Title :DARK MATTER AND DARK ENERGY OF THE UNIVERSE
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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 using the new model of dark matter we are naturally led to propose a new geometrical model of Universe, finite, that is different from all geometrical models proposed by the Standard Cosmological Model (SCM). We then study according to our theory of dark matter and dark energy the different possible distributions of dark matter around galaxies and in galaxy clusters, and the velocities of galaxies in galaxy clusters. Then we expose a new model of expansion of the Universe based on the new geometrical form of the Universe and on the interpretation of the CMB Rest Frame (CRF), that has not physical interpretation on the SCM. We then propose 2 possible mathematical models of expansion inside the new model of expansion. The 1st proposed mathematical model is based on General Relativity as the SCM and gives the same theoretical predictions of distances and of the Hubble's constant as the SCM. The 2nd proposed mathematical model is mathematically much simpler than the mathematical model used in the SCM, but we will see that its theoretical predictions are in agreement with astronomical observations. Moreover, this 2nd mathematical model of expansion does not need to introduce the existence of a dark energy contrary to the mathematical model of expansion of the SCM. To end we study the evolution of the temperature of dark substance in the Universe and we make appear the existence of a dark energy, due to our model of dark matter.

Key words: Tully-Fisher's law, dark matter, dark halo, CMB, galaxy clusters, gravitational lensing, galaxy rotation curve, velocity of galaxies, dark energy.

1.INTRODUCTION

In the first part of the article, we expose a theory of dark matter. In this part, we propose that a new physical element, called *dark substance*, constitutes the dark matter. According to the proposed model of dark matter, 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. We remind 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. A simple mathematical expression of the density of dark matter (in $1/r^2$) permitting to obtain this flat rotation curve has already been proposed, but it has not been proposed a model of dark matter permitting to justify theoretically this mathematical expression (in $1/r^2$). The theory called MOND theory [1] proposes also a theoretical justification of the flat rotation curve of some galaxies, but this theory is contrary to Newton's attraction law and moreover it is contradicted by some astronomical observations. We see that our new model of dark matter leads to propose according to our theory of dark matter a new geometrical model of Universe, finite, that is not proposed by the

Standard Cosmological Model. We then study according to our theory of dark matter the different models of distribution of dark matter in galaxies. We see that this theory gives theoretical predictions concerning the velocities of galaxies inside clusters and the masses of clusters that are in agreement with astronomical observations. Then we see that this theory permits also theoretical predictions of the dark radius of galaxies, in agreement with observations, and also of the mean density of dark matter in the Universe, that is the origin of some anisotropies of the CMB.

Concerning the theory called MOND [1], (proposed by Milgrom) we remind that according to this theory, it only exists ordinary matter constituted of baryonic and leptonic particles, and we must replace the fundamental law of Newtonian dynamics **F**=m**a** (**a** acceleration of a particle with a mass m) by the law:

$$\mathbf{F} = m\mu(\frac{a}{a_0})\mathbf{a} \qquad (0a)$$

With $\mu(x)=1$ if $x>>1$ and $\mu(x)=x$ if $x<<1$.

We then obtain easily with the preceding law, for a star of a spiral galaxy situated at the distance r from the centre of the galaxy, with the conditions on the variable r $a/a_0<<1$ and $M(r)^{1/2}\approx M^{1/2}$, M(r) being the mass inside the sphere with the radius r and centre O centre of the galaxy and M being the total mass of the galaxy, modeling M(r) as a punctual mass in O:

$$a = \frac{\sqrt{GMa_0}}{r} \qquad (0b)$$

Therefore we obtain, with $a=v^2/r$, v orbital velocity of the considered star and with the conditions on r $a/a_0<<1$ and $M(r)^{1/4}\approx M^{1/4}$:

$$v=(GMa_0)^{1/4} \qquad (0c)$$

The theory of dark matter exposed in this article is very different from the MOND theory because according to the former theory, it exists a kind of dark matter different from ordinary matter. As the MOND theory, we will see that it also gives a very simple model of galaxies with a flat rotation curve. But in the theory MOND, the equation (0c) is valid only with the conditions on the variable r $a/a_0<<1$ and $M(r)^{1/4}\approx M^{1/4}$. In the model of galaxies with a flat rotation curve proposed by the new theory of dark matter, we find a constant orbital velocity whatever be r, if we neglect the ordinary matter. Moreover, the fundamental law of MOND theory (0a) is very artificial, whereas the model proposed by the new theory of dark matter is compatible and uses the fundamental law of Newtonian dynamics **F**=m**a**.

In the same way both theories permit to obtain the baryonic Tully-Fisher's law observed by S. Mc Gaugh [2] ($M=Kv^4$, M baryonic mass of the galaxy, v orbital velocity of stars in this galaxy, K constant). But those theories use completely different hypothesis in order to obtain this law. Moreover in the MOND theory in order to obtain this law we use the equation (0c), which as we saw previously requires some conditions on the variable r in order to be valid.

Concerning galaxy clusters, the theory of dark matter exposed in this article is compatible with the observed properties of clusters, which is not the case of the MOND theory. For instance, the new theory predicts some relations between the velocities of galaxies of a cluster and its mass in agreement with astronomical observations which is not the case of the MOND theory. Moreover in the new theory the effect called gravitational lensing exists and is interpreted in a very simple way which it is not the case of the MOND theory. Indeed, MOND theory needs another theory (much more complicated than the interpretation of gravitational lensing by the new theory of dark matter), called TeVeS [(3)] in order to interpret gravitational lensing observed for clusters. But this theory TeVeS meets important problems of instability [(4)] and needs the existence of neutrinos in the galaxy cluster with important masses [(5)].

Moreover the new theory of dark matter predicts the existence of a density of dark matter in the Universe that could be the origin of some anisotropies of the CMB, which is not the case of the MOND theory. To end the new theory proposes a very attractive Cosmological model based on the new theory of dark matter (2nd part of the theory) whereas it does not exist any Cosmological model built on the MOND theory.

In the 2nd part of the article, we will see that our theory of dark matter and dark energy proposes a model of expansion of the Universe that is based on the new geometrical form of the Universe introduced in the 1st part of the article, and also on the physical interpretation of the CMB Rest Frame (CRF), that has not physical interpretation in the SCM. We will see that the model of expansion proposed by our theory permits to define distances in Cosmology that are completely analogous to distances in Cosmology defined by the SCM. As the SCM, we see that our theory of dark matter and of dark energy is compatible with Special Relativity and General Relativity (locally) because according to this new theory the CRF cannot be detected using usual laboratory experiments but only observing the CMB. We will see that our new theory of dark matter and dark energy proposes 2 possible mathematical models of expansion of the Universe. The 1st mathematical model of expansion is based as the SCM on the equations of General Relativity. We see that this 1st model gives theoretical predictions of distances used in Cosmology, of the Cosmological redshift and of the Hubble Constant that are identical to their theoretical predictions by the SCM.

The 2nd proposed mathematical model of expansion is not based on General Relativity but is mathematically much simpler. Nonetheless its theoretical predictions, in particular predictions of Hubble's Constant and of distances used in Cosmology, are in agreement with astronomical observations. Moreover, this 2nd model does not need the existence of a dark energy (contrary to the 1st mathematical model and to the SCM), and consequently brings a solution to the enigma of dark matter.

To end we study according to our theory of dark matter and dark energy the evolution of the temperature of dark substance in the Universe and we see that according to this theory it exists a dark energy in the Universe, that is the internal energy of the dark substance modeled as an ideal gas.

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 [(6)]. Our article proposes such a new paradigm.

We will see that the theory of dark matter and dark energy exposed in this article remains compatible with the SCM [(7)(8)(9)] in order to interpret most astronomical observations not directly linked to dark matter or dark energy, for instance primordial elements abundance, the apparition of baryonic particles (for the same Cosmological redshift z as in the SCM), formation and apparition of stars and galaxies (for the same z as in the SCM), apparition of the CMB (for the same z as in the SCM), evolution of the temperature of the CMB (in 1/(1+z)), anisotropies of the CMB….

2. DARK MATTER

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 owns a mass and obeys to the Boyle's law (called also Mariotte's law), to the Charles'law (called also Gay-Lussac's law), and to the following law that is their synthesis:
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:
$PV=k_0mT$

The preceding law is valid for a given ideal gas G_0, replacing k_0 by a constant $k(G_0)$, and this is a consequence of the *universal gas equation*, which is also obtained using Boyle and Charles'laws. For this reason we will call it the *Boyle-Charles'law*.

We have 2 remarks consequences of this Postulate1:

-Firstly despite of its name, the dark substance is not really dark but translucent. 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 "emptiness" is not empty in reality: It is filled with 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 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 $k_1=k_0T$:

$$PV=k_1m \qquad (2)$$

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

$$P=k_1\rho \qquad (3a)$$

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, in gravitational equilibrium.

We 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 centre is the center O of the galaxy. S(O,r) is the sphere filled with dark substance with a radius r and the centre O.

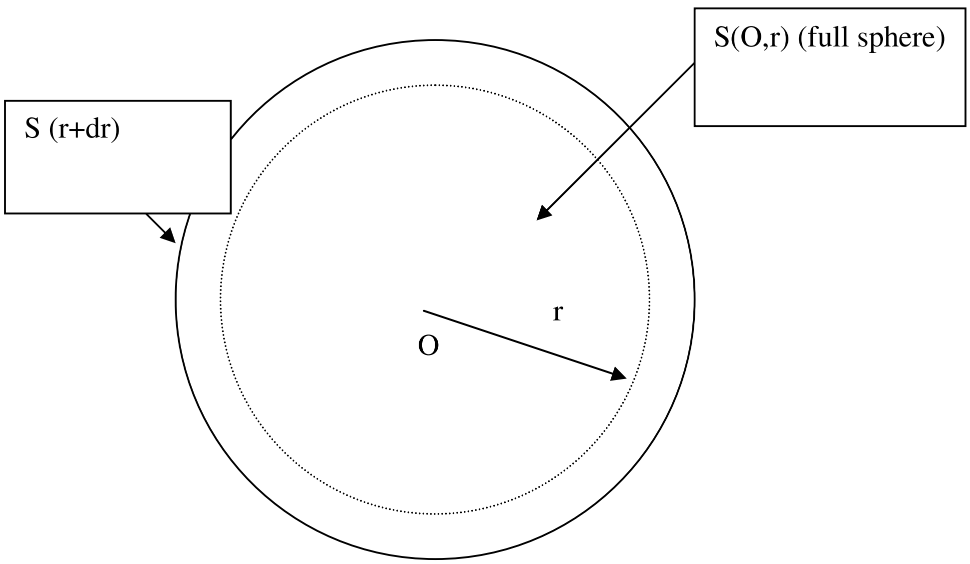

Figure 1:The spherical concentration of dark substance

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

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

Assuming a spherical symmetry for the density of dark substance, using Newton's law (Σ**F**=**0** for a material element in equilibrium with a mass m, $\mathbf{F}_G$(r)=m**G**(r), $\mathbf{F}_G$(r) gravitational force acting on the element, **G**(r) gravitational field defined by Newton's universal law of gravitation) and Gauss theorem in order to obtain **G**(r), we obtain the following equation (4) of equilibrium of forces on an element dark substance with a surface dS, a width dr, situated between S(O,r) and S(r+dr):

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

Eliminating dS, we obtain the equation:

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

And using the equation (3) obtained using the Boyle-Charles'law assumed in the Postulate 1, 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 the evident solution:

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

(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 proposed a model of dark matter permitting to justify theoretically this density in $1/r^2$ or to obtain the constant k_2. Here we give a theoretical justification of this density in $1/r^2$ and we are going to give the expression of the constant k_2 (Equation (8)). This is the consequence of the model of dark substance as an ideal gas, Postulate 1)

In order to obtain k_2 , we replace ρ(r) given by the expression (7) inside the equation (6), and we obtain immediately that this equation is verified for the following expression of k_2:

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

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

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

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 equality (10) that the velocity of a star in a galaxy is independent of its distance to the centre 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 cases 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:

$$M=K_2v^4 \qquad (12)$$

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

The more recent observations of Mc Gaugh [2] 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.

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 thermal energy. We can expect that this thermal energy is very low, but because of the expected very low density of the dark substance and of the considered times (we remind that the baryonic diameter of galaxies can reach 100000 light-years), it can lead to appreciable temperatures of dark substance. A priori we could expect that this loss of thermal 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 lost thermal energy by all the 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 thermal 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:

$$p=np_0 \qquad (13)$$

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") with a temperature T_0 and 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. We will call R the *dark radius* of the galaxy. 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 at the temperature T is in thermal interaction with the medium constituted of intergalactic dark substance at the temperature T_0 surrounding this sphere. The simplest and most natural thermal transfer is the convective transfer. We admit this in the Postulate 2b):

Postulate 2b):

The thermal interaction between the spherical concentration of dark substance constituting the galaxy (with a density of dark substance in $1/r^2$ and a homogeneous temperature T) and the surrounding intergalactic dark substance (at the temperature T_0) can be modeled as a 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:

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

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:

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

Using then the equation (18) :

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

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 :

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

And then according to the equation (10) :

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

So :

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

So we finally obtain :

$$M=K_6v^4 \qquad (29)$$

The constant K_6 being defined by:

$$K_6 = \left(\frac{1}{2k_0 K_5}\right)^2 = \frac{4\pi K_4^2 h}{4k_0^2 K_3} \qquad (30)$$

$$K_6 = \frac{4\pi h}{4k_0^2 K_3} \times \frac{2k_0}{4\pi G\rho_0} \qquad (31)$$

$$K_6 = \frac{m_0 h}{2k_0 G\rho_0 p_0} \qquad (32)$$

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 $T_0 \ll T$ (T temperature of the spherical concentration of dark substance in a galaxy). Consequently the previous hypothesis would lead to very high temperatures of spherical concentrations of dark substance constituting galaxies. We will see further that according to the theory of dark matter exposed here, the temperature T_0 of the intergalactic dark substance is not equal to the temperature of the CMB, except for a particular cosmological redshift z.

We could be in the following cases:

a)The temperature T_0 of the intergalactic dark substance at the present age of the Universe (equation (21)) is far less than the temperature of the CMB. (If the temperature of the dark halos of galaxies with a density of dark matter in $1/r^2$ is inferior to 300°K.)

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 dark substance being not ordinary baryonic matter, it can own very special thermal properties. Moreover we will see in the Part 3 of the article that the energy transmitted by baryonic particles to dark substance could be not thermal energy)

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 through S would be nil. We know that it is not possible because we assumed that the temperature T_0 of the intergalactic dark substance surrounding galaxies is much lower than the temperature T of the concentrations of dark substance constituting galaxies with a flat rotation curve. So it seems that according to our model of dark substance it cannot exist an infinite or finite isotropic Universe.

Nonetheless with our model of dark matter, 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. Moreover the SCM did not assume the existence of the concept of a dark substance filling all the Universe and it is precisely this concept that permitted us to define this new finite model of Universe with borders.

Nonetheless with this spherical model of Universe, we must admit in our theory of dark matter and dark energy that our galaxy is sufficiently far from the borders of the spherical Universe in order that this Universe appears to be isotropic observed from our planet. We also remark that the existence of a medium called “nothingness” is not incompatible with the SCM: We can consider that it was the medium before the Big-Bang.

Despite of the finite and spherical form of the Universe, it is possible to keep a model of expansion of the Universe, that is quasi identical to the model of expansion of the Universe proposed by the SCM. Indeed, we can keep all the equations of the SCM permitting to give the Cosmological redshift z, the distances used in Cosmology, the Hubble constant. In this 1^{st} part of the article, we will keep the model of expansion of the Universe of the SCM, with only the geometrical form of the Universe modified. So with this model of expansion, we obtain as in the SCM that the factor of expansion of the Universe can be expressed as f=1+z, z being the Cosmological redshift, and we obtain z with the same equations as in the SCM, according to which the densities of dark matter, of baryonic matter and of dark energy are homogeneous in the Universe, and we keep the values admitted by the SCM for those different densities. But we can expect, if t_1 and t_2 are 2 ages of the Universe and 1+z is the factor of expansion of the Universe between t_1 and t_2, $R_U(t_1)$ and $R_U(t_2)$ being the radius of the spherical Universe between t_1 and t_2:

$R_U(t_2)=(1+z)R_U(t_1)$ (33)

We will propose in the 2nd part of our theory concerning dark energy a new model of expansion of the Universe based on the spherical form of the Universe obtained in this 1st part of the theory concerning dark matter and on the physical interpretation of the CMB rest frame. But we will see that also with this new model of expansion $R_U(t_2)=(1+z)R_U(t_1)$.

Concerning the CMB, we can admit as in the SCM that it appeared for a Cosmological redshift z of the order of 1500. Keeping the model of expansion of the Universe of the CMB, we also obtain as in the CMB that the temperature of the CMB evolves in 1/(1+z). The hypothesis according to which at the age of the Universe corresponding to this redshift z the temperature of dark substance and the temperature of the CMB were equal, is very attractive. Indeed with this hypothesis, assuming that the dark substance was homogeneous in temperature when the CMB appeared (for z of the order of 1500), we obtain that the temperature T_{aCMB} of the CMB when it appeared was homogeneous in the Universe, and consequently the temperature of the CMB at the present age of the Universe (approximately $T_{aCMB}/1500$) is homogeneous in the Universe, and consequently the temperature of the CMB appears to be isotropic observed presently. We will see that what precedes remains valid in the model of expansion of the Universe proposed by our theory of dark matter and dark energy. So our theory of dark matter proposes a new phenomenon, different from the phenomenon called *inflation*, in order to explain the quasi isotropy of the CMB observed at the present age of the Universe.

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_2 being a variable or a constant:

$$\varphi=h_2(T_0-0)=h_2T_0 \quad (34)$$

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, $R_U(t)$ étant le rayon de l'Univers à l'âge t de l'Univers:

$$K_3M = 4\pi R_U(t)^2\,\varphi = 4\pi R_U(t)^2\,h_2T_0(t) \quad (35)$$

So we see that if the Universe increases from a factor 1+z, according to the equations (33)(35), if h_2 is a constant (independent of the density of the intergalactic dark substance), then the temperature $T_0(t)$ of the intergalactic dark substance decreases from a factor $(1+z)^2$. (If we had supposed that $h_2=C_2\rho_0$, ρ_0 being the mass density of the intergalactic dark substance and C_2 being a constant, we would have obtained that if the Universe increases from a factor 1+z, then T(t) also increases by a factor 1+z which is impossible).

With the hypothesis of the equality between the temperature of the CMB and the temperature of the dark substance filling the Universe when the CMB appeared, we obtain that presently the temperature of the dark substance (evolving in $1/(1+z)^2$) is approximately 1500 times lower than the present temperature of the CMB (evolving in $1/(1+z)$).

We remark that the geometrical model of the Universe proposed by our theory of dark matter, finite and spherical, can easily be conceived by the human mind, contrary to the geometrical models of the Universe proposed by the SCM that are either infinite either finite but without borders.

2.6 Displacement of a galaxy inside the intergalactic dark substance.

Let us consider a spherical concentration of dark substance with a density in $1/r^2$ moving in the space. We could expect that its velocity or its mass be modified because of its motion, because of the Archimedes's force or because of the absorption or of the loss of dark substance by the moving concentration of dark substance. This effect could be negligible, but we have a justification that it is nil much more interesting.

Indeed according to this theory the dark matter has 2 possible behaviors: It can behave as a substance owning a mass or as absolute emptiness. For baryonic particles immerged inside dark substance, it always behaves as it was absolute emptiness and consequently the velocity of baryonic particles is never modified due to an Archimedes's force generated by the motion of baryonic particles through the dark substance. According to our theory of dark matter, the intergalactic dark substance in which the spherical concentration of dark substance is immerged also behaves as it was absolute emptiness concerning the displacement of this spherical concentration of dark substance, and consequently, neither the velocity nor the mass of the spherical concentration of dark substance are modified by its motion through the intergalactic dark substance. In order to interpret this phenomenon, we will say that the spherical concentration of dark substance is a *superposed sphere* on the intergalactic dark substance surrounding it. We will see in the study of galaxy clusters, that this new concept is very important in our theory of dark matter.

We know that in the Newton's theory of gravitation, it is assumed that only baryonic density exists, which is not the case in our theory of dark matter, and also that the Universe is static, which is also not the case in our theory of dark matter. Consequently the equations of the Newtonian mechanics must be adapted to our theory of dark matter, and we are going to see 3 very simple examples of adaptation of those equations to this theory of dark matter.

In section 2.2, in order to obtain our model of a superposed sphere with a density in $1/r^2$, we assumed that we had a spherical symmetry around the centre of the galaxy O_{GA}. But we will see that usually it is not the case if the galaxy is inside a cluster. It is possible that applying the equations of Newtonian mechanics, our model remains valid with a good approximation. But it is also possible that in this case the equations of Newtonian mechanics must be adapted to our theory of dark matter, taking into account the fact that the dark substance in which the superposed sphere is immerged can also behave as absolute emptiness.

The rule of adaptation is the following:

In the case of a galaxy G_A constituted of a superposed sphere with a centre O_{GA} and a radius R_{GA}:
a)In order to obtain the velocities and trajectories of the stars inside the superposed sphere in the frame whose the origin is O_{GA}, in order to obtain the gravitational field $\mathbf{G}_{GA}$ and the

gravitational potential U_{GA} permitting to obtain those velocities and trajectories, we take $\rho(r)=0$ in the equations of Newtonian mechanics if $r>R_{GA}$.

b)O_{GA} is accelerated by an acceleration $\mathbf{G}(O_{GA})$, $\mathbf{G}(O_{GA})$ being approximately equal to the gravitational field generated in O_{GA} by the dark substance in which G_A is immerged. ($\mathbf{G}(O_{GA})$ is defined by $\mathbf{F}_G(G_A)=m(G_A)\mathbf{G}(O_{GA})$, with $\mathbf{F}_G(G_A)$ is the gravitational force generated on G_A by the dark substance in which G_A is immerged, $m(G_A)$ mass of G_A. So the dark substance in which G_A is immerged acts on G_A as if G_A was a solid).

We remark that the preceding rule of a adaptation of the equations of Newtonian mechanics is equivalent to say that the dark substance in which G_A is immerged generates a field uniform and equal to $\mathbf{G}(O_{GA})$ defined previously in all the galaxy. The preceding rule of adaptation involves that the model that we used in order to obtain a superposed sphere with a density of dark substance in $1/r^2$ is always valid.

So this is a possible 1st example of adaptation of the equations of Newtonian dynamics to our theory of dark matter, that is very simple as will be all examples, and also involving great simplifications, as also will be all our examples. We remind nonetheless that it is possible that the preceding rule of adaptation be useless and that applying the classical equations of the Newtonian mechanics, we obtain that the model that we used remains valid with a good approximation.

2.7 Baryonic and dark radius of a galaxy.

We saw in the Section 2.1 that if r is the distance to the centre O of a spherical concentration of dark substance constituting a galaxy, then the expression of the density of dark substance $\rho(r)$ is given by, k_3 being a constant (See section 2.2, equation (7) $k_3=k_2/4\pi$):

$$\rho(r)=\frac{k_3}{r^2} \qquad (36)$$

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

$$M(r)=4\pi k_3 r \qquad (37)$$

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

$$v^2=\frac{GM}{r}=4\pi k_3 G \qquad (38)$$

Consequently:

$$k_3=\frac{v^2}{4\pi G} \qquad (39)$$

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)):

$$\rho(R)=\frac{k_3}{R^2}=\rho_0 \qquad (40)$$

Consequently:

$$R = \sqrt{\frac{k_3}{\rho_0}} = v\sqrt{\frac{1}{4\pi G\rho_0}} \qquad (41)$$

In a previous section, we called 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 of the galaxy. 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.

2.8 Other models of distribution of dark matter in galaxies.

In addition to the 1st model exposed in the section 2.2 of distribution of dark substance with a density in $1/r^2$, obtained for galaxies with a flat rotation curve, we must also consider a 2nd model of distribution of dark substance with a constant density $\rho(r)=\rho_0$, ρ_0 density of dark substance in which the galaxy is immerged. Generally, ρ_0 is the density of the intergalactic dark substance that we assumed to be homogeneous in temperature and in density in section 2.2.

This 2nd model of distribution of dark substance is the consequence of an important property of the dark substance that is a tendency to be homogeneous in temperature and in density. This property justifies our assumption that the intergalactic dark substance was homogeneous in temperature and in density. This property could be an effect of the expansion of the Universe that would cancel in some cases the effect of gravitation on the dark substance. Nonetheless it is more likely that this property be an intrinsic property of the dark substance, that consists in a 2nd example of adaptation of the equations of the Newtonian mechanics to our theory of dark matter. (A first example has been proposed in section 2.6). This rule of adaptation is the following:

If we have a spherical celestial object C, constituted of baryonic matter and dark substance, with a radius R_C, surrounded with dark substance with a constant density ρ_0, then we cannot have $\rho_{DM}(r)<\rho_0$, ($\rho_{DM}(r)$ density of dark substance), and therefore we have:

a)If applying the equations of Newtonian mechanics without taking into account the condition $\rho_{DM}(r)=\rho_0$ for $r>R_C$, we find a solution for the density of dark substance $\rho(r)$ such that:
If $r<R_C$, $\rho(r)\geq\rho_0$
If $r=R_C$, $\rho(r)=\rho_0$
If $r>R_C$, $\rho(r)\leq\rho_0$

Then according to the properties of dark substance, a solution is $\rho_{DM}(r)$ with:
If $r<R_C$ $\rho_{DM}(r)=\rho(r)$
If $r\geq R_C$ $\rho_{DM}(r)=\rho_0$

b) If applying the equations of Newtonian mechanics without taking into account the condition $\rho_{DM}(r)=\rho_0$ for $r>R_C$, we find a solution for the density of dark substance $\rho(r)$ such that whatever be r, $\rho(r)<\rho_0$, then according to the properties of dark substance, a solution is $\rho_{DM}(r)$ with:
Whatever be r: $\rho_{DM}(r)=\rho_0$.

It is clear that the point a) involves the validity of the model of a superposed sphere with a density of dark matter in $1/r^2$ surrounded by dark substance with a density constant and equal to ρ_0, meaning our model of distribution of dark substance for galaxies with a flat rotation curve.

The point b) involves the validity of a distribution of dark substance with a density constant and equal to ρ_0, for galaxies, but also stars and planets.

It must exist other models of distribution of dark matter, for instance in the case in which 2 galaxies with a flat rotation curve collide. Nonetheless, this latter case must be very rare. In what follows, we will consider only those 2 models of distribution of dark substance, and we will see that it will lead to theoretical predictions in agreement with astronomical observations in the case of clusters. For the same reason, we will consider that for planets and stars, we have the 2nd model of distribution of dark matter (constant density).

2.9 Other observations of dark matter.

We are now going to interpret using our new theory of dark matter experimental data linked to the velocities of galaxies in clusters.

According to what precedes, the velocity of a galaxy in a cluster is determined by:

-The baryonic mass inside the cluster (stars, gas..)
-The mass of the dark halos of galaxies.
-The mass of the intergalactic dark substance.

We admit using the preceding section that the galaxy cluster contains only either galaxies with a density of dark substance in $1/r^2$ as defined in the section 2.1 (1st model of distribution of dark matter around galaxy) or galaxies with a homogeneous density of dark matter equal to ρ_0, density of the intergalactic dark substance (2nd model of distribution of dark matter around galaxy).

We obtain a very interesting result concerning the mean density of galaxies corresponding to the 1st model of distribution (density of dark substance in $1/r^2$):

Indeed, according to the equation (18), for those galaxies the dark radius is:

$$R_S=(2k_0T/4\pi G\rho_0)^{1/2} \qquad (42)$$

According to the equation (8) :

$$k_2=2k_0T/G \qquad (43)$$

Consequently :

$$R_S=(k_2/4\pi\rho_0)^{1/2} \qquad (44)$$

So according to the equation (9) the total mass of the dark halo is:

$$M_S(R_S)=\frac{k_2^{3/2}}{(4\pi\rho_0)^{1/2}} \qquad (45)$$

Let us now calculate the mass of a sphere with the same radius R_S and a density equal to the density of the intergalactic dark substance ρ_0 :

$$M_I(R_S) = \rho_0 \frac{4}{3}\pi(\frac{k_2}{4\pi\rho_0})^{3/2} = \frac{1}{3}\frac{k_2^{3/2}}{(4\pi\rho_0)^{1/2}} \quad (46)$$

Consequently :

$$M_I(R_S)=M_S(R_S)/3 \quad (47)$$

So the mean density of the halos of galaxies belonging to the 1st model of distribution of dark matter is equal to $3\rho_0$, whatever be the radius and the temperature of the considered halo, and consequently whatever be the orbital velocity of stars in the considered galaxy.

According to the previous equation (47) we can expect that the dark mass of a cluster be much greater than the baryonic matter in the galaxies of this cluster. Indeed we have seen that according to the theory of dark matter exposed here, for a galaxy corresponding to the 1st model of distribution of dark substance, R_B being the baryonic radius of the galaxy, then the mass $M_B(R_B)$ of baryonic matter contained in the sphere with a radius R_B (centre O, centre of the galaxy) was much lower than the mass $M_S(R_B)$ of the dark substance contained in the same sphere. And consequently, because $R_B<R_S$, the total mass of the dark halo $M_S(R_S)$ is much greater than the total mass of baryonic matter contained by the galaxy . But according to the equation (47), the mean density of the halo is only 3 times of the minimum density of dark matter inside the cluster. (Because we supposed that only the 1st and the 2nd model of distribution of dark matter existed for galaxies). Consequently we can expect that the dark mass of clusters be much greater than the baryonic mass of the galaxies belonging to this cluster.

So for a cluster A with a mean density ρ_{mA}, we obtain if we neglect the baryonic density :

$$\rho_0<\rho_{mA}<3\rho_0 \quad (48)$$

Consequently the mean densities of clusters permit to obtain an estimation of the density ρ_0 of the intergalactic dark substance. Moreover if A1 and A2 are 2 clusters with mean densities ρ_{mA1} and ρ_{mA2} with for instance $\rho_{mA1}<\rho_{mA2}$, then according to the previous relation :

$$\rho_{mA2}<3\rho_{mA1} \quad (49)$$

We will see that the preceding theoretical prediction is in agreement with astronomical observations.

It is interesting to introduce the mean volume of dark halo corresponding to the 1st model of distribution of dark substance per galaxy Vol_{SG}. Then if clusters contain the same kind of galaxies in the same proportions (which is not always the case), we can express the mean density of dark substance ρ_{mA} as a function of N_A the number of galaxies inside the cluster A, and Vol_{SG}. Indeed we immediately obtain, using that the mean density of dark halos corresponding to the 1st model of distribution of dark substance is equal to $3\rho_0$ (Equation (47)) and that elsewhere the density of dark substance is equal to ρ_0 ,Vol_A being the volume of the cluster:

$$\rho_{mA} = \frac{1}{Vol_A}[3\rho_0 N_A Vol_{SG} + \rho_0(Vol_A - N_A Vol_{SG})] \quad (50)$$

So we obtain, ρ_{mAG} being the mean density of the number of galaxies in the cluster, $\rho_{mAG}=N_A/Vol_A$:

$$\rho_{mA}=\rho_{mAG}(2\rho_0 Vol_{SG})+\rho_0 \quad (51)$$

Moreover, $Vol_A(H)$ being the volume of dark halo of galaxies belonging to the 1st model in the cluster A, we have always, still using that the mean density of dark halos corresponding to the 1st model of distribution of dark substance is equal to $3\rho_0$ (Equation (47)) and that elsewhere the density of dark substance is equal to ρ_0:

$$\rho_{mA} = \frac{1}{Vol_A}[3\rho_0 Vol_A(H) + \rho_0 (Vol_A - Vol_A(H))] \quad (52)$$

$$\rho_{mA} = 2\rho_0 \frac{Vol_A(H)}{Vol_A} + \rho_0 \quad (53)$$

An important particular case is the case in which we have $Vol_A(H)/Vol_A<<1$ for all clusters. Then we have for all clusters ρ_{mA} very close to ρ_0 for all clusters. This implies, ρ_0 depending on the Cosmological redshift z, that clusters corresponding to the same z have approximately the same mean density ρ_{mA} very close to $\rho_0(z)$.

We remind that we assumed that we could neglect the contribution of baryonic matter in order to obtain the mean density of the cluster ρ_{mA}. In what follows we will assume that we have generally for clusters $Vol_A(H)/Vol_A<<1$ and consequently $\rho_{mA}\approx\rho_0$. We remind that ρ_0 depends on t, age of the Universe. We will see further that the previous assumption is in agreement with astronomical observations.

Now we are going to study 3 dynamical models of clusters permitting to obtain some relations between the mass of clusters and the velocities of galaxies belonging to those clusters. Only the 3rd model is new and the 2nd model is generally admitted in the SCM, but without model of dark matter. We will see that the 3 models have theoretical predictions that are close one another concerning the relations for a given cluster A between the mass of this cluster, its radius, and the dispersion velocity of the galaxies or the maximal recession velocity of galaxies of this cluster A. Nonetheless, we will see that the 1st model is not compatible with astronomical observations, and the 3rd model is based on our model of dark matter and moreover permits to interpret some astronomical observations not interpreted by the 2nd model.

According to a 1st dynamical model of clusters, galaxies turn around the centre of a cluster the same way planets turn around the sun or stars turn around the centre of the Milky Way. So we will call the *planetary dynamical model* of clusters this 1st model.

R_A being the radius of a cluster A, V_{MA} being the orbital velocity of a galaxy at a distance R_A from the centre O_A of A (We will obtain that V_{MA} is also the maximal orbital velocity of galaxies according to this 1st dynamical model), M_A being the mass of the cluster A, we obtain assuming a spherical symmetry of the distribution of the dark substance and neglecting the baryonic matter, using as in the previous sections the Newton's Universal law of attraction, the Gauss theorem and the classical Newton's dynamic law $\mathbf{F}_G=m\boldsymbol{\gamma}$:

$$\frac{GM_A}{R_A^2} = \frac{V_{MA}^2}{R_A} \qquad (54)$$

$$\frac{GM_A}{R_A} = V_{MA}^2 \qquad (55)$$

Nonetheless, some astronomical observations that are very important in order to study the validity of our different dynamical models of clusters have been realized concerning the Coma cluster that we will name A4 [(10)]. Using some astronomical observations of the Coma cluster, some astrophysicists realized a graph giving for some galaxies G belonging to the Coma cluster the recession velocity $V_R(G)$ observed from a point O_T close to the earth and being the origin of an inertial frame R_T in which the velocity of the earth is small relative to c, as a function of the angle a(G) between the lines (O_T,O_4) and (O_T,O_G), with O_4 the centre of the Coma cluster and O_G the centre of the galaxy G.

According to this graph, the gap between the maximal recession velocity and the minimal recession velocity is maximal for an angle a(G)=0 (5000 km/s). Then it decreases.

And this contradicts the 1st planetary dynamical model of clusters because according to this model for a galaxy with a(G)=0 the velocity of G (as a vector) is perpendicular to the line (O_T,O_G) and consequently the recession velocity v(G) should be close to 0 for a(G)=0. And also according to this model the gap between the maximal recession velocity and the minimal recession velocity should increase with a(G). So the previous astronomical observations concerning the Coma cluster contradict the 1st planetary dynamical model of clusters.

A 2nd possible dynamical model of clusters is the model generally used in the Standard Cosmological Model (SCM)[(8)] based on the Virial's theorem. So we will name this model the *Virial's dynamical model* of clusters.

According to this model, if σ_A is the velocity dispersion inside a cluster A, M_A being the mass of the cluster and R_A its radius:

$$\frac{GM_A}{R_A} \approx \alpha_A \sigma_A^2 \qquad (56)$$

In the previous expression, α_A is of the order of the unity and depends on the cluster A. Very often we take it equal to 1 or 2. We can also replace in the preceding expression R_A by the Abel radius [(7)].

We remind that the equation (56) obtained by the Virial's model seem to be approximately in agreement with astronomical observations. We will see that it will be also the case for the 3rd dynamical model of cluster.

We are now going to propose a 3rd dynamical model of clusters based on our model of dark matter. In this model, G_A being a galaxy of a cluster A situated at a point P of the cluster, we consider only the gravitational potential generated in P by the dark substance. So we will name this 3rd model the *dynamical model of the dark potential* of clusters.

In order to obtain in this 3rd model the gravitational potential generated by the dark substance at any point of the cluster, it is necessary to expose the elements of our theory of dark matter permitting to calculate the gravitational field **G** and the gravitational potential U at any point of the Universe. We have already seen 2 examples of adaptation of the equations of Newtonian mechanics to our theory of dark matter (Section 2.6 and 2.8). We have seen that those adaptations are necessary because in the Newton's Theory of Gravitation, only baryonic matter exists and moreover, there is no expansion, which is not the case in our theory of dark matter. In order to obtain **G**(Q) and U(Q) at a point Q of the Universe using the equations of Newtonian mechanics, in order to take into account the density of dark substance at a point P, we must distinguish the cases in which P is inside a concentration of baryonic matter or if it is not the case:

a)Let us suppose that P is a point of the Universe belonging to none concentration of baryonic matter, but belonging to the intergalactic dark substance. We know that the density of dark substance in P is equal to ρ_0 (Section 2.3 and 2.8). Because of the expansion of the Universe, we will admit in our theory of dark matter that there is a symmetry for all points P with the preceding properties, involving that we must take $\rho(P)=0$ in the equations of Newtonian mechanics in order to obtain **G**(Q) and U(Q) at a point Q. This means that dark substance behaves as it was absolute emptiness in P, the same way as in Section 2.8.

So the previous rule a) justifies that between clusters, dark matter behaves as absolute emptiness, in agreement with astronomical observations.

b)If P belongs to an important concentration of baryonic matter (cluster, galaxy, star..), then the symmetry in P is broken: We must take $\rho(P)=\rho_0$ (or $\rho(P)$ is equal to the density of dark substance in P) in the equations of Newtonian mechanics in order to obtain **G**(Q) and U(Q).

So we have a 3rd example of adaptation of the equations of Newtonian mechanics to our theory of dark matter that is due to the expansion of the Universe, that did not exist in the Newton's Theory of Gravitation.

In this 3rd dynamical model of cluster, we model a cluster as a system (ideal cluster) with the following properties:

a)The cluster is a sphere with a radius R_A, containing galaxies and dark substance, presenting a spherical symmetry.

b)In order to obtain **G** and U in the cluster, permitting to obtain the velocities, accelerations and energies of the galaxies of the cluster, those galaxies being modeled as punctual masses (coinciding with their centre of mass), we can consider that inside the cluster, the density is homogeneous and equal to ρ_{mA}. (Because of the equation (53), assuming $Vol_A(H)/Vol_A<<1$ and neglecting the baryonic matter of the cluster).

Concerning the galaxies of the cluster, the velocities and energies are calculated in the frame whose the origin is O_A centre of the cluster. Galaxies of the cluster are modeled the following way :

c)We define for a galaxy G_A the ratio $r(G_A)$ defined by $r(G_A)=E_T(G_A)/m(G_A)$ ($E_T(G_A)$ total energy of the galaxy G_A and $m(G_A)$ mass of G_A) and r_{AMax} as being the maximal value of this ratio. Then according to our model of galaxy cluster:
(i)The radius R_A of the cluster is the maximal possible distance between a galaxy G_A of the cluster and O_A centre of the cluster (with the condition $r(G_A)\leq r_{AMax}$).

(ii)The galaxies G_A with $r(G_A)=r_{AMax}$ have a great density in the cluster (not compulsory homogeneous). This means that at any point Q of the cluster, it exists a galaxy G_A close to Q such that $r(G_A)=r_{AMax}$. Moreover in the case in which $Q=O_A$ centre of the cluster, because of the spherical symmetry if **u** is any unitary vector, it exists a galaxy G_{A0} close to O_A with $r(G_{A0})=r_{AMax}$ such that, $\mathbf{V}(G_{A0})$ being the vector velocity of G_{A0}: $\mathbf{V}(G_{A0}).\mathbf{u} \approx V(G_{A0})$, with $V(G_{A0})$ norm of $\mathbf{V}(G_{A0})$. (This means that the vector $V(G_{A0})$ is approximately collinear to **u**).

d)The galaxies G_A such that $r(G_A)=r_{AMax}$ keep their energy and their mass, and consequently r_{AMax} is constant.

Therefore we obtain according to the preceding property a) of our model of cluster and also to our adaptation of the equations of the Newtonian mechanics (Preceding example):

$$U(R_A)=-GM_A/R_A \qquad (57a)$$

$$\mathbf{G}(R_A)=-GM_A/R_A^2\ \mathbf{u} \qquad (57b)$$

Moreover, G_A being a galaxy situated at a distance r from O_A, $m(G_A)$ and $V(G_A)$ being the mass and the velocity of G_A the total energy $E_T(G_A)$ of G_A is therefore, U(r) being the gravitational potential at a distance r from O_A:

$$E_T(G_A)=(1/2)m(G_A)V(G_A)^2+m(G_A)U(r) \qquad (58)$$

Using the spherical symmetry of our model of cluster, applying the Gauss theorem, M(r) being the mass of the sphere with the centre O_A and the radius r, the gravitational field **G**(r) is then:

$$\mathbf{G}(r) = -G\frac{M(r)}{r^2}\mathbf{u} \qquad (59)$$

According to the property b) of our model of cluster, M(r)=(4/3)πr3ρmA and consequently :

$$\mathbf{G}(r) = -G\frac{4}{3}\pi r\rho_{mA}\mathbf{u} \qquad (60)$$

By definition **G=-Grad**(U), so we obtain, C_{AU} being a positive constant at a given age of the Universe:

$$U(r)=G(4/6)\pi r^2\rho_{mA}-C_{AU} \qquad (61)$$

This equation can also be written, in the approximation that the density of dark matter in the cluster is approximately constant an equal to ρ_{mA}, M(r) being the mass of the sphere with the centre O_A and a radius r :

$$U(r)=GM(r)/2r-C_{AU} \qquad (62)$$

Consequently we have, $M_A=M(R_A)$ being the mass of the cluster, using the equation (57a) :

$$\frac{GM_A}{2R_A} - C_{AU} = -\frac{GM_A}{R_A} \qquad (63)$$

So we finally obtain, with M_A and R_A depending a priori on t, age of the Universe:

$$C_{AU} = \frac{3}{2}\frac{GM_A(t)}{R_A(t)} \qquad (64)$$

Therefore, using the equation (58), for a galaxy at a distance r from O_A :

$$\frac{1}{2}m(G_A)V(G_A)^2 + Gm(G_A)\frac{M(r)}{2r} = E_T(G_A) + m(G_A)C_{AU} \quad (65a)$$

Moreover we have defined, in the property c) of our model of cluster, r_{AMax} as being the maximal value of $r(G_A)=E_T(G_A)/m(G_A)$. So we have for any galaxy G_A:

$$\frac{1}{2}V(G_A) + G\frac{M(r)}{2r} \leq r_{AMax} + C_{AU} \qquad (65b)$$

We are now going to consider a galaxy G_{Al} at the limits of the cluster ($r=R_A$) and a galaxy G_{A0} in O_A (r=0).

According to the property c)(i) of our model of cluster, the radius R_A of the cluster is the maximal possible distance between a galaxy G_A of the cluster and O_A the centre of the cluster with the condition $r(G_A) \leq r_{AMax}$. Considering the previous inequality (65b) we have therefore for a galaxy G_{Al} at the limit of the cluster, $V(G_{Al})=0$ and:

$$G\frac{M(R_A)}{2R_A} = r_{AMax} + C_{AU} \qquad (66)$$

For a galaxy G_{A0} situated at the centre of the cluster (r=0), such that $r(G_{A0})=r_{AMax}$, according to the equation (65a):

$$\frac{1}{2}V(G_{A0})^2 = r_{AMax} + C_{AU} \qquad (67)$$

Therefore, because of the equation (65b), $V(G_{A0})$ is equal to the maximal velocity of the galaxies in the cluster V_{MA}. Consequently, using the equations (66) (67) we obtain:

$$V_{MA}^2 = \frac{GM_A}{R_A} \qquad (68a)$$

Moreover according to the property c) of our model of cluster, **u** being any unitary vector, it exists a galaxy G_{A0} close to O_A such that $r(G_{A0})=r_{AMax}$ and $\mathbf{V}(G_{A0}).\mathbf{u} \approx V(G_{A0})$ ($\mathbf{V}(G_{A0})$ vector velocity of G_{A0} and $V(G_{A0})$ its norm). Consequently if we define $V_{MA}(\mathbf{u})$ as the maximal value of $\mathbf{V}(G_A).\mathbf{u}$, considering all galaxies G_A of the cluster, then $V_{MA}(\mathbf{u}) \approx V_{MA}$.

In the astronomical observations, G_A being a galaxy of the cluster, **u** being the unitary vector of the direction of observation, we measure $V_T(G_A)(\mathbf{u}) = \mathbf{V}_T(G_A).\mathbf{u}$, component on **u** of the vector velocity $\mathbf{V}_T(G_A)$, velocity of G_A in an inertial frame R_T whose the origin is a point O_T close to the earth, and in which the velocity of the earth is small relative to c. We then obtain $V_{MA}(\mathbf{u})$ by the following expression, with evident notations:

$$V_{MA}(\mathbf{u})=(1/2)[\mathrm{Max}_A(V_T(G_A)(\mathbf{u}))-\mathrm{min}_A(V_T(G_A)(\mathbf{u}))] \qquad (68b)$$

Considering that the validity of our model of cluster described by the properties a)b)c)d) is only an approximation, we introduce a constant β_A, depending on the cluster and on the vector **u**, such that, $V_{MA}(\mathbf{u})$ being defined by the previous expression (68b):

$$V_{MA}(\mathbf{u})^2 = \beta_A \frac{GM_A}{R_A} \qquad (69)$$

So we obtain in our 3rd model of the dark potential an equation analogous to the equations (55)(56). Nonetheless, this 3rd model predicts that the velocity of galaxies is maximal for galaxies close to the centre of the cluster, in agreement with astronomical observations [7], which is not the case for the 2nd Virial's model.

Moreover, A_i and A_j being 2 clusters, using $M_{Ai}=(4/3)\pi\rho_{mAi}R_{Ai}^3$, we obtain immediately, using the equation (68a) :

$$\frac{\rho_{mAj}}{\rho_{mAi}} = (\frac{V_{MAj}}{V_{MAi}})^2(\frac{R_{Ai}}{R_{Aj}})^2 \qquad (70a)$$

But we have seen in the equation (53) that if Ai and Aj are 2 galaxy clusters corresponding to the same Cosmological redshift z, if moreover $Vol_{Ai}(H)/Vol_{Ai}<<1$ and $Vol_{Aj}(H)/Vol_{Aj}<<1$, then $\rho_{mAj}/\rho mAi$ should be close to the unity.

Let us consider for instance the Virgo cluster A2 ($z_2<0{,}01$) and the Coma cluster A4 ($z_4=0{,}03$). According to astronomical observations considering the galaxies NGC4388 and IC3258 we obtain $V_{MA2}(\mathbf{u}_2)=1500$ km/s [11]. Moreover we can take $R_{A2}=2{,}2$ Mpc [12]. For the Coma cluster, we can take $V_{MA4}=2500$ km/s [10] and $R_{A4}=12{,}5$ million l.y=3,8 Mpc [13] . (We took a median value among values given by scientific literature). Then we obtain using the previous experimental data and the equation (70a) $\rho_{mA4}/\rho_{mA2}=0{,}93$. The agreement between this value and the theoretical prediction (ρ_{mA4}/ρ_{mA2} close to 1) is good because an error of only 10% on one of the parameters involves an error of 20% on the final result.

In order to obtain the evolution of the mass and of the radius of a galaxy cluster, we use that according to the property d) of our model of cluster, r_{AMax} keeps itself. According to the equation (64), replacing the Cosmological time t by the corresponding Cosmological redshift z, $C_{AU}(z)=(3/2)GM_A(z)/R_A(z)$. So using the equation (66) we obtain:

$$r_{AMax} = -G\frac{M_A(z)}{R_A(z)} \qquad (70b)$$

Therefore, because according to the property d) of our model of galaxy cluster r_{AMax} keeps itself, $M_A(z)/R_A(z)$ also keeps itself. Moreover $M_A(z)=(4/3)\pi R_A(z)^3\rho_{mA}(z)$, and according to the equation (53), with $Vol_A(H)/Vol_A<<1$, $\rho_{mA}(z)\approx\rho_0(z)$, $\rho_0(z)$ being the density of the intergalactic dark substance for the Universe corresponding to a Cosmological redshift z. Therefore, according to the previous equation (70b), the evolution of $M_A(z)$ and $R_A(z)$ is in $1/\rho_0(z)^{1/2}$. But we will see further in this section that $\rho_0(z)\approx\rho_0(0)(1+z)^3$. Consequently we have:

$M_A(z)\approx M_A(0)/(1+z)^{3/2}$

$R_A(z)\approx R_A(0)/(1+z)^{3/2}$ (70c)

For instance we obtain $M_A(2)\approx M_A(0)/5$, $M_A(1)\approx M_A(0)/3$. Which means that for instance the Coma cluster was approximately 5 times less massive for an Universe corresponding to a Cosmological redshift z=2.

The fact that it seems that there is more dark matter close to the centre of clusters could be explained by the fact that the most massive galaxies with a flat rotation curve are close to the centre of clusters.

The density of the intergalactic dark substance depends on the age of the Universe. We will use as previously the notation $\rho_0(0)$ in order to represent the density of dark matter at the present age of the Universe (z=0) and $\rho_0(z)$ in order to represent the density of the intergalactic dark substance at the age of the Universe corresponding to a cosmological redshift z. The estimation of the intergalactic density $\rho_0(0)$ obtained using the previous 3^{rd} dynamical models of clusters permits other theoretical predictions confirming the validity of our model of dark matter.

Indeed, according to the equation (18), for a galaxy corresponding to the 1^{st} model (density of dark substance in $1/r^2$) immerged in the intergalactic dark substance, the radius R_S of this galaxy is given by, at the present age of the Universe:

$$R_S=\left(\frac{2k_0T}{4\pi G\rho_0(0)}\right)^{1/2} \qquad (70d)$$

Therefore, v being the orbital velocity of stars in this galaxy, according to the equation (10):

$$R_S=\frac{v}{(4\pi G\rho_0(0))^{1/2}} \qquad (70e)$$

But the dynamical model of the dark potential exposed previously permits to obtain an estimation of $\rho_0(0)$. Let us for instance consider the case of the Milky Way. In order to get $\rho_0(0)$, we apply the dynamical model of the dark potential to the Virgo cluster A2(z_{A2}<0,01). According to the equation (68) we obtain, ρ_{mA} being the mean density of the cluster A, and using $M_A=\rho_{mA}(4/3)\pi R_A^3$:

$$\rho_{mA}=\frac{1}{(4/3)\pi G}\frac{V_{MA}^2}{R_A^2} \qquad (70f)$$

If A is a cluster with z_A very close to 0, and assuming $Vol_A(H) << Vol_A$ in the equation (53), then $\rho_{mA} \approx \rho_0(0)$. Therefore we obtain, replacing $\rho_0(0)$ in the equation (70e) by ρ_{mA} given by the equation (70f):

$$R_S = \frac{v}{\sqrt{3}} \frac{R_A}{V_{MA}} \qquad (70g)$$

Taking as the cluster A the Virgo cluster A2, with the preceding experimental data , $z_{A2}<0{,}01$, $R_2=2{,}2$ Mpc=7,3 million l.y, $V_{M2} \approx 1500$ km/s and $v \approx 210$ km/s, we find the dark radius of the Milky Way $R_{SM.W} \approx 550000$ l.y. This result is not only coherent, but it gives also a dark radius of the Milky Way superior to the distance between the centre of the Milky Way and the Magellanic clouds (approximately 250000 l.y) [14]. So this is also a new and remarkable prediction of our model of dark matter.

We know that we observe an effect called *gravitational lensing*, predicted by General Relativity, that consists in a deviation of luminous rays due to the mass of clusters. We have seen, according to the 3rd example of adaptation of the equations of Newtonian mechanics, that the dark substance between clusters behaved as it was absolute vacuum in the equations of Newtonian mechanics. Consequently, generalizing this to the equations of General Relativity, in order to obtain the deviation of a luminous ray by a cluster, we can apply the equations of General Relativity as if the cluster was surrounded by absolute vacuum. It would be interesting to compare the mass of a cluster obtained by gravitational lensing with the mass obtained using the previous 3rd dynamical model of cluster.

Moreover we know that the study of the CMB shows the existence of anisotropies due to the density of dark substance in the Universe. We can distinguish 2 kinds of density of dark matter: The 1st kind of density is the density of dark matter with a gravitational effect. Then in order to obtain the mean density of dark matter in the Universe corresponding to this 1st kind of density, we must only take into account the dark matter inside clusters. We easily obtain this density $\rho m_{UG}(z)$ as a function of the volume of the Universe $Vol_U(z)$, of the total volume of clusters $Vol_U(A)(z)$ and of the intergalactic density $\rho_0(z)$ (corresponding to a Cosmological redshift z). We assume that the mean densities of clusters is approximately equal to the intergalactic density $\rho_0(z)$:

$$\rho_{mUG}(z) = \rho_0(z) \frac{Vol_U(A)(z)}{Vol_U(z)} \qquad (70h)$$

The 2nd kind of density of dark matter takes into account all the dark substance in the Universe. We are now going to obtain this last density $\rho_{mU}(z)$.

As in the case of clusters, it is interesting to introduce $Vol_U(z)$ volume of the Universe corresponding to a Cosmological redshift z and $Vol_U(H)(z)$ the volume of dark halos corresponding to distributions of dark substance with a density in $1/r^2$ in this Universe. We then obtain the same way we obtained the equation (53), neglecting baryonic matter, $\rho_{mU}(z)$ being the mean density of dark substance in a Universe corresponding to a Cosmological redshift z:

$$\rho_{mU}(z)=2\rho_0(z)(Vol_U(H)(z)/Vol_U(z))+\rho_0(z) \qquad (70i)$$

(If we take into account the dark substance on which are superposed the dark halos, we must replace in the previous equation the factor 2 by the factor 3).

With the approximation $Vol_U(H)(z)/Vol_U(z)<<1$ we obtain:

$$\rho_{mU}(z)=\rho_0(z) \qquad (70j)$$

We also remark that if we assume that the dark mass of the Universe keeps itself, 1+z being the factor of expansion of the Universe between the age of the Universe corresponding to the redshift z and the present age of the Universe:

$$\rho_{mU}(z)=\rho_{mU}(0)(1+z)^3 \qquad (70k)$$

Therefore, according to the equation (70j):

$$\rho_0(z)=\rho_0(0)(1+z)^3 \qquad (70l)$$

We have seen that we could obtain an estimation of $\rho_0(0)$, consequently we can obtain a prediction of $\rho_0(z)$, that we used previously in the study of the evolution of clusters.

3.DARK ENERGY IN THE UNIVERSE

3.1 Introduction

In the preceding Part 2. we exposed a theory interpreting the whole of astronomical observations linked to dark matter. We have seen that the concept of dark substance filling all the Universe led to propose a spherical geometrical form for the Universe. In this Part 3. concerning dark energy we are going to propose a new model of expansion of the Universe based on the spherical form of the Universe introduced previously in our theory of dark matter and also on the physical interpretation of the CMB Rest Frame (CRF). We will see that in this new model of expansion we can define distances that are completely analogous to distances used in Cosmology in the Standard Cosmological Model (SCM), (angular distance, luminosity distance, commoving distance, light-travel distance) and also a Hubble constant analogous to the Hubble constant defined in the SCM. We will see that the model of expansion of the Universe proposed by our theory of dark matter and of dark energy is physically much simpler and more understandable than the model of expansion of the Universe proposed by the SCM. We are going then to propose inside the new model of expansion 2 possible mathematical models of expansion (permitting to obtain the factor of expansion 1+z and the Cosmological redshift z). The 1st mathematical model of expansion is based as the model of expansion of The Universe of the SCM on the equations of General Relativity. As the SCM it needs the existence of a dark energy, and it predicts the same values as the SCM for the Cosmological distances used in Cosmology and the Hubble's constant. The 2nd mathematical model of expansion is much simpler but despite of its simplicity, it predicts values of the Hubble's constant and of Cosmological distances that are in excellent agreement with astronomical observations. Moreover this 2nd mathematical model of expansion has the remarkable property of not needing the existence of dark energy, contrary to the 1st mathematical model of expansion and to the mathematical model of expansion of the SCM. Nonetheless we will see that our theory of dark matter and of dark energy predicts the existence in all the Universe of a dark energy that is the internal energy of the dark substance that we modeled as an ideal gas in this theory. It will appear in this Part 3. as in the Part 2. of this article that our theory of dark matter and of dark energy is compatible with Special Relativity and General Relativity, because according to this theory the CMB Rest Referential cannot be detected by usual physical experiments in laboratory but only by the observation of the CMB. So we will admit (locally) in this Part 3. as in Part 2. the validity of Special Relativity and General Relativity even if its is not the only possibility [(15)(16)].

As in the Part 2., we will see in this Part 3. that our theory of dark matter and of dark energy remains compatible with the SCM [(3)(4)(5)], in order to interpret most Cosmological phenomena that are not directly linked to dark matter or dark energy, for instance primordial elements abundance, apparition of baryonic particles (for the same z as in the SCM), formation and apparition of stars and galaxies (for the same z as in the SCM), apparition of the CMB (For the same z as in the SCM), evolution of the CMB (in 1/(1+z) as in the SCM, anisotropies of the CMB…

3.2 Physical Interpretation of the CRF. Local and Universal Cosmological frames.

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 in our theory of dark matter and dark energy a physical interpretation of this frame, which will permit to define a new model of expansion of the Universe that is also based on the geometrical model of the Universe (spherical), admitted in our theory. This new model of expansion of the Universe permits to define Cosmological variables (Cosmological time, distances used in Cosmology, Hubble Constant) completely analogous to their definition in the SCM. In order to obtain the Cosmological redshift z, which is fundamental in the new model of expansion of the Universe as it was in the SCM, our theory of dark matter and of dark energy proposes 2 mathematical models of expansion. The 1st mathematical model is based on the equations of General Relativity as the SCM. According to this 1st mathematical model of expansion, Cosmological variables, and in particular the Cosmological redshift z, are given by the same mathematical expressions as in the SCM, but for a flat Universe because according to the new model of expansion of the Universe, the Universe is flat. The 2nd mathematical model of expansion of the Universe is much simpler. Despite of this its theoretical predictions are in excellent agreement with astronomical observations.

Concerning the physical interpretation 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 astronomical observations. Indeed this hypothesis implies that the Cosmological time is also with a very good approximation the time of our earth. Indeed let us suppose that the Cosmological time is the time of the CRF. We then will call the CRF *local Cosmological frame*, and we will designate it as R_{LC}. Let H_S be a clock linked to the sun and giving the time of the inertial frame R_S linked to the sun, and V_S the velocity of R_S relative to R_{LC}. According to Special Relativity the transformations between R_S and R_{LC} are Lorentz transformations, and consequently if T_S is a time measured by H_S corresponding to a Cosmological time T_C of R_{LC}, then: $T_S=T_C(1-V_S^2/c^2)^{1/2}$. Consequently if $V_S<<c$, which is the case (V_S is the velocity of the sun relative to the local CMB rest frame and observation of the CMB gives $V_S\approx$ 300km/s) we get $T_S\approx T_C$. We remark that it is completely impossible that locally all the inertial frames (with Lorentz transformations between themselves) give the Cosmological time (Age of the Universe) and consequently it was not at all evident that the time of our sun be approximately the Cosmological time.

-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 keeps itself, as a vector or as a norm. We will call *local velocity* this velocity **c**. The problem is the evolution of this local velocity, the photon traveling in the Universe. It is clear that the simplest hypothesis would be that the local velocity of the photon keeps itself the photon traveling in all the Universe, and consequently being situated in many different CRF. Here also we will see that this simple 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, meaning given by clocks at rest in any 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.

Considering its important in Cosmology, according to our theory of dark matter and dark energy, we will also call the CRF *local Cosmological frame*.

We remind that 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. We remark that according to astronomical observations, locally (meaning close to the Milky Way) all galaxies have a local velocity (meaning relative to the local CRF) very small relative to c. Consequently, according to the Postulate 3b) the time of any star of any galaxy close to the Milky Way is very close to the Cosmological time.

It is natural to assume that the previous property can be generalized to all the Universe, then we obtain that the time of any star (and consequently of any planet) of the Universe is approximately the Cosmological time.

We know need to define completely all the CRF. We have seen previously that according to our theory of dark matter the Universe was finite with borders and we will assume that it is spherical, with a centre O. We remind that it is possible to generalize what follows for many other geometrical models of finite Universes, with borders. So we assume that the Universe is modeled as a sphere in expansion with a centre O, and with a radius $R_E(t)$, t being the Cosmological time. We have seen in Section 2.5 that $R_E(t)=R_E(t_0)(1+z)$, t and t_0 being any Cosmological times ($t>t_0$), with 1+z factor of expansion of the Universe between t and t_0. We will see further how we can get 1+z, using mathematical models of expansion.

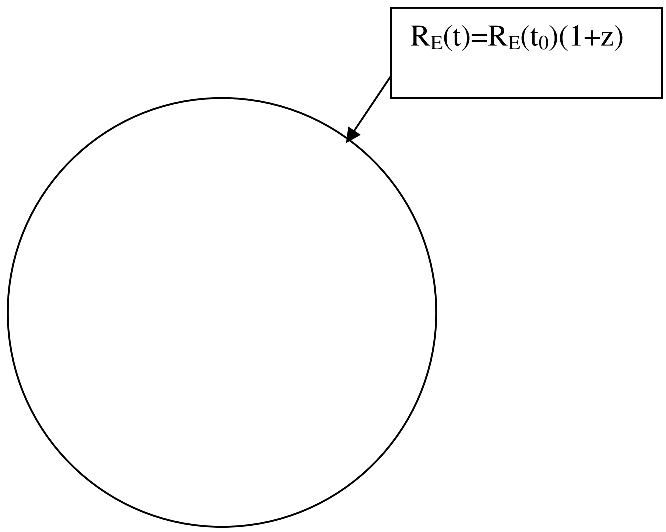

Figure 2:The spherical model of the Universe in expansion.

In order to define completely the CRF (or equivalently the local Cosmological frames) we introduce a new kind of frame R_C, called *Universal Cosmological frame*, whose the origin is O centre of the Universe. The time of the Universal Cosmological frame R_C is defined as being the Cosmological time of the CRF (See Postulate 3b)). Moreover the axis of R_C are defined as being parallel to the corresponding axis of the RRC (Postulate 3a)), and as giving locally the same distances as the RRC.

The Universal Cosmological frame R_C permits to define distances between any couple of points (A,B) of the Universe, contrary to local Cosmological frames (RRC) that give only local distances. We will see that we can express all the classical Cosmological distances used in the SCM (luminosity distance, angular distance, commoving distance and light-travel distance) as functions of the distances measured in R_C, of the Cosmological time and of the Cosmological redshift z.

We are now going to define very important points of the Universal Cosmological frame R_C, called *commoving points* of the sphere in expansion.

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

A *commoving point* $A(t)$ of the sphere in expansion is defined by :

-A(t) remains on the segment [O,P(t)]
-$OA(t)=aOP(t)$, a being a constant belonging to [0,1]. (71)

So O and P(t) are particular commoving points of the sphere in expansion. Moreover if A(t) and B(t) are 2 commoving points of the sphere in expansion, 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 of the Universe between t_1 and t_2) then we have the 2 relations:

$$A(t_2)B(t_2)=(1+z)A(t_1)B(t_1) \qquad (72)$$

And :

$$[A(t_2),B(t_2)]//[A(t_1),B(t_1)] \qquad (73)$$

(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)

We are going to show using Thales Theorem that the previous relations (72)(73) remain valid, A(t), B(t) being any couple of commoving points of the sphere in expansion (defined by relations (71)), not compulsory belonging to the same segment [O,P(t)].

Let us consider any 2 commoving points (different from O) $A(t_1)$ and $B(t_1)$ at a Cosmological time t_1. We assume that A(t) belongs to the segment [O,P(t)], P(t) point belonging to the border of the sphere in expansion, and in the same way B(t) belongs to the segment [O,Q(t)].

t_2 being a Cosmological time strictly superior to t_1, according to the relations (71), $O,B(t_1)$ and $B(t_2)$ belong to the same straight line, and it is also the case for $O,A(t_1),A(t_2)$. We then consider the triangle $(O,A(t_2),B(t_2))$. In this triangle, according to the relations (71), 1+z being the factor of expansion of the Universe between t_1 and t_2:

$$OA(t_2)/OA(t_1)=OP(t_2)/OP(t_1)=1+z \qquad (74)$$

And in the same way:

$$OB(t_2)/OB(t_1)=1+z \qquad (75)$$

Therefore:

$$OA(t_2)/OA(t_1)=OB(t_2)/OB(t_1)=1+z \qquad (76)$$

Consequently applying the converse of Thales Theorem to the triangle $(O,A(t_2),B(t_2))$ we obtain the same relations as the relations (72)(73):

$A(t_2)B(t_2)=(1+z)A(t_1)B(t_1)$ (77)

And :

$[A(t_2),B(t_2)]//[A(t_1),B(t_1)]$ (78)

The preceding properties, valid A(t), B(t) being any couple of commoving points, are very remarkable and very important in the model of expansion of the Universe proposed by our theory of dark matter and dark energy.

We remark that if A(t) is a commoving point of a segment [O,P(t)], according to the relations (71), if $V_P(t)$ and $V_A(t)$ are respectively the velocities of P(t) and A(t) measured in the Universal Cosmological frame R_C, we obtain, a being a constant:

$V_A(t)=aV_P(t)$ (79a)

The previous definition of the commoving points of the sphere in expansion permits us to complete the definition of the local Cosmological frames (CRF), in the following Postulate 4:
Postulate 4:

a)The Universe is a sphere in expansion.

b) The origins of the local Cosmological frames (CRF) are the comoving points of this sphere in expansion.

Now we need to express the factor of expansion 1+z in our new model of expansion of the Universe. We propose are going to propose 2 possible mathematical models of expansion inside our new model of expansion of the Universe, permitting to obtain 1+z. Both mathematical models are not equivalent and do not give the same expression of 1+z. Nonetheless we will see that both models give theoretical predictions in good agreement with astronomical observations. Determining the mathematical model which has the best theoretical predictions should be an important element in order to know which is the best model.

According to the 1st mathematical model of expansion, 1+z is obtained as it is obtained in the SCM, with a flat Universe: We apply locally the equations of General Relativity, assuming the same values as in the SCM for the densities of dark substance, baryonic matter and dark energy and assuming that those densities and that the Universe is flat. And consequently in this 1st mathematical model, the factor of expansion 1+z can be mathematically expressed the same way as in the SCM for a flat Universe. We will see that a consequence of this is that the 1st mathematical model of expansion predicts distances used in Cosmology and a Hubble constant that have the same mathematical expression as their expression in the SCM, for an observer sufficiently far from the borders of the Universe.

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 the local velocity of light, the velocity $V_E(t)$ of the borders of the Universe measured in R_C (defined by $V_E(t)=d(R_E(t))/dt$, t Cosmological time) be equal to a constant C. There is no reason for which C should be equal to the local velocity of light c. So in our 2nd mathematical model of expansion, we assume that the velocity of the borders of the spherical Universe measured in the Universal Cosmological frame R_C is equal to a constant C. We will see further that it is possible to obtain an inferior limit to this constant C. And we will also see that despite of this great simplicity, the theoretical predictions of this 2^{nd} mathematical model are in agreement with all astronomical observations. Then if P(t) is a point belonging to the border of the sphere OP(t)=Ct. And we have a very simple expression of the factor of expansion 1+z: Between t and t_0 (t_0>t), the factor of expansion 1+z is given by:

$$1+z=(Ct_0)/(Ct)=t_0/t \qquad (79b)$$

We saw that the model of expansion of the Universe proposed by the SCM needed the existence of an enigmatic dark energy, and it is also the case for our 1^{st} mathematical model of expansion of the Universe. In the 2^{nd} mathematical model of expansion of our theory of dark matter and dark energy, this enigma is solved because this 2^{nd} mathematical model does not need the existence of a dark energy. And this is an important and attractive advantage of this 2^{nd} mathematical model. But nonetheless, we will see further that according to our theory of dark matter and dark energy, it exists a dark energy in the Universe.

In our model of expansion of the Universe we can prove that as in the model of expansion of the SCM, if 2 photons move on the same straight line towards the origin O of R_C, then between t_1 and t_2 2 cosmological times (with t_2>t_1), then the distance between the 2 photons and the lengths of wave of the 2 photons are increased by the factor of expansion of the Universe between t_1 and t_2 1+z .This is true for both mathematical models of expansion. We will see further that it is possible to replace O by any commoving point O' of the sphere in expansion.

Indeed let us consider 2 photons ph1 and ph2. We take the following notations: At the Cosmological time t ph1 is situated at the point ph1(t) of R_C, and ph2 is situated in the point ph2(t) of R_C. Let us suppose that at a given Cosmological time t_1, ph1(t_1) coincides with a commoving point $A_1(t_1)$ and ph2(t_1) with a commoving point $A_2(t_1)$. We also assume that it exists a unitary vector **u** of R_C, such that $A_1(t_1)$,$A_2(t_1)$ belong to the same segment [O,P(t_1)], with (O,P(t)) parallel to **u**, and that the local velocities of ph1 and ph2 are identical and equal to **c**=c**u**. We remind that according to the Postulate 3, those local velocities keep themselves. Let 1+dz the factor of expansion of the Universe between t_1 and t_1+dt. Then we have according to the properties (77) of commoving points:

$$A_1(t_1+dt)A_2(t_1+dt)=(1+dz)A_1(t_1)A_2(t_1)=(1+dz)ph1(t_1)ph2(t_1) \qquad (79c)$$

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

$$A_1(t_1+dt)ph1(t_1+dt)=A_2(t_1+dt)ph2(t_1+dt)=cdt \qquad (79d)$$

According to properties (relations (77)) of commoving points, and the local velocities of ph1 and ph2 being parallel to **u**, O, $A_1(t_1+dt)$, ph1(t_1+dt),$A_2(t_1+dt)$,ph2(t_1+dt) are aligned on the same straight line as O, $A_1(t_1)$ and $A_2(t_1)$ (with the direction **u**) and moreover we assume that they are ranked in this order. Therefore:

$$ph1(t_1+dt)ph2(t_1+dt)=A_1(t_1+dt)ph2(t_1+dt)-A_1(t_1+dt)ph1(t_1+dt) \qquad (79e)$$

$$ph1(t_1+dt)ph2(t_1+dt)=A_1(t_1+dt)A_2(t_1+dt)+ A_2(t_1+dt)ph2(t_1+dt)-A_1(t_1+dt)ph1(t_1+dt)$$

Consequently according to the equation (79d) :

$$ph1(t_1+dt)ph2(t_1+dt)=A_1(t_1+dt)A_2(t_1+dt) \qquad (79f)$$

Therefore, according to the equation (79c) :

$$ph1(t_1+dt)ph2(t_1+dt)=(1+dz)ph1(t_1)ph2(t_1) \qquad (80a)$$

So between t_1 and t_1+dt, the distance between ph1(t_1) and ph2(t_1) is increased by the factor of expansion between t_1 and t_1+dt 1+dz. Consequently between t_1 and t_2 the distance between ph1(t_1) and ph2(t_2) is increased by the factor of expansion of the Universe between t_1 and t_2 1+z :

$$ph1(t_2)ph2(t_2)=(1+z)ph1(t_1)ph2(t_1) \qquad (80b)$$

In order to show the previous effect on the lengths of wave of ph1 and ph2, we proceed as previously : We model the photon ph1 as a system whose extremities are 2 mobile points a(t) and b(t), the length a(t)b(t) being the length of wave of the photon. ph1(t) belongs as previously to a segment [O,P(t)], with (O,P(t) parallel to the unitary vector **u** and ph1(t) driven with a local velocity **c**=c**u**. We assume that for any photon ph1(t) a(t) and b(t) are driven with the same local velocity **c**, and that a(t),b(t) belong also to [O,P(t)]. We proceed then with a(t) and b(t) exactly the same way we proceeded with ph1(t) and ph2(t). So we obtain in our new model of expansion of the Universe, λ(t) being the length of wave of a photon, a relation analogous to (80b):

$$\lambda(t_2)=\lambda(t_1)(1+z) \qquad (80c)$$

We remind that the relations (80b)(80c) were also valid in the model of expansion of the SCM. It is because of the previous relation (80c), valid for any photon according to our theory of dark matter and dark energy as it was in the SCM, that we use the notation 1+z in order to represent the factor of expansion in the Universe. We remind that in the previous relation (80c), $\lambda(t_1)$ and $\lambda(t_2)$ must be measured in the local Cosmological frame (CMB rest frame) in which is situated the photon, that also gives the distances measured in the Universal Cosmological frame R_C according to the definition of R_C.

We can show more generally using an analogous way that if we only suppose that ph1 and ph2 own the same local velocity (ph1(t), ph2(t) not compulsory belonging to the same straight line containing O), then between 2 Cosmological times t_1 and t_2 the distance measured in R_C between ph1 and ph2 increases by the factor of expansion of the Universe between t_1 and t_2 1+z (as in the equation (80b)), and moreover we have the relation (ph1(t_2),ph2(t_2))//(ph1(t_1),ph2(t_1)).

We remark that for any commoving point of the swelling sphere O'(t) we can define a Cosmological frame R_C' whose the origin is O'(t), the time is the Cosmological time (time of R_C), the axis are parallel to the corresponding axis of R_C and defining the same distances between 2 points, at a given Cosmological time t, as the distances defined by R_C. We will call R_C' *secondary Universal Cosmological frame*.

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 (72)(73), if 1+z is the factor of expansion of the Universe between t_1 and t_2:

$O'(t_2)A(t_2)=(1+z)O'(t_1)A(t_1)$
$(O'(t_2),A(t_2))//(O'(t_1),A(t_1))$ (81)

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

Consequently the relations (71)(72)(73) remain valid, replacing R_C by R_C'and O by O'. P(t) is still defined as a point belonging to the borders of the sphere in expansion, but we have no more $OP(t)=R_E(t)$, $R_E(t)$ radius of the sphere in expansion at a Cosmological time t.

Therefore it should have been possible to define commoving points in R_C' the same way we defined them in R_C. Consequently the expressions of the distances used in Cosmology and of the Hubble constant obtained in R_C are also valid in R_C'.

We will see that generally it is not possible to observe all the Universe from any commoving point O'(Which was also the case in the SCM: According to SCM it is not possible to observe all the Universe from our planet), but if O' is sufficiently far from the borders of the Universe, then the Universe observed from O' is approximately identical to the Universe observed from O.

The spherical form of the Universe could be confirmed if some celestial bodies would not own a homogeneous distribution in the Universe, but a distribution presenting a spherical symmetry relative to a point O. According to our models, O would be then the centre of the spherical Universe.

3.3 Hubble's law-Distances used in Cosmology.

We keep the notations of the previous section, RC is the Universal Cosmological frame, O is the origin of RC centre of the Universe. (We remind that we can generalize what follows replacing O by any commoving point O' (sufficiently far from the borders of the Universe, and RC by a secondary Universal Cosmological frame RC', with O' as origin). Let us suppose that a photon is emitted from a star S at a point $Q(t_E)$ of R_C (Q(t) being commoving point of the sphere in expansion) at a Cosmological time t_E towards O. We assume that the photon reaches O 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 :

$D_T=c(t_0-t_E)$ (82)

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 of the photon at the point $Q(t_E)$ and the reception of the photon in O, at the Cosmological time t_0.

According to the 1^{st} mathematical model of expansion of the Universe, the theoretical prediction of the distance D_T, given by the equation (82), as a function of Cosmological variables z_0, t_0…, is identical to the theoretical prediction of the SCM, because the equations giving D_T are identical in those both models (equations of the General Relativity).

But in the 2^{nd} mathematical model of expansion of the Universe, we obtain very easily the Hubble's Constant using the light-travel distance defined previously:

Indeed according to this 2^{nd} mathematical model and the equation (79b), 1+z0 being the factor of expansion of the Universe between t_E and t_0:

$$1+z_0=(Ct_0)/(Ct_E)=t_0/(t_0-D_T/c) \qquad (83a)$$

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 (83a) 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 for the previous examples of obtainment of D_T according to our 2^{nd} mathematical model of expansion a present Cosmological time (present 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 often taken for the Hubble's constant H a value of 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 [(17)] in a very recent article (October 2012).

So it is very remarkable that according to the 2^{nd} mathematical model of expansion of our theory of dark matter and dark energy, 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 1^{st} model), the obtainment of Hubble's constant was much more complicated and moreover it was not exactly equal to $1/t_0$.

We still assume that a photon is emitted by a star S at a commoving point $Q(t_E)$, t_E age of the Universe when the photon is emitted, and reaches the origin O of the Universal Cosmological frame R_C at the present age of the Universe t_0. We have seen in section 3.2 that we could assume that the local velocity of S is small relative to c, the same way local velocities of stars close to our Milky Way (measured in the local CMB Rest frame) are small relative to c. Consequently if the photon emitted by S at a Cosmological time t_E owns the length of wave λ_0 measured in the inertial frame linked to S, if it reaches at time t_0 a planet T very close to O, with a local velocity very small relative to c, then if $\lambda_T(t_0)$ is the length of wave of the photon measured in the inertial frame linked to the planet T (at t_0), according to the equation (80c), $1+z_0$ being the factor of expansion of the Universe between t_E and t_0:

$$\lambda_T(t_0) \approx (1+z_0)\lambda_0 \qquad (83b)$$

We then can define in our model of spherical Universe in expansion other kinds of distances used in Cosmology in a completely analogous way to their definition in the SCM:

We have seen (Equation (82)) that we can express the light-travel distance as:

$$D_T = \int_{tE}^{t0} c\,dt \qquad (84)$$

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 sphere in expansion, is increased by the factor of expansion of the Universe $1+z=t_0/t$ between t and t_0 (See equation (79b)).

In complete analogy with the SCM, we will call *commoving distance* between O and S the distance between $Q(t_0)$ and $O(t_0)$ measured in the Universal 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:

$$D_C = \int_{tE}^{t0} c(1+z)dt \qquad (85)$$

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:

$$D_L=(1+z_0)D_C \qquad (86a)$$

$$D_A=D_C/(1+z_0) \qquad (86b)$$

The distance D_A appears to be the distance measured in R_C between $Q(t_E)$ and O. 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 3.2 (Equations (80b)(80c)) that this effect, predicted by the SCM, was also true in the model of expansion of the Universe proposed by our theory of dark matter and of dark energy.

The mathematical expressions of the different kinds of distances used in Cosmology (85)(86a)(86b) are in agreement with their mathematical expression in the SCM, in which the commoving distance D_C is usually expressed as a function of the variable z, for a flat Universe.

In the 1st mathematical model of expansion, since 1+z has the same mathematical expression as in the SCM the mathematical expression of those distances used in Cosmology as a function of z_0 is identical to their mathematical expression in the SCM. Consequently we also obtain an identical Hubble's constant.

In the 2nd model, the expressions of distances used in Cosmology are much simpler. Using $1+z=t_0/t$ we obtain (Equation (79b) and (85)):

$$D_C = \int_{tE}^{t0} c(1+z)dt = \int_{tE}^{t0} c(t_0/t)dt \qquad (87)$$

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

$$D_C=ct_0\mathrm{Log}(t_0/t_E)=ct_0\mathrm{Log}(1+z_0) \qquad (88a)$$

Here also this simple expression is in good agreement with the usual admitted experimental values for the commoving distance. We deduce very easily from this expression the expression of the luminosity distance and of the angular distance (86a)(86b). We remark that in this 2nd model, according with the previous equations we have as in the SCM for z_0<<1:

$$D_T \approx D_C \approx D_A \approx D_L \approx ct_0 z_0 \qquad (88b)$$

We know that according to the 2nd mathematical model, the velocity measured in R_C of any commoving point Q(t) is constant. (According to the equation (79a) with $V_P(t)=C$ according to the definition of the 2nd mathematical model of expansion of the Universe.) Let V_Q be this velocity. Then the distance in R_C between O and $Q(t_0)$, that we called also the commoving distance D_C is also equal to $V_Q t_0$. Therefore, according to the equation (88a):

$$V_Q = c\mathrm{Log}(1+z_0) \qquad (89)$$

We can interpret in our new model of expansion of the Universe the observation of the explosion of a supernova 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 the distances between photons moving on the same axis (Equations (80b)(80c)). So our new model of expansion of the Universe can interpret the astronomical observations concerning the explosion of a supernova [18] the same was as the model of expansion of the SCM.

3.4 Cosmological limits of the observable Universe.

In our model of finite Universe in expansion we cannot, as it was also the case in the SCM, observe the Universe (through the observation of galaxies) before a given time t_{OU}. This implies that observing the Universe from a commoving 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 $O'(t_0)$. In this section we are going to see how we can obtain this time t_{OU} according to our model of finite Universe in expansion, and more precisely according to the 2nd mathematical model of expansion of the Universe, that is much simpler than the mathematical model of the SCM. We must proceed the same way, just modifying mathematical expressions, in order to obtain t_{OU} according to the 1st mathematical model of expansion of our theory of dark matter and dark energy.

We keep in our theory the hypothesis admitted in the SCM of the existence of a dark age in the Universe during which light cannot propagate in the Universe. Let t_D be the end of this dark age. It is evident that t_{OU} must be superior to t_D. 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 according to our model of spherical Universe in expansion. This is very clear in our 2nd model:

According to the equation (89), V_Q being compulsory inferior to C, we have:

$$C \geq c\mathrm{Log}(1+z_0) \qquad (90)$$

Consequently, with the notations of the previous section:

$$t_0/t_E = 1+z_0 = \leq \exp(C/c) \qquad (91)$$

Which implies that the Universe cannot be observed in $O(t_0)$ (We remind that t_0 is the present age of the Universe) before the time t_I defined by:

$$t_I=t_0\exp(-C/c) \qquad (92)$$

So according to our theory of dark matter and of dark energy, t_{OU}, minimal Cosmological time for which the Universe can be observed is the 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.

We remark that the equation (90) permits to give an inferior limit to the constant C of the 2nd 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.

We must use analogous methods if our galaxy is situated not in O but in another commoving point O'(t). Then only t_I is modified, depending of the distance between $O'(t_0)$ and the borders of the spherical Universe.

3.5 The Cosmic Microwave Background.

As in 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 3.2 (Equations (80b)(80c)) , we obtain in our theory of dark matter and dark energy that if the CMB appears at a Cosmological time t_{iCMB} corresponding to a temperature T_{iCMB}, then at a Cosmological 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 $(1+z)^3$ (Because the radius of the Universe $R_E(t)$ increases by a factor 1+z) and the lengths of wave of photons are increased by a factor (1+z)(Equation (80c)). Therefore, our new model of expansion of the Universe is in agreement with the observation of the CMB corresponding to a great redshift z_0 [(3)] .

We remind that we saw in section **2.5 Form of the Universe** that with the hypothesis of an initial equality of the temperature of the CMB and the temperature of the homogeneous dark substance filling the Universe, taking a thermal model similar to the convective thermal model used in order to obtain the baryonic Tully-Fisher's law (Section 2.3), then we obtained that at the present age of the Universe the temperature of the intergalactic dark substance (evolving in $1/(1+z)^2$) is approximately 1500 times less than the temperature of the CMB (evolving in $1/(1+z)$).

But now we have given a very complete physical interpretation of the CMB Rest Frame that did not exist in the SCM, permitting to define completely the CMB rest frame (Postulate 4) at any point of the Universe, and giving also fundamental physical properties of the CMB Rest Frame (Postulate 3. As we have seen in our 1.INTRODUCTION, our theory of dark matter and dark energy remains compatible with the SCM in order to interpret the anisotropies of the CMB .

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 would be that the photon is reflected, taking exactly as new local velocity after reflection the opposite of its local velocity before reflection (as a vector).

3.6 Dipole contribution of the CMB.

We know that according to the SCM we have the following fluctuations of temperature of the CMB [3]:

$$(\frac{\Delta T}{T}) = \frac{1}{4\pi}\sum_{l} l(2l+1)C_l \qquad (93)$$

We will keep this expression in our theory of dark matter and dark energy. But according to the preceding theory, l=1 is the dipole contribution, corresponding as in the SCM to the motion of the earth relative to the CRF (CMB Rest Frame). So this dipole contribution is completely interpreted by our theory of dark matter and dark energy, which was not the case in the SCM, in which the CMB rest frame has non physical interpretation.

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

In the Sections 2.5 and 2.6 , we have seen that in our theory of dark matter and dark energy, the Universe was a sphere filled with 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 this nothingness. The convective flow F was then in given by 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 with K_3 constant (K_3 given by the Equation (14)) , M_B baryonic mass of the Universe, $R_E(t)$ radius of the Universe at a Cosmological time t:

$$K_3M_B=4\pi R_E(t)^2(h_nT_0(t)) \qquad (94a)$$

So we obtain that $T_0(t)$ evolves in $1/(1+z)^2$, 1+z factor of expansion of the Universe. In our theory of dark matter and dark energy, 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 assume 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 2.1).

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, that the initial temperature of the CMB was also homogeneous in all the Universe. And so the previous hypothesis justifies the isotropy of the CMB relative to the

CRF at the present age of the Universe (and at any age), without needing to introduce the phenomenon of inflation, as it was the case in the SCM.

3.8 Dark energy in the Universe.

We saw in the first part of our theory (**2.Dark matter in the Universe**) that according to this theory, the Universe was filled with a dark substance that could be modeled as an ideal gas (Section 2.1). So it is natural to assume that as an ideal gas this dark substance owns an internal energy, that can be identified with a dark energy, existing in all the Universe.

Nonetheless, in order to obtain the evolution of the temperature of the dark substance in $1/(1+z)^2$, we used the equation (94a), that we remind here, $R_U(t)$ being the radius of the Universe at a Cosmological time t, $T_0(t)$ temperature of the intergalactic dark substance at the Cosmological time t, K_3 being a constant defined by the equation (14), M_B baryonic mass of the Universe:

$$K_3M_B=4\pi R_U(t)^2(h_nT_0(t)) \qquad (94b)$$

In order to obtain $T_0(t)$ in the previous equation, and we did not take into account the evolution of the internal energy of the dark substance nor the internal energy lost because of the dilatation of the volume of the intergalactic dark substance, modeled as an ideal gas. We will call 1st *model of the evolution of the temperature* of the intergalactic dark substance the preceding model. We remark that in the preceding section 3.7 we assumed its validity only for $z<1500$.

Let us consider a 2nd *model of the evolution of the temperature of the intergalactic dark substance* in which on the contrary we neglect the energy transferred from the baryons towards the dark substance (energy that is obviously nil before the apparition of baryons) and also the energy lost by the intergalactic dark substance at the borders of the Universe through the convective transfer defined previously in comparison with the variation of the internal energy of the intergalactic dark substance and also with the energy lost because of the variation of the volume of the intergalactic dark substance (modeled as an ideal gas). We assume that in this 2nd model, the dark substance is homogeneous in all the Universe, because we consider its validity only for $z>1500$, and for this cosmological redshift z the galaxies did not exist. Consequently the dark substance obeys to the Boyle-Charles law (Postulate 1) and moreover we assume that it also obeys to Joule's law for ideal gas: It exists a constant K_{ES} such that T(t) being the temperature of the dark substance, M_S being the total mass of the dark substance and U(T(t)) being the total internal energy of the dark substance for an age of the Universe t:

$$U(T(t))=K_{ES}M_ST(t) \qquad (95).$$

Moreover the energy lost that is the work corresponding to a variation of the volume of the dark substance dV under the pressure P is equal to:

$$W=-PdV \qquad (96)$$

We assume in this 2nd model of the evolution of the temperature of the dark substance that the transformation is adiabatic reversible. Consequently we can apply the Laplace's law: It exists a constant γ such that, V being the volume of the Universe for a temperature T at an age of the Universe t, and V_1 its volume for a temperature T_1 at an age t_1:

$TV^{\gamma-1}=T_1V_1^{\gamma-1}$ (97)

Consequently if 1+z is the factor of expansion of the Universe between t_1 and t, $V(t)=V(t_1)(1+z)^3$ and:

$T(t)=T(t_1)/(1+z)^{3(\gamma-1)}$ (98)

In a 3rd *model of evolution of the temperature of the intergalactic dark substance* we take into account every kind of energy received or lost by the dark substance. Nonetheless, we consider in this model that the dark substance is homogeneous in density and temperature in all the Universe, without taking into account the dark halos of galaxies with a flat rotation curve, and we have seen that this was justified because the total volume of those dark halos was very small relative to the total volume of the Universe. We will take the following notations:

dW(t,t+dt) is the energy received by the dark substance as a work (negative) due to the variation of volume of the dark substance between the ages of the Universe t and t+dt.

$dE_{TF}(t,t+dt)$ is the energy received by the dark substance (negative) due to the thermal transfer between the dark substance and the medium that we called "nothingness" between t and t+dt. $R_U(t)$ being the radius of the Universe at the age of the Universe t, we have seen (equation (94b)):

$dE_{TF}(t,t+dt)=(-h_nT(t))(4\pi R_U(t)^2)dt$ (99)

$dE_{TB}(t,t+dt)$ is the energy received by the dark substance (positive) received from the baryons , (Equation (14) and Equation (94b)) between t and t+dt. $M_B(t)$ being the mass of the baryons at the age t of the Universe we have:

$dE_{TB}(t,t+dt)=K_3M_B(t)dt$ (100)

Then the equation of equilibrium of the energy received and lost by the intergalactic dark substance between t and t+dt is:

$dU(t,t+dt)=dW(t,t+dt) + dE_{TF}(t,t+dt) + dE_{TB}(t,t+dt)$ (101)

We remind that according to the Boyle-Charles law, M_S being the total mass of the dark substance (assumed to be constant):

$P(t)V(t)=k_0M_ST(t)$ (102)

And, $R_U(t)$ being the radius of the Universe, $V(t)=(4/3)\pi R_U(t)^3$ and $d(R_U(t))=dzR_U(t)$ (1+dz being the factor of expansion of the Universe between t and t+dt), $dV(t)=4\pi R_U(t)^2dR_U(t)=4\pi R_U(t)^3dz$ and consequently $dV(t)/V(t)=3dz$. So we have:

$dW(t,t+dt)=-PdV(t)=-k_0M_ST(t)(dV(t)/V(t))$ (103a)

$dW(t,t+dt)=-3k_0M_ST(t)dz$ (103b)

So we obtain the following differential equation in T(t), because dz and $R_U(t)$ can be expressed as a function of t:

$d(K_{ES}M_ST(t))=-3k_0T(t)dz-h_nT(t)(4\pi R_U(t)^2)dt+K_3M_B(t)dt$ (104a)

$K_{ES}M_S(dT(t)/dt)=-3k_0M_ST(t)(dz/dt)-h_n(4\pi R_U(t)^2)T(t)+K_3M_B(t)$ (104b))

We can easily prove that with the previous notations, the parameter γ used in Laplace's equation (97) can be expressed by:

$\gamma=1+k_0/K_{ES}$

Consequently in analogy with existing gas modeled as ideal gas, k_0 should be of the order of K_{ES}. Using the previous equation (104b) we can express the conditions of validity of the 1st model of the evolution of the temperature of the dark substance, in which we neglected the variation of internal energy and the work received by the dark matter due to the variation of its volume. Those conditions are:

$-K_{ES}M_S(dT(t)/dt)<< K_3M_B(t)$

$-K_{ES}M_S(dT(t)/dt)<< h_n(4\pi R_U(t)^2)T(t)$

$3k_0M_ST(t)(dz/dt)<< K_3M_B(t)$

$3k_0M_ST(t)(dz/dt)<< h_n(4\pi R_U(t)^2)T(t)$ (106)

The conditions for which the 2nd model of the evolution of the temperature of dark substance be valid are the inverse conditions (replacing "<<" by ">>")

3.9 Evolution of the temperature of dark substance- 2nd model of expansion.

We are going to consider the application of the preceding section 3.8 in the case of the 2nd mathematical model of expansion of the Universe, meaning with $R_U(t)=Ct$, (C constant, see Section 3.2), and consequently between t and t+dt, 1+dz=(t+dt)/t, so dz=dt/t.

We remark that in the 1st model of evolution of the temperature T(t) evolves in $1/(1+z)^2$, consequently for this 2nd model of expansion in $1/t^2$. In the 2nd model of the evolution of the temperature, T(t) evolves in $1/(1+z)^{3(\gamma-1)}$ with γ>1, consequently in this 2nd model of expansion in $1/t^{3(\gamma-1)}$. So in both cases T(t) evolves in $1/t^p$, with p>0. For such a function T(t), we obtain that for t tending towards the infinite both functions T(t) and (dT(t)/dt)/T(t) tend towards 0. So for t sufficiently great the relations (106) are valid and the 1st model of evolution of the temperature of dark substance is also valid.
On the contrary for t tending towards 0, the functions (dT(t)/dt)/T(t) and T(t) tend towards the infinite and consequently for t sufficiently small (for instance just after the Big-Bang), the inverse of the relations (106) are valid and consequently the 2nd model of the evolution of the temperature of dark substance is also valid.

3.10 Dark energy of baryonic particles.

We have seen in Section 3.8 that according to our theory of dark matter and dark energy it existed in all the Universe a dark energy that could be identified with the internal energy of the dark substance. We are going to see in this section that it is also possible that baryonic particles also contain a dark energy, meaning an energy that cannot be detected using classical laboratory experiments. Nonetheless, this hypothesis, even if it is interesting and must be considered, is not necessary to our theory.

We defined in the Postulate 1 the Boyle-Charles'law for an element of dark substance with a pressure P, a volume V, a temperature T and a mass m, k_0 being a constant:

$$PV=k_0mT \qquad (107)$$

Using the previous law and the Newton's Universal law of gravitation, we obtained the equation (10), valid for all galaxies with a flat rotation curve. For instance for the Milky Way, T_{MW} being the temperature of the dark halo of the Milky Way and v_{MW} being the orbital velocity of stars in Milky Way, we have the equation:

$$v_{MW}^2 \approx 2k_0T_{MW} \qquad (108)$$

Consequently taking $v_{MW} \approx 2.\ 10^5$m/s we obtain $k_0T_{MW} \approx 2.\ 10^{10}$ U.S.I .

Let us compare the equation (108) with the analogous equation valid for hydrogen modeled as an ideal gas. We know that it exists a constant k_H such that for a hydrogen element with a mass m_H, a volume V, at a temperature T and a pressure P:

$$PV=k_Hm_HT \qquad (109)$$

We know that for a mole of hydrogen, for $T=T_K=273°K$, $V=20.\ 10^{-3}$, $P=10^5$ Pa, $m_H=10^{-3}$ kg, we have:

$$k_HT_K \approx PV/m_H=10^5 \times 20.\ 10^{-3} \times 10^3= 2.\ 10^6 \text{ U.S.I} \qquad (110)$$

If we assume that dark substance and hydrogen obeys to Joule's law, we therefore obtain that the internal energy of a kg of hydrogen at the temperature T_K is of the order of k_HT_K meaning $2.\ 10^6$ Joules despite that the internal energy of a kg of dark substance belonging to the halo of the Milky Way is of the order of k_0T_{MW} meaning $2.\ 10^{10}$ Joules, and therefore the latter energy is by far superior to the former (We use the equation (105), assuming that as for all existing gas modeled as ideal gas, k_0/K_{ES} is of the order of the unity). Considering this important difference of energy, we must consider a 2[nd] possible model of energetic transfer from baryons towards the dark substance, permitting a transmitted power much greater than a power corresponding to a diminution quasi imperceptible of the temperature of the baryonic matter. In this 2[nd] model of energetic transfer, the transferred energy is *dark energy*. In this 2[nd] model, baryonic particles contain a very important quantity of dark energy, but this dark energy must not be taken into account in the mass appearing in the classical equations $E=mc^2$ or $E_p=mU$. Consequently we cannot detect this dark energy using classical laboratory experiments. According to our theory of dark matter and dark energy, in order that the results of section 2.3 remain valid (permitting to obtain the baryonic Tully-Fisher's law), the power of dark energy transmitted from baryons towards dark substance has the same expression as in the 1[st] model of energetic transfer (thermal power):

$$P_r=K_{3S}M \qquad (111)$$

With M the mass of the considered baryonic particles and K_{3S} constant. p_{0S} being the power of dark energy lost by nucleus and m_0 being the mass of a nucleus we obtain $K_{3S}=p_{0S}/m_0$.

The hypothesis of a dark energy for baryonic particles is very attractive because not only it permits the transmission of an energy from baryonic particles to dark substance that could be much greater than thermal energy, but also because it justifies that this transmitted energy is independent of the temperature of those baryons and the temperature of this dark substance.

Nonetheless, the hypothesis of a dark energy for baryonic particles is not a hypothesis that is necessary to our theory of dark matter. Indeed according to our model of evolution of the temperature of dark matter (Section 2.8), we can expect that the initial temperature of the concentrations of dark substance be very high, equal to the temperature of the intergalactic dark substance, and then decreases till it reaches its final temperature. Consequently the variation of the internal energy of a spherical concentration of dark substance as defined in this article is very slow, and is therefore compatible with a very low thermal power emitted by baryonic particles towards the dark substance.

4.CONCLUSION

In the theory of dark matter and dark energy exposed in this article, we have modeled dark matter as a dark substance whose the physical properties, and in particular the fact that it can be modeled as an ideal gas, permitted to interpret all the astronomical observations linked to dark matter. For instance, those physical properties permitted us to justify theoretically the flat rotation curve of galaxies and the baryonic Tully-Fisher's law. In order to obtain this, we interpreted galaxies with flat rotation curve as spherical concentrations of dark substance in gravitational equilibrium. We have also seen that our concept of dark substance led naturally to propose a new geometrical form of the Universe, flat, finite and spherical.

We have studied according to our theory of dark matter the effects of the displacement of a concentration of dark substance on its mass and its velocity. We saw that this theory permitted to define, in agreement with astronomical observations 2 kinds of radius for galaxies: The baryonic radius and the dark radius. We then exposed according to this theory the different models of distribution of dark matter in galaxies. Then we have seen that this theory predicted important relations between the masses of clusters and the velocities of galaxies in those clusters, and also relations between the mean densities of some clusters corresponding to the same Cosmological redshift. Finally we saw that our theory of dark matter permitted to give an estimation of the dark radius of galaxies, and we gave this estimation for the Milky Way, and also the mean density of the Universe and the density of the intergalactic dark substance.

In the 2nd Part of our article (3.DARK ENERGY IN THE UNIVERSE), we have proposed a new model of expansion of the Universe based on the geometrical form of the Universe obtained in the 1st Part (spherical), and also on the Physical Interpretation of the CMB Rest Frame (CRF) that we also called the *local Cosmological frame*. We remarked that this physical interpretation remained compatible with Special Relativity because according to this physical interpretation, the CRF could not be detected using classical laboratory experiments, but only observing the CMB. So we assumed the validity of Special Relativity and of General Relativity (locally) in all the article. This Physical Interpretation of the CRF permitted us to give a simple interpretation of the Cosmological time, in agreement with all astronomical observations. Our new model of expansion of the Universe led us to define a new and fundamental frame, called *Universal Cosmological frame*. Then we defined inside our new model of expansion of the Universe a 1st mathematical model of expansion of the Universe ,based as the SCM on General Relativity with most theoretical predictions identical to the predictions of the SCM. We also have seen that a 2nd mathematical model of expansion, much simpler than the 1st one, led despite its great simplicity to theoretical predictions in agreement with astrophysical observations, for instance the theoretical predictions of luminosity distance, angular distance, light-travel distance, commoving distance and Hubble's constant. Moreover this 2nd mathematical model of expansion of the Universe did not need a dark energy, contrary to the SCM and to the 1st mathematical of expansion of the Universe, and consequently brought a solution to the enigma of dark energy. It should be possible to compare the agreement with the theoretical predictions and the astronomical observations for the model of expansion of the SCM and for the 2nd mathematical model of expansion, even they both have theoretical predictions that are approximately in agreement with astronomical observations. For instance we have seen that according to the 2nd mathematical model of our theory, the value of the Hubble's constant was exactly equal to $1/t_0$, t_0 present age of the Universe, which was not the case according to the SCM (And according to the 1st mathematical model of expansion whose theoretical predictions are identical to those of the SCM). Finally we studied according to our theory of dark matter and dark energy the evolution of the temperature of the dark substance from the Big-Bang till the present age of the Universe, and we have seen the existence in all the Universe of a dark energy that could be identified with the internal energy of our model of dark matter, the dark substance, identified with an ideal gas.

We remarked that a very attractive element in favor of the geometrical model of the Universe proposed by our theory of dark matter and dark energy is that this geometrical model of Universe, finite, spherical and with borders, can be easily conceived by the human mind, 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.

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