permits to measure distances between any 2 points of the Universe contrary to CRF that permit to measure only local distances. We will call *primary Cosmological distance* (in R_C) the distances measured in R_C. We will see that we can express all the classical Cosmological variables (For instance the comoving distances, the angular distance, the light- travel distance..) as a function of distances measured in R_C (That we called primary Cosmological distances) and of the time of R_C (Cosmological time).

So we assume that the Universe is a sphere with a centre O, full of dark substance, and in expansion. Let $R_E(t)$ be the radius of this sphere , t being the Cosmological time. In analogy with the SCM, we assume that $R_E(t)=R_E(t_0)(1+z)$, 1+z being the factor of expansion of the Universe between t_0 and t. We will see further how we can get 1+z.

We are now going to define very important and particular points of the frame R_C, called *comoving points of the swelling sphere*.

We assume that P(t) is any point belonging to the border of the swelling sphere, t being the Cosmological time, with **OP**(t) (O is the centre of the swelling sphere) remaining in the same direction **u**, fixed vector R_C.

A comoving point A(t) of the swelling sphere is defined by :

-A(t) remains on the segment [O,P(t)]
-OA(t)=aOP(t), a being a constant belonging to [0,1]. (28f)

So in particular O and P(t) are comoving points of the swelling sphere. Moreover if A(t) and B(t) are 2 comoving points of the swelling sphere, belonging both to a radius [O,P(t)], and if t_1 and t_2 are 2 ages of the Universe, if $1+z=OP(t_2)/OP(t_1)$), (Here 1+z is the factor of expansion between t_1 and t_2) then we have the 2 relations:

$A(t_2)B(t_2)=(1+z)A(t_1)B(t_1)$ (28g)

And :

$[A(t_2),B(t_2)]//[A(t_1),B(t_1)]$ (28h)

(We classically note, P,Q being 2 points of R_C, PQ is the distance between P and Q measured in R_C, [P,Q] is the segment with extremities P and Q, (P,Q) is the straight line containing P and Q)

Using Thales theorem we obtain the 2 previous relation (28g) (28h) A(t) and B(t) being any comoving points of the swelling sphere (not compulsory belonging both to the same radius [O,P(t)]).

So we see that the comoving points of the swelling sphere verify the expected relations between the origins of the CRF (Meaning that the distance between them increases by the factor of expansion of the Universe.)

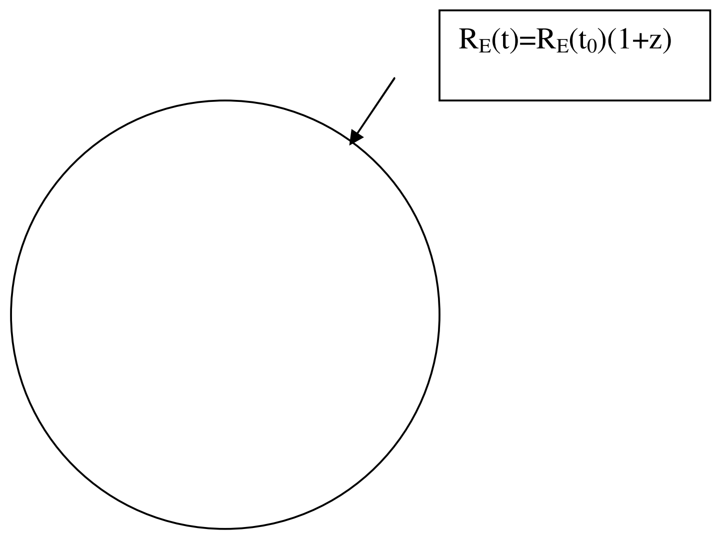

Figure 2:The model of the swelling sphere of the Universe.

Consequently the comoving points of the swelling sphere previously defined permit to complete the definition of the CRF, in the Postulate 4:

Postulate 4:
The origins of the CRF are the comoving points that we defined previously.

Now we need to express the factor of expansion 1+z as a function of the Cosmological time. We propose 2 models.

According to our 1st model, 1+z is obtained as it is obtained in the SCM: We apply locally the equations of General Relativity, assuming that the densities of dark substance, baryonic matter and dark energy own identical values to their values in the SCM and are homogeneous in all the Universe. A priori, we cannot apply the equations of General Relativity as in the SCM in a zone close to the borders of the Universe because we have no more isotropy of density in this zone. But we will assume that the dimensions of this zone are very small relative to the radius of the swelling sphere. Moreover, we will see that according to our model, in many cases this zone cannot be observed. And consequently in this 1st model, if the previous zone is sufficiently small, the factor of expansion 1+z used in the expression of $R_E(t)$ and to define the comoving points of the swelling sphere remains identical to its expression in the SCM. We will see that this equality involves that our 1st model of our Physical Interpretation of the CRF predicts Cosmological distances and a Hubble Constant that are mathematically equal to those predicted by the SCM.

Nonetheless, a priori, it is possible that the factor of expansion 1+z be not obtained by the equations of General Relativity. It is possible that as for the (local) velocity of light, the *Cosmological velocity* of the borders of the Universe relative to R_C (defined by $V_E(t)=d(R_E(t))/dt$, t Cosmological time) be as simplest as possible, meaning that it is equal to a constant C. There is no reason for which C should be equal or inferior to the velocity of light c because C is not the local velocity (defined in Postulate 3) of a photon or of a particle. So in our 2nd model, we assume that the Cosmological velocity of the borders of the Universe is equal to a constant C. We will see that we can give an inferior limit to this constant C. And we will also see that despite of this great simplicity, the predictions of this 2nd mathematical model are in agreement with all astronomical observations. Then if P(t) is a point of the border of the sphere OP(t)=Ct. And we have a very simple expression of 1+z: Between t_0 and t, $1+z=t/t_0$.

We saw that the SCM needed the existence of a mysterious dark energy, and it is also the case for our 1st model. But we see that in the 2nd model this enigma is solved because it does not need the existence of a dark energy. And this is a very attractive point of this 2nd model. This 2nd model is also clearly the simplest mathematical model of expansion of the Universe that can exist.

2.*6.2 The theoretical consequences of our Physical Interpretation of the CRF.*

As a consequence of our Physical Interpretation of the CRF, we can prove that as it was also the case in the MSC, if 2 photons ph1 and ph2 move in the same direction on a straight line towards the point O origin of R_C (We will see further that this remains true replacing O by any comoving point O' of the swelling sphere), then between 2 Cosmological times t_1 and t_2, the distance in R_C between the 2 photons and the length of wave of each photon increase by the factor of expansion 1+z between t_1 and t_2 .

Indeed let us consider 2 photons defined as previously. So they have an identical local velocity **c** (with a direction being the direction of the straight line). We take the following notations: At the Cosmological time t ph1 is in the point ph1(t) of R_C, and ph2 is in the point ph2(t). Let us suppose that for a given Cosmological time t, ph1(t) coincides with a comoving point $A_1(t)$ and ph2(t) with a comoving point $A_2(t)$. Let 1+dz the factor of expansion of the swelling sphere between t and t+dt. Then we have according to the property (28g) of comoving points:

$A_1(t+dt)A_2(t+dt)=(1+dz)A_1(t)A_2(t)=(1+dz)ph1(t)ph2(t)$.

Moreover, the local velocity of photons being equal to c:

$A_1(t+dt)ph1(t+dt)=A_2(t+dt)(ph2(t+dt)=cdt$

And consequently (It is evident on a figure):

$ph1(t+dt)ph2(t+dt)=A_1(t+dt)A_2(t+dt)=(1+dz)(ph1(t)ph2(t)$

We can show in an analogous way that if we suppose only that ph1 and ph2 own the same local velocity (as a vector), and are not compulsory moving on a straight line towards O, then the primary Cosmological distance between ph1(t) and ph2(t) is increased by the factor of expansion 1+z and moreover $(ph1(t_1),ph2(t_1))//(ph1(t_2),ph2(t_2))$

We remark that in any commoving point of the swelling sphere O'(t) we can define a Cosmological frame R_C' whose the axis are parallel to the corresponding axis of R_C and defining the same Cosmological variables as R_C (primary Cosmological distance at a given Cosmological time t and Cosmological time).

Then if A(t) is any commoving point of the swelling sphere defined previously, t_1 and t_2 being 2 Cosmological times, according to the properties of commoving points (28g)(28h), if 1+z is the factor of expansion of the Universe between t_1 and t_2:

$O'(t_2)A(t_2)=(1+z)O'(t_1)A(t_1)$ et $(O'(t_2),A(t_2))//(O'(t_1),A(t_1))$

And consequently $(O'(t_1),A(t_1))$ et $(O'(t_2),A(t_2))$ are in the same direction **u**.

Consequently the properties (28f), replacing R_C by R_C' and O by O', remain valid, P(t) being still a point of the border of the sphere. (But here O'(t)P(t) is no more equal to $R_E(t)$ nor constant). Consequently the expressions of Cosmological distances and Hubble's constant are obtained in R_C' exactly the same way as in R_C.

So we see how we can define in a complete analogous way comoving points of any finite convex volume with a finite surface, using a Cosmological Referential whose the origin is any point of this volume.

We will see that according to our Physical Interpretation of the CRF we cannot observe all the Universe from $O(t_0)$ (or $O'(t_0)$, (t_0 present age of the Universe), which was also the case in the SCM. Moreover the properties of $R_C'(t)$ involve that if $O'(t_0)$ is sufficiently far from the borders of the Universe, then according to our Physical Interpretation of the CRF the Universe observable from $O'(t_0)$ is identical to the Universe observable from $O(t_0)$. In particular in that case the Universe is isotropic observed from $O'(t_0)$, as it was observed from O.

It is possible to elaborate a complete physical theory of the CRF [(4)], but presently it is not possible to verify experimentally this theory and moreover the validity of the models exposed in this article is completely independent of this theory.

2.7 Hubble's law-Cosmological distances.

We keep the preceding model and notations. Let us suppose that a photon is emitted from a star S at a point $Q(t_E)$ of R_C (Q(t) is a commoving point of the swelling sphere) and at a Cosmological time t_E towards $O(t_E)$ origin of R_C. We suppose that the photon reaches $O(t_0)$ at the present Cosmological time t_0. We assume that between t_E and t_0 the factor of expansion of the Universe is $1+z_0$.

Between t and t+dt, we know that the photon covers the local distance cdt. Consequently between t_E and t_0 the sum of the local distances covered by the photon will be :

$$D_T=c(t_0-t_E) \qquad (29a)$$

We will call this distance, which is completely identical to the *light- travel distance* in the SCM, by the same name. We can also call it *time-back distance* because it permits to obtain the Cosmological time between the emission and the reception of the photon.

We will see further how in the 1st model of our Physical Interpretation of the CRF Cosmological distances and Hubble's Constant have the same mathematical expressions as their expressions in the SCM, and are also obtained the same way.

But in the 2nd model we obtain very easily the Hubble's Constant using the light-travel distance defined previously.

Indeed according to this 2nd model:

$1+z_0=(Ct_0)/(Ct_E)=t_0/(t_0-D_T/c)$ (29b)

When $D_T/ct_0 << 1$ we obtain $z_0 \approx D_T/ct_0$ and consequently the Hubble's constant is equal to $1/t_0$. The preceding equation (29b) is very simple and can easily be verified. For instance taking t_0=15 billion years, for z_0=0.5,we obtain D_T=5 billion light years and for z_0=9 we obtain D_T=13.5 billion years. These predicted values are in agreement with the usual admitted experimental values for the light-travel distance D_T.

We took a present Cosmological time (age of the Universe) equal to 15 billion years corresponding to a Hubble's constant $H=1/t_0$ approximately equal to 65 km/sMpc^{-1} despite that it is generally admitted that the Hubble's constant H is approximately equal to 72km/sMpc^{-1} corresponding to a time $t_0=1/H$ approximately equal to 13,5 billion years.

Nonetheless many astrophysicists disagree with a Hubble's constant approximately equal to 72 km/s Mpc^{-1} and find a Hubble's constant approximately equal to 65km/sMpc^{-1}, for instance Tammann and Reindl (5) in a very recent article (October 2012). There is also a second possibility: light-travel distance could be superior to present estimations by a factor of 5% to 7%.

So it is very remarkable that according to the 2nd model, the value of Hubble's constant is very easily obtained and is equal to $1/t_0$, t_0 present age of the Universe, in agreement with the observation. In the SCM (and in the 1st model), the obtainment of Hubble's constant was much more complicated and moreover it was not exactly equal to $1/t_0$.

We then can define in our Physical Interpretation of the CRF Cosmological distances in a completely analogous way to their definition in the SCM:

So we can express the light-travel distance as:

$$D_T = \int_{tE}^{t0} cdt \qquad (29c)$$

The local distance covered by the photon between t and t+dt is, according to the Postulate 3 equal to cdt. This local distance, considered as a distance between 2 commoving points of the swelling sphere, is increased by the factor of expansion of the Universe $1+z=t_0/t$ between t and t_0 (See equation (28g)). Of course we will assume that the star S remains coinciding with the commoving point Q(t).

In complete analogy with the SCM, we will call *comoving distance* between O and S the primary Cosmological distance between $Q(t_0)$ and $O(t_0)$ (Meaning their distance measured in the Cosmological frame R_C), which is the sum of all the local distances cdt covered by the photon, increased by the factor 1+z. Let D_C be this distance:

$$D_C = \int_{tE}^{t0} c(1+z)dt \qquad (29d)$$

From this expression we define the *luminosity-distance* D_L between O and S (at the Cosmological time t_0) and the *angular-distance* D_A between O and S in complete analogy with their definition in the SCM:

$D_L=(1+z_0)D_C$

$D_A=D_C/(1+z_0)$ (29e)

The distance D_A appears to be the primary Cosmological distance (distance in R_C) between $Q(t_E)$ and $O(t_E)$. In complete analogy with the SCM it permits to obtain some angles with a summit O in R_C.

The distance D_L , in complete analogy with its definition in the SCM, appears to be obtained measuring the luminous flow of a supernova taking into account the effect of the expansion of the Universe on the lengths of wave of the photons and on the distances between 2 photons (moving on the same axis). We saw in the section 2.6.2 that this effect, predicted by the SCM, was also true in the Physical Interpretation of the CRF.

The mathematical expressions of the Cosmological distances (29c)(29d)(29e) are in agreement with their mathematical expression in the SCM, in which they are usually expressed as a function of the variable z.

In the 1st model of our Physical Interpretation, since 1+z has the same mathematical expression as in the SCM (as a function of the Cosmological time t) the final expression of those Cosmological distances as a function of z is identical to their final expression in the SCM. Consequently we also obtain an identical Hubble's constant.

In the 2nd model, the expressions of Cosmological distances are much simpler. Using $1+z=t_0/t$ we obtain:

$$D_C=\int_{tE}^{t0} c(1+z)dt=\int_{tE}^{t0} c(t_0/t)dt$$

So we obtain finally the expression of the comoving distance, using $1+z_0=t_0/t_E$:

$D_C=ct_0\mathrm{Log}(t_0/t_E)=ct_0\mathrm{Log}(1+z_0)$ (29f)

Here also this simple expression is in agreement with the usual admitted experimental values for the comoving distance. We remark that in our 2nd model, according with the previous equations we have as in the SCM for $z_0<<1$, $D_T\approx D_C\approx D_A\approx D_L\approx cz_0$.

We obtain easily that according to the 2nd model, the Cosmological velocity of the borders of the sphere being constant and equal to C (in R_C), then the Cosmological velocity of any comoving point of the swelling sphere is constant and inferior or equal to C (measured in R_C, using that with our notations $OA(t)=aR_E(t)$ (equation (28f)). Let V_Q be the Cosmological velocity of Q(t). Then consequently the distance in R_C between $O(t_0)$ and $Q(t_0)$, that we called D_C is also equal to V_Qt_0. Consequently because of the previous equation (29f) we have:

$V_Q=c\mathrm{Log}(1+z_0)$

We can interpret in our Physical Interpretation of the CMB the observation of the explosion of a supernova [6] the same way as in the SCM, taking into account the effect of the expansion of the Universe on the lengths of wave of photons and on distances between photons moving on the same axis. We remind that we obtained this effect, that is also true in the SCM, in the section 2.6.2.

2.8 Cosmological limits of the observable Universe.

In our Physical Interpretation of the CRF we cannot, as it was also the case in the SCM, observe the Universe (observing the galaxies) before a given time t_{OU}. This implies that observing the Universe from a comoving point $O'(t_0)$ (t_0 present Cosmological time) sufficiently far from the borders of the Universe, the observable Universe is isotropic and also that in many cases, the borders of the Universe cannot be observed from $O'(t_0)$. Here we are going to see how we can obtain this time t_{OU} in our Physical Interpretation of the CRF, and more precisely according to the 2[nd] mathematical model, that is much simpler than the mathematical model of the SCM.

It is clear that in our Physical Interpretation of the CRF as in the SCM, the Universe cannot be observed before the end of the dark age, at a Cosmological time t_D, because we admit as in the SCM that before t_D light cannot propagate inside the Universe. Moreover, galaxies cannot be observed before the Cosmological time t_G, that is the time of the apparitions of the first galaxies. It exist another limit in our Physical Interpretation of the CRF, that is due to the finitude of the Universe in this Interpretation. This is very clear in our 2[nd] model:

According to the equation (29g), V_Q being compulsory inferior to C, we have:

$C \geq c\text{Log}(1+z_0)$ (29h)

Consequently, with the notations of the previous section:

$t_0/t_E=1+z_0=\leq\exp(C/c)$ (29i)

Which implies that the Universe cannot be observed in $O(t_0)$ before the time t_I defined by:

$t_I=t_0\exp(-C/c)$ (29j)

So in our Physical Interpretation of the CRF, t_{OU} is the greatest time between t_I, t_G and t_D. Moreover if $t_{OU}>t_I$, we cannot observe the borders of the Universe from $O(t_0)$.

We remark that the equation (29h) permits to give an inferior limit to the constant C of the 2[nd] model: The fact that we have observed some redshift z equal to 10 implies that C>2,3c. If we take C=10c, we obtain t_I of the order of 1million years.

The previous equations permit to obtain, according to the 2[nd] model, the minimal distance in R_C' (Cosmological frame with an origin O'(t) defined in section 2.6.2) between $O'(t_0)$ and the borders of the Universe (at the Cosmological time t_0) for which the Universe appears to be isotropic observed from $O'(t_0)$ (Which means that the borders of the Universe cannot be observed from $O'(t_0)$).

2.9 The Cosmic Microwave Background.

In complete agreement with the SCM, we admit the apparition of a CMB at a Cosmological time very close to the Big-Bang (We admit as in the SCM that the Big Bang occurs at a Cosmological time equal to 0). Proceeding exactly as in the SCM, taking into account the effect of the expansion of the Universe on the lengths of wave of photons and on photons moving on the same axis (effect obtained in section 2.6.2) , we obtain in the Physical Interpretation of the CRF that if the CMB appears at a Cosmological time t_{iCMB} corresponding to a temperature T_{iCMB}, then at an absolute time t superior to t_{iCMB}, if the factor of expansion between t_{iCMB} and t is 1+z, then the CMB at a Cosmological time t corresponds to a temperature $T_{CMB}(t)=T_{iCMB}/(1+z)$. (This is obtained exactly the same way as in SCM, because we have in both Cosmological models that with the same notations the density of photons is divided by $(1+z)^3$ and the lengths of wave of photons are increased by a factor (1+z)). And consequently our Physical Interpretation of the CRF is in agreement with the observation of the CMB corresponding to a great redshift z_0 [(7)(8)] .

But now we have given a very complete physical interpretation of the CRF that did not exist in the SCM. In our Physical Interpretation of the CMB we interpret the interpretation of the anisotropies of the CMB as the SCM.

It is important to know what happens to a photon reaching the borders of the spherical Universe. It could be absorbed but it is not the only possible hypothesis. The simplest hypothesis according which the photon is not absorbed, that we will admit in our Physical Interpretation of the CRF, would be that it be reflected, taking exactly the opposite of its local velocity (as a vector). With this last hypothesis we could expect to see reflected images of some galaxies. But there are several explanations to the fact that it is not the case:

We keep the notations of the previous section 2.8, defining the limits of the Cosmological time before which it cannot be observed:

We obtain easily that if $t_G>t_I$ or $t_I<t_D$ then we cannot observe the reflection of images of galaxies on the borders of the Universe. Indeed in the 1st case the reflected images of galaxies reach O after t_0 and in the 2nd case the reflected photons are absorbed.

2.10 Dipole contribution of the CMB.

We know that according to the SCM we have the following fluctuations of temperature of the CMB [(7)]:

$$(\frac{\Delta T}{T}) = \frac{1}{4\pi}\sum_{l} l(2l+1)C_l \qquad (30)$$

In the previous expression l=1 is the dipole contribution, corresponding to the motion of the earth relative to the CRF. In our Physical Interpretation of the CRF, we keep the previous expression, but then we can interpret the dipole contribution of this equation, which was not the case in the SCM.

3.COMPLEMENTS

In the Part 2 of this article, we presented a new model of dark matter, called dark substance, and a Physical Interpretation of the CRF. In this Part 3, we study the consequences of these models, as for instance the motion of a spherical concentration of dark substance (constituting some galaxies with a flat rotation curve according to the preceding article), the thermal effects on the spherical concentration of dark substance due to this motion, and the effects of this motion on the mass and the velocity of this spherical concentration. We will see that it exists 2 kinds of radius in a galaxy, the 1st one being the baryonic radius (visible) and the 2nd one, called *dark radius*, being the radius of the spherical concentration of dark substance. We will give the mathematical expression of this dark radius as a function of the Cosmological time, and we will study a particular case, the case of the milky way at a Cosmological time equal to 5 billion years. We will also study the concentration of dark substance around stars and planets, and we will make appear the existence of new kinds of galaxies.

3.1 Motion of a galaxy inside the intergalactic dark substance.

We could think that a spherical concentration of dark substance constituting a galaxy, moving through the intergalactic dark substance, is submitted to some modifications of its mass and velocity because of this motion.

In fact, we have the 2 following properties for the concentration of dark substance:

a) The moving spherical concentration keeps its mass.
b) The moving spherical concentration keeps its velocity: It is not slowed down nor accelerated.

Indeed, let us consider a spherical concentration of dark substance constituting the dark matter of a galaxy (center O) driven with a local velocity **V** relative to the intergalactic dark substance (In fact we can assume that locally, the dark substance is at rest relative to the local CRF, and consequently **V** is also the local velocity (relative to the local CRF) of the spherical concentration of dark substance). Let us consider the disk whose the center is O, the radius is the radius of the spherical concentration, and that is perpendicular to the velocity **V**. Let S be the surface of the disk. Then in an interval of Cosmological time dt, we have the 2 phenomena:

c) A volume SVdt of dark substance is absorbed by the spherical concentration.(In front of the sphere).
d) A volume SVdt is emitted by the spherical concentration (to the back of the sphere).

Moreover we remark that according to our model the emitted and the absorbed dark substance have the same density, that is the one of the intergalactic density. Consequently the emitted mass and the absorbed mass are equal, which implies that the spherical concentration keeps its mass (Property a)). Moreover we can assume that the emitted dark substance(in its final state) and the absorbed dark substance have the same local velocity (velocity of the surrounding intergalactic dark substance, which we can assume being equal to 0), and consequently the velocity of the spherical concentration is not modified (Property b)).

We have a second possible justification:

Let us suppose that the moving spherical concentration of dark substance lose a little more dark substance than it absorb. Let us suppose for instance that the total loss be δm. Then the equation of equilibrium (6) remaining the same, we can assume that the spherical concentration of dark substance will absorb also the missing mass δm, coming back to the equilibrium. Consequently the mass of the concentration of dark substance remains the same. Moreover we can assume as previously that lost dark substance (in its final state) and absorbed dark substance have the same velocity (velocity of the surrounding intergalactic dark substance). Consequently, this is a second and more general justification that the spherical concentration of dark substance is not accelerated nor slowed down.

It is also possible that lost dark substance and absorbed dark substance have not exactly the same local velocity. Then the velocity of the traveling concentration of dark substance is slightly modified, but it is possible that this effect be completely negligible and that the velocity of this galaxy in its galaxy cluster as a function of the Cosmological time remains constant. We remark also that it is very difficult to observe the evolution of the local velocity of a galaxy as a function of the Cosmological time.

3.2 Baryonic and dark radius of a galaxy.

We know that the galaxy Andromeda is approximately at 2.5 billions year-light of our galaxy the milky way. We consider for instance the case of the milky way in order to study the 2 kinds of radius of a galaxy. We suppose that we are in the 2nd mathematical model of the Physical Interpretation of the CRF (Section 2.6.1) because of its great simplicity.

We saw in the Section 2.2 that if r is the distance to the center O of a spherical concentration of dark substance constituting a galaxy, then the expression of the density of dark substance ρ(r) is given by, k_3 being a constant (See section 2.2, equation (7) $k_3=k_2/4\pi$):

$$\rho(r) = \frac{k_3}{r^2} \qquad (31)$$

So we obtain, M(r) being the mass of the sphere having its center in O and a radius r (See equation (9)):

$$M(r)=4\pi k_3 r \qquad (32)$$

Consequently, v being the velocity of a star at a distance r of O (see equation (10)):

$$v^2 = \frac{GM}{r} = 4\pi k_3 G \qquad (33)$$

Consequently:

$$k_3 = \frac{v^2}{4\pi G} \qquad (34)$$

We know also that if ρ_0 is the local density of the intergalactic dark substance surrounding the spherical concentration of dark substance constituting the galaxy, then the radius R of this concentration of dark substance is given by the expression (See equation (15)):

$$\rho(R) = \frac{k_3}{R^2} = \rho_0 \qquad (35)$$

Consequently:

$$R = \sqrt{\frac{k_3}{\rho_0}} = v\sqrt{\frac{1}{4\pi G\rho_0}} \qquad (36)$$

We will call R the *dark radius* of the considered galaxy.

So in a galaxy for which it exists a spherical concentration of dark substance with a density in $1/r^2$, we have 2 different kinds of radius:

The 1st kind of radius, called *dark radius*, is the radius of the spherical concentration of dark substance. The 2nd kind of radius is the radius of the smallest sphere containing all the stars. We will call *baryonic radius* this second kind of radius. We remark that at a given time, the dark radius must be greater than the baryonic radius.

Let $\rho_0(5)$ be the density of the intergalactic dark substance when the age of the universe (Cosmological time) was 5 billion years, and $\rho_0(15)$ this density at an age of 15 billion years (meaning presently).

We know, with the model of the swelling sphere exposed in the Section 2.6.1 of this article, that if f=1+z is the factor of expansion of the universe between 5 and 15 billion years, assuming that:
a)The total mass of the intergalactic dark substance remains approximately the same.
b) The density of the intergalactic dark substance is the same in all the Universe.
, and remarking that in our model the (finite) volume of the Universe increases by a factor f^3 between the Cosmological times 5 and 15 billion years, we obtain:

$\rho_0(15)=\rho_0(5)/f^3$ (37)

Moreover according to the 2nd model, f=15/5=3 (See Section 2.6.1).

We note $r_B(15)$ the present baryonic radius of the milky way. We know that $r_B(15)$ is approximately equal to 50000 years light . If R(15) is the present dark radius of the milky way, let us suppose that R(15) is approximately 10 times greater than $r_B(15)$ (meaning approximately 500000 light-years):

$R(15)\approx 10r_B(15)$ (38)

Of course we ignore the real value of R(15),we can only know its minimal value (It must be superior to the baryonic radius). We are going to see that our hypothesis (38) leads to coherent results. Let $r_B(5)$ be the baryonic radius of the milky way when the age of the Universe was 5 billion years. Considering that the baryonic radius increases with time, we have the relation:

$r_B(15)\geq r_B(5)$ (39)

We have seen and justified theoretically in the Section 2.3 of this article that according to the baryonic Tully-Fisher's law the velocity of stars in a galaxy with a flat rotation curve depended only on the baryonic mass of this galaxy. Consequently if we suppose that between 5 and 15 billion years, the baryonic mass of the galaxy remains approximately the same, the velocity v used in the equation (36) remains unchanged between 5 and 15 billion years. Using this equation (36) and the equation (37), taking f=3 and $\sqrt{(27)}\approx 5$, we obtain, R(5) being the dark radius of the milky way at an age of the Universe equal to 5 billion years:

$R(5)\approx R(15)/5\approx 2r_B(15)$ (40)

Using the equations (39) and (40) we obtain that at an age of the Universe of 5 billion years, the dark radius was greater than the baryonic radius:

$r_B(5)\leq r_B(15)\approx R(5)/2\leq R(5)$ (41)

We remark that the previous relation (41) would have also be valid for a galaxy with the same dark radius R'(15)=500000 light-years but with a baryonic radius $r'_B(15)$ twice greater than the radius of the milky way meaning 100000 light-years. (We just take $r'_B(15)\approx$ 100000 years light and replace the equation (38) by the equation: $R'(15)\approx 5r'_B(15)$). Our model remains obviously valid if the final baryonic radius is reached after 5 billion years.

3.3.Thermal transfer of a moving galaxy.

We remark that the phenomenon of absorption and of emission of dark substance by a galaxy that we described in the Section 3.1 modifies the thermal equilibrium that we used in the Section 2.3 of this article in order to obtain the Tully-Fisher's law. Indeed the absorbed dark substance (cold, because it is intergalactic dark substance) is not at the same temperature than the lost dark substance (hot, because it is the temperature of the spherical concentration of dark substance).

Nonetheless we can consider that the previous phenomenon leads to a power ε(t) dissipated by the spherical concentration of dark substance. ε(t) mainly depends on the radius of the moving spherical concentration, of its velocity relative to the local intergalactic dark substance, of the density of the intergalactic dark substance, and of the temperature of the concentration of dark substance.

If we assume that ε(t) is negligible compared with the power emitted by the baryons of a galaxy towards the spherical concentration of dark substance (whose we supposed the existence in order to obtain the baryonic Tully-Fisher's law, see Postulate 2a in section 2.3), then our thermal model used in order to get the Tully-Fisher's law remains valid. We can a priori neglect ε(t) because in one second, the distance covered by the moving spherical concentration in one year (the local velocity of the spherical concentration of dark substance is assumed to be of the order of 300km/s (10^{-3}c)), is very low relative to the dark radius of the considered galaxies (At least of the order of 100000 light-years).

3.4.Concentration of dark substance around stars and planets.

It is natural to assume that because of gravitation, there is a concentration of dark substance around planets and stars.

Let us for instance consider a star S with a (baryonic) mass M. The same way as for galaxies with a flat rotation curve, we can assume that there is a concentration of dark substance around the star, in equilibrium at a given temperature T, and presenting a spherical symmetry.

The equation of equilibrium is, for an element of dark substance situated at a distance r from O the centre of S, with a density ρ(r), a width dr, a surface dS , a pressure P(r), assuming that r is greater than the baryonic radius R_B of the star S, neglecting the gravitational attraction due to the sphere of dark substance having r as radius :

$$P(r+dr)dS - P(r)dS + \frac{GM\rho(r)drdS}{r^2} = 0 \qquad (42)$$

We remind (See Section 2.2, equation (2)) that we have $P(r)=k_1\rho(r)$ with $k_1=k_0T$, T temperature of the concentration of dark substance.
So we obtain, solving easily the previous differential equation:

$$\rho(r) = K\exp(\frac{GM}{k_1 r}) \qquad (43)$$

Let ρ_0 be the density of dark substance surrounding the concentration of dark substance around the star. Generally ρ_0 is not the density of the intergalactic dark substance contrary to the galaxies that we studied. It is very often the local density of the spherical concentration of dark substance constituting the galaxy to which the star belongs.

A first model is $K=\rho_0$. Then we have:

$$\rho(r) = \rho_0 \exp(\frac{GM}{k_1 r}) \qquad (44)$$

This model leads to incoherencies ($\rho(r)$ too great)

A second possible model is the following one. Let R_D be the radius of the concentration of dark substance around the star S. We can assume in the 2^{nd} model $R_D=R_B$, with $\rho(R_D)=\rho_0$. This defines the constant K. Then the equation (43) leads then to densities inferior to ρ_0 for $r>R_D=R_B$. But this is acceptable as in the case of galaxies studied in Section 2.3.3. Indeed we have seen in the Section 2.3.3 that R_D being the dark radius of the galaxy, we had for $r>R_D$ a density of dark substance equal to ρ_0 (density of the intergalactic dark substance surrounding the galaxy) despite that the equation (7) predicted a density $\rho(r)<\rho_0$ for our choice of R_D. We can then evaluate T, temperature of the spherical concentration of dark substance, the same way as for galaxies in the Section 2.3, using the Postulate 2. We obtain $\rho(r)$ for $r<R_D=R_B$ using a new equilibrium equation, in which we can consider only the attraction of the baryonic mass of the star. This second model can also be valid for some galaxies.

In a third model, there is no concentration of dark substance around the star S, the dark substance around the star is identical to the surrounding dark substance. There is not an equation of equilibrium as the equation (42). In particular, in this case, the local density is $\rho(r)=\rho_0$, there is no equation of equilibrium giving $\rho(r)$ and the local temperature of the dark substance coinciding with the star is the temperature of the surrounding dark substance. As in the second model, this is justified if we find in the second model for $r<R_D=R_B$ a density inferior to ρ_0 model. There is also a second more general justification: We can admit that naturally the dark substance tends to be homogeneous in density and temperature. The fact (that we admitted in our Physical Interpretation of the CRF) that the intergalactic dark substance be homogeneous in density and temperature appears to be a consequence of this effect. Let us call *homogenization effect* this effect. (It existed, locally for a gas an we saw that dark substance have physical properties close to those of a gas). We can consider that in the case of spherical concentrations with densities of dark substance in $1/r^2$ that we studied in Section 2.2, the gravitational effect canceled the homogenization effect for $r<R_D$, but when $r>R_D$ it was the homogenization effect that canceled the gravitational effect. So it is natural to assume that in some case (galaxies or stars) the homogenization effect predominates and in that case we have $\rho(r)=\rho_0$ for $r<R_B$.

Generalizing what precedes to the case of galaxies, we see 2 new kinds of galaxies, corresponding to the 2^{nd} or 3^{rd} previous case. In this 3^{rd} case we have some galaxies for which the density of dark substance is equal to ρ_0, ρ_0 being the density of the intergalactic dark substance or of the local concentration of dark substance in which they are immerged (In the case of galaxies satellite).

We can suppose that the galaxies that are satellites of the milky way, as for instance the Magellanic clouds, correspond to those new kinds of galaxies. We remind that those dwarf galaxies have a velocity close to the velocities of the stars of the milky way, and consequently this involves according to our Physical Interpretation of the CRF that the dark radius of the milky way is superior to the distance between those galaxies satellites and the center of the milky way, in agreement with our assumption in Section 3.2. We remind that some models without dark matter exist for those galaxies satellites [(9)] .

3.5 Link between the CMB and the temperature of the intergalactic dark substance.

In the Sections 2.5 and 2.6 , we have seen that according to our Physical Interpretation of the CRF, the Universe was a sphere filled of dark substance, surrounded by a medium called "nothingness". We saw in the Section 2.5 that we could model a convective thermal transfer between this spherical Universe and the nothingness. The convective flow F was then in agreement with the expression $F=h_nT_0(t)$, $T_0(t)$ being the temperature of the intergalactic dark substance at a Cosmological time t. It is easy to verify that it is impossible that we have a constant C_2 such than $h_n=C_2\rho_0(t)$ contrary to the case in which we had also a convective transfer but between 2 mediums constituted of dark substance in section 2.3. (Indeed in this case we would obtain that $T_0(t)$ increases). We saw in Section 2.5 that it is nonetheless possible that h_n be constant, independent of the density of the intergalactic dark substance. Indeed in this case, because of the Postulate 2a) we have the equation of thermal equilibrium $K_3M=4\pi R_E(t)^2(h_nT_0(t))$, with K_3 constant (Equation (14)) , M baryonic mass of the Universe, $R_E(t)$ radius of the Universe at a Cosmological time t. We obtain that $T_0(t)$ evolutes in $1/(1+z)^2$, $(1+z)$ factor of expansion of the Universe. We admit as in the SCM that the apparition of the CMB in the Universe corresponds to a redshift z approximately equal to 1500. If we admit that for this value of z, the temperature of the intergalactic dark substance was equal to the temperature of the CMB, we obtain that presently (with an age of the Universe of 15 billion years), the temperature of the intergalactic dark substance is 1500 times lower than the temperature of the CMB, which is an acceptable value, justifying our approximation in Section 2.3 expressing that the temperature of the intergalactic dark substance can be neglected in comparison with the temperature of spherical concentrations of dark substance (corresponding to galaxies with flat rotation curve, see Section 2.).

Moreover the hypothesis of the initial temperature of the CMB and the temperature of the intergalactic dark substance implies, because we assumed that the latter was homogeneous in all the Universe (see the homogenization effect in the previous section) , that the initial temperature of the CMB was also homogeneous in all the Universe. And so this hypothesis justifies the isotropy of the CMB observed from the CRF, without needing to introduce the phenomenon of inflation, as it was the case in the SCM.

4.CONCLUSION

So in this article we proposed the existence of a dark substance whose physical properties are in agreement with observations connected to dark matter. In particular those physical properties, despite of their simplicity, permitted to us to justify theoretically the flat rotation curve observed for many galaxies and the baryonic Tully-Fisher's law. In order to obtain those laws, we interpreted galaxies with a flat rotation curve as spherical concentrations of dark substance in thermal equilibrium.

We have also exposed a Physical Interpretation of the CMB Rest Frame (CRF). This Interpretation permitted to us to define in a simple and new way the Cosmological time, in agreement with all astronomical observations and with the definition of Cosmological time in the SCM. This Interpretation has also permitted to us to introduce a new kind of frame, called Cosmological frame, that is fundamental for the description of the Universe. Then using these new concepts, we proposed a new model of Universe, flat and finite, not proposed by the SCM. Despite of this difference we have seen that according to a 1st mathematical model of expansion of the Universe ,based as the SCM on General Relativity, the observable Universe was identical to the one predicted by the SCM (in particular it is isotropic), provided that it be observed from a point sufficiently far from the borders of the Universe. We also have proposed a 2nd mathematical model of expansion, much simpler than the mathematical model of the SCM, and we have seen that the theoretical predictions of this 2nd were nonetheless in agreement with astrophysical observations. Moreover this 2nd mathematical model did not need a dark energy, contrary to the SCM.

In section 3 we studied the effects of the motion of a spherical concentration of dark substance on its velocity and its mass. We also studied the 2 kinds of radius for a galaxy, the dark radius and the baryonic radius.

So our exposed theory has many perspectives in experimental astrophysics. Indeed it is necessary to find observations permitting to confirm or infirm the theoretical models presented here. Concerning our model of dark substance, it is necessary for instance to verify if this model is compatible with the properties of dark matter observed in galaxy clusters. We remind that those observations contradicted MOND theory [(1)] .

Nonetheless we have seen that 2 very simple Postulates expressing the properties of dark substance permitted to obtain the very specific laws that are the flat rotation curve of some galaxies and the Tully-Fisher's law. It would be very surprising that this be an effect of random. So we can really expect that our model of dark substance is valid.

Concerning the Physical Interpretation of the CRF, finding some observations permitting to compare our 1st model and the SCM will be a greater challenge because we have seen that they both predicted the same observable Universe. It should be nonetheless possible to find astronomical observations permitting to compare the phenomenon used in our Physical Interpretation of the RRC to justify the isotropy of the CMB in our 1st model (equality of the initial (Cosmological time t_{ICMB}) temperature of the CMB and the temperature of intergalactic dark substance (also Cosmological time t_{ICMB}), Section 3.5) and the corresponding phenomenon in the SCM (inflation) permitting to justify the observed isotropy of the CMB.

It should be easier to find astronomical observations permitting to compare the predictions of our 2nd model with the predictions of the SCM because they are mathematically different. For instance we have seen that in our 2nd model, the Hubble's constant is precisely equal to $1/t_0$, t_0 age of the Universe. In the same way Cosmological distances have not the same mathematical expression in our 2nd model as in the SCM (See Section 2.7).

But a very attractive element in favor of the model of the Universe proposed by our Physical Interpretation of the CRF is that this model of Universe can be conceived by the human spirit, which was not the case for models of Universe proposed by the SCM that were either infinite or finite but without borders. It is our model of dark substance that permitted to us to define easily such a Universe, flat and finite.

References:

1.M.Milgrom, A modification of the Newtonian dynamics as a possible alternative to the hidden mass hypothesis, Astrophysical Journal 270 (1983)

2.P.Kroupa,M.Pawlowski,M.Milgrom, The failures of the standard model of Cosmology require a new paradigm, International Journal of Physics D21 (2012)

3.Stacy Mc Gaugh, A Novel Test of Modified Newtonian Dynamics with Gas rich Galaxies, Physical Review Letter, open archives arXiv.

4.Thierry Delort, Théories d'or 7e édition, Editions Books on Demand, Paris (2014)

5.G.A Tammann and B.Reindl, Astronomy and Astrophysics 549(2013)

6.Perlmutter et al, Dicovery of a supernova explosion at half the age of the Universe, Nature 391, 51-54 (1998)

7.D.J Raine,E.G Thomas,An introduction to the science of Cosmology,Institute of physics, London (2001).

8.J.V Narlikar, An introduction to Cosmology, Cambridge University press,Cambridge (2002)

9.D.R Alves, C.A Nelson, The rotation curve of the Large Magellanic cloud and the implications for Microlensing. The astrophysical journal (October 2000).