October 20, 2022

Using the Doppler type redshift in Galactic Recession

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ABSTRACT

This paper intends to present an alternative Cosmological model to the standard one, proposing a different calculation for the Galactic Recession. By predicting measurements for Stellar distances and Time dilations, it therefore can be falsified through observations.

About this, starting from the data of the Supernova *SN 1995K* and after the recalculation of the Distance Modulus μ without using the K Correction of FLRW (in my opinion wrong: it should not increase μ), we successfully carried out a test on the Time Dilation and one on the Luminosity distance. The results obtained from those verification of this Stellar distance ($d = 1{,}300\ Mpc$) and this Time dilation *(*Lorentz factor $\gamma = 1.078$ which makes *SN 1995K* to *SN 1990N* similar*)* are reported in viXra: [2207.0051] , [2208.0040] and [2208.0152].

I think these are good results even if limited in number and not definitive. Seen also the today's debate among ΛCDM with *FLRW* and alternative models, this model should not be discarded.

Here, the Universe lies on the surface of a hypersphere which expands at a constant rate with its radius stretching as $r = ct$. Given the constant expansion speed, it is not necessary to define a new specific type of Redshift (Cosmological) to be associated with the Galactic Recession.

Here the redshift is Gravitational or Doppler.

Other models hypothesize a hypersphere that expands as $r = ct$. The novelty of 4-Sphere lies in its definition of the Hubble constant: Its geometry, indeed, suggest a linear relation between the Galactic Recession and the arc angle (not the arc length).

Even if the validity our model stops (and, with it, the scientific speculation too) at the last 10 billion years, we anyhow need for an explanation as to how this shape of the Universe developed. As we shall see, our idea starts from what in the theory of Bing Bang is referred to as "Last scattering" (we date its Timeline to 720,000 years with a very high temperature). We do not have to change the ΛCDM sequence of events up to the Nucleosynthesis, the Thompson Scattering and the Recombination; so as not to miss many important successful predictions and scientific results of the standard model (as a first check, the Blackbody spectrum of the CMB is preserved after the Last Scattering).

It is still early to say but, if most of ΛCDM were safeguarded, then this model with its different metric could solve many, if not all, the problems deriving from the latest observations of the James Webb telescope.

(Limited to the recession calculus, you can find the key points in pages 7-9 and 19-26)

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SUMMARY

The arrival of the James Webb space telescope *(JWST)* opens new opportunities for verifying (or better falsifying) cosmological models, raising a debate among alternative models to *ΛCDM* and *FLRW. ΛCDM* predicts the Big Bang and estimates the age of the Universe at 13.8 billion years *(Gyr).*

At the time of writing nothing is certain yet, but *JWST* begins to image galaxies at ever greater distances, with ever longer travel times of light, let us say 13.5 *Gyr*. If now, at one of these distances, a galaxy were found, whose age *ΛCDM* itself were to deny it could be less than 300 *Myr*, (due to its structural characteristics) then the standard cosmology would have a big problem:

All standard assumption together would be indefensible, or we should discard these distances traveled by the light, or we should discard the constancy of light velocity, or we should discard the existence of the Big Bang!

In this context, but above all, in the light of what has been stated about it: in viXra: [2207.0051], [2208.0040] and [2208.0152], this speculation proposes a different calculus of the Galactic Recession. In the model, the Universe lies on the surface of a hypersphere which expands at a constant rate with its radius which increases as $r = ct$. Validity extends to our observable Universe, the radius of which (an arc of great circle) is $4.23 * 10^3$ megaparsecs (*Mpc*), with a Redshift $z \to +\infty$ and a time horizon of approximately 5 billion years (That is: *we cannot see light beams originating from a Universe younger than 5 billion years*. Or otherwise: *based on the redshift alone, whatever it is, we cannot say that a galaxy is younger than 5 billion years*). For example, our distance calculus for the faraway galaxy GN-z11 gives $4.17 * 10^3$ *Mpc*. The GN-z11 image we are receiving dates back to about 5 billion years after the Big Bang, but not before. The Elsewhere zone of Special Relativity begins beyond $4.23 \ * 10^3$ *Mpc*.

In the exposure, the coherence of the Time dilation was verified as far as possible, and this also applies to distances: the formula for the Luminosity distance from the Redshift was compared with that resulting from the Distance Modulus.

The model meets the requirements for now.

Even if the validity our model stops at the last 10 billion years, dutifully, we give an explanation as to how this shape of the Universe developed. As we shall see, our conjecture starts from what

in the Bing Bang theory is referred to as "Last scattering"(we date its Timeline to 720,000 years). What happened before is not about this discussion.

The mathematical construction foresees a Universe of finite dimensions, in expansion, homogeneous and isotropic. Here all the points are equivalent and from each one there are no preferential directions.

Given the constant expansion speed hypothesized for the Universe, it is not necessary to define a new specific type of redshift (Cosmological) to be associated with the Galactic Recession. Here the redshift is Gravitational or Doppler. In fact, for the Galactic Recession the Redshift is of the Doppler type (except for special cases in which the gravity of the star cannot be neglected) while for the Cosmic Background Radiation *(CMB)* it is exclusively of the gravitational type.

In **Chapter 1 - Introduction** an intuitive explanation is given to Galactic recession and the Lorentz transformations. Gravity is needed to clarify some aspects of the model but is treated only at a qualitative level. Definitions, data and formulas used can be easily found on the internet. To complete the whole, there is also a simple verification based on astronomical observations.

The next step would be to add gravity, building a physical model with matter and radiation. In **Chapter 3 - A model for the observable Universe**, you can find the resulting model as an approximation for the Galaxy Epoch. It is based on the Einstein's solution for weak fields to the field equation of General Relativity. Although approximated, it adequately represents the solution for the observable Universe. This equation is not intended to replace General Relativity, it is only useful to justify our calculation for the Galactic Recession. Here no superluminal motion can be derived from the field equation of the Universe, so that, in this solution, Galactic Recession and General Relativity arise and develop separately.

Since the model is applied only for the calculation of the Galactic Recession, it was considered appropriate, to describe particular events, to refer to the eras described in the Big Bang, without however accepting, with this, all the assumptions that may derive from that theory.

Then in **Chapter 5 - Universe shape and equilibrium**, with regard to the shape of the Universe, we will see that it is the radiation, with its radial motion that drags the Universe. In fact, accepting our conjecture which predicts a radial component c for the photon's velocity, then we must conclude that the disordered radiation freed at the Last Scattering, with its overall tangential velocity equal to zero, has the effect of dragging with it also the matter. The consequence is that both Cosmic Background Radiation (CMB) and matter, and therefore the whole Universe, expand constrained, lying on the surface of a hypersphere with radius increasing as $r = ct$. Other aspects concerning the CMB will be dealt with here; we will see also how radiation friction can counteract the gravitational acceleration but not the Galactic Recession. Outside of the scientific speculation we will also see how Thompson Scattering and Recombination could be addressed.

Being understood that the main purpose is the alternative view of the Galactic Recession, we anticipate an interesting consideration: Referring to the relationship between space and time, in this model Relativity on our Universe excludes Absolute Space and this in turn excludes Galileo's Absolute Time. This is true however a hypothetical reference frame is chosen. Despite these considerations it is still possible to formulate a conjecture to admit the existence of the tachyon. This and other conjectures are the subject of **Chapter 4 - Still conjectures about the model**.

Finally, it is important to point out that this speculation leads to a falsifiable theory. In this regard, **Chapter 2 – Verification of the model and comparison with the standard model** was dedicated to the model verification and the comparison with the Friedmann-Lemaître-Robertson-Walker (FLRW) metric. The verification concerns only the Galactic Recession. Taking the values of the Apparent Magnitude, obtained from the observed ones in the context of Special Relativity, we will see how the Luminosity distances from Distance Modulus are compatible with those calculated in this speculation. Therefore, the observations of the Supernovae type Ia, with their assumed distances and time dilations, do not rule out the use of the Doppler type redshift in Galactic Recession.

Based on what has been said in [vixra:2207.0051], should other types of observations validate this model, it could be said instead that *FLRW* has been falsified here.

Chapter 1 - Introduction

WHY THIS SEARCH

From the theory of Big Bang we consider Universe what is occupied by matter and not an empty container of infinite dimensions in which matter expands. There are various cosmological models that respect both the laws of physics and the astronomical observations. Starting from a new point of view, this speculation concerns the analysis of a new different one.

Simply to accept a scientific evidence or to investigate it, depends on what it is about and on the way of thinking of each of us. What made me think is superluminal motion, possible in Galactic Recession [*]. With the latter and relative motion in mind, I looked for a geometry from which both the principle of Relativity and the Recession mechanism arise together.

This was the target but, about real motivations, I am convinced that with another dimension it is explained isotropy and homogeneity. With this idea as a new starting point, I looked then for a model in which the metric of the Universe is not what appears to us but it is only the result of our perception of a four dimensional space.

These are the reasons that led me to this search.

By accepting the idea of a fourth dimension, we would consider what it is entails, for a three-dimensional observer, studying a four-dimensional Universe. Eventually we should change, in agreement, the laws of our physics, applying the older, as we usually do, only as approximations.

The way chosen to set the problem is very rudimentary.

For simplicity, we can think to an observer who can move in one dimension, only along the circumference of a circle: that is the Universe he perceives. Now imagine that the circle gets larger over time: for that Universe, the present is on the circumference, the future outside it and the past inside. An arc belonging to the past is longer when measured in the present.

Let's apply this idea to our Universe, so that it lies on the surface of a hypersphere [**] whose radius continues to stretch. We cannot observe recent galaxies if these are far away, as their rays of light haven't reached us yet. We can instead observe images of the older ones that, born closer to the center, now lay on the surface. Speeds higher than light are possible but here nothing is moving: is the hypersphere inflating.

By analogy with the surface of a sphere, all points in this hypersphere's surface are equivalent and from each one there are no preferential directions. This geometry gives a space homogeneous and isotropic.

In this hypothesis no changes are needed, all our physics can be applied locally in the whole Universe even if the whole Universe moves, expanding over time.

We cannot directly observe the fourth dimension of space, e.g. the radius in this geometry, simply because it does not belong to the Universe.

[*] – [arXiv/astro-ph/0011070]: Superluminal Recession Velocities

[**] - The idea is not new. This is not the only model that places the Universe on the surface of a 4-dimensional hypersphere. The World-Universe Model offers an alternative to the Big-Bang Model: it is developed through several articles by [viXra]: Vladimir S. Netchitailo. Among others, Hypersphere Cosmology it is also developed by Peter J Carroll and Alexander F Mayer.

VELOCITY–DISTANCE RELATION AMONG GALAXIES

To introduce the discussion of the hypersphere is useful to consider an intuitive solution in 2d or 3d spaces. Here is immediate the linear relation between recessional velocity and distance, as from of the Hubble's law:

$s = r\Theta \quad v_r = \Theta dr/dt$ where s is the distance of the galaxy and Θ is constant over time

For a 4-sphere [*] in polar coordinates it holds: [1]

$x_1 = r \cos(\Theta_1)$

$x_2 = r \sin(\Theta_1) \cos(\Theta_2)$

$x_3 = r \sin(\Theta_1) \sin(\Theta_2) \cos(\Theta_3)$

$x_4 = r \sin(\Theta_1) \sin(\Theta_2) \sin(\Theta_3) \sin(\Theta_4)$

We have $x_{Oi}(\Theta_i)$ for the galaxy of the observer and $x_{Fi}(\varphi_i)$ for the faraway galaxy. If we make a couple of axis rotations to set $\Theta_1 = \varphi_2 = 0$ what remains $(with\ \phi_1 = \varphi_1 - \Theta_1)$ is:

$x_{O1} = r$

$x_{O2} = 0$

$x_{F1} = r \cos(\phi_1)$

$x_{F2} = r \sin(\phi_1)$

which brings us back, as we might expected (even if it was not obvious), to the case of the arc in a 2d circle.

To travel the arc to us, from a faraway galaxy, the ray of light started from a distant past. As we will see, the redshift refers to that remote instant but the recession velocity was the same than now.

[*] – By 4-sphere we mean the hypersphere embedded in four-dimensional space R4 (someone call it 4-ball too); its surface is named by topologists a S^3 sphere.

GALACTIC RECESSION

Distances increase with the passage of time but, apart from the galactic recession, we do not measure other appreciable differences in lengths. Through the Hubble constant we can measure a stretch of $7.35 * 10^{-8}\ m\ year^{-1}$ on $10^{6}\ km$: the effect is not negligible. It is reasonable then to assume that gravity, within its action range, effectively counteract the expansion to the point of canceling its effect. In a binary system in equilibrium, the two stars, while moving away from us, should maintain the same distance between them. Recession due to expansion is in no way counteracted in the large zones of intergalactic vacuum. [*]

Now we consider the radius and we put $r = v_r\, t = ct$, where we assume $v_r\,(t) = const$ and name the constant c. Next step is trying to assign a value to this constant:

velocity c = speed of light in vacuum [**]

The 4-sphere's geometry, then, suggest a linear relation between the arc angle Θ and the galactic recession, in this way constant over time ($ds/dt = c\Theta$). Otherwise, in Hubble's recession $v_{rec}\,(z) = Hl$, the redshift *z* increases with distance *l* (the arc length not the angle) and depends on time

$$v_{rec} \propto l \quad and \quad z = f(\Theta, t)$$

However, for the Hubble constant *H,* measurement sampling, obtained with the Hubble Space Telescope HST, is based on stars (Cepheids) within 20 Megaparsec from us. For those relatively small distances we can use the Doppler redshift to obtain the present proper distance.

If now we consider the relation (we assumed $v_{rec}\,(t) = const, \quad \partial z/\partial t = 0$ during period concerned)

$$v_{rec} \propto \Theta \quad and \quad z = f(\Theta)$$

a cosmological model can be questioned but the Hubble's law is preserved unchanged giving a recession velocity constant over time. The calculated recession velocity from Doppler redshift (its radial component from Special Relativity formula) at the time the ray of light started is the same as now and not needs any correction due to expansion (resulting velocity refers to a Heliocentric frame).

As we will see in Chapter 3 this choice for the Galactic Recession is also comforted from the presence of a term $c\Theta dt$, part of the reasoning that led to our solution for the field equation of the Universe. The metric tensor used derives from an exact differential from which that Recession term had been taken away.

Actually the comparison with the experimental data is not very satisfactory. The article [***] reports the results of a study, carried out with HST, on a group of Cepheids in the galaxy NGC 4603 of the Centaurus constellation, determining a distance (Luminosity distance), based on their "Standard Candles" properties [****], of

$$33.3^{+1.7}_{-1.5} \quad (\text{random}, 1\,\sigma) \quad {}^{+3.8}_{-3.7} \quad (\text{systematic}) \qquad \text{Megaparsec}$$

The peculiar velocity measures the motion relative to the recession itself. NGC 4603 belongs to the Cen 30 branch of the Centaurus cluster and has a peculiar velocity that is very difficult to isolate. We need to correct its redshift before use it for distance calculation.

Wanting to use the redshift anyway without isolating the peculiar velocity, in our hypothesis, the calculated distance traveled by the light beam [*****] (4-sphere Luminosity distance), based on the galaxy redshift $z = 0.00865$ [******], would be 36.27 Megaparsec corresponding to a proper distance of 36.43 Megaparsec. To obtain a consistent distance and give an idea of the quantities involved, we should for example assume a peculiar velocity $v_{pec} = 6.2 * 10^{-4} c$ that would give a redshift equal to 0.00803, due only to the Galactic Recession. Then we would have a proper distance equal to 33.83 Megaparsec and a luminosity distance equal to 33.69 Megaparsec. With an error equal to 0.39 Megaparsec the model should not be discarded.

Distance measurements determine the value of Hubble's recessional velocity H_0 but, as explained in Analysis of Hubble Tension [*******], "The results of measurements of Hubble constant H_0, which characterizes the expansion rate of the universe, shows that the values of H_0 vary significantly depending on Methodology ...".

It is therefore legitimate to expect fixes to reduce discrepancies between distance and redshift in order to eliminate the Hubble Tension. Only then it will make sense to compare measurements of the distance traveled by the light beam, based on the Standard Candles properties, with the same distance provided by this model, calculated through the galaxy's redshift.

This is the proposed verification that can falsify this speculation.

Finally we note that:

The fact that a galaxy moves away at superluminal speed should not suggest that we can observe it: its rays of light will never reach us. That galaxy is an object in the elsewhere zone, as it always has been from the distant past: But eventually one of its satellite galaxies can cross the relativistic light cone.

References:

The first two references reported below lean on parametric down-conversion (PDC) and parametric up-conversion (PUC) as the mechanisms that favor the energy conservation of radiation. They are dependent on the expansion/reduction of volume:

[*] – The following publication, which deals with the expansion of the Universe, also explains the effect of gravity on the galactic recession in vacuum and in the presence of matter:

Science Journal: A. Bennun – December 18, 2007 - A simulation shows the distinct roles of matter curving and CMB expanding space

[**] – A correlation between the galactic recession and space-time parameters with velocity of light is described in:

Science Journal: A. Bennun - February 3, 2008 - Recession velocity and the space-time parameters are restricted by the velocity of light

[***] – [arXiv:astro-ph/9904368] - A Cepheid Distance to NGC 4603 in Centaurus

[****] – Australia ATNF - Cepheid Variable Stars & Distance Determination

[*****] – See later the paragraph APPLYING 4-SPHERE'S FORMULAS TO GALACTIC RECESSION

[******] – NED NASA/IPAC Extragalactic Database - NGC 4603

[*******] – [viXra:2112.0031]: Analysis of Hubble Tension

THE LORENTZ TRANSFORMATIONS

In this context, the space we know is a frame of reference, consisting of three Cartesian axes, always tangent to the expanding 4-sphere. An exact solution seems to be impractical due to its extreme complexity. However, if we neglect the effects of curvature but have the foresight to consider the effect due to expansion, the error is negligible at least for regions of space close to us.

Now we look at the geometry: everything is bound to a 3d-surface in which geodesics are 4-sphere's arcs.

With respect to the receiver, a ray of light emitted from a source, always travels the shortest path along a circumference arc $s = r\Theta$ at a speed $v_t = v_r = c$ [*] *without being dragged by the speed of the source. Radial velocity v_r different from c are not possible because in this geometry this would entail abandoning the 4-sphere surface and take a journey out of the world.*

Looking at the 4-sphere surface as if it were seen from a point of belonging, to apply Special Relativity we must verify the Lorenz transformations. In our case the simplest and most straightforward method is to remember that the latter were obtained to satisfy

$$\alpha(v + c) = c$$

But this expresses in formula what has just been said!

The fact that the expansion rate of the Universe equals the speed of light in vacuum may not be a coincidence. In our assumption, as we will see, this is a constraint for light, therefore in the 4-sphere $v_t = v_r$ where $v_r = c$ is the condition for light not to abandon the Universe!

What we have achieved with this geometry is a Universe where the laws of Special Relativity are deduced and never violated. This also applies when we expect the presence of superluminal motion for some farthest object. We can foresee but not observe it.

[*] –The tangential velocity is the maximum reachable in the physics we know. As we will see later, we do not exclude the tachyon.

EVIDENCE FROM OBSERVATIONS

The time has come to do a simple check (Mpc stays for Megaparsec, ly for light years).

The assumption is that $r = ct$ where c is light speed in vacuum:

$1\ Mpc = 3.09 * 10^{19}\ Km$

Time elapsed from Big Bang = $1.38 * 10^{10}\ years = 4.35 * 10^{17} s$ [2]

Light velocity $c = 3 * 10^{8}\ m\ s^{-1} = 3.17 * 10^{-8}\ ly\ s^{-1}$

we have:

$r = 4.23 * 10^{3}\ Mpc$ (c * Time elapsed from Big Bang)

$\Theta_{1\ Mpc} = 1\ Mpc\ /\ r = 2.36 * 10^{-4}\ rad$

4-sphere's recessional velocity $H_{sphere} = c\Theta_{1\ Mpc} = 70{,}9\ Km\ s^{-1}\ (per\ \Theta_{1\ Mpc})$

Hubble's recessional velocity $H = 72\ Km\ s^{-1}\ Mpc^{-1}$

Even if rough, 4-sphere recessional velocity H_{sphere} seems a quite good result.

APPLYING 4-SPHERE'S FORMULAS TO GALACTIC RECESSION

In our assumption the relationship between speed of light and expansion, resulting in the geodesics $ctv_\Theta = ctd\Theta/dt = c$, implies that when the expansion is constant also the tangential speed is constant, at the expense of the angular velocity. The constancy of the tangential velocity over time is a necessary condition to be able to apply the Doppler-type redshift.

Calculating 4-sphere recession velocity from the radial relativistic Doppler's redshift we have: [3]

$1 + z = (1 + \beta)^{1/2}(1 - \beta)^{-1/2}\ where\ \beta = v/c$ and $\beta = ((1 + z)^2 - 1)/((1 + z)^2 + 1)$.

where we must keep in mind that a strong gravitational field of the star can affect the result.

For very distant galaxies there is no problem of identifying their peculiar velocities. At great distances peculiar velocity is negligible compared to recession velocity.

Then, applying 4-sphere's formulas to the farthest known galaxy GN-z11: [4]

Spectroscopic redshift *z = 11.09*

Calculated β = *0.986*

Calculated $\Theta = v/c = \beta$ = *0.986 rad*

Distance $r\Theta$ = $4.17 * 10^3\ Mpc$

The present proper distance of $4.17 * 10^3\ Mpc$ against a distance of our antipodal point ($\Theta = \pi$) of $1.33 * 10^4\ Mpc$ seems good. A recessional velocity < c and an arc $\Theta < 1\ rad$ are proper of an object in the observable zone. This passes the test too. [*]

To roughly test the age of a galaxy (getting a time between its birth and dead) we can use the time spent by the light ray to travel the arc Θ. The calculation concerns the age of the light beam not of the galaxy itself: a small value of the redshift z does not imply that the star is young.

$ctv_\Theta = ctd\Theta/dt = c$	the geodesic equation
$\Delta s = \Delta r = c(t_1 - t_0)$	t_0 is the time the ray started
$t_0 = t_1 e^{-\Theta}$	t_1 is today

For GN-z11 $t_0 = 5.15 * 10^9\ years$

All the above results seem consistent. A birth around 400 to 900 million years after the Big Bang and a lifespan not less than 6-7 billion years is acceptable for an old galaxy. [5]

Is to be emphasized that the physical distance traveled by the light beam is $\Delta s = \Delta r = c\Delta t$ because in our conjecture the radial dimension cannot be perceived in any way. This distance is the one to use in calculations based on apparent magnitude [6]. Is also to be emphasized that our calculation is based on the conditions relative to the origin of the light beam and that the whole speculation can be falsified with experimental evidence to refute this result.

To summarize, the 4-sphere preserves the meaning of Proper distance and Luminosity distance, defined here just as the distance traveled by the light beam, [7] but does not define a Comoving distance [8]. The concept of the latter is represented by the angle Θ. [**]

The short study in [viXra:2207.0124] highlights the simplicity of use of these formulas.

Finally note that, also if we were able to perform astronomical observations at even greater distances, finding galaxies even further away, we should be not able to find GN-z11 (with a different recessional velocity) by looking in the exactly opposite direction.

Assuming as valid the Hubble's law even for GN-z11 in the opposite direction:

$\Theta = 2\pi - 0.97 = 5.31\ rad$

Distance = $2.25 * 10^4\ Mpc$

Hypothesized recessional speed = $1.59 * 10^6\ Km\ s^{-1}$

The resulting $\Theta > 1$ with its corresponding speed > c puts the galaxy in the relativistic elsewhere zone, out of our possible observations. No galaxy can be observed in either direction.

[*] - However, I would like to point out that, according to the model currently accepted, a redshift of z = 11.09 for GN-z11 makes it match the origin of the light beam to that of the galaxy. [4] Then, I believe that the calculations for distance of the 4-sphere deserves a chance.

[**] - You can find an interesting insight into the topic of distance in cosmology in the article:

[arXiv:astro-ph/9905116]: Distance measures in cosmology

Chapter1 - References from Wikipedia:

[1] - N-sphere

[2] - Big_Bang

[3] - Redshift

[4] - GN-z11

[5] - Chronology_of_the_Universe

[6] - Distance_modulus

[7] - Distance measures (cosmology)

[8] - Comoving and proper distances

Chapter 2 – Verification of the model and comparison with the standard model

ON THE CALCULATION OF GALACTIC RECESSION USING THE DOPPLER REDSHIFT

In the past the Doppler type redshift for the Galactic Recession was abandoned with the advent of the Friedmann-Lemaître-Robertson-Walker *(FLRW).* Presently perhaps, the most relevant objection to the use of the Doppler effect (SR) in calculating the Cosmological redshift is the time dilation of the Supernovae.

Before proceeding, it is appropriate to clarify the difference between the Doppler-type redshift of this model compared to the standard cosmological one: *FLRW*, which is based on the scale factor $a(t)$.

In the 4-sphere model the Universe expands but the redshift of a galaxy is influenced only by its recession velocity. Since that velocity is constant over time, the redshift is of the Doppler type. *The Universe is ever expanding, but if we repeated the measurement of the redshift for the same galaxy every billion years, we would always obtain the same value.*

In the *FLRW* metric, instead, the expansion of space continuously stretches the wavelength of light during the whole journey [*] and affect its redshift based on the formula:

$$a(t_{obs})/a(t_{emit}) = \lambda_{obs}/\lambda_{emit} \ = 1 + z$$

Formulas from this metric give different distance's result from that of SR and for time dilation too. *FLRW* gives:

$$dt_{obs}/dt_{emit} = a(t_{obs})/a(t_{emit}) \ = 1 + z$$

while 4-sphere gives:

$$dt_{obs}/dt_{emit} = (1 - \Theta^2)^{-1/2} = \gamma \text{ the Lorentz factor of Special Relativity}$$

where with $\beta = v/c$, for motion in the radial direction the Lorentz factor is:

$$\gamma = (1 - \beta^2)^{-1/2} \quad \text{with} \quad \beta = ((1+z)^2 - 1)/((1+z)^2 + 1)$$

We can observe a time dilation between two events on a star that is moving away from us or is immersed in a gravitational field; knowing relative velocity or gravity we can deduce the other term. [**]

At great distances peculiar velocity is negligible compared to recession velocity and this does apply to gravity too. For it to be necessary to isolate peculiar motions and gravitational fields the distance must be small. This model too foresees a calculation of the gravitational redshift because gravity in Cosmic Background Radiation, of the Universe in the past eras, was higher than now. As we will see in Chapter 3 the value of that gravitational redshift for of the farthest observed galaxy, is $z = 1.86 * 10^{-4}$. We are talking about a very low value whose contribution can be neglected in the calculation with the Doppler redshift.

The point is that if, observing a star, we were to find a time dilation value that cannot be explained by SR recession, peculiar velocity or by gravitational fields, we should accept the presence of an unknown acceleration, which has acted over time, and discard the hypothesis of a constant speed for the Galactic Recession with its calculation formulas.

Astronomers assert that type Ia Supernovae provide the equivalent of a cosmic clock. Their observations try to relate the Time dilation of this clock with the redshift z of the Supernova so as to identify the cosmological model that best fits the results.

The $FLRW$ metric that is part of Lambda Cold Dark Matter (ΛCDM), the currently most developed model with important successful predictions and scientific results, bases its superiority, over alternative models, above all on the results of the Time dilation analysis of the Supernovae: its prediction gives the value $1 + z$ where z is its Redshift.

Then, there are two verifications that a correct calculation of the Galactic Recession must overcome. Analyzing a supernova:

1. The Luminosity distance calculated by the model must be verified through its Distance Modulus. Once validated, we can use its Recession velocity
2. The Time dilation computed from the Recession velocity must be coherent with the result of other observations related to the supernova

About this, starting from the data of the Supernova SN 1995K, we successfully carried out a test on the Time Dilation and one on the Luminosity distance. The results are for this Stellar distance ($d = 1{,}300\ Mpc$ confirmed through its Distance Modulus) and for this Time dilation ($\gamma = 1.078$ which makes SN 1995K to SN 1990N similar).

The verification for the 4-Sphere Galactic Recession relies on:

1. What is written about the Apparent magnitude in: [vixra:2207.0051]
2. What about the Time dilation in: [vixra:2208.0040]
3. What about the Star distance in: [2208.0152]

[*] – [arXiv:1312.1190]: Astronomical Redshifts and the Expansion of Space

[**] – Regarding the redshift and velocity formulas; [From the website of Tobias Westmeier] - Redshift and velocity

OTHER ASPECTS CONCERNING THE DIFFERENCE WITH THE STANDARD METRIC

Another important consideration is:

- With *FLRW*, at least theoretically, we could observe the oldest Eras of the Universe.
- With 4-Sphere and its Timelike zone of Special relativity, that ends with rays of light from a Universe over 5 billion years old, we could not.

So, with reference to important events in the chronology, while we can observe the end of the Reionization Era (even if with a Timeline corresponding to $z = 6$ different from that of standard model), we could never observe the Reionization beginning, estimated by *ΛCDM* around 1 billion years from the Big Bang.

Regarding Dark Matter and Dark Energy, the model itself does not need neither of the two.

Furthermore, as far as astronomical observations are concerned, the presence of Dark Matter is not proven, being often the effects attributed to it explained differently as in [*]:

"In particular, the measured rotation curve of galaxies provided much experimental support to the dark matter concept. However, most theories used to explain the rotation curve have been restricted to the Newtonian potential framework, disregarding the general relativistic corrections associated with mass currents."

[*] – The European Physical Journal C volume 81, Article number: 186 (2021) - Galactic rotation curve and dark matter according to gravitomagnetism

CONCLUSIONS OF THE CHAPTER

My most significant criticisms of the current scientific discussion on *FLRW* mainly concern the use, in my opinion unjustifiable privileged, of statistical analysis. This hides, in a simple minimization of the overall χ^2, the physical descriptions of the variables that, seen individually, can significantly contribute to understand the metric, questioning or verifying its validity.

Said this, over the last 10 billion years, as opposed to the standard model, we have:

- On one hand, the 4-sphere that uses the Doppler effect, present in nature, and the Einstein's field equation in its original form.
- On the other, the *FLRW* metric that is part of *ΛCDM*, the currently most developed model with important successful predictions and scientific results.

What to say? Given the resources available, the completeness of *ΛCMD* is not in question and, in this respect, perhaps no alternative model [*] will soon be able to compete with it. But we cannot deny what was said previously about the distances and travel times of the light beam in *FLRW*:

“All standard assumption together may in a while become indefensible, or we will discard these distances traveled by the light, or we will discard the constancy of its velocity, or we will discard the existence of the Big Bang!”

If, among these, will be the *FLRW* distances to be rejected, then this 4-Sphere model may have a chance.

[*] – [arXiv:2202.12897] - Alternative ideas in cosmology

Chapter 3 - A model for the observable Universe

SUMMARY

Remember that this speculation describes a cosmological model with a 4-sphere [*], in expansion, on the surface of which our Universe extends, but as we will see, with an internal part that could interact with it.

The involvement of the fourth spatial dimension is unavoidable but it does not imply reintroducing the concept of an absolute space and not even that of absolute time. On the contrary, the model excludes both.

The geometry described finds an application in the calculations of Galactic Recession: those calculations are confirmed here after adding gravity.

In this subsequent formulation an explanation is sought as to why, in this "empty" space, a ray of light is bound to move on the 4-sphere surface. Then, we proceed by building a physical model, in which that empty space is filled with matter and radiation, and we try to check for any flaws. We will also show that this geometry, with its expansion mechanism, infers Relativity.

Since the model is applied only for the calculation of the Galactic Recession, it was considered appropriate, to describe particular events, to refer to the eras described in the Big Bang, without however accepting, with this, all the calculations that may derive from this theory.

Given the constant expansion speed hypothesized for the Universe, no new particular type of redshift is due to expansion itself. Here the Cosmological redshift is Gravitational and Doppler.

In this conjecture the surface of the 4-sphere (like a kind of bubble expanding over time) goes through a continuum of states of equilibrium in which the cohesion of the Universe acting as a surface tension is due solely to the effects of gravity and pressure of the Cosmic Background Radiation *(CMB)*. As we will see, no other actor acts on equilibrium, however, during the discussion there may be references to the analogy between the usual bubble and this expanding hyper-bubble. The aspects relating to the equilibrium of the Universe will be explored in Chapter 5.

About Entropy, we note that the expanding bubble does not perform external work, but neither can it be considered in free expansion since if we decrease volume, we restore gravity accordingly. That is, entropy is conserved in this expansion.

Resulting model is a solution for the Galaxy Epoch and the observable Universe. It is based on the Einstein's solution for weak fields to the field equation of General Relativity. This equation is not intended to replace General Relativity, it is only useful to justify our calculation for the Galactic Recession.

These following points can have interesting consequences:

1. this geometry infers Relativity which, in this way, is not considered a consequence of postulates
2. there may or may have been an energy exchange between the surface and its interior so that the two sides could communicate

About the pros and cons on the model:

1. Advantages: Galactic Recession and Relativity separation. Use of the Doppler effect, present in nature, and the Einstein's field equation in its original form. Model does not need dark matter and dark energy.
2. Disadvantages: The idea rests on the non-measurable radial effects of the gravitational and electromagnetic force. They act in the 4-Sphere like r-components: the fourth dimension of space.

We briefly summarize what was previously said:

a) Our Universe lies on a 4-sphere surface $x_1^2 + x_2^2 + x_3^2 + x_4^2 = c^2t^2$ where radius is $r = ct$ with c as light velocity and t as time elapsed from Big Bang.
b) Radial velocity $v_r = c$ is constant except during the initial period.
c) Also tangent velocity $v_t = ctd\Theta/dt = c$ is constant over time. Galactic redshift is due to Doppler effect. [3]
d) Our relativistic time-like zone is a portion of space delimited, in every direction, by an arc of length $ct\Theta \; with \; \Theta = 1 \; rad$.

[*] – By 4-sphere we mean the hypersphere embedded in four-dimensional space R4 (someone call it 4-ball too); its surface is named by topologists a S^3 sphere.

OTHER ASSUMPTIONS

In the naive energy balance that follows we will calculate the proper energy in a generic region of space, for a bubble that expands over time.

In this generalization, we hypothesize a 4-sphere that expands over time after of an explosion at its center:

1. About the kinetic energy, with a constant expansion speed, $\Delta E_k = 0$.
2. Referring to the 4-sphere surface a work E_γ is done by gravity acting like a surface tension: the cohesion force of the surface is $\gamma = f(r)$.
3. We cannot be sure that transformations are adiabatic: heat could flow out from surface through some mechanism like thermal radiation or something else.
4. Following the analogy with the usual bubble is interesting: About the pressure gradient on the bubble Δp_{4-dim} we assumed a null external pressure so that no additional work is done by volume expansion. By analogy with the surface tension, we put $\gamma dS_{4-sphere}$ for the work done by the cohesion forces. The equilibrium relation, then, could take the form:

$p_{4-dim}(t)dV_{4-sphere} = \gamma(t)dS_{4-sphere}$.

5. Equilibrium is maintained in expansion. If $p_{4-dim}(t) = f(\gamma)$ then the equality must hold for every value of $r = ct$. The continuous succession of states of equilibrium over time suggests a reversible expansion.

With reference to our Universe and considering the cohesion energy E_γ as part of its Internal Energy U_{Univ} we have:

$\Delta U_{Univ} = q - w$. Both w and q are negative, w is work done by internal pressure p_{4-dim}, q is the heat given up:

$$dU_{Univ} = dE_m + dE_r + \gamma dS_{4-sphere} = q - w$$

where E_m is energy from matter, E_r from radiation.

We can write:

$$dE_m + dE_r + \gamma dS_{4-sphere} = q - w$$

If ρ is the density of radiation, $V = S_{4-sphere}$ and $E_r = \rho V h\nu$ (where $h\nu$ is the energy of a photon) then:

$$dE_m + dE_r = c^2 dm + (V + dV)(\rho + d\rho)(h\nu + hd\nu) - \rho V h\nu = c^2 dm + \rho V h\delta\nu + d(\rho V)h\nu$$

But

$-c^2 dm = d(\rho V)h\nu$ (from the mass-energy equivalence) and the result is

$$dU_{Univ} = \rho V h\delta\nu + \gamma dS_{4-sphere} = q - w$$

Now neither of the two terms that determine the variation of the Internal energy U can be assimilated to heat. In our assumption the cosmological redshift is of gravitational type and therefore let us assume $q = 0$.

In our bubble that expands over time, equilibrium is maintained in expansion suggesting a reversible expansion.

About Entropy indeed, we note that the expanding bubble does not perform external work but neither can it be considered in free expansion since if we decrease the internal pressure, we restore gravity accordingly. That is, entropy [*] is conserved in this expansion.

To conclude, for the equilibrium of the expanding bubble, w is the resulting work and we can write:

$$dU_{Univ} = -w.$$

[*] – The entropy of *CMB* seen as disordered radiation uniform in temperature.

ABOUT ASSUMING A METRICAL TENSOR

By relating time to the 4th spatial dimension we obtain the usual curved space-time. After this, we no longer need the equation of the surface: $x_1^2 + x_2^2 + x_3^2 + x_4^2 = c^2t^2$*. As we will see later, fourth dimension of space* x_4 *will appear again in a mathematical context but no longer in physics.*

The generic procedure to get the metric of 4-sphere curved space-time sems extremely complex in a Cartesian reference frame.

The solution is not even simplified using polar coordinates:

1. Let's choose a reference frame based on a radius $r = ct$ as time coordinate and on three angles θ, φ, ψ as space coordinates $(0, 2\pi)$. As reference points, unfortunately, we cannot choose known stars as "Alpha Ursae Minoris – Polaris" or "Delta Orionis – Mintaka" on the Orion's Belt. This because of their proximity to us.
2. The three coordinates on the surface are given by the angles θ, φ, ψ where the first two are the equivalent of Longitude and Colatitude (using zenith angle $= 90^0 -$ Latitude) and where we will call the third "Universe Height". Astronomic Celestial coordinate Declination and Right ascension are relative to our observable Universe, here Universe Colatitude and Longitude refers to the whole 4-sphere. As convention we indicate a point P as $P(\varphi, \theta, \psi)$, with Colatitude before Longitudes.
3. Let's establish a position $P_N(0, 0, 0)$ for the "North pole" of our 4-sphere. Since all the points on the surface are equivalent, we can choose "Ursa Major GN-108036". Then we chose a Prime Meridian $P_{M0}(undef, 0, undef)$, passing through some other known point in space (say passing through "Sculptor A2744 YD4"). Note that all points $P_{EM-}(\pi/2, 0, \ undef)$ on the Universe Equator are out of our observable Universe. A third point $P_{EM}(\pi/2, 0, \pi/2)$ is at Universe Height $\pi/2$ on the Universe Equator, at $\pi/2$ from P_N measured on Prime Meridian.

The corresponding Cartesian coordinate can be useful:

1. $x_1 = ct\sin(\psi)\sin(\varphi)\cos(\theta)$
2. $x_2 = ct\sin(\psi)\sin(\varphi)\sin(\theta)$
3. $x_3 = ct\sin(\psi)\cos(\varphi)$
4. $x_4 = ct\cos(\psi)$

Note that θ, φ are the Longitude and Colatitude of the sphere.

Also are useful the 4-vector $\boldsymbol{r} =$
$(ct\sin(\psi)\sin(\varphi)\cos(\theta),\quad ct\sin(\psi)\sin(\varphi)\sin(\theta),\quad ct\sin(\psi)\cos(\varphi),\quad ct\cos(\psi))$

and its derivatives ($t = \text{const}$ on the surface):

1. $\mathbf{r}_\theta = (-ct\sin(\psi)\sin(\varphi)\sin(\theta),\ ct\sin(\psi)\sin(\varphi)\cos(\theta),\quad 0,\quad 0)$
2. $\mathbf{r}_\varphi = (ct\sin(\psi)\cos(\varphi)\cos(\theta),\ ct\sin(\psi)\cos(\varphi)\sin(\theta),\quad -ct\sin(\psi)\sin(\varphi),\quad 0)$
3. $\mathbf{r}_\psi = (ct\cos(\psi)\sin(\varphi)\cos(\theta),\ ct\cos(\psi)\sin(\varphi)\sin(\theta),\quad ct\cos(\psi)\cos(\varphi),\ -ct\sin(\psi)))$

These are 4-vectors of a Euclidean space: for us, there is the inner product and the angles it defines.

The three inner products are all equal to zero: $\mathbf{r}_\theta \cdot \mathbf{r}_\varphi = \mathbf{r}_\varphi \cdot \mathbf{r}_\psi = \mathbf{r}_\theta \cdot \mathbf{r}_\psi = 0$: they are orthogonal.

Once the angle ξ between two points, P_1 *with vector* $\mathbf{r}_1$ and P_2 *with vector* $\mathbf{r}_2$, has been calculated:

$$\xi = \left|\arccos\left(\frac{1}{c^2t^2}\mathbf{r}_1 \cdot \mathbf{r}_2\right)\right|$$

you can refer to the arc of great circle $r\xi$ to simplify the reasoning on light geodesics.

Saw the variables to use, it seems hard to set up the latter relation. Space and time variables are tightly coupled: it is not at all obvious to formulate a covariant expression for this space-time interval: $ds^2 = g_{\mu\nu}dx^\mu dx^\nu$.

In a coordinate system with origin in the center of the 4-sphere and with respect to which the observer is stationary [*], we have seen that the maximum achievable speed for an object bound to the 4-sphere surface is $v_t = ctd\xi/dt = c$. The overall speed of a ray of light is not constrained by the constant *c:* it is its tangential component.

Now let us consider a solution in the form: $ds^2 = -h_{r\xi}d(r\xi)^2 + h_t c^2dt^2$ and the differential of the product $r\xi$: $d(r\xi) = ctd\xi + c\xi dt$. To obtain the desired geodesic we must put $c\xi dt = 0$ as if the radius *r* were a constant.

In our hypothesis the only possible spatial displacement in the radial direction occurs at constant velocity: the term $c\xi$ gives the Galactic Recession. As we will see, by considering the Universe expansion as a succession of equilibrium states [**], the velocity $v_r = dr/dt$ does not anyway appear in the Stress-Energy tensor nor directly in our application of the Einstein's equation. Holding out Galactic Recession from calculation for the metric $g_{\mu\nu}$, the tightly coupling of variables disappears so that we can look for a solution in the form $ds^2 = -h_\xi c^2t^2d\xi^2 + h_t c^2dt^2$. Here the expansion of the Universe manifests itself through the increasing term c^2t^2. Dilation of the distance, due to expansion, can only be felt at the interstellar level.

In this speculation we have not yet talked about the Covariance principle. Although it is possible to express the same metric in other coordinates, our quantity $g_{\mu\nu}$ does not transform as a tensor: we have just defined a pseudo-tensor. This lack of generalization is the weakness of the logic plant but does not invalidate it. It is difficult to think of another representation of coordinates in which the same metric can be equally easily expressed but the use of this model is reserved for the geodesic of light.

Thus, we have variables whose differentials only partially enter the metric pseudo-tensor *because in our conjecture the radial dimension cannot be perceived in any way*. Quantities to be used are therefore *cdt* and *ctdξ* where the first describes a variation of time, the second a variation along the expanding 4-sphere arc.

Notwithstanding the equation of geodesic $ctd\xi/dt = c$, the speculation deals with the use of the Doppler-type redshift for the calculation of the galactic recession. The purpose of the following analysis is to verify how much the presence of a gravitational redshift can modify our result. The idea is then to consider a sufficiently small zone of the universe where the Cartesian variable x can be merged with our arc ξ, so that $\Delta x \simeq ct\Delta\xi$, and to evaluate there the trend of the gravitational field over the last 10 billion years. Under these conditions our pseudo-tensor becomes a tensor.

This is what will be done in the next paragraph.

[*] – You can find a discussion about coordinate transformation between inertial frames and uniformly rotating ones with also paradoxes in:

[Springer:10.1140/epjc/s10052-014-3098-6 - On Franklin's relativistic rotational transformation and its modification](Springer:10.1140/epjc/s10052-014-3098-6)

[**] – Despite its finite speed, expansion is reversible and entropy is constant.

AN APPROXIMATE SOLUTION FOR THE GALAXY EPOCH FROM EINSTEIN'S WEAK FIELDS

The very small curvature of space in our present period is the confirmation of a current weak gravitational field. We can resume the analysis with the previously described coordinates $dx^\mu = ctd\varphi,\ ctd\theta,\ ctd\psi,\ cdt$: We look for a model that approximates an almost flat space-time in a neighborhood of any point on the surface. From this part of the whole we expect to derive the field equation for the present and to apply it back in time so that we can observe rays of light from the most distant galaxies.

We have already seen before that, for each point $P(\varphi, \theta, \psi)$, the tangents to Colatitude, Longitude and Height are orthogonal: the angles between the coordinates φ, θ, ψ are always $\pi/2$. Then the differential arc is:

$$c^2t^2d\xi^2 = c^2t^2\sin^2(\psi)d\varphi^2 + c^2t^2\sin^2(\psi)\sin^2(\varphi)d\theta^2 + c^2t^2d\psi^2$$

If the vectors $\mathbf{e}_\varphi, \mathbf{e}_\theta, \mathbf{e}_\psi$ can be assumed as an orthogonal covariant basis of this space we note that, with the 4-sphere radius $\boldsymbol{r} = ct\,\mathbf{e}_t$, the basis $\mathbf{e}_t$ for our time coordinate is orthogonal to the previous ones too (so it had to be on the basis of the Principle of Equivalence).

For the basis $\mathbf{e}_\varphi, \mathbf{e}_\theta, \mathbf{e}_\psi, \mathbf{e}_t$, a double angle rotation on ψ and φ is function of the current values of ψ_0 and φ_0

$$f_\psi = \sin(\psi) \quad \text{and} \quad f_\varphi = \sin(\varphi)$$

and it is given by:

$$\mathbf{C}(\psi, \varphi) = \begin{bmatrix} f_\psi & 0 & 0 & 0 \\ 0 & f_\psi f_\varphi & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The compound transformation $g'_{\mu\nu} = \mathbf{C}(\psi,\varphi)\mathbf{C}(\psi,\varphi)\, g_{\mu\nu}\mathbf{C}^{-1}(\psi_0,\varphi_0)\mathbf{C}^{-1}(\psi_0,\varphi_0)$ gives the metric tensor for the rotation.

All points are equivalent, to simplify we choose the point at the Universe Equator in $P_{EM}(\pi/2, 0, \pi/2)$, then what remains is $c^2t^2 d\xi^2 = c^2t^2(d\varphi^2 + d\theta^2 + d\psi^2)$.

Now let us solve the following field equation (we assume the cosmological constant $\Lambda = 0$):

$$\frac{8\pi G}{c^4} T_\mu^\nu = R_\mu^\nu - \frac{1}{2} R g_\mu^\nu$$

to get the tensor $g_{\mu\nu}$ for the interval $ds^2 = g_{\mu\nu} dx^\mu dx^\nu$.

The analysis begin with the Einstein's solution for weak fields $g_{\mu\nu} = h_{\mu\nu} + \eta_{\mu\nu}$ where $\eta_{\mu\nu}$ are the constant Galilean values for Special relativity and $h_{\mu\nu}$ are small correction terms. $\mathcal{E}_{0r}$ and $c^2\rho_{0m}$ are respectively the current proper energy density of radiation and matter. The surface cohesive force of this model is attributable to uniform radiation pressure p.

As an expression for volume we put $V = 2\pi^2 c^3 t^3$ for 4-sphere surface and, for the previous assumptions about gravity, $\rho_0 V_0 \simeq \rho V$ is constant over time. [*] We can, then, calculate mass (or energy) density and volume at present time. Moreover ρ_0 can be considered the density of a perfect fluid composed of a mix of matter and radiation.

Let us remember the precedent qualitative description of the 4-sphere model in which we put the relation $dU_{Univ} = -w$. The latter will be used in the next calculation in which, for an infinitesimal element of volume δV, we have a work $-\delta w$ done to keep the Universe in its shape so as to satisfy the relationship:

$$\frac{\partial(c^2\rho\delta V)}{\partial t} dt = \delta w - p\frac{\delta V}{\partial t} dt \qquad \textit{as measured by a local observer}$$

in which matter, in the form of discontinuities in mass distribution, has no rule. You can eliminate it from the Stress Energy tensor.

From the equilibrium condition the right member is zero, then the Stress Energy tensor for this disordered radiation is:

$$T^{\mu\mu} = 0 \quad \mu = 1{,}3\ , \ T^{44} = \frac{G\mathcal{E}_r}{c^4} \quad \textit{and} \quad T_\mu^\nu = \frac{G\mathcal{E}_r}{c^4}\,\delta_\mu^\nu \ \ (\textit{where}\ \ \delta_\mu^\nu\ \ \textit{is the Kronecker delta})$$

With the quantities $h_\mu^\lambda = \eta^{\lambda\alpha} h_{\mu\alpha}$ *and* $h = \eta^{\lambda\alpha} h_{\alpha\lambda}$, the field equation result

$$\left(h_\mu^\nu - \frac{1}{2}\delta_\mu^\nu h\right) = 4\int \frac{T_\mu^\nu}{r} dV = \frac{G}{c^4 ct}\delta_\mu^\nu \int \mathcal{E}_r\, dV$$

We put $r = ct = const$ over V because the "interesting point" of the Einstein's solution, here is any point in time of the 4-sphere surface.

Integrating on V, after calculating the quantity $\mathcal{E}_{0r}V_0 = \int \mathcal{E}_r\, dV \simeq const$, we get:

$$\left(h_\mu^\nu - \frac{1}{2}\delta_\mu^\nu h\right) = \frac{4GE_r}{c^4 ct}\delta_\mu^\nu \quad \mu = \nu \qquad 0 \ \ \mu \neq \nu \qquad E_r = \mathcal{E}_{0r}V_0 \simeq const$$

We can see that $h_{\mu\nu} = \eta_{\mu\nu} h_0$. Values of h_μ^λ are all equals, say to $4h_0$, and with $h = 4h_0$ then follows:

$$h_0 = -\frac{2\mathrm{G}E_\mathrm{r}}{\mathrm{c}^4 ct}$$

and the space-time interval is

$$ds^2 = \eta_{\mu\nu}(1 + h_0)dx^\mu dx^\nu$$

but coordinates are isotropic, that is all points of space are equivalent, so the latter expression holds for all spatial rotations, in this case the rotation $\mathbf{C}(\psi, \varphi)\mathbf{C}(\psi, \varphi)\ \eta_{\mu\nu}(1 + h_0)$ giving:

$$\mathrm{ds}^2 = -\mathrm{c}^2\mathrm{t}^2(1 + h_0)[\sin^2(\psi)\mathrm{d}\varphi^2 + \sin^2(\psi)\sin^2(\varphi)\mathrm{d}\theta^2 + \mathrm{d}\psi^2] + (1 + h_0)\mathrm{c}^2\mathrm{dt}^2$$

The equation is valid in a sufficiently small zone of the universe where the Cartesian variable x can be merged with our arc ξ so that $\Delta x \simeq ct\Delta\xi$. You can use it to evaluate the trend of the gravitational field over the last 10 billion years. It leads to the usual light geodesic: $d\xi = dt/t$. We must conclude that Relativity is an approximation but its application has an undetectable margin of error until we operate below the large interstellar distances.

Let us do some calculation:

Calculation for h_0. (We assume that mass E_r is constant over time)

- Today energy density of CMB $\mathcal{E}_{0\mathrm{r}} = 4.02 * 10^{-14}\, J\, m^{-3}$ [**]
- Constant over time, energy $E_\mathrm{r} = \mathcal{E}_{0\mathrm{r}} V = 2\pi^2 r^3 \mathcal{E}_{0\mathrm{r}} = 1.69 * 10^{66}\, J$
- Constant $h_0 = -2.23 * 10^{-4}\, ly$

Verification of the gravitational redshift relative to the time when ray of light started from the farthest galaxy.

- The expansion speed c is constant over time. In the absence of other factors, it means that the distance, measured from source and receiver, between two successive wave crests does not change over time. <u>There is no redshift due to the expansion itself</u>.
- In absence of a relative angle ξ, that gives the Doppler effect, the redshift is the quotient between the proper times of receiver and transmitter $(g_{44\,today}/g_{44\,early})^{1/2}$, not in relative motion with respect to each other, as for the Schwarzschild metric:

$$1 + z = \frac{\sqrt{1 - \frac{2GE_\mathrm{r}}{c^5 t_{today}}}}{\sqrt{1 - \frac{2GE_\mathrm{r}}{c^5 t_{early}}}}$$

For a galaxy at its maximum distance (ξ ≃ 1), $t_{Max} \simeq 5 * 10^9\ years$ value is $z = 1.86 * 10^{-4}$. [***]

The latter value is the confirmation that throughout the Galaxy Epoch gravity remained negligible.

The initial assumption $\Delta x \simeq ct\Delta\xi$ was applied only in the final steps where we set the spatial terms g_{11}, g_{22}, g_{33} in our expression of ds^2. The large time interval used in this last calculation does not invalidate the entire formula but only concerns these terms of no interest in Gravitational Redshift.

With this consideration and gravity negligible throughout the Galaxy Epoch, the Einstein's model for weak fields has been correctly applied. This equation correctly represents the observable Universe.

<u>Accepting a negligible error, Galactic redshift can always be calculated as Doppler redshift</u>.

If Relativity is an approximation, could the exact solution be needed?

Beyond the complexity, perhaps only a numerical solution could bring a result, I don't think we would be able to find a context in which the calculations provided by this model are better than those provided by Relativity. The distances to be treated, between any two given gravitationally unbound points, may be too large to obtain accurate measurements. I believe that, at least for now, the use of this equation is limited to justifying our calculations for the Galactic Recession in a context where General Relativity applies independently.

[*] - We assume that the mass of matter does not change from past. About the energy of radiation, its constancy, as an approximation over the range of time in question, is due to the Weak Fields hypothesis.

[**] - See later in the paragraph USING 4-SPHERE FORMULAS.

[***] - Here, for the age of the Universe, the time used $t = 1.36 * 10^{10}\ years$ is different from the value of other models as the ΛCDM. [7] However, a verification regards the time elapsed from the Big Bang is possible, through a simple calculation on the observed Hubble constant:

Hubble's recessional velocity H = 72 $Km\ s^{-1}\ Mpc^{-1}$
Calculated $\Theta_{1\ Mpc} = H/c = 2.4 * 10^{-4}\ rad$
Time elapsed from Big Bang $t_{now} = 1/c\Theta_{1\ Mpc} = 3.26 * 10^{6}/c\Theta_{1\ Mpc} = 1.36 * 10^{10}\ years$
Corresponding time from ΛCDM $t = 1.37 * 10^{10}\ years$

GALACTIC COORDINATES

The observable Universe is a volume, on the surface of the 4-sphere, delimited in the three spatial dimensions by an arc of $\Theta = 1\ rad$. In this volume we are at the center O.

Fixed the origin for the time axis t coinciding with the Big Bang, we can use three angles as a galactic coordinate system: the position of an astronomic object A can be defined by the direction of the 4-sphere arc OA and the angle λ of this one. For the direction we can adopt the usual coordinates: Right ascension α and Declination δ. About the 4-sphere arc angle, say "Arc λ", knowing the Galactic redshift *z,* you have:

$$\lambda = ((1+z)^2 - 1)/((1+z)^2 + 1)\ rad$$

Present proper distance $s = ct_{now}\lambda$

Moving on 4-sphere surface coordinates, Colatitude, Longitude and Height, is quite complicate. Maybe it needs the aid of a computer program or some more suitable mathematical method. Here we give only some tools and a way to approach the solution:

Let's recall the coordinate in the 4-sphere space **U**: $P = P(\varphi, \theta,\ \psi)$:

1. $x_1 = ct \sin(\psi) \sin(\varphi) \cos(\theta)$
2. $x_2 = ct \sin(\psi) \sin(\varphi) \sin(\theta)$
3. $x_3 = ct \sin(\psi) \cos(\varphi)$
4. $x_4 = ct \cos(\psi)$

The 4-vector $\boldsymbol{r} =$
$(ct \sin(\psi) \sin(\varphi) \cos(\theta)\,,\quad ct \sin(\psi) \sin(\varphi) \sin(\theta)\,,\quad ct \sin(\psi) \cos(\varphi),\quad ct \cos(\psi))$

and its derivatives:

1. $\mathbf{r}_\theta = (-ct \sin(\psi) \sin(\varphi) \sin(\theta)\,,\ ct \sin(\psi) \sin(\varphi) \cos(\theta)\,,\quad 0,\quad 0)$
2. $\mathbf{r}_\varphi = (ct \sin(\psi) \cos(\varphi) \cos(\theta)\,,\quad ct \sin(\psi) \cos(\varphi) \sin(\theta),\quad - ct \sin(\psi) \sin(\varphi),\quad 0)$
3. $\mathbf{r}_\psi = (ct \cos(\psi) \sin(\varphi) \cos(\theta)\,,\quad ct \cos(\psi) \sin(\varphi) \sin(\theta),\quad ct \cos(\psi) \cos(\varphi)\,,\quad - ct \sin(\psi)))$

After converting δ using zenith angle $=\ 90^0 - \text{Declination}$, in the space **O** of observable Universe, for a point, $U = U(\delta, \alpha, \lambda)$:

1. $y_1 = \sin(\delta)\cos(\alpha)$
2. $y_2 = \sin(\delta) \sin(\alpha)$
3. $y_3 = \ \cos(\delta)$
4. $y_4 = ct\lambda$

The vector $\boldsymbol{u} = (\sin(\delta) \cos(\alpha),\quad \sin(\delta) \sin(\alpha),\quad \cos(\delta))$ (with unit length)

and its derivatives:

1. $\mathbf{u}_\alpha = (-\sin(\delta) \sin(\alpha),\quad \sin(\delta) \cos(\alpha)\,,\ \ 0,)$
2. $\mathbf{u}_\delta = (\cos(\delta) \cos(\alpha),\quad \cos(\delta) \sin(\alpha)\,,\quad 0)$

Note that two stars can be nearby on **U** but distant on **O**: it complicates approximations.

An angle on the 4-sphere is given by:

$$\xi = \arccos\left(\frac{1}{c^2 t^2} \mathbf{r}_1 \cdot \mathbf{r}_2\right)$$

while the one on the observable Universe (that is on the 4-sphere surface, between the Earth and two star) is:

$$\gamma = \arccos\left(\mathbf{u}_1 \cdot \mathbf{u}_2\right)$$

To use Right Ascension and Declination we need the formulas effective for arcs and angles on the surface. For this purpose, given three points, we can set the 4-plane that passes through them and the center of the 4-sphere. Once got it, we have a 3-sphere so to use the Sine Theorem and other tools.

Here calculations in polar coordinates are hard so let's move on to Cartesian ones:

$x_1^2 + x_2^2 + x_3^2 + x_4^2 = c^2t^2$
$x_4 = ax_1 + bx_2 + cx_3$ (where this 4-plane passes through the North Pole and the Earth).

We have $x_1^2 + x_2^2 + x_3^2 - c^2t^2 = -(ax_1 + bx_2 + cx_3)^2$.

This means that if a point belongs to the 3-plane: $ax_1 + bx_2 + cx_3 = 0$ and belongs to the 3-sphere: $x_1^2 + x_2^2 + x_3^2 = c^2t^2$ then it also belongs to the 4-sphere after we put

$$x_4 = ax_1 + bx_2 + cx_3.$$

About the steps to find the position of an unknown star $P_x(\varphi, \theta, \psi)$, variables must be chosen so that the point lies both on of the sphere and the plane. That gives a first condition $F(\varphi, \theta, \psi) = 0$. Note that parameters a, b, c, for the equation of the 3-plane, are not linearly independent but we need all them later to set x_4. [*]

For the whole procedure to be valid, we should demonstrate that the transformation preserves angles and distances between the three points in question. To avoid calculations, we see that the same is true in 3d when we intersect a sphere with a plane, passing through the center, to get a circle.

For triangulations of the 4-sphere we start getting coordinates of some points. We use our Earth, Ursa Major GN-108036, Sculptor A2744 YD4 and Piscis Austrinus BDF-3299:

1. Our Earth Us $P_0(\varphi, \theta, \psi)$ and $U_0(0, 0, 0)$
2. Ursa Major GN-108036 $z = 7.2$ $P_N(0, 0, 0)$ and $U_1(0.4863,\ 3.3003,\ 0.9707)$ - Boreal Hemisphere
3. Sculptor A2744 YD4 $z = 8.38$ $P_{EP-}(undef, 0, undef)$ and $U_2(-1.0405,\ 0.0629,\ 0.9775)$ – Austral Hemisphere
4. Piscis Austrinus BDF-3299 $z = 7.11$ $P_3(\varphi, \theta,\ \psi) = U_3(-0.9570,\ \ 5.8827,\ 0.9700)$ – Austral Hemisphere
5. … and so on …

We can give here the trace of a solution for our North Star Polaris. In these coordinates, it is close to the Earth:

1. Alpha Ursae Minoris – Polaris $z = 0.000055$ $U_4(0.0128,\ 0.6624,\ 0.000055)$ – Boreal Hemisphere
2. Our Earth $\mathbf{r}_0 = (a, b, c, d)$
3. Ursa Major GN-108036 $\mathbf{r}_\mathrm{N} = (0, 0, 0, ct)$
4. Sculptor A2744 YD4 $\mathbf{r}_2 = (e, 0, f, g)$

With respect to the Earth $P_0(\varphi, \theta, \psi)$, the coordinates of Alpha Ursae Minoris – Polaris are: $P_4(\varphi + x, \theta + y,\ \psi + z)$ where x, y, z are unknown.

We follow these steps:

1. Define a point P_W on the direction $P_0\ P_N$ at the same distance $P_W\ P_N =\ P_4\ P_N$. U_W lies on the segment $U_0\ U_N$.
2. The first condition on x, y, z comes from the sphere and plane passing through $P_0\ P_N\ P_4$
3. Calculate the angle between P_N and P_4 in **O:** $\gamma = \arccos(\mathbf{u}_\mathrm{N} \cdot \mathbf{u}_4) = 0.8788$
4. Use the Sine Theorem in the triangle $P_0\ P_W\ P_4$, right in P_W: $|\arcsin(\lambda\gamma)| = \varepsilon = 0.000048$
5. Calculate the other cathetus with the Cosine theorem: $\cos\lambda = \cos\varsigma \cos\gamma$ and $\varsigma = 0.000027$

Now we abandon the 3-sphere $x_1^2 + x_2^2 + x_3^2 = c^2t^2$ and, back to the 4-sphere equation, we can solve the displacement between $P_0\ P_4$:

1. the value $\sin(\psi)\sin(\varphi)\,\Delta\theta$ is equal to ε.
2. the value $\sin(\psi)\,\Delta\varphi$ is equal to ς.

[*] - Since for the North Pole we arbitrarily assumed $x_4 = 0$, it is not strange that all the points are constructed in the same way and all satisfy the condition of coplanarity on x_4. In this construction, we can reasonably think that, for every three points of the 4-sphere, passes a sphere that preserves angles and distances between them.

USING 4-SPHERE FORMULAS

This surface formulas can be used:

$V = 2\pi^2c^3t^3$ $\quad M = (\rho_r + \rho_m)2\pi^2c^3t^3$ where ρ_r, ρ_m are the densities of radiation and matter and M is the total mass.

As an example, we calculate the mass $M_r = \rho_r 2\pi^2c^3t^3$ equivalent to the total energy of CMB and $M_m = \rho_r 2\pi^2c^3t^3$ corresponding to the total mass of matter:

$E_{avg} = 3.83k_bT = 3.83 * 1.38 * 10^{-23}JK^{-1} * 2.7K = 1.43 * 10^{-22}J$
Where E_{avg} is the average energy of a photons (as a blackbody) [8]
$\mathcal{E}_r = aT^4 = 7.566 * 10^{-16}Jm^{-3}K^{-4} * 2.7^4K^4 = 4.02 * 10^{-14}Jm^{-3}$
where $a = 4\sigma/c$ is the radiation constant [5]
$\rho_r = \mathcal{E}_r/E_{avg} = 2.82 * 10^8m^{-3}$ (the number of CMB photons per cubic meter)
$M_r = \mathcal{E}_r c^{-2}2\pi^2c^3t^3 = 1.88 * 10^{49}\ Kg$
$\rho_{nH} \simeq 0.225$ hydrogen atoms m^{-3} [6]
$\rho_H = \rho_{nH}uMA/u = 0.225 * 1.00784\ *1.66 * 10^{-27} = 3.76 * 10^{-28}\ Kg\ m^{-3}$ (other sources give a value of approximately $1.50 * 10^{-33}\ Kg\ m^{-3}$)
$M_m = \rho_H 2\pi^2c^3t^3 = 1.58 * 10^{52}\ Kg$

STILL CONSIDERATIONS

A ray of light can travel an entire expanding great circle and return to the starting point (much forward in time). However, we cannot detect in any way a radiation from a galaxy outside the relativistic Light Cone. Whatever the frame of reference, only radiation emitted by objects belonging to one's own time-like zone can be detected. These photons continue to go round in circles along a geodesic. Outside the limits of the observable Universe (at angular distances ϴ >

1 in every direction) the light ray, during the entire route, cannot meet anything because everything flies ahead at faster speeds. In vacuum it cannot be deflected or absorbed in any way.

Up to now, no hypothesis has been made on the "empty" space delimited by this geometry. To proceed, the fourth dimension of space is involved. Accepting the idea of by a giant explosion, we place the Big Bang at the center of the 4-sphere and assume that all the primordial *ylem* (hot plasma), initially expanding, at some point was blocked onto a sort of event horizon. There remained, squeezed on the surface. Over time, reactions took place and cooling changed the conditions. The event horizon somehow shrank, radiation was released, and expansion resumed. Our speculation starts here.

Although, as we will see now, all the radiation emitted as Cosmic Background Radiation has the same energy in all points of the Universe including our Elsewhere zone, it does not have the characteristics of the Ether. In fact, due to the Universe expansion every point recedes together with the *CMB* that surrounds it. By construction of this model, a traveler perceives the CMB as if every point of the Universe were a source. For a star with its own peculiar velocity, it follows that effects such as radiation friction cannot be attributed to *CMB*.

GALACTIC REDSHIFT IN COSMOLOGICAL EPOCHS

During Recombination [*] and earlier, in the Radiation Era, pressure and energy density were so high that radiation itself were imprisoned. At the end of Recombination era, all radiation has been released. These relic photons reach us with the same redshift. Note that to reach us, a radiation emitted in the end of Recombination Era (we date it at 720,000 years from Big Bang), traveled one or more full laps. [**]

We must then look for different models for specific eras:

- Immediately after release of relic photons and throughout an initial period, gravity is strong and uniform, decreasing with time. It depends on matter and on strong radiation energy.
- Later, during the Galaxy Epoch, close to a star, the uniform component of gravity, from radiation, is negligible compared to that generated by the star [***]. If gravity has changed since the light ray started, this may be due to a change in mass of the star or to some other reason.

During the last 10 billion years, the period that affects this speculation, we should say that (g is gravity):

$$z = z(\Theta, g) \ and \ \partial z/\partial t = 0$$

but, as our weak field solution predicts,

$$\partial g/\partial t = 0 \text{ and } z = z(\Theta)$$

As long as the expansion speed remains constant, the redshift is not attributable to the expansion itself. From the time of last scattering onward, the redshift is both gravitational and Doppler while in the Galaxy Epoch it is due to the Doppler effect. In between time it is of mixed type.

[*] - Time to the end Recombination Era is computed in Chapter 5

[**] - We can calculate the angle traveled by relic photons to reach us $\Theta = 5/2\pi + 2.63$. You can use:

$$\Theta = \ln\left(\frac{t_{today}}{t_{past}}\right) \quad for\ every\ \Theta$$

[***] - The observed surface gravitational redshift of a massive neutron star is about $z = 0.4$

COSMIC BACKGROUND RADIATION

The assumption that at "time of Last scattering" expansion velocity was almost null is necessary for CMB to respect the observed value of the standard deviation in its radiation temperature:

$$T = 2.7255 \pm 0.0006K.$$

As we will see, the Universe that precedes Last Scattering may not always follow all the physical laws we know. However when it happens, if some exceptions must be made, Thermodynamics is the ideal candidate.

The validity of the 4-sphere is limited to the last 10 billion years but, for some calculations, it refers to the eras described by the theory of Big Bang. It could be argued that ΛCDM is based on the $FLRW$ metric in which the expansion of space continuously stretches the wavelength of radiation.

However, not all formulas in ΛCDM enclose the factor $1 + z$ from $FLRW$ assumption. For example, for the Radiation era and earlier, 4-sphere accepts the same adiabatic expansion of ΛCDM:

$$TV^{\gamma-1} = const \quad equivalent \quad to\ T \propto a(t)^{-3(\gamma-1)}\ with\ \gamma = C_P / C_V = 4/3 \quad for\ radiation$$

Let us, now, specify the meaning of "almost zero" for the expansion rate of Recombination Era.

From redshift component

$$1 + z_{obs} = (1 + z_{vel})\left(1 + z_{grav}\right)$$

(where the subscript *vel* stay for the relative velocity due to the increasing rate of 4-sphere radius), also assuming $z_{grav} \gg z_{vel}$, we have:

CMB deviation ≈ $z_{velm} z_{grav} where\ velm\ now\ stays\ for\ the\ mean\ (\pi/2)\ dr/dt.$

With a tolerable deviation of 0.0002, 4-sphere cannot admit the presence of any Doppler effect.

Therefore, to conclude that the Redshift of the *CMB* has no appreciable Doppler component, we must assume that, at the Last Scattering, the Universe was at rest. Indeed also accepting a uniform acceleration from 0 to c would still not solve the CMB deviation problem.

Then, until part of the Recombination or earlier, we can admit an adiabatic expansion but at the time of the Last scattering, cooling could not have taken place by expansion: we assume an isochoric transformation $P/T = const$ until the temperature of the Hydrogen atom production is reached.

For the 4-sphere, the redshift of the Cosmic Background Radiation is exclusively of gravitational type. It could be now a question of verifying its trend over time. Now as just said, our weak field solution, which predicts, over time, a strong hyperbolic decrease in gravity, cannot be used for this purpose, but we will still provide the solution in Chapter 5.

THE SPECIAL RELATIVITY APPROXIMATION

At "time of Last Scattering", after the of Recombination era [4], relic photons were released and traveled along 4-sphere's surface arcs as geodesics. This radiation has not disappeared, it is still present today as Cosmic Background Radiation (CMB) [1] providing the "vacuum" with sufficient energy and pressure that, in a homogeneous space, still provide the gravity to maintain these geodesics. As we saw in Chapter 1, the flat space of Special Relativity enters the context of this curved surface.

From the assumptions made previously, at "time of Last Scattering" expansion velocity was null. In absence of relative motion, rays, started from any point on the surface, can reach any other point. Since then (or as we shall see simultaneously), expansion resumes, maintaining a constant speed.

The subsequent constancy of radial velocity $v_r = c$, hypothesized in the previous chapters, implies that also tangent velocity $v_t = ctd\Theta/dt = c$ does not change over time. This is valid for the whole period in which gravity has maintained these geodesics, that is, for the whole period concerned.

Let us write the geodesic equation with reference to 4-sphere geometry:

$$ct\frac{d\Theta}{dt} = c \quad or \quad \frac{d\Theta}{dt} = \frac{1}{t} \quad and \quad \frac{t_2}{t_1} = e^{\Theta} \quad for\ every\ \Theta$$

Knowing the angle Θ we can easily get the time the ray started: $t_{past} = t_{today}e^{-\Theta}$.

From the interval of flat space-time $ds^2 = -dx_1^2 - dx_2^2 - dx_3^2 + c^2dt^2$ we put $dx_1^2 + dx_2^2 + dx_3^2 = (ctd\Theta)^2$

With $ds^2 = 0$ for a light-like interval, we obtain $ctd\Theta = cdt$ that is the geodesic equation $v_t = ctd\Theta/dt = c \ \ and \ \ d\Theta = dt/t$.

Today the arc approximated here by a segment has a curvature of $2.40 * 10^{-4} Mpc^{-1} = 7.77 * 10^{-27} m^{-1}$: Special Relativity is a very close approximation for this curved surface.

In the context of the Principle of Equivalence, get easily the *proper coordinates* for ourselves as observer, marks a positive point for the 4-sphere hypothesis.

Chapter 3 - References from Wikipedia:

[1] - Cosmic background radiation

[2] - Surface tension

[3] - Redshift

[4] - Recombination (cosmology)

[5] - Stefan-Boltzmann constant

[6] - Friedmann equations

[7] - ΛCDM model

[8] - Planck's law

Chapter 4 - Still conjectures about the model

ON THE EDGE OF PHYSICS AND BEYOND: SPHERES, BUBBLES, WORK AND ENERGY

I find that the 4-sphere surface is an interesting entity that we can find also in the interior solution of the Schwarzschild metric, as its space-time geometry. Then, you could think that, in extreme physical conditions, fluids can settle in this geometry and that, when conditions cease, this geometry may be preserved in a following expansion. How it was possible to preserve this geometry for our Universe is the main topic of Chapter 5.

What we have done so far has been to constrain one of the 4 hypothesized dimensions to time. Here variable time is free but, with $r = ct$, the radius of the 4-sphere is not, being constrained because all that belongs to the Universe moves continuously with radial speed *c*. The laws of physics apply to this reality, and we can think of excluding from the expansion only a small period of the existence of the Universe. When needed, we can try to extend them to other contexts and even to other dimensions, but later it is not certain that we will find a way to validate them.

Speculation predicts that the expansion is absent or occurs at speed *c*, and that in some periods (at least one) the Universe is stationary.

When stationary, in order not to get stuck, we can accept Relativity as an axiom, or we can rely on our intuition to develop some modest hypothesis in the doubt of not being able to verify it. In the first case we have a powerful tool, in the second we have little or nothing. From a logical point of view, however, little changes. Anyhow some powerful tool is necessary even for the purposes of this speculation. So, we will follow the second path with exception for Thermodynamics and other basic principles of physics.

Current cosmology accepts an *origin* for time and, referring to the Big Bang, it speaks of a "*singularity*". We have not changed philosophy too much, here, if we replace the concept of "*singularity*" with a point in another dimension that cannot ever be reached and measured by us.

The sphere and the bubble have a symmetry that lends themself to be easily generalized. We can think of the 4-sphere surface as a bubble where the cohesion force is due not to a surface tension [2] but to gravity. Because of its high discontinuity in space, mass from matter should be irrelevant for great values of radius *r*. The effects of gravity and pressure from radiation, instead, may be essential.

We will start by following the analogy with our bubble physics but the nature of the forces acting for the equilibrium will be the subject of a more detailed discussion later.

Taking up with the previous balance $dU_{Univ} = -w$ where w is the work done by the system on its surroundings then assuming that energy is not conserved could reintroduce the concept of absolute space. However, if we accept a work w from an adiabatic expansion in the interior of the 4-Sphere, then for the energy balance it would be: $U_{4-sphere} = \ const$ favoring the idea, stated above, that fluids in extreme physical conditions were disposed on the surface of a 4-sphere and that particular geometry was subsequently preserved for our Universe.

Isotropy, homogeneity, circular path for radiation, energy and entropy are the essential discussion in this speculation.

To avoid collapsing, the cohesive force of the 4-sphere surface needs to be balanced by another force. The lack or not of Universe energy conservation, leaves us more possible conjectures to proceed:

a) $U_{4-sphere} = \ const$. Work $-w$ comes from a radiation propagates inside the 4-sphere exerting some form of pressure on the inside of the surface. The 4d state equation of its adiabatic expansion is unknown. For whole system it applies $U_{4-sphere} = \ const$.
b) $U_{Univ} = const$ with some unknown and non-directly measurable form of energy belonging to our Universe, opposes radiation pressure.
c) $U_{Univ} = const$. where the cohesion force is due to gravity only, as we will see later in a specific Chapter, object of a more detailed discussion.

In any case the 4-sphere surface model can survive as a curvature for space-time.

Choice a

Here are some hypothetical calculations.

Assuming zero for variable t at the beginning of the expansion (after the Last Scattering), it follows ($scat$ stays for "relative to Last Scattering"):

1. From the 4d balance: $p(t)dV = \gamma(t)dS$ it follows $p(t) = 3\gamma(t)/ct$
2. but $\gamma(t) = \rho/3$ where the latter is the is the expression for the pressure of a disordered radiation of density ρ
3. we put $\rho = (\rho_{scat}S_{scat}/S)/ct$ for the CMB density, decreasing with S and redshift z as $(ct)^{-4}$
4. the result is $p(t) = \rho/ct \ = p_{scat}/(ct)^5 = aV^{-5/4}$ where a is constant.

The state equation of a 3d reversible adiabatic expansion for radiation is $PV^{4/3} = const$. Here for the above internal 4d expansion we obtained $PV^{5/4} = const$. Due to our equilibrium hypothesis, only by accepting this result as a 4d reversible adiabatic expansion we could keep the analogy with the bubble.

The purpose of these calculations is only to describe qualitatively, but using a language that we know, the functioning of this model. Nevertheless, the calculations will be useful because, even if verification could be hard, it will instead be possible to falsify them.

Referring to the Galaxy epoch, the 4-sphere hypothesis a) incudes that:

- The surface of the 4-sphere (like a kind of bubble expanding over time) goes through a continuum of states of equilibrium in which an internal pressure by a radiation, in a reversible adiabatic expansion, balances the cohesion of the Universe.
- For the energy balance of the whole 4-sphere, it would be: $U_{4-sphere} = const$ without heat exchange between the surface and the inside.

From the macroscopic point of view, also this choice is an interesting conjecture but, as we will see, further developments will not be taken for granted. We anticipate that we will discard it.

Choice b

It predicts the Dark Energy that we have discarded.

Choice c

It is the subject of Chapter 5. The Universe is an isolated thermodynamic system, also from the relativistic point of view. With $\gamma dS_{4-sphere} = -\rho V h \delta \nu$ part δw of the energy of CMB is expected to be continuously expended to keep the Universe balanced in its shape. Here, it holds:

- There is no Entropy increase due to the Cosmological redshift of radiation: it is of gravitational origin.
- It is not reintroduced the concept of absolute space.

Finally, regardless of the choice, let us note what these assumptions entail for the 4-sphere surface as seen from a point of belonging:

1) It is not possible to identify a privileged reference frame or to recognize its state of motion whatever it is.
2) Light propagates through empty space with a definite speed c independent of the relative speed of source and observer.

Relativity is inferred in this conjecture assuming that the observed value c is due, for light, to the constraint: tangential velocity = radial velocity. The uniform value c of the radial velocity is necessary to ensure the cohesive forces that keep the Universe in equilibrium in its shape.

With respect to a point A and with a point B in relative motion: <u>For a beam of light from B, the ratio = 1 between tangential and radial velocity must be preserved. This condition would be violated if the speed of light were added to that of B</u>.

If we add to this the considerations on the Principle of Equivalence, expressed above in the paragraph on Special Relativity, we can affirm that the requirements of Relativity can be said to be satisfied and that this model infers it without the need for postulates.

A BRIEF EXCURSUS: HOW COULD BE THE PHYSICS OF THE ENTIRE 4-SPHERE

The simplicity with which, until now, you arrive at the conclusion that this model is totally consistent with all the concepts expressed by Relativity, also giving a coherent answer for Galactic Recession has a price: all the difficulties have been moved in the part that has to treat the Recombination Era.

Let us remember what entails, for our model with a constant recession speed, the very low standard deviation detected in the Cosmic Background Radiation: At the time of the “Last Scattering”, when all the cosmic radiation was released, there must have been almost no expansion and the energy was the same for the whole CMB.

The idea we are trying to pursue is that an initial period of inflation was followed by at least a period in which expansion temporarily stopped and then resume. Last time at the "Last Scattering" with the recombination of the hydrogen atom (see Ch. 5). The total time in which this expansion was not constant is small compared to the age of the Universe so we can think that the current recession speed practically coincides with its average value.

As said above, for our Universe and during the Galaxy epoch, we hypothesized a bubble that expands in the absence of an external pressure, where no heat is exchanged, and the only work is done by the cohesion forces to maintain intact its surface. Actually, we could consider the hypothesis of the existence of a vacuum outside the bubble completely absurd: absolute space has been excluded, so it makes no sense to speak of an external vacuum or pressure even to affirm that the latter is naught. Anyhow, even looking at the whole thing from the point of view of our Universe, we must still conclude that the work done as the result of the expansion is null. The container of our Universe, in fact, despite having a finite volume, paradoxically has no edges or walls: Particles of matter and radiation expand freely in all directions without ever meeting any boundaries.

As regards the period concerning the Recombination, in our assumption existing plasma was disposed on the surface of a 4-sphere and, as we will see, this geometry was preserved in its subsequent states. However when expansion stopped, the existing radiation was not bound to arrange itself in the same way and some of it could leave the surface abandoning the plasma. In every case slowly and without generating any expansion.

It is, then, in these conditions that, in our speculation, we must think about the way in which the cooling, hypothesized by the theory of Big Bang, took place. If the cooling was not due to the expansion, then the heat must have left our Universe.

In practice, we must demonstrate that radiation, even in the presence of extreme gravity conditions, does not necessarily arrange itself like the rest of the plasma. The conclusions follow assuming a slow diffusion of photons towards the inside or the outside of the 4-sphere so that the ratio between the amount of radiation absorbed and emitted by the plasma was affected by a progressive decrease in the concentration of photons determining a slow but continuous cooling.

Our conjecture considers Relativity not arising from two postulates but as a consequence of the shape of the Universe and its expansion, through the stretching of its radius as $r = ct$. This certainly does not make things easier: sometime in the Recombination the heat transmission took place leaving the 4-sphere surface and it is there that we must study the phenomenon. Rejecting Relativity as an axiom leaves us in the absence of any physical law known!

To proceed with our analysis, the most reasonable solution consists, then, in looking for a physics that applies to the entire 4-sphere and that is reduced to Einstein's field equation on its surface when expanding.

In this new model can we think of a time coordinate as the Galileo's absolute time? Its reintroduction could seem reasonable because the presence of the radial coordinate allows you to identify a privileged reference frame: *the motionless center*. But we have discarded absolute space, and as we have seen, the CMB itself cannot be a reference of any kind, so when we have two points in relative angular motion what is the fixed one?

We got to the point: <u>Relativity on the surface excludes absolute space and this in turn excludes Galileo's absolute time</u>.

Let us then think of our Universe expanding with $r = ct$ and fix the origin of our reference frame in the center. Here we have two points A and B in relative angular motion between them and with the same radial velocity c. With our reference frame rotating with A, if B emits a ray of light, its tangential speed, always equal to the radial velocity and without being dragged by the B speed, must be equal to the radial speed c to not abandon the surface:

$$\begin{cases} v_t = |r d\xi/dt| = c \\ v_r = dr/dt \quad\;\; = c \end{cases}$$

From the separation between Galactic Recession and Relativity follows that, safeguarding math of its geodesic, regardless of the value assumed by the radial component, the radiation, seen by us, always has the same properties. (We cannot measure any r-component of any motion).

It is said that, after decades of development, the science of cosmology is akin to an iceberg hiding 95% of its content. This model, adding the latter new condition for light, does the same making the concept clear.

However, we can consider Last Scattering as a limit situation where our equations would be safeguarded. Then, in order to give an explanation to the shape chosen for the model and leaving the light geodesic unchanged $0 = -h_\xi c^2 t^2 d\xi^2 + h_r c^2 dt^2$, we have to change our assumption so that the second constraint can be broken under certain conditions:

$$v_r = dr/dt = c \quad \textit{this is a brokenable constraint}$$

Otherwise, in absence of expansion, light cannot exist.

Again, keeping or breaking the second constraint has no effect in what we measure.

Going further we could also think of the Hyperphoton: The speed of light constrains our physics with limits, such as negative square roots, which turn out to be insurmountable, but what would change if out of the surface, in the cooling before the Last Scattering, the constraint for light were reduced to the following geodesic equation (s stay for space):

$v = ds/dt = \kappa$ *not in the vicinity of the plasma*

Then we would have the light that once off the surface could acquire speed with a stream of Hyperphoton that, meeting afterwards the surface, could interact with the matter in the Universe.

In this short excursus we cannot ignore the *tachyon* seen as particle which exhibits non-local [*] behaviors or as force carrier capable of mediating quantum entanglement [1]. The next paragraph is devoted to this.

I did not go any further looking for (not verifiable) intervals and field equations such as to justify the arrangement of the plasma and then the resumption of expansion. If we want in future to move forward with this conjecture, we must apply this idea to a falsifiable theory by linking it to phenomena that General Relativity is not able to explain.

Among all branches of science, the best candidate for our scopes is Quantum Mechanics and maybe, within this, the phenomenon to be chosen is "non-locality".

Summarizing the idea behind it all:

1. A bubble with an increasing radius $r = ct$ is the shape chosen for Universe to explain Galactic Recession. [**]
2. In absence of Absolute Space, the additional assumption that light is constrained by radial speed = tangential speed gives rise to Relativity. Not to abandon Universe, everything moves at radial velocity c.
3. For the Universe, a progressive cooling in absence of expansion is a logical consequence to the almost null deviation in the measure of Cosmic Background Radiation. At the Last Scattering all the radiation was released almost simultaneously contributing to the achievement of the expansion velocity c.
4. The fact that Relativity is inferred from shape and rate of expansion of the Universe may require a different reformulation of the laws of physics to deal with past eras where we hypothesize a null expansion.

[*] - Non-locality [2] can also be explained assuming the existence of compactified higher dimensions as in the following article:

MDPI 2076-3417/9/24/5406; Quantum Correlations and Quantum Non-Locality: A Review and a Few New Ideas

[**] – The nature of the forces acting for the equilibrium of this bubble will be the subject of a more detailed discussion later on.

THE THEORY OF RELATIVITY AND THE TACHYON AS A PARTICLE

Taking up what was said before on what binds an entity to move without leaving the Universe, the following is about my perception of the Relativity principles.

Speaking of relative velocity, the speed of light constrains our physics with limits, such as negative square roots, which turn out to be insurmountable. In this context, the existence of the tachyon does not appear to be a sustainable hypothesis. The forces, at least those we know, are transmitted at a finite speed, lower than that of light, so as to induce the Principle of locality [3]. But non-locality has been demonstrated in Quantum Mechanics.

In my opinion is reasonable separate the motion of an object with respect to an observer from its interaction with an actor, thus allowing the existence of the tachyon. But does the theory itself negate the tachyon?

Suppose now we have, in the same Lightcone, two interacting actors A and B and an observer O. Until the two actors do not leave their Lightcone, the theory does not prohibit one of the two (say A) from leaving the observer's Lightcone and enter the O Elsewhere zone. All this without violating the Principle of locality.

It might also be interesting to think of the tachyon as a lightweight particle that it is pushed for a while, by external forces that we cannot even measure; that particle, once the push has ceased, "reappears" somewhere in the Universe, and can be observed again.

However, these considerations are of no practical use: in fact, until we isolate an actor who interacts locally with it, nothing can yet be said about the tachyon. To proceed, and to introduce a new point of view, we can use a new actor: in our case and accepting some 4-dimensional form of radiation friction or photon-particle collision, the actor is the hyperphoton.

We recall that for this, out of the 4-sphere surface, we could generalize its geodesics:

$$v = \frac{ds}{dt} = \kappa \qquad\qquad \textit{with possible large values of } \kappa$$

that way, we get a new metric for the spacetime interval of Special Relativity.

Einstein's Locality principle cannot be violated given the impossibility of interacting with the forces that originate the boost. Knowing the origin of the boost, we can build other metrics in the same way and use them, as a first approximation, to predict the scattering of the tachyon. As a practical case, If the superluminal scattering of the neutrino were experimentally confirmed, the hyperphoton-particle collision could be the mechanism.

Proceeding with the tachyon or not depends on finding the connection with Quantum Field Theory and Non-locality. We are still far from this.

We left Quantum Entanglement out of speculation without addressing the problem. This model does not appear to offer any exploitable solution.

[*] - Not even the Galactic Recession violates this rule. If a galaxy now is in the Elsewhere zone, then it has always been, because: *"in this geometry nothing crosses the relativistic light cone".*

CURIOSITIES AND FEATURES OF THE MODEL

A ray of light, which travels the most recent circle and reaches us after a rotation of 2π, had an age of 25.4 million years when started. In that period and before no stars still exist. No images may overlap, nor ghost images exist, and we never could ask ourselves if the ray had traveled an arc Θ or a $\Theta + 2n\pi$ one.

From what can be deduced from this geometry, what belongs to our universe is bound to remain on the surface of the 4-sphere and therefore anything, stationary or moving, cannot have a radial velocity other than the speed of light *c*. The latter rule is not violated if we admit the existence of the *tachyon*, whose motion cannot be detected. This also applies to possible Quantum Entanglement carriers for which it has been shown that information on the state of a quantum object is transmitted at a speed greater than that of light.

I wanted to present this model even if incomplete, limiting its scope to what, in these hypotheses, could be studied with General Relativity: Galaxy Epoch and the last 10 billion years. In my opinion, the model fully explains the isotropy and homogeneity of the Universe, as well as it provides a circular path for CMB and radiation in general. It is also totally consistent with all the concepts expressed by Relativity, giving a coherent answer for the most distant galaxies: *In this geometry, at all times, due only to Recession, galaxies never cross the relativistic light cone.* Galactic recession with its superluminal motion does not enter the Einstein's equation. *From this model the principle of relativity and the recession mechanism arise together separately.*

Accepting the 4^{th} spatial dimension does not imply reintroducing the concept of an absolute space and not even that of absolute time, observed Relativity excludes them both. The attempt to associate the local reality with its possible representation in R^n was dictated by the desire to go deeper into the field of Ontology.

Chapter 4 - References from Wikipedia:

[1] - Quantum entanglement

[2] - Quantum nonlocality

[3] - Principle of locality

Chapter 5 - Universe shape and equilibrium

INTRODUCTION

In this Chapter we try to clarify what concerns the shape of the Universe and the aspects that are connected to it. Remember that it is about a cosmological model with a 4-sphere [*], in expansion, on the surface of which our Universe extends but with an internal part in which some form of radiation may exist.

Even if from a scientific point of view it is limited to calculating the recession, the entire speculation cannot be considered satisfactory until, as far as possible, clarity is made on the shape of this 4d-bubble and on the aspects relating to its equilibrium.

Therefore, taking up what said previously about the energy balance, we consider two possible choices:

1. Equilibrium is achieved through forces that act from the interior of the 4-sphere
2. Equilibrium is achieved by gravity alone

Point 1 will not result the correct choice and will be discarded but, given its importance for its analogy with the bubble we know, it will be discussed anyway.

Point 2 will be the accepted choice. Radiation with its radial motion causes the whole Universe to expand together with its cohesive forces, for the benefit of its shape.

[*] – See previous chapters.

UNIVERSE SHAPE AND EQUILIBRIUM

Taking up what said about the energy balance in Chapter 3

$$dU_{Univ} = -w \qquad \text{and} \qquad dU_{Univ} = \gamma dS_{4-sphere} + \rho S_{4-sphere} h\delta\nu$$

Now we will consider two possible choices:

- Equilibrium is achieved through forces that come from within the 4-sphere and we can generalize the thermodynamic expression for work, so as to have:

  $$w = P_{4dim} dV_{4-sphere} \qquad \textit{here we keep the analogy with the bubble with } PdV$$

  that gives the equilibrium condition for the bubble $dU_{Univ} = P_{4dim} dV_{4-sphere}$

- Equilibrium is guaranteed only by gravity acting in the 4-sphere surface:

$$dU_{Univ} = \gamma dS_{4-sphere} + \rho S_{4-sphere} h\delta\nu = 0$$

In both hypotheses we assume that all the primordial *ylem* (hot plasma from Big Bang), arranged itself stuck in the geometry of a stationary 4-sphere surface, here blocked until cooling took place.

POINT 1

Point 1 bases on hyperphoton, see Chapter 4:

$$v = \frac{ds}{dt} = \kappa \qquad\qquad with\ possible\ large\ values\ of\ \kappa$$

Concerning the analogy with our physics, the favorite hypothesis of a disordered radiation acting from inside the bubble must be discarded:

A calculation of the entropy, indeed, did not confirm the possibility that a continuum of states of equilibrium can be maintained between the internal pressure of that radiation and the cohesive forces of the Universe.

Although perhaps this conjecture should not be discarded with certainty, we will not proceed with the discussion because the hypothesis in point 2 offers such a simple solution that it cannot be ruled out.

POINT 2

Photon hypothesis on radial velocity enters point 2. With that said, it is the radiation, with its radial motion that drags the Universe:

$$\begin{cases} v_t = |rd\xi/dt| = c \text{ always} \\ v_r = dr/dt \ = c \text{ not ever} \end{cases}$$

In fact, accepting our conjecture which predicts a radial component c for the photon's velocity, then we must conclude that the disordered radiation freed up at the Last Scattering, with its overall tangential velocity equal to zero, has the effect of dragging with it, by gravity, also the matter. The consequence is that both Cosmic Background Radiation and matter, and therefore the whole Universe, expand constrained, lying on the surface of a 4-sphere with radius increasing as $r = ct$.

Therefore, unlike what is commonly accepted, it was not the expansion that caused the Last Scattering, but it was the Last Scattering that caused the expansion. All that so as to justify the measurement of an almost zero standard deviation for the Cosmic Background Radiation. It is the most reasonable conjecture, if we accept the idea that the universe lies on the surface of a 4-sphere.

Also with the choice of point 2, the same reasoning about entropy guarantees the maintenance of a continuum of states of equilibrium and nothing changes with respect to the effects on the acting forces.

Although no longer involved in equilibrium and perhaps, but not with certainty, not even in the cooling prior to Last Scattering, the interior of the 4-sphere remains because of this specific geometry. For now, this unknown part, where our physics does not apply, is a weakness for the model but one day, being able to get in contact with every point of our Universe, it could prove useful in the study of some inexplicable phenomena.

And what changes, with reference to energy conservation?

Point 2 implies that: $U_{Univ} = const$ with the quantity $\rho S_{4-sphere} h\delta\nu$ that is spent to keep universe in its shape, with $\gamma dS_{4-sphere}$ like a potential energy. Note that the energy $\rho S_{4-sphere} h\delta\nu$ increases if the volume were to decrease but is hard to think that, at any moment, the radial component of the photon's motion can be inverted.

Also, without a conceivable energy exchange between interior and surface nothing can be said about $U_{4-sphere}$.

PHOTON GAS

Given the central role of Cosmic Background Radiation in this model, it is appropriate to investigate some of the properties of disordered radiation that are similar to those of conventional gases [1]. Of all the properties of gases, the one that interests us the most is the ability to occupy vacuum and to distribute itself uniformly in space. We can say that the shape of the Universe is maintained by CMB only if its pressure has the characteristics just described.

From a mechanical point of view the radiation needs to interact with matter to exert a form of pressure. We can then think that the radiation behaves like a gas only in the presence of gas or dust, but our request concerns only the uniformity of distribution and this can also be obtained statistically (In the physics of radiation we already apply the laws of statistical mechanics).

What has been just said seems to be experimentally confirmed. From the examination of the spectrum of the CMB, indeed, we note that it is the same as that of the Blackbody Radiation.

This spectrum for CMB is due to the Thompson Scattering after the Nucleosynthesis and before the Recombination. We can say that the Universe behaves like an opaque, non-reflective and isothermal cavity. Temperature fluctuations may be present, but this is due, locally, to different thermodynamic conditions. Thus, the presence of zonas where radiation is almost absent would violate the isothermal requirement.

A last interesting feature for some aspects of our model is the friction drag exerted by the radiation on matter [*]. Negligible in the usual applications, radiation could oppose the movement of a galaxy with a very high peculiar velocity [**]. Finally, since we are dealing with light sources, a not negligible effect is given instead by the radiation pressure [2] suffered when approaching a galaxy.

[*] - On the Development of Our Views Concerning the Nature and Constitution of Radiation

See also: The African Review of Physics, Vol 10 (2015): RADIATION FRICTION: SHEDDING LIGHT ON DARK ENERGY

[**] - [arXiv:1111.4352] - Radiation pressure on a moving body: beyond the Doppler effect

NOTHING BUT AN IDEA BEHIND THE DRAGGING OF MATTER

In the hypothesis that all the radiation present has been the subject of the Thompson Scattering to confer the current spectrum to the CMB, we must assume that sometime after nucleosynthesis expansion had stopped.

This paragraph is perhaps the most dubious and problematic of speculation. The idea behind the speculation if that the radial motion of matter and radiation originates from resulting radial effects of the gravitational and electromagnetic force. At the moment, it is difficult even to think how to translate this idea into a future scientific speculation.

We emphasize then that the following are not supported by the laws of physics:

1. Gravity acts on radiation and matter where radiation can radially drag matter or vice versa
2. If the radiation moves away in its radial motion, it progressively drags the matter with it. Do not drag it, then most only moves tangentially.
3. The lightest particles are the first to be dragged. The free electrons, alone, cannot leave the plasma due to the strong electromagnetic attraction. This stops the following radial transfer of matter.
4. Light must satisfy $v_t = v_r = c$ only at the regime expansion, together with matter. Otherwise, v_r decreases also to zero.

At the start of the expansion the first to be carried away by the radiation are the particles with the smallest mass. During the Radiation Era, when the radiation dominates the mass, the latter is entirely dragged into the expansion. Later things change. After the Nucleosynthesis Thompson Scattering occurs, radiation try to drag the free electrons out of the plasma, but electrons are attracted to the resultant positive charge of plasma and stop the whole radial motion. Thermal equilibrium is maintained between radiation and matter. Some radiation escape and the cooling took place exclusively in an isochoric transformation. From this moment on, matter remains practically at rest. This is what speculation required.

When the temperature drops below a certain limit, the hydrogen atom recombines, the electron concentration collapses, and the radiation is no longer retained. The expansion then resumes.

No calculations can help to describe motion in the radial direction: our physics does not apply to the fourth dimension of space.

We can only note that if ρ_r, ρ_m are the densities of radiation and matter [*], the hypothesis that, because of this dragging, the radial velocity of light v_r could also depend on the ratio ρ_r/ρ_m, would confirm anyway the constancy of the expansion rate of the Universe (for at least the last 10 billion years) as ρ_r/ρ_m too has remained almost constant over time. [**]

Concerning the movement of matter, remember that the resultant of the tangential component of this disordered radiation is zero and that therefore, with reference to the position on the surface of the 4-sphere, any deviation of the celestial bodies from the straight radial trajectory drawn by the expansion of the Universe is determined only by the attraction that they exercise among themselves. Note that radiation friction does not anyway counteract Galactic Recession.

Note, finally, that the condition to be satisfied is the stationarity of matter when all the radiation is emitted. Matter does not need to instantly acquire velocity *c* to reach immediately the radiation. Subsequently matter and radiation move together.

[*] – See above in USING 4-SPHERE FORMULAS.

[**] – See above in AN APPROXIMATE SOLUTION FOR THE GALAXY EPOCH.

OTHER ASPECTS OF THE EXPANSION

Gravity, within its action range, effectively counteract the expansion to the point of canceling its effect but Recession is in no way counteracted between distant galaxies [*].

Then, the question is: it is conceivable to think of an equilibrium point between gravity and Galactic Recession? Can we calculate the distance to which there is no Recession between two galaxies? Although unlikely, a calculation of this type could also prove useful for verifying a cosmological model. Indeed, concerning two near, very ancient, galaxies, with age determination using nuclear Cosmochronology [**], if the two still exist, the alternatives are:

1. Their calculated initial distance was greater than the equilibrium distance
2. Their current distance remained almost equal to the equilibrium distance

In the first case, the model predicts that matter is dragged, in its radial motion, by Cosmic Background Radiation. During their motion on the 4-sphere surface, in case of two approaching galaxies, each undergoes the radiation pressure of the other, whose strength, depending on the light intensity, decreases with the square of the distance, as for gravity. The more they move away in the interstellar spaces, the more we can neglect both the effects of gravity and those of radiation coming from distant galaxies. (See [***] for an alternative by appealing to Dark Energy).

In the second case, the Recession speed would be zero and the two galaxies would orbit, one around the other, following Kepler's laws.

We will now address the problem in an extremely simplified way by considering the gravity binding between our Milky Way with mass $1.5 * 10^{12}\ M_{\odot}$ and Andromeda with mass $1.15 * 10^{12}$ $M_{\odot}$. [$M_{\odot}$ *is the Solar Mass*].

With an estimated age for Andromeda between 5 and 10 billion years (The Milky Way is older), we would calculate the gravitational binding as it could have been 10 billion years ago.

But, seeing its Redshift $z = -0.001$ we immediately realize that it is a Blueshift and that the two galaxies are probably orbiting.

In this case we need an estimate of the distance independent of Hubble's law in order to check if the strength of the gravitational bond is compatible with the current radius of the orbit. If so, the two galaxies have been orbiting together for the past 5-10 billion years.

This basic idea remains but our simplistic calculation is not necessary because the problem has already been solved comprehensively for the orbits of the entire Local Group. [****]

In the end however, some reasoning is necessary. For the past 10 billion years Andromeda's distance had been $2.5 * 10^6\ ly$ with a corresponding $\Theta = v/c = 1.05 * 10^{-4}$.

If 10 billion years ago Andromeda had not been gravitationally bound, its redshift, constant over time, would be $z = 0.0001$, a very low value. We can conclude that the 4-sphere can support this situation.

[*] – The problem was discussed in the standard model:

[arXiv:1005.5052] - Does gravity operate between galaxies? Observational evidence re-examined

[**] – [The Astrophysical Journal 855,2]: Ages and Heavy Element Abundances from Very Metal-poor Stars in the Sagittarius Dwarf Galaxy

[***] – [arXiv:astro-ph/9909454]: Dark Energy and the CMB

[****] – [PASJ Japan Vol 57,3]: A Dynamical Model for the Orbit of the Andromeda Galaxy M31 and the Origin of the Local Group of Galaxies

THE REACTIONS AT THE LAST SCATTERING AS AN EXPLANATION FOR POINT 2

The main recombination reaction is:

$$H^+ + e^- \rightleftarrows H + h\nu$$

where the backward reaction requires photons with at least 13.6 eV of energy, and it is favored at high temperatures.

Without introducing a significant margin for error, we will assume that, at the Last Scattering, only the production reaction of the Hydrogen atom took place, without other competing reactions.

When the CMB temperature drops below 52,000 K the backward reaction can no longer take place, having only:

$$H^+ + e^- \rightarrow H + h\nu$$

We can then think that the forward reaction produces Hydrogen in its ground state with photon emission at 10.2 eV or 13.6 eV.

Here, the reactants electrons are being consumed and the whole radiation escapes from the plasma. The main reactant $h\nu$ of the backward reaction is missing allowing us to think of a very high reaction kinetics.

The chemical equilibrium will be reached only after, when the plasma and the radiation expand together, with an immediate lowering of the photon energy. As we have hypothesized, indeed, matter reaches radiation sometime after expansion is resumed, and in this phase we cannot find H_{II} regions because there are no stars yet; the reionization of Hydrogen can only take place if the temperature of the CMB allows it.

Then, for the photoionization or, in any case, when photon is a reactant which is being consumed, the main reactions to consider are: [*]

1. $H + h\nu \rightarrow H^+ + e^-$ our forbitten backward reaction for the Recombination
2. $H^- + h\nu \rightarrow H + e^-$ a competing step reaction for the molecular Hydrogen production
3. $H_2 + h\nu \rightarrow H + H$ the backward reaction for the molecular Hydrogen production

However, we can affirm that the radiation absorbed (as number of photons) in these reactions is negligible compared to the CMB. We can ignore these reactions in this discussion.

[*] – [arXiv:astro-ph/0506221] - Cosmological Implications of the Uncertainty in H- Destruction Rate Coefficients

AN ESTIMATED VALUE FOR THE COSMIC AGE OF THE LAST SCATTERING

Our geometric shape is very far from the shapes we are used to. Inside, the physical quantities do not have gradients, they only change over time. The system is isolated from the standpoint of relativistic thermodynamics too, without having to worry about boundary conditions, simply because the system have no boundaries.

Here we neglect matter which, in our hypothesis, does not interact with the cohesive forces of the Universe, and we assume that the volume of our 4-Sphere surface is solely filled with the Cosmic Background Radiation.

To obtain the relationship between pressure P and volume V of the CMB with its temperature, we apply the Virial theorem to our radiation:

$$dU_{Univ} = \frac{3}{2} PV$$

But:

$$\left(\frac{\partial U}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V - P \quad \text{giving} \quad P \propto T^4$$

and, from the, experimentally confirmed, equality of the spectrum of the CMB with that of the Blackbody Radiation , we get the usual result:

$$P = \frac{1}{3}aT^4 \quad \text{where } a = 7.566 * 10^{-16} Jm^{-3}K^{-4} \text{ is the Radiation constant}$$

Our conjecture begins with Last Scattering and it used, until now, the solution for weak fields. But note that if in the following equation we replace h_0 with the time dependent h_t

$$\mathrm{ds}^2 = -\mathrm{c}^2\mathrm{t}^2(1 + h_t)[\sin^2(\psi)\mathrm{d}\varphi^2 + \sin^2(\psi)\sin^2(\varphi)\mathrm{d}\theta^2 + \mathrm{d}\psi^2] + (1 + h_t)\mathrm{c}^2\mathrm{dt}^2$$

the condition for the weak fields $h_t \ll 1$ is missing and the solution can no longer be applied. A similar drastic trend in gravity is not admissible even by the Schwarzschild metric (which offers a similar math expression for the time coefficient). The mass present seems not sufficient.

But here the mass, deriving from $m = E/c^2$, drops precipitously!

All this was to be expected because the model applies to the observable Universe, with more than 5 billion years while the Last Scattering occurred much earlier.

So proceeding, note that, for the thermodynamic quantities we are interested of, the result does not change if we fix a reference system such that the variations of the quantities involved do not depend on position but only on time.

As previously done, also remember that, to simplify, we can choose the point at the Universe Equator in $\mathrm{P}_{EM}(\pi/2, 0, \pi/2)$, so that for the 4-Sphere arc it applies $\mathrm{d}\xi^2 = \mathrm{d}\varphi^2 + \mathrm{d}\theta^2 + \mathrm{d}\psi^2$.

So, we have for density and pressure: $\rho = 3P$ and for spatial volume: $dV = c^3t^3 d\varphi\, d\psi\, d\theta$.

Finally, our hypotheses predict that, after the Last Scattering, the equation of state of the CMB is that of a reversible adiabatic expansion for a Blackbody radiation:

$$PV^{4/3} = const \qquad \text{or for us} \qquad ctT = const$$

For our calculation, we will use the actual data: the temperature $2.725K$ of the CMB and 13.8 billion years for the age of the Universe. About the estimated temperature for the Last Scattering, we will accept the value of $52{,}000K$ from the previous paragraph.

Then

$$ctT = 3.76 * 10^4 K^{-1}\, Mly^{-1}$$

with an estimate age for the Last Scattering of 720,000 years after the Big Bang.

An analysis on the coherence with the past eras of ΛCDM is not provided here, we only remember that a not negligible part of the cooling did not occur by adiabatic expansion but at constant volume.

CONCLUSION

To follow the analogy with the bubble is too complex, with too many basic assumptions. The hoped-for connection with Quantum Non-locality [*] cannot offer such results as to guarantee an experimental verification of this conjecture. We must abandon it and opt for a simpler solution. [**]

I expect the whole conjecture, regarding the fourth dimension of space, to be viewed with suspicion: the nature of the subject provides for it. The quote that follows certainly does not refer to border science, but I still would like to conclude with it:

"It is, however, one of the main functions of theoretical science, not merely to describe in complicated fashion those facts that are already known, but to extrapolate as wisely as may be into regions yet unexplored but pregnant with human interest."

(Richard C. Tolman)

[*] – Further speculations based on interaction of light particles, such as the neutrino, with something acting from within the 4-sphere, as a possible cause of superluminal scattering (supposing it shows up), don't seem viable now.

[**] – If we don't want to leave POINT 2 as a mere idea, this part of the conjecture must be capable of being physically falsified. But, even here, the connection with Quantum Field Theory, which seems to be the only possible way, don't seem viable now.

Chapter 5 - References from Wikipedia:

[1] - Photon gas

[2] - Radiation pressure