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In search of the fourth dimension of space

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ABSTRACT

This is a scientific speculation that presents an unusual, but at the same time intuitive, idea of a cosmological model. The model is simple and requires no parameters; born for proposing an alternative view of the Galactic Recession involves other interesting developments.

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. Gravity is needed to clarify some aspects of the model but is treated only at a qualitative level.

An intuitive explanation is given to Galactic recession and the Lorentz transformations. 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 energy. In the following publication [viXra:2008.0015] 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 and you can use this only in the context of observable Universe, during the lasts 10 billion years. 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.

Being understood that the main purpose is the alternative view of the Galactic Recession, we anticipate from [viXra:2008.0015] 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.

Finally, it is important to point out that this speculation leads to a falsifiable theory.

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.

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} (Θ_i) for the galaxy of the observer and x_{Fi} (φ_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 $v(z) = Hl$, the redshift z increases with distance l (the arc length not the angle) and depends on time

$$v_r \propto l \quad and \quad z = f(\Theta, t)$$

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 $v_r\,(t) = const, \quad \partial z/\partial t = 0$ during period concerned)

$$v_r \propto \Theta \quad and \quad z = f(\Theta)$$

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 [viXra:2008.0015] 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

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

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: in this geometry nothing crosses 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

ON THE CALCULATION OF GALACTIC RECESSION USING THE DOPPLER REDSHIFT

Thinking again in terms of Relativity (the only physics we know of), perhaps the most relevant objection to the use of the Doppler effect (SR) in calculating the Cosmologic redshift is the observation of an unexpected dilation of time in the study of supernovae.

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.

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.

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.

Also this model 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 [viXra:2008.0015] 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.

Astronomers assert that type Ia supernovae provide the equivalent of a cosmic clock. From this point on, given the complexity of the subject, it is advisable to avoid evaluations and rely on those who have studied the problem thoroughly. For this purpose, I have identified 2 articles, one against the use of Doppler redshift and one not, both useful for an in-depth analysis.

The first cited article [*] intends to exclude the use of the Doppler Redshift for the calculation of the Galactic Recession by stating that correlation between the time dilation and the redshift of the supernova it is not the one obtained with SR. The following [**] states instead that methods adopted in the observations on supernovae cannot be used to investigate cosmology.

[*] – [arXiv:0804.3595]: Time Dilation in Type Ia Supernova Spectra at High Redshift

[**] – [arXiv:1711.11237]: A problem with the analysis of type Ia supernovae

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 the maximum possible speed* $ds/dt = c$ *without being dragged by the speed of the source. Tangential speeds greater than the radial velocity c are not possible because in this geometry this would entail abandoning the surface, falling inside the 4-sphere and entering the past Universe.*

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

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

<u>But, in the 4-sphere, this is the condition on the tangential velocity not to reverse the arrow of time!</u>

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.

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 (for a Minkowski space) 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 $\beta = 0.986$

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 $t_0 = 5.07 * 10^9\ years$

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. [*]

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.

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

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

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