To the memory of
Albert Einstein.
His intuitions
have made possible
this work.

A NOVEL SPACETIME MAP OF THE UNIVERSE

Sebastiano Tirrò

ABSTRACT

A new cosmological model is proposed, which is based on two important intuitions of Albert Einstein. The model is built using the values currently considered correct for the most important system parameters (mass budget, Hubble constant, universe age). Universe dimensions, expansion velocity and total mass are computed. The highly questioned inflation hypothesis is abandoned, and the matter-antimatter unbalance strongly reduced. As a consequence, the *dark side* of the cosmos assumes new, much smaller, dimensions.

The first part of the paper shortly reviews the current situation of cosmology. In the second part the new model is discussed and evaluated from a quantitative viewpoint. The third part describes the novel spacetime map, including the derivation of luminosity distances from measured redshifts, and the discussion of the horizon problem.

COSMOLOGY TODAY

Experimental results

At the end of the 19th century most scientists were convinced that almost everything was understood. As a matter of fact, the theories set up by Newton, Maxwell, Boltzmann and other major scientists were so powerful to justify this position. But an experiment[1] performed by Michelson in 1881, then again with improved precision by Michelson and Morley in 1887, caused a major scientific crisis. It was thought, by similarity with the acoustic waves propagation, that an elastic medium existed also for the propagation of the electromagnetic waves; this medium was called “ether”. On the basis of this model, the Earth rotation was expected to produce an “ether wind”, and the light propagation velocity was expected to be slightly different in the direction of the wind and orthogonally to that direction. Interferometric techniques were used to detect the very small expected difference, but the result of the experiment was negative: the light propagation velocity was independent of the propagation direction, and the existence of the luminiferous ether was radically questioned.

The failure of the Michelson-Morley experiment was the start of new reflections by scientists like Lorentz, Poincaré, Heaviside. In 1904 Albert Einstein published his Special Relativity Theory[2][3], which brilliantly concluded this phase of theoretical developments. The publication of Einstein's General Relativity Theory[4] followed in 1916. The first experimental confirmation of the General Relativity Theory was given in 1919 by Arthur Eddington, who succeeded in measuring, thanks to a total solar eclipse, the deviation of the light emitted by a star visible close to the Sun corona.

In1933 Edwin Hubble discovered that the spectrum of the light received from far galaxies is shifted towards the red, the shift amount being proportional to the galaxy distance. This means that galaxies are moving away from the Earth, with a velocity which is proportional to the galaxy distance. The phenomenon is measured by the so-called Hubble constant in [Km/sec/Megaparsec].

Extrapolating back in time the present behavior of the universe, Georges Lemaître proposed first the idea that the universe comes from a primordial explosion. This evolutionary model was for many years in competition with a stationary model of the universe, supported, among others, by the British scientist Fred Hoyle, who named the primordial explosion "Big Bang"; the intention of Hoyle was to kill with his humour the evolutionary model, but the name he suggested became the official name of a very successful model.

According to the cosmological principle, the macrostructure of the universe should be more or less the same everywhere; the very primitive structures existing shortly after the Big Bang are not present today, in any part of the universe. However, we are not able to observe the distant regions of the universe as they are today; as a matter of fact, we observe a celestial body thanks to the light, or, more generally, the electromagnetic radiation it has emitted in the past; since the light velocity is limited, we cannot see the celestial body as it is today, but only as it was when light was emitted. If the distance of the celestial body is 1 [Gly], we see the celestial body as it was 1 [Gy] ago. But this limitation produces a wonderful gift: the primitive structures do not exist any more, but we can observe them thanks to the limited value of the light velocity! This is the reason why the Cosmic Microwave Background Radiation (CMBR) is called, by similitude with paleontology, the fossil radiation; we cannot observe the very primitive structure, but we can see its fossil remains, the microwave radiation which was emitted 13,893 [Gy] ago and still propagates throughout the universe. The same applies to all past structures of the universe: they are like extinct species, that we cannot observe alive, but only through their fossil remains, i.e. the radiations they emitted in the past, which still travel the universe, and will continue to travel it in the future.

The definitive proof that the Big Bang model is correct was obtained at the beginning of the '60s by Arno A. Penzias and R. W. Wilson[5], who detected for the first time the CMBR and measured its level. This was a clear case of serendipity, since Penzias and Wilson were unaware of the importance of their discovery; they were in fact not involved in scientific research, but worked as electronic engineers in the Bell Laboratories, with the responsibility to develop the low-noise receiving system for the Telstar experimental satellite; their receiving system was so low-noise and so well identified that they were able to understand that an excess noise was received from the sky. At short distance from them a scientific team, headed by R. H. Dicke[6][7], was looking for the CMBR, but was not able to find it, because their receiving system was not adequate.

After the Penzias-Wilson discovery, the CMBR has constantly been a subject of experimental research. Several scientific satellites have been launched to measure the CMBR with increasing accuracy, like the COBE[8], the Wilkinson Microwave Anisotropy Probe (WMAP)[9], and Planck[10][11]. Stratospheric balloons have also been used to this purpose[12][13]. All the measurements have confirmed that the early universe was homogeneous and isotropic; the most recent result, due to the Planck spacecraft, is that the universe is homogeneous and isotropic to one part in 100.000. Of course homogeneity and isotropy are not absolute characteristics in the present universe, which is characterized by the presence of structures, i.e. by local unbalances; going back in time, however, a de-structuration process takes place, so that in the very early phase of its life the universe was homogeneous and isotropic.

Major experimental research efforts have been devoted in the '90s to the determination of the acceleration of the universe expansion. The expectations were that, due to gravitational attraction, the expansion velocity of the universe decreases; this means that, looking to the far regions of the universe, i.e. in a remote past time, one should measure a significantly higher velocity of expansion. Due to these expectations, published papers talk about the measurement of a "deceleration parameter"; but the surprising result was the universe expansion is accelerating!

Two parallel research programs, named respectively "High-z Supernova Project"[14][15] and "Supernova Research Project"[16], reached the same conclusion: the universe is accelerating.
As a result, it is generally accepted today that the universe is composed by:
- about 4% of baryonic mass;
- about 26% of dark mass;
- about 70% of dark energy (which is needed to support the accelerated expansion of the universe).

It is interesting now to compare this situation with the scientific belief at the end of the 19^{th} century; scientists were then convinced to have understood almost everything, whereas the adjective "dark" is associated today with 96% of the reality.

Einstein contributions

The most important theoretical contributions to modern cosmology are due to Albert Einstein; more than that, it can be affirmed that Einstein has founded modern cosmology. The key point of his General Relativity Theory (GRT) is that spacetime is curved by matter. Although Einstein defined the field equation he never solved it; shortly after the GRT publication, two solutions were found, by Friedmann and Schwarzschild, the first showing, among others, the possibility of the Big Bang, the second leading to the conception of the Black Hole.

To avoid the gravitational collapse of the universe, Einstein arbitrarily introduced in his field equation a constant term that he named "cosmological constant", accounting for some form of repulsive gravity. Subsequently, he considered the cosmological constant as "the biggest mistake of my life". However, the recent discovery that the expansion of the universe is accelerating proves that Einstein was correct also in this case. Although most scientists prefer to talk about "dark energy", we will propose a cosmological model based on repulsive gravity, as suggested by Einstein.

Since space is curved by matter, if we assume a uniform distribution of matter, we should have a constant curvature of space, therefore our tridimensional space should be curved. Einstein suggested also this possibility in a paper published in 1917[17]. This is the second basic characteristic of the cosmological model proposed in this work.

Inflation

CMBR measurements have clarified that the early universe was homogeneous and isotropic. Immediately after, the building of structures started, but the absolute homogeneity and isotropy of the early ages guarantees that similar structures are present everywhere in the universe (cosmological principle). However a major problem arises here, since to reach homogeneity and isotropy some form of physical communication between the various parts of the universe is required, and we know that all forms of physical communication cannot exceed the speed of light.

In the current Big Bang model, expansion of the universe is assumed to start from a geometric point, which is a singularity; it is difficult, in this context, to create the conditions which guarantee homogeneity and isotropy in the early universe; a solution named *inflation* was therefore proposed at the beginning of the '80s.

The inflation is a very quick increase of the universe dimensions in a small fraction of the first second of life of the universe. The inflationary epoch lasts from 10^{-36} seconds to 10^{-32} seconds after the Big Bang; in this very short period of time the universe linear dimensions increase by a factor of at least 10^{26} to around 10 centimeters. This dimension may seem, and in fact is, very small, but, when the extremely short time duration is considered, one understands that a velocity much higher than the speed of light is required! The inflationary theory is based therefore on a major infringement of a basic postulate established by Einstein.

The inflation theory was developed in the late '70s and early '80s by several theoretical physicists, including Alexei Starobinsky at Landau Theoretical Physics Institute, Alan Guth[18][19] at Cornell University, and Andrei Linde at Lebedev Physical Institute. The theory explains the origin of the large-scale structure in the cosmos. Quantum fluctuations in the microscopic inflationary region, magnified to cosmic size, become the seeds for the growth of structure in the universe. Many physicists also believe that inflation explains why the universe appears to be the same in all directions (isotropic), why the CMB radiation is evenly distributed, why the universe is flat, and why no magnetic monopoles have been observed.

The detailed particle physics mechanism responsible for inflation is unknown. The basic inflationary paradigm is accepted by most physicists, as a number of inflation model predictions have been confirmed by observation. However, a substantial minority of scientists dissent from this position.

Many physicists, mathematicians and philosophers of science claim that the theory has produced untestable predictions and lacks serious empirical support. In 1999, John Earman and Jesús Mosterín[20] published a thorough critical review of inflationary cosmology, concluding: “We do not think that there are, as yet, good grounds for admitting any of the models of inflation into the standard core of cosmology.” Paul Steinhardt[21], one of the founding fathers of inflationary cosmology, has recently become one of its sharpest critics. Ijjas, Steinhardt and Loeb[22] claimed that the inflationary paradigm is in trouble in view of the data from the Planck satellite.

But the most severe criticisms come perhaps from Roger Penrose[23][24]. He points out that, in order to work, inflation requires extremely specific initial conditions of its own, so that the problem of initial conditions is not solved: “There is something fundamentally misconceived about trying to explain the uniformity of the early universe as resulting from a thermalization process. […..] For, if the thermalization is actually doing anything […..] then it represents a definite increasing of the entropy. Thus, the universe would have been even more special before the thermalization than after.” Penrose considered all possible configurations: some lead to inflation, some others lead to a uniform, flat universe directly, without inflation. Obtaining a flat universe is unlikely overall. Penrose’s shocking conclusion is that obtaining a flat universe without inflation is much more likely than with inflation, by a factor of 10 to the googol (10 to the 100) power!

Major problems in today cosmology

We feel three major problems in today cosmology:
- 96% of reality is labeled “dark”;
- the inflation process is highly questionable;
- although antimatter has been proven possible, it gets immediately annihilated when in contact with matter, and an absolute unbalance between matter and antimatter exists.

In the following we propose a cosmological model which allows some interesting steps forward in these respects. It is important to recognize that this model is based on two major Einstein intuitions, i.e. repulsive gravity and curved 3-dimensional space. These two hypotheses offer a very simple explanation of the observed phenomena. In fact a hyperspherical surface explains very well how the universe can be expanding in all directions in a uniform way. On the other hand, repulsive gravity can explain why the universe expansion is accelerating, as recently established by Supernovae observations.

DESCRIPTION AND ANALYSIS OF THE PROPOSED COSMOLOGICAL MODEL

Cosmological model description

Figure 1 shows the proposed cosmological model. Space has four dimensions. An antimatter white hole is placed at the center of a curved 3-dimensional universe of matter, with curvature radius R_u. In other words, the universe occupies the surface of a hypersphere of radius R_u, therefore the volume of the universe is $2\pi^2 R_u^3$ [m^3].

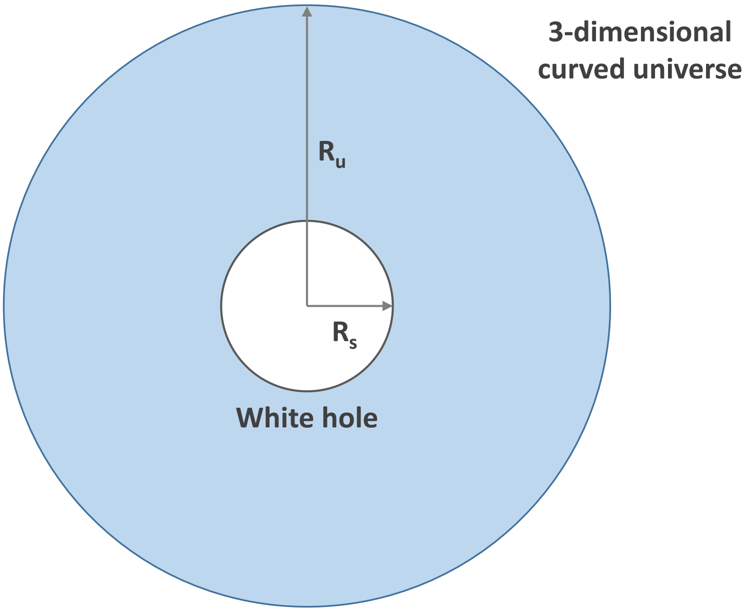


Fig. 1 – The proposed cosmological model

R_s = White hole Schwarzschild radius

R_u = Universe radius

The equation of the hypersphere in Cartesian coordinates is:

$$(x_1 - x_{10})^2 + (x_2 - x_{20})^2 + (x_3 - x_{30})^2 + (x_4 - x_{40})^2 = R_u^2 \qquad (1)$$

where $C(x_{10}, x_{20}, x_{30}, x_{40})$ is the center of the hypersphere.

The equation can also be written in polar coordinates as follows:

$$x_1 = R_u \cos\varphi_1$$

$$x_2 = R_u \sin\varphi_1 \cos\varphi_2$$

$$x_3 = R_u \sin\varphi_1 \sin\varphi_2 \cos\varphi_3$$

$$x_4 = R_u \sin\varphi_1 \sin\varphi_2 \sin\varphi_3 \qquad (2)$$

where:

$$0 \leq \varphi_1 \leq \pi$$

$$0 \leq \varphi_2 \leq \pi$$

$$0 \leq \varphi_3 \leq 2\pi$$

The infinitesimal element of the hypersphere surface is:

$$\mathrm{d}S = R_u^3 \sin^2\varphi_1 \sin\varphi_2 \mathrm{d}\varphi_1 \mathrm{d}\varphi_2 \mathrm{d}\varphi_3 \qquad (3)$$

It is assumed that the matter of the universe and the antimatter of the white hole are in relation through a gravitational force of repulsive nature, the modulus of which is given by the usual Newton law. Mass and electrical charge should behave in opposite ways: whereas electrical charges of different signs attract each other, antimatter should push matter away. This behavior is predicted by theory, and an experimental confirmation is expected within few years[25]. The matter of the universe could be a CPT transformation of antimatter precipitating in the white hole (*ibidem*).

These assumptions give a beautiful explanation of the cosmological constant and of the accelerating universe expansion. And another intuition of Einstein would prove correct!

Of course the *push* given by the antimatter white hole would be counteracted by the *pull* due to the universe matter; without the push, in the long term the universe would collapse, and this is the very reason why Einstein introduced the cosmological constant in his field equation. As a matter of fact, our calculations show that the push due to white hole repulsive action prevails over the pull due to universe matter attraction, so that the universe continues to expand, as also confirmed by the Supernovae measurements.

The repulsive force due to the antimatter white hole

The antimatter located at the center of our cosmos is a white hole for the matter, which is pushed away. Due to the enormous mass value, an event horizon will exist, given by the formula:

$$R_s = \frac{2GM_{wh}}{c^2} \qquad (4)$$

where:
- R_s = Schwarzschild radius of the white hole, i.e. event horizon [m];
- M_{wh} = white hole mass [Kg];
- G = gravitational constant = $6{,}6743 \cdot 10^{-11}$[$m^3 Kg^{-1} s^{-2}$];
- c = velocity of light = 299.792.458 [m/s].

If we assume:

$$R_s = 100 \text{ million [light-years]} \qquad (5)$$

we may easily compute from formula (4):

$$M_{wh} = 6{,}382 \cdot 10^{50} \text{ [Kg]} \qquad (6)$$

The repulsive force, acting on the unit universe mass, due to the white hole mass will be:

$$F_{wh}(R_u) = -G\frac{M_{wh}}{R_u^2} \qquad (7)$$

and the potential of this force field will be:

$$P_{wh}(R_u) = G\frac{M_{wh}}{R_u} \qquad (8)$$

The attractive force due to the 3-dimensional universe of matter

It is generally accepted today that the universe is composed by:
- about 4% of baryonic mass;
- about 26% of dark mass;
- about 70% of dark energy.

In our cosmological model we explain the accelerating expansion of the universe (i.e. the cosmological constant, i.e. the dark energy) by the presence of a gigantic antimatter white hole, so that also the dark energy corresponds to a mass, the value of which we have just computed. In our bipolar (matter-antimatter) model, however, we call "universe" just what is composed by matter, which accounts for 30% of the total; we call instead "cosmos" the sum of the antimatter white hole and of the 3-dimensional curved universe made of matter; the mass of the cosmos is therefore 100% of what exists.

The mass of the universe will therefore be:

$$M_u = \frac{3}{7} \cdot M_{wh} = 2{,}7352 \cdot 10^{50} \text{ [Kg]} \qquad (9)$$

Let now compute the attractive force due to the universe, which would in the long term cause the universe to collapse, if not counteracted by the repulsive gravity due to the white hole.

The universe density is given by:

$$\rho_u = \frac{M_u}{2\pi^2 R_u^3} \text{ [Kg/m}^3\text{]} \qquad (10)$$

and the mass of the infinitesimal element of hypersphere surface will be:

$$\mathrm{d}M_u = \frac{M_u}{2\pi^2 R_u^3} \cdot \mathrm{d}S = \frac{M_u}{2\pi^2} \cdot \sin^2\varphi_1 \sin\varphi_2 \mathrm{d}\varphi_1 \mathrm{d}\varphi_2 \mathrm{d}\varphi_3 \text{ [Kg]} \qquad (11)$$

Suppose now, just in order to simplify the calculations, that a unit mass element is located at the North Pole of our universe. This element will be subject to gravitational attraction by all other mass elements constituting the universe. The distance between the polar element of Cartesian coordinates (R_u, 0, 0, 0) and the generic element of Cartesian coordinates given by (2) is:

$$D = R_u \cdot \sqrt{2 \cdot (1 - \cos \varphi_1)} \qquad (12)$$

The distance D depends only on the angle φ_1 thanks to the choice to put the unit mass element at the North Pole. As shown in figure 2, the generic element $\mathrm{d}M_u$ located in B attracts the unit mass element located in A (=North Pole) with a force of intensity:

$$\mathrm{d}F = G \frac{\mathrm{d}M_u}{D^2} \qquad (13)$$

This force, however, is directed from A to B, whereas we are interested in the component of this force directed from A to O (=white hole), that we will call element of the universe force $\mathrm{d}F_u$. It is easily seen that:

$$\mathrm{O\hat{A}B} = \frac{\pi}{2} - \frac{\varphi_1}{2}$$

therefore:

$$\mathrm{d}F_u = \mathrm{d}F \cdot \cos \mathrm{O\hat{A}B} = \mathrm{d}F \cdot \sin \frac{\varphi_1}{2} \qquad (14)$$

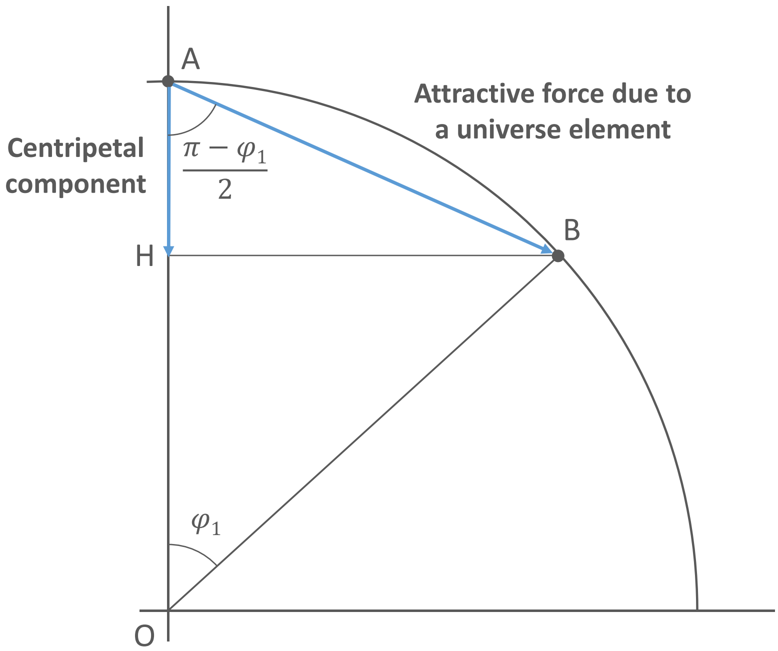


Fig. 2 – The centripetal component of the attractive force due to the universe

By substitution of (12) and (13) in (14) we obtain:

$$\mathrm{d}F_u = G \cdot \frac{\mathrm{d}M_u}{2R_u^2(1 - \cos\varphi_1)} \cdot \sin\frac{\varphi_1}{2} \qquad (15)$$

Substituting (11) in (15) we obtain:

$$\mathrm{d}F_u = \frac{1}{4\pi^2} \cdot \frac{GM_u}{R_u^2} \cdot (1 + \cos\varphi_1) \cdot \sin\frac{\varphi_1}{2} \cdot \sin\varphi_2 \cdot \mathrm{d}\varphi_1\mathrm{d}\varphi_2\mathrm{d}\varphi_3 \qquad (16)$$

To obtain the attractive force due to all the universe we must now integrate (16) with respect to φ_1, φ_2 and φ_3, obtaining the triple integral:

$$F_u = \frac{1}{4\pi^2} \cdot \frac{GM_u}{R_u^2} \int_0^{\pi}\int_0^{\pi}\int_0^{2\pi} (1 + \cos\varphi_1) \cdot \sin\frac{\varphi_1}{2} \cdot \sin\varphi_2 \cdot \mathrm{d}\varphi_1\mathrm{d}\varphi_2\mathrm{d}\varphi_3 \qquad (17)$$

This triple integral can be split in the product of three simple integrals as follows:

$$F_u = \frac{1}{4\pi^2} \cdot \frac{GM_u}{R_u^2} \int_0^{\pi} (1 + \cos\varphi_1) \cdot \sin\frac{\varphi_1}{2} \cdot \mathrm{d}\varphi_1 \int_0^{\pi} \sin\varphi_2 \,\mathrm{d}\varphi_2 \int_0^{2\pi} \mathrm{d}\varphi_3 \qquad (18)$$

Recalling the cosine duplication formula, we obtain:

$$\int_0^{\pi} (1 + \cos\varphi_1) \cdot \sin\frac{\varphi_1}{2} \cdot \mathrm{d}\varphi_1 = \frac{4}{3}$$

therefore:

$$F_u = \frac{1}{4\pi^2} \cdot \frac{GM_u}{R_u^2} \cdot \left(\frac{4}{3}\right) \cdot (2) \cdot (2\pi) = \frac{4}{3\pi} \cdot \frac{GM_u}{R_u^2} \qquad (19)$$

Recalling (7) and (9) we finally obtain:

$$F_u = \frac{4}{7\pi} \cdot \frac{GM_{wh}}{R_u^2} = -\frac{4}{7\pi} F_{wh} \qquad (20)$$

Total gravitational potential

The unit mass element of the universe will be subject to the total force:

$$F_t = F_{wh} + F_u = -\left(1 - \frac{4}{7\pi}\right) \cdot \frac{GM_{wh}}{R_u^2} \qquad (21)$$

The total gravitational potential will therefore be:

$$U(R_u) = -\int_{R_u}^{\infty} F_t \,\mathrm{d}R_u = \left(1 - \frac{4}{7\pi}\right) \cdot \frac{GM_{wh}}{R_u} \qquad (22)$$

Radial expansion velocity of the universe

We can now compute the increase of the radial expansion velocity of the universe from R_s (white hole Schwarzschild radius) to R_u (universe radius). The increase of kinetic energy e-quals the decrease of potential energy, according to equation:

$$\Delta E = \frac{1}{2} \cdot m \cdot (v_u^2 - v_s^2) = \Delta U = U(R_s) - U(R_u) \qquad (23)$$

where:

$$m = \frac{m_0}{\sqrt{1 - \frac{v_u^2}{c^2}}} \qquad (24)$$

is the relativistic value of the mass, corresponding to a rest value m_0. Since the mass rest val-ue equals 1, and v_s equals 0, we obtain:

$$\frac{1}{2} \cdot v_u^2 = \left(1 - \frac{4}{7\pi}\right) \cdot \left(\frac{GM_{wh}}{R_s} - \frac{GM_{wh}}{R_u}\right) \cdot \sqrt{1 - \frac{v_u^2}{c^2}} \qquad (25)$$

$$\frac{1}{2} \cdot v_u^2 = \left(1 - \frac{4}{7\pi}\right) \cdot \frac{GM_{wh}}{R_s} \cdot \left(1 - \frac{R_s}{R_u}\right) \cdot \sqrt{1 - \frac{v_u^2}{c^2}} \qquad (26)$$

Recalling now formula (4), we obtain:

$$\frac{v_u^2}{c^2} = \left(1 - \frac{4}{7\pi}\right) \cdot \left(1 - \frac{R_s}{R_u}\right) \cdot \sqrt{1 - \frac{v_u^2}{c^2}} \qquad (27)$$

As R_u tends to infinity, the radial expansion velocity tends to a value which does not depend on R_s; in other words, the limit value of the radial expansion velocity does not depend on the total mass of the cosmos; this limit value is easily computed to be 222.181.791 m/s.

To find the value of v_u we need to square both members of equation (27) and to introduce the auxiliary variable:

$$y = \frac{v_u^2}{c^2} \qquad (28)$$

obtaining the quadratic equation:

$$y^2 + \left(1 - \frac{4}{7\pi}\right)^2 \cdot \left(1 - \frac{R_s}{R_u}\right)^2 \cdot y - \left(1 - \frac{4}{7\pi}\right)^2 \cdot \left(1 - \frac{R_s}{R_u}\right)^2 = 0 \qquad (29)$$

This equation can be easily solved for each value of the parameter R_s/R_u finding $v_u = c \cdot \sqrt{y}$.

Solving process and estimates of present values

The solving process has been programmed on an EXCEL sheet for:

$$K = \frac{R_{u,k}}{R_s} = 1{,}01 \div 130,\ \text{step } 0{,}01 \qquad (30)$$

Fixing a value for the events horizon, i.e. for the cosmos total mass, we obtain the universe radius in the K_{th} time interval:

$$R_{u,k} = K \cdot R_s \qquad (31)$$

The time needed to cover the distance $0{,}01 \cdot R_s$ in the K_{th} time interval is:

$$T_k = \frac{0{,}01 \cdot R_s}{v_{u,k}} \qquad (32)$$

The distance in time between the K_{th} time interval and today is given by the formula:

$$L_k = \sum_{K}^{130} \frac{0{,}01 \cdot R_s}{v_{u,k}} \qquad (33)$$

In other words, the K_{th} time interval is located at time $-\ L_k$ with respect to today.

If we take K = 1,01 in (33), we obtain the life of the universe:

$$L = \sum_{1{,}01}^{130} \frac{0{,}01 \cdot R_s}{v_{uk}} \qquad (34)$$

For similarity, the specific expansion velocity of the universe (i.e. the Hubble parameter) equals the specific radial expansion velocity (i.e. the radial velocity normalized to the universe radius). The value of the Hubble parameter in the K_{th} time interval is therefore found using the formula:

$$H(R_{u,k}) = \frac{v_{u,k}}{R_{u,k}} \qquad (35)$$

The present value of the Hubble parameter is estimated to be within 67÷72 Km/s/Mparsec. The life of the universe is estimated to be within 13,4÷14,0 billion years.

The values of R_s and K_{max} must be chosen so as to reasonably comply with these estimates. If we choose $R_s = 100$ million [light − years] and $K_{max} = 101{,}70$, we obtain the following estimates for today's universe:

H = 71,03 [Km/s/Megaparsec]
L = 13,893 [Billion years]
$R_{u,0}$ = 10,170 [Billion light-years] (36)

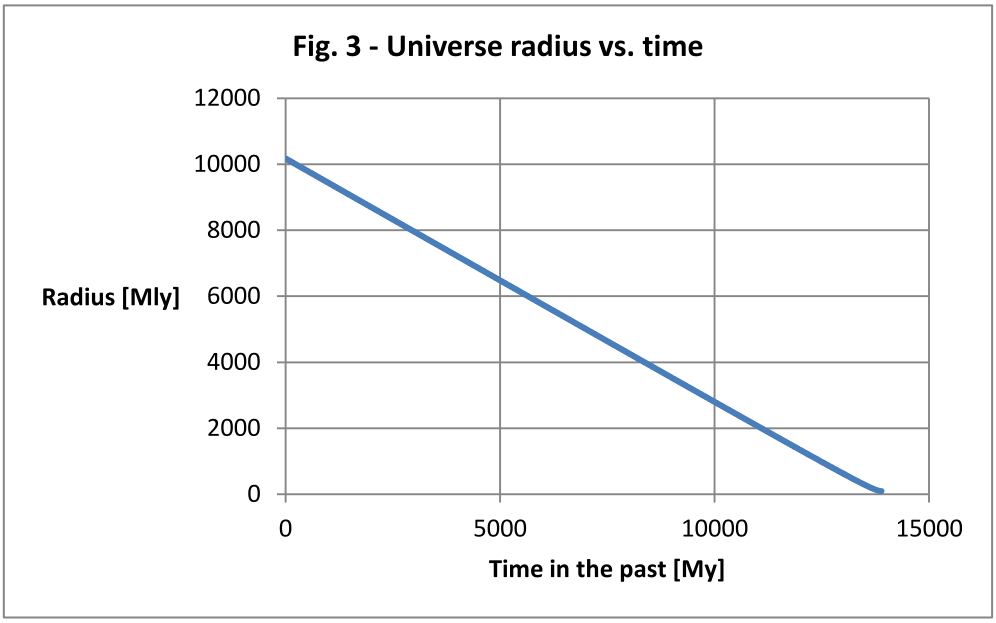
$$M_{wh} = 6{,}382 \cdot 10^{50} \text{ [Kg]}$$
$$M_u = 2{,}735 \cdot 10^{50} \text{ [Kg]}$$

The order of magnitude of the mass is in reasonable agreement with most current estimates.

Evolution of the universe

The results of our calculations have been summarized in some figures.

Fig. 3 shows the increase of the universe radius during the universe life; it is an almost linear trend, with the exception of the early universe (see fig. 3a).



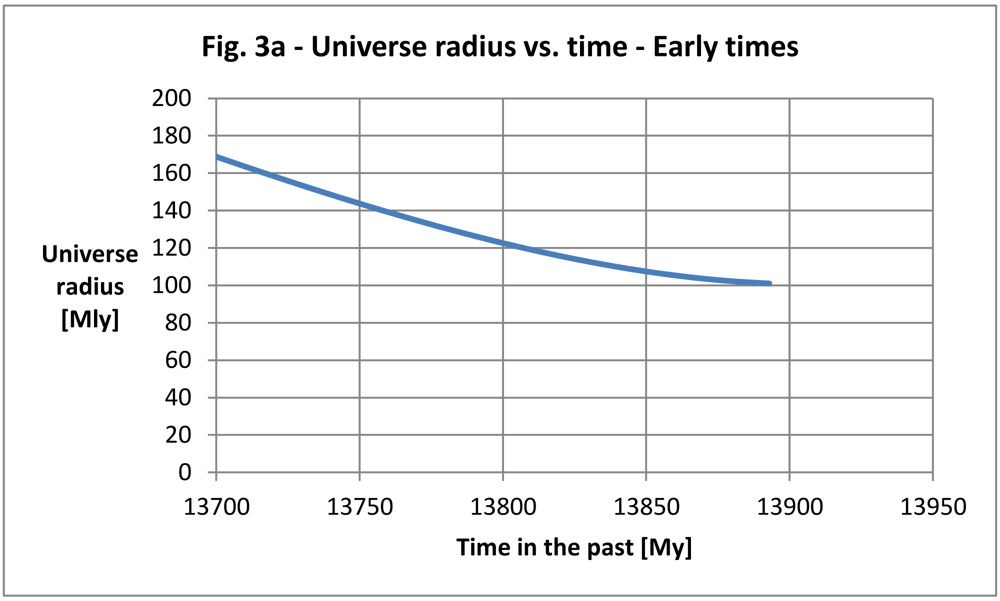


Fig. 4 shows the increase of the radial expansion velocity, which tends however to a limit value as time goes to infinity.

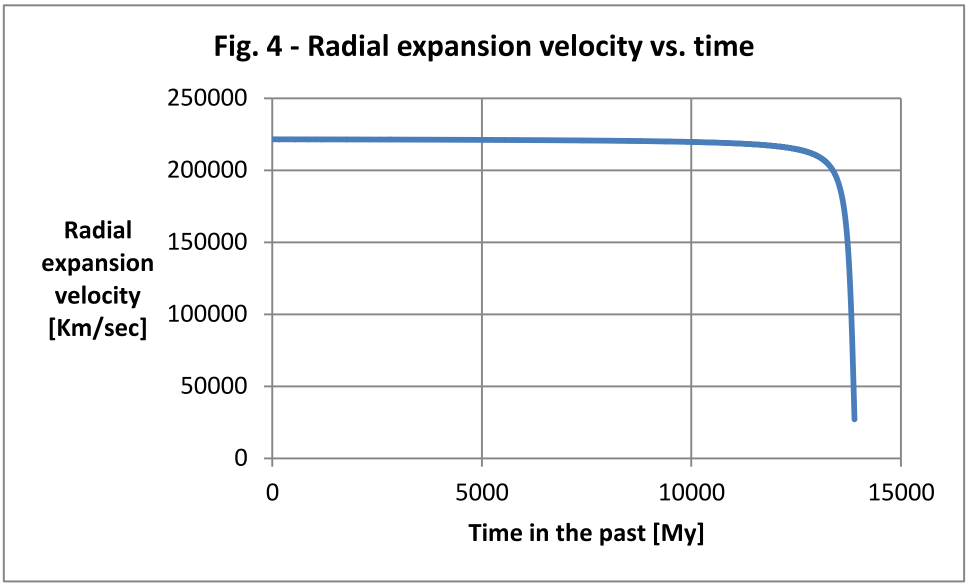


Fig. 5 shows the behavior of the Hubble parameter: it increases very rapidly in the first phase of the universe life, to reach a maximum value of about 3.190 Km/sec/Megaparsec after 144 Million years; today the value is 71,03 Km/s/Mp, but will tend to zero as time tends to infinity.

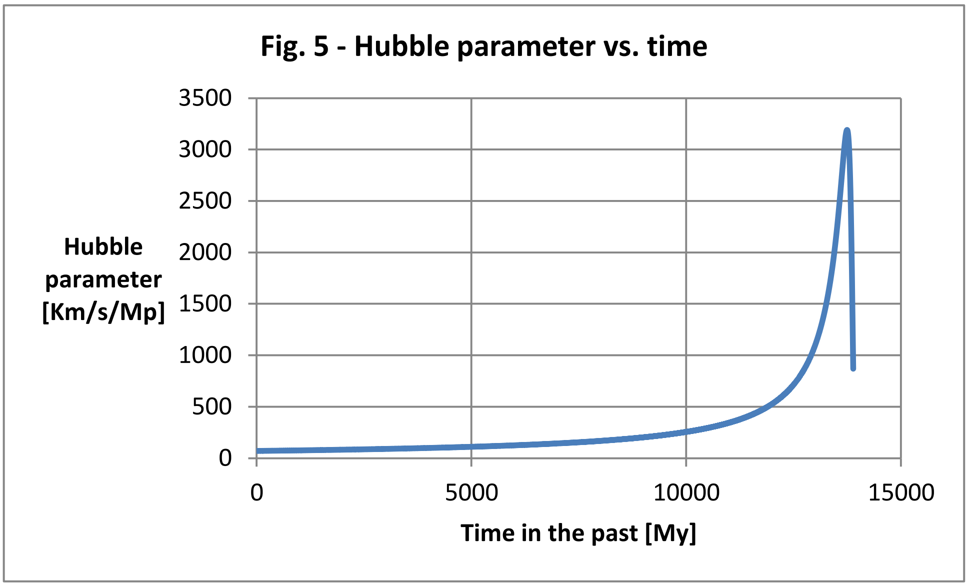


Fig. 6 shows the acceleration of the expansion of the universe: it decreases rapidly, today is very small, and will tend to zero as time tends to infinity. Fig. 6a gives a better view, thanks to the use of the logarithmic scale.

Fig. 6 - Universe acceleration vs. time

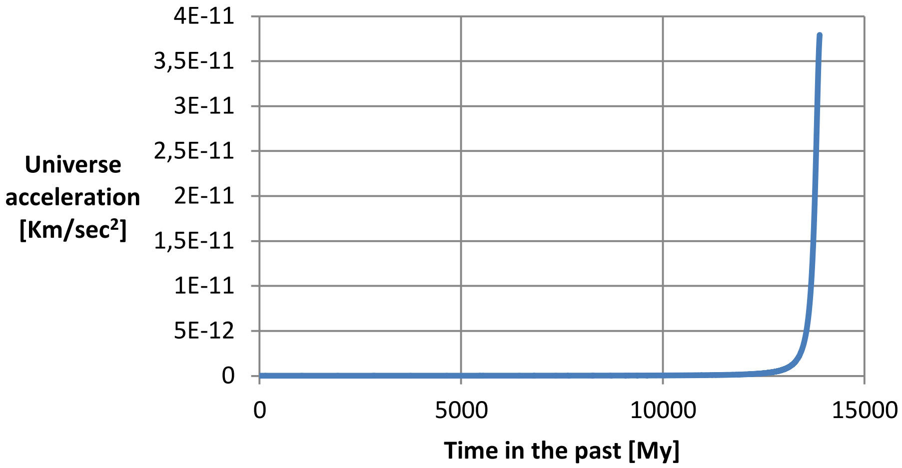
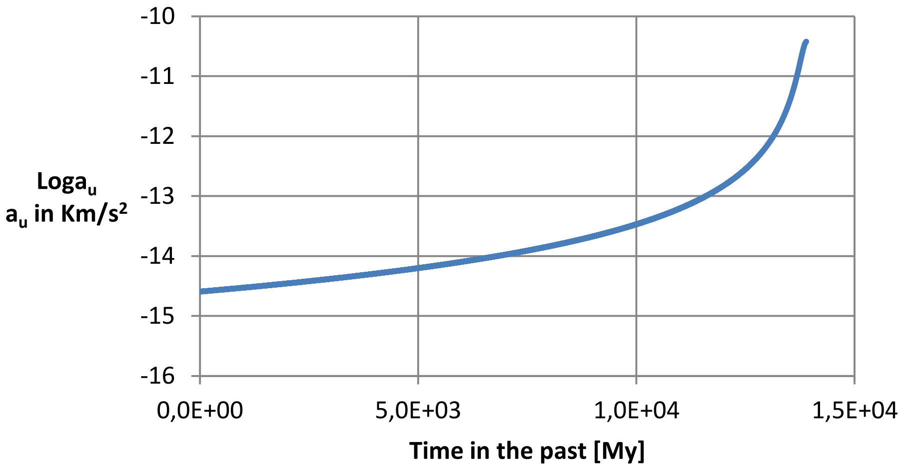


Fig. 6a - Universe acceleration vs. time (log scale)



SPACETIME MAP OF THE UNIVERSE

A 4-dimensional model for our observations

In the previous chapters we have proposed and discussed a 4-dimensional model of the cosmos (four *space* dimensions). The total mass of the cosmos is subdivided in white hole anti-matter (70%) and universe matter (30%). Due to repulsive gravity, the universe is expanding with a small radial acceleration, and has reached at present a radius of 10,170 [Gly]. During its 13,893 [Gy] life, the universe has evolved from elementary particles to atoms, therefore molecules, gas clouds, stars, planets, until a comfortable environment was created to host life and intelligent beings, who are able to observe the universe and understand its structure and its history.

As already clarified, thanks to the limited value of the light velocity, we can observe today all past structures of the universe, which do not exist any more.

We will now use the same 4-dimensional model which was proposed for the distribution of mass in the universe to understand the meaning of our observations. Again, if we put our observation point (the Earth) in the North Pole of the universe $(R_u, 0, 0, 0)$, the distance to a generic point of the universe will depend only on the colatitude φ_1, and not on the angles φ_2 and φ_3 (see formula (12)). This means that for each distance (or colatitude) we will have ∞^2 directions of arrival of the radiation; in other words, the observation point can be reached by the radiation through ∞^2 different paths, each defined by a different pair of $(\varphi_2,\ \varphi_3)$ values.

For symmetry reasons the light will follow similar paths, whichever the direction from which it arrives; the light path can be evaluated in the simplest way if we assume $\varphi_2 = \varphi_3 = 0$. This is the polar equation of the $(R_u,\ \varphi_1)$ plane. In this case the generic point coordinates become $(R_u \cos\varphi_1, R_u \sin\varphi_1,\ 0,\ 0)$, and we may call φ_1 the separation angle between the celestial body and the observation point. Formula (12) gives the chord-distance between the observer and the celestial body, but what matters here is the arc-distance, since the light is forced by gravitation to travel through the universe, following a curved path; the arc-distance is generally expressed by the formula $R_u \cdot \varphi_1$, but it is important here to distinguish three different values of distance:

- the *physical distance*, which equals $R_{u,e} \cdot \varphi_1$, where $R_{u,e}$ is the radius of the universe when radiation is emitted by the celestial body;
- the *luminosity distance*, which equals $R_{u,r} \cdot \varphi_1$, where $R_{u,r}$ is the universe radius when radiation is received by the observer;
- the *light-covered distance*, which equals $c \cdot \Delta T_{e-r}$, where ΔT_{e-r} is the time employed by the light emitted by the celestial body to reach the observer; the light-covered distance is intermediate between the physical distance and the luminosity distance, and equals the length of the quasi-spiral arc connecting the celestial body and the observer in the $(R_u,\ \varphi_1)$ plane.

From cosmological redshift to luminosity distance

The two Supernovae Research Projects reached the conclusion that the universe expansion is accelerating by comparing redshifts and luminosity distances of far Supernovae with those of close Supernovae. Of course we took benefit of their results, and built a cosmological model which allows to compute redshift and luminosity distance versus time, so that the luminosity distance can now be derived directly from redshift measurements, which are much more precise.

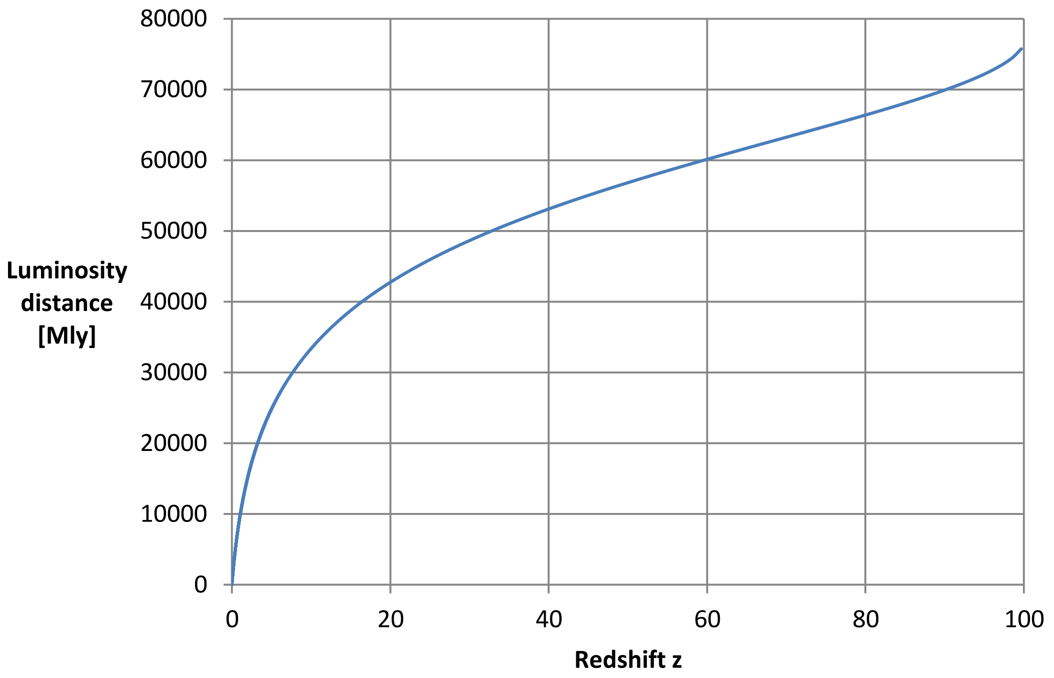
The redshift value is computed by the simple formula:

$$z = \frac{R_{u,0}}{R_u} - 1 \qquad (37)$$

As concerns the luminosity distance, we must start from formula (32), which gives the time needed to cover the distance $0{,}01 \cdot R_s$ in the K_{th} time interval; during this time the light will cover the distance $c \cdot T_k$, which is then magnified by the factor $R_{u,0}/R_u$, due to universe expansion. The K_{th} contribution to the luminosity distance will therefore be:

$$d_{LK} = 0{,}01 \cdot R_s \cdot \frac{1}{v_u} \cdot c \cdot \frac{R_{u,0}}{R_u} \qquad (38)$$

Fig. 7 - Luminosity distance vs. redshift (today)



By simple rearrangements we obtain:

$$d_{LK} = 0{,}01 \cdot R_{u,0} \cdot \frac{1}{\frac{v_u}{c}} \cdot \frac{1}{K} \qquad (39)$$

where $R_{u,0}$ is the universe radius today, and all quantities are known.

The luminosity distance is simply obtained by integration between the K_{th} time and today, which gives:

$$D_{LK} = \sum_{K}^{101,70} d_{LK} \qquad (40)$$

Fig. 7 gives the luminosity distance versus the redshift for today's universe. Similar curves can be easily computed for other epochs of the universe life.

It is also easy to compute the angular separation between the light emitting star and our planet:

$$\alpha_K = \frac{D_{LK}}{R_{u,0}} \cdot \frac{180}{\pi} \quad [\text{deg}] \qquad (41)$$

This allows to obtain a polar representation of all the stars observed from our planet today, in a $(R_u,\ \alpha)$ plane; the α angle is the same as the colatitude φ_1. Similar representations can be obtained for other epochs of the universe life. Fig. 8 shows the results if the R_u scale is linear; the trend of the curves gets confused in the proximity of the white hole, where big variations of the angular separation are masked by the scale inadequacy. A better visibility of what happens in the proximity of the white hole is obtained if a logarithmic scale is adopted for R_u (see fig. 9); conversely, the curves get closer for big values of R_u.

The curves which we have obtained are spiral-like, as expected. In fact a spiral is obtained by combination of a circular uniform motion and a linear radial uniform motion. Our curves are not perfect spirals, because the circular motion (light travelling the universe) is uniform, but the linear motion (the expanding universe) is not uniform, since the expansion velocity is ever increasing; however, as time tends to infinity, the radial expansion velocity of the universe tends to a constant value, and the curve tends to a perfect spiral.

The length of the curve corresponding to today's universe equals the distance covered by the light during the universe life, i.e. 13,893 billion light-years, which must be compared to a universe radius of 10,170 billion light-years.

The redshift corresponding to a given angular separation keeps almost constant throughout universe life for small values of the angle, whereas large variations appear beyond a separation of about 60 degrees.

The quasi-spiral curves are geodesics, i.e. minimal-length paths for the light to connect two points in the given gravitational field. The observation point and the light source move on two

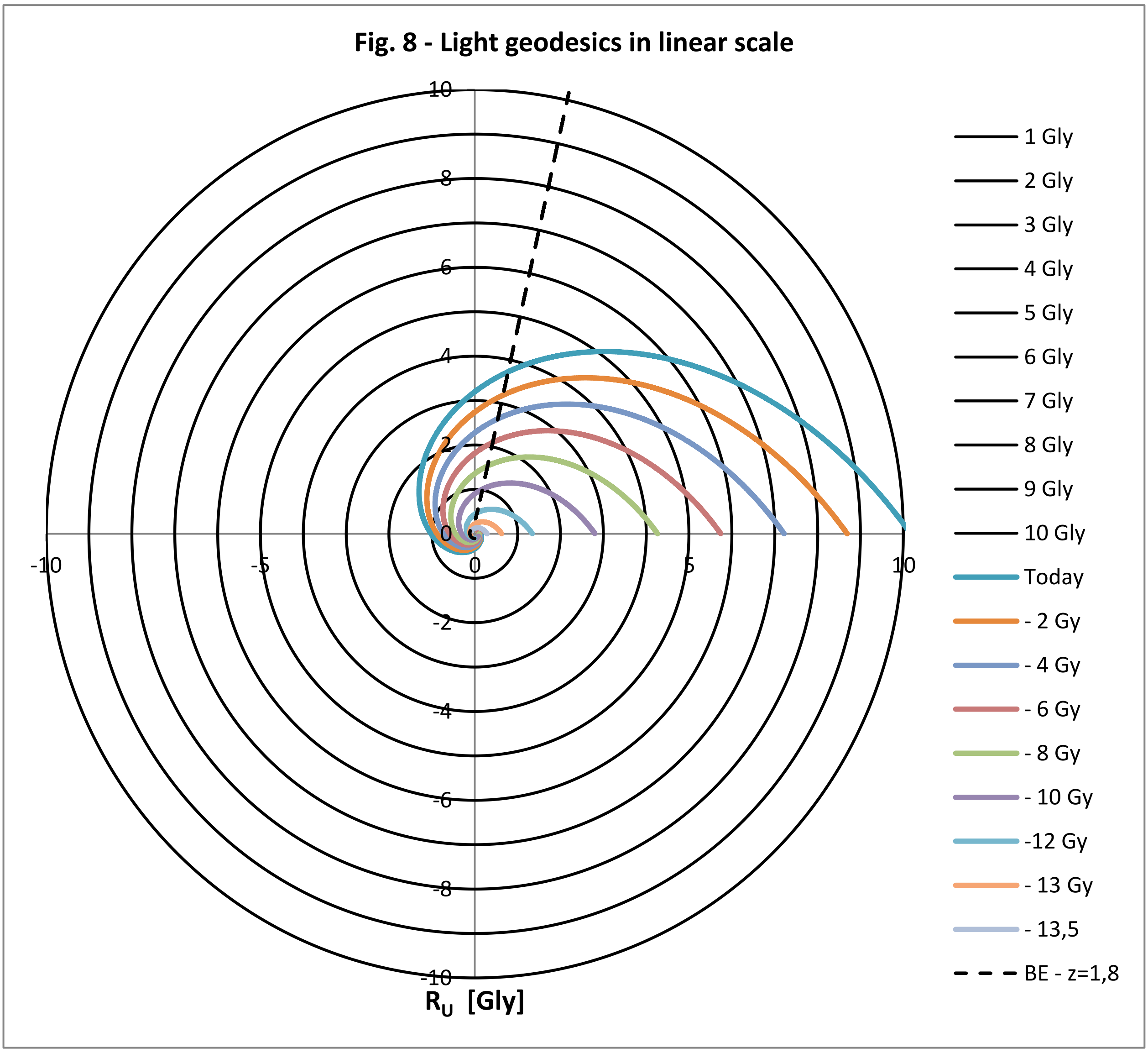


Fig. 8 - Light geodesics in linear scale
10
8
6
4
2
0
-2
-4
-6
-8
-10
-10
-5
0
5
10
R_U [Gly]
1 Gly
2 Gly
3 Gly
4 Gly
5 Gly
6 Gly
7 Gly
8 Gly
9 Gly
10 Gly
Today
- 2 Gy
- 4 Gy
- 6 Gy
- 8 Gy
- 10 Gy
-12 Gy
- 13 Gy
- 13,5
BE - z=1,8

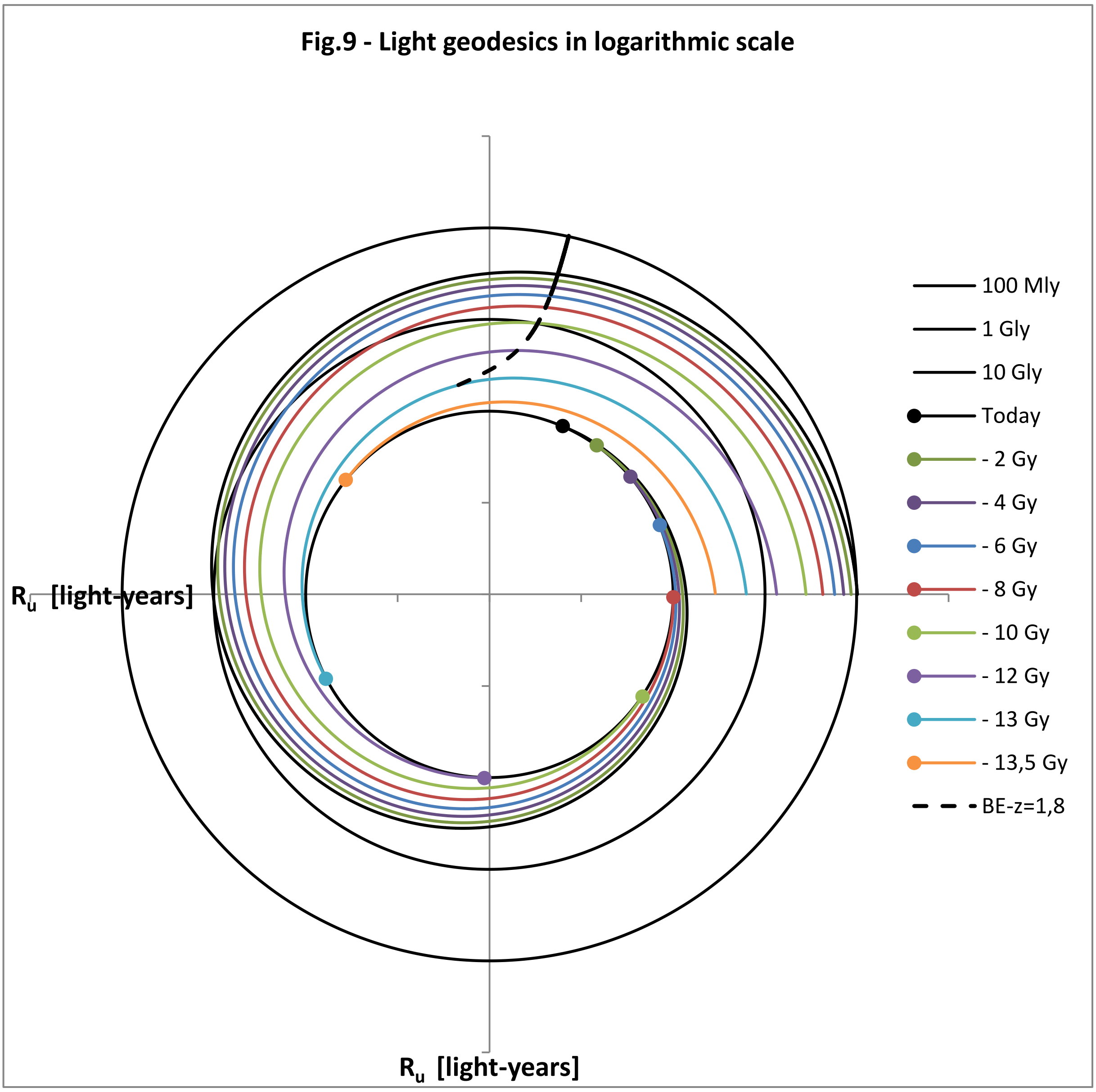


Fig.9 - Light geodesics in logarithmic scale
R_u [light-years]
R_u [light-years]
100 Mly
1 Gly
10 Gly
Today
- 2 Gy
- 4 Gy
- 6 Gy
- 8 Gy
- 10 Gy
- 12 Gy
- 13 Gy
- 13,5 Gy
BE-z=1,8

different radii separated by an angle $\alpha = \varphi_1$ (the colatitude); points located on the observation radius and on the source radius cannot be connected by the light in an arbitrary way, but a biunivocal correspondence exists between the two ensembles. At the beginning of universe life, the geodesic keeps close to the white hole event horizon, but after a few billion years the geodesic rolls out, so that very large regions of the universe do not seem observable for a long time to come; one could even question if some far regions of the universe will ever be observable. This has originated the very complex problem of the *horizon*, which will be discussed in a subsequent paragraph.

Detecting the acceleration of the universe expansion

Recent measurements have demonstrated that the expansion of the universe is accelerating. This has been possible only recently because the expansion velocity was significantly different only in a sufficiently remote past, i.e. at large distances from the observation point. Our cosmological model allows to easily evaluate the increase of the luminosity distance due to universe acceleration, with respect to the constant velocity expansion.

Let us assume that the radial expansion velocity has been constantly equal to the present value during all the life of the universe, i.e. $c/v_u = \text{constant} = 1{,}35347$; equation (38) becomes therefore:

$$d_{L0} = 1{,}35347 \cdot R_{u,0} \cdot \frac{dR_u}{R_u} \qquad (42)$$

having replaced $0{,}01 \cdot R_S$ by the infinitesimal quantity dR_u, since now we are able to compute the integral in closed form; the pedix "0" in the distance indicates that we are considering here the case of zero-acceleration. We will obtain:

$$D_{L,0} = 1{,}35347 \cdot 10.170 \cdot \int_{R_u}^{10.170} \frac{dR_u}{R_u} = 1{,}35347 \cdot 10.170 \cdot (\ln 10.170 - \ln R_u)$$

Changing the base of the logarithm from e to 10, we obtain:

$$D_{L,0} = 1{,}35347 \cdot 10.170 \cdot 2{,}302585 \cdot (\log 10.170 - \log R_u)$$

Recalling equation (37), we finally obtain:

$$D_{L,0} = 31694{,}6 \cdot \log(1 + z) \quad [\text{Mly}] \qquad (43)$$

If we assume a logarithmic scale for the (1+z) axis, this is the equation of a straight line.

If the universe expansion is accelerating, this means that the expansion velocity in the past was smaller than today, therefore the T_K values will be higher, and the distances traveled by light higher than given by equation (43). The difference ΔD_L between the value given by equation (40) (accelerating universe) and the value given by equation (43) (constant velocity expansion) is very small for R_u close to 10.170, and becomes significant only for large distances in space and time. Fig. 10 shows this difference. The difference is only 0,006% for

$z = 0{,}01$, and becomes 0,145% for $z = 1$. A maximum value of about 20% is reached for $z{\sim}100$, close to the Big Bang. Fig. 10a shows the difference in logarithmic scale.

Fig. 10 - Acceleration vs. constant velocity (linear scale)

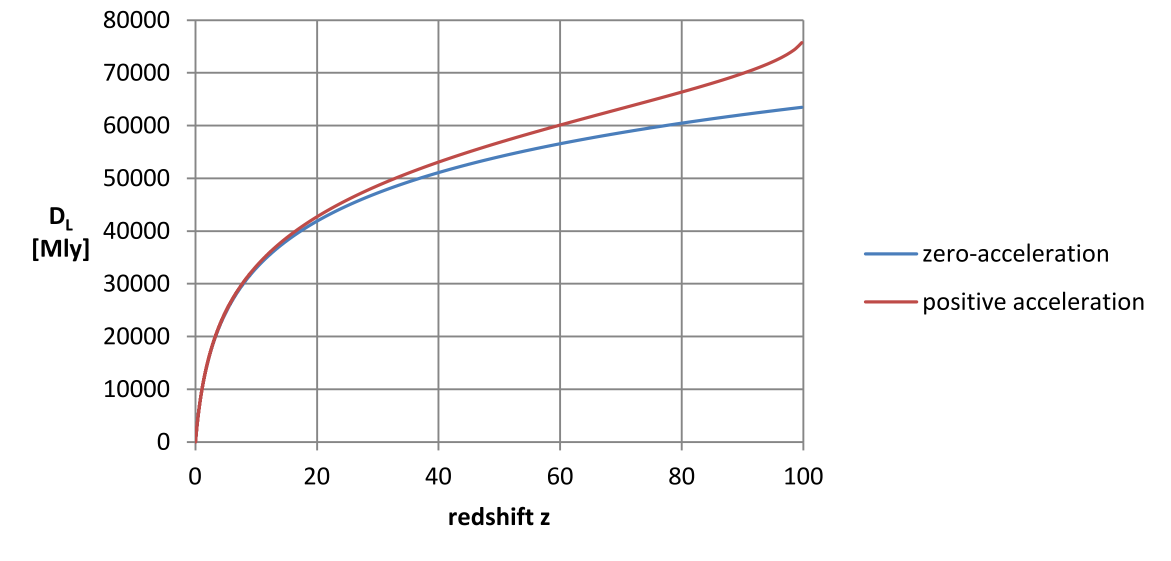
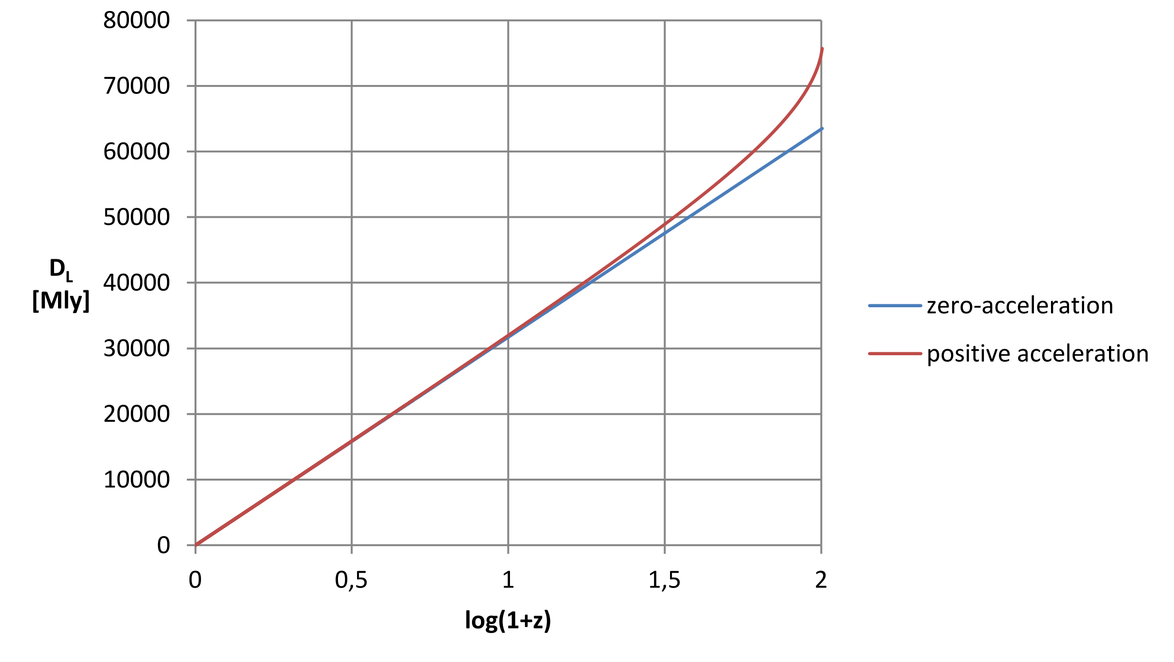


Fig. 10a - Acceleration vs. constant velocity (log scale)



Computed versus measured luminosity distances for several Supernovae

Table 1 compares the measured luminosity distance with the value predicted by our cosmological model, for the close Supernovae used for a precise assessment of the Hubble parameter (Calán-Tololo set). A fair agreement is obtained.

Table 2 compares the measured luminosity distance with the value predicted by our cosmological model, for the far Supernovae used to detect the acceleration of the universe expansion. The agreement in this case looks less satisfactory: the luminosity distance is underevaluated by a factor which increases with the redshift, and is about 2 in the region of interest.

Table 3 shows the comparison between the luminosity distances computed using our cosmological model for the case of constant expansion velocity and for the case of positive acceleration. The difference in percent is negligible for small redshift values, and starts to be sensible only for far Supernovae; therefore it is not surprising that the acceleration of the universe expansion was discovered only by the observation of far Supernovae; on the contrary, it is surprising that the acceleration was detected in a reliable way, despite the very low value.

As concerns the disagreement between computed and measured results, more work is required on the side of the cosmological model, but perhaps also on the side of the luminosity distance measurements. It is important to recall here a prudent statement in the paper by Riess et al.[14]: "How reliable is this conclusion? Although the statistical inference is strong, here we explore systematic uncertainties in our results with special attention to those that can lead to overestimates of the SNe Ia distances." (page 18).

The horizon

The luminosity distance has been computed starting from the observation point, and is related to the past history of the universe: it can be defined as the distance existing today between the observer and a star, the light of which was emitted in the past and is being received today. But if we change the viewpoint, and consider the light starting today from a star in the direction of the observer, what will happen? Are we sure that this light will be able to reach the stated observation point at some time in the future, despite the universe expansion? The answer is certainly positive if the angular separation between the star and the observation point is small, but could be negative if the separation angle is very large; in this case, how can we determine the break-even separation? These questions originate the concept of *horizon*, which is rather ambiguous and may easily give rise to misunderstandings and misconceptions.

A comprehensive discussion of the possible definitions of *horizon*, and of the related misconceptions is given by T. H. Davis and C. H. Lineweaver [26].
The first possibility of confusion originates from the fact that the recession velocities of very far objects can exceed the velocity of light. In fact, if H is the Hubble parameter, the recession velocity at distance D is $v_{rec} = H \cdot D$, which exceeds the velocity of light for $D_{HS} = c/H$.

Table 1 - Luminosity distance versus redshift for close Supernovae (Calán/Tololo)

Supernova	Redshift z*	μ**	D_L [Mly] Measured	D_L [Mly] Computed
1990af	0,050	36,67	703,8	672,6
1992P	0,026	35,59	428	355
1992ag	0,026	35,53	416,3	355
1992al	0,014	34,13	218,5	192,2
1992aq	0,101	38,33	1511,6	1326,1
1992bc	0,020	34,77	293,4	273,4
1992bg	0,036	36,49	647,8	487,7
1992bh	0,045	36,87	771,7	607,4
1992bl	0,043	36,53	659,8	580,5
1992bo	0,018	34,88	308,6	247,2
1992bp	0,079	37,96	1274,8	1048,7
1992br	0,088	38,09	1353,4	1163,1
1992bs	0,063	37,63	1095	842,8
1993O	0,052	37,31	945	699,6
1993ag	0,050	37,11	861,8	672,6

* Source: Perlmutter

**Source: Riess

Table 2 - Luminosity distance versus redshift for remote Supernovae (Riess/Perlmutter)

Supernova	Redshift z	μ*	D_L [Gly] Measured	D_L [Gly] Computed
1996E**	0,43	41,74/42,03	7,25	4,928
1996H**	0,62	42,98/43,01	12,97	6,648
1996I**	0,57	42,76/42,83	11,8	6,216
1996J**	0,30	41,38/40,90	5,80	3,613
1996K**	0,38	41,63/42,21	8,17	4,437
1996U**	0,43	42,55/42,34	9,85	4,928
1997cc**	0,44	41,95/42,26	8,17	5,025
1997cj**	0,50	42,40/42,70	10,32	5,587
1997ck**	0,97	44,39/44,30	24,6	9,347
1995K**	0,48	42,45/42,49	9,8	5,402
1997ap***	0,83	43,67	17,5	8,331

* First value by MLCS method - Second value by Template Fitting method

** Source: Riess

*** Source: Perlmutter

Table 3 - Luminosity distance vs. redshift - Positive acceleration vs. constant velocity comparison

Supernova	Redshift z	D_L [Mly] Measured	D_L [Mly] Computed Positive acceleration	D_{L0} [Mly] Computed Zero acceleration	ΔD_L [Mly]	ΔD_L [%]
			Calán/Tololo			
1992al	0,014	218,5	192,17	192,16	0,014	0,0072
1992bo	0,018	308,6	247,18	247,16	0,019	0,0078
1992bc	0,020	293,4	273,38	273,36	0,022	0,008
1992ag	0,026	416,3	355,08	355,05	0,032	0,009
1992P	0,026	428	355,08	355,05	0,032	0,009
1992bg	0,036	647,8	487,67	487,62	0,052	0,0106
1992bl	0,043	659,8	580,54	580,47	0,068	0,0117
1992bh	0,045	771,7	607,39	607,32	0,073	0,012
1990af	0,050	703,8	672,62	672,53	0,086	0,0128
1993ag	0,050	861,8	672,62	672,53	0,086	0,0128
1993O	0,052	945	699,65	699,56	0,09	0,013
1992bs	0,063	1095	842,8	842,7	0,125	0,015
1992bp	0,079	1274,8	1048,7	1048,5	0,18	0,017
1992br	0,088	1353,4	1163,1	1162,9	0,22	0,019
1992aq	0,101	1511,6	1326,1	1325,85	0,27	0,02
			Riess/Perlmutter			
1996J	0,30	5800	3613,8	3612	1,82	0,05
1996K	0,38	8170	4437,5	4434,8	2,74	0,062
1996E	0,43	7250	4927,9	4924,5	3,4	0,069
1996U	0,43	9850	4927,9	4924,5	3,4	0,069
1997cc	0,44	8170	5024,1	5020,6	3,5	0,07
1995K	0,48	9800	5402	5397,9	4,1	0,076
1997cj	0,50	10320	5586,9	5582,5	4,4	0,079
1996I	0,57	11800	6216,2	6210,7	5,5	0,088
1996H	0,62	12970	6648,7	6642,4	6,3	0,095
1997ap	0,83	17500	8331	8320,8	10,2	0,12
1997ck	0,97	24600	9347	9333,8	13,2	0,14

This is physically possible because it is due to the expansion of space, whereas all physical objects (i.e. the parts of the universe) move with speed always lower than the speed of light; for instance, in our cosmological model the physical objects move radially, and the distances between them may increase even at superluminal velocity. The distance D_{HS} beyond which the recession velocity becomes superluminal is the radius of the Hubble Sphere, which is not an horizon, since it is possible to see beyond it.
Davis and Lineweaver define two different horizons:
- the *particle horizon*, which is the distance travelled by light in the past, to reach the observation point;
- the *event horizon*, which is the distance light will have to travel in the future, to reach the observation point.
If we consider now the CMBR received today on the Earth, the particle horizon will equal the age of the universe, but the corresponding luminosity distance will be much larger, due to space expansion. With our cosmological model we obtain:

Age of the universe = 13,893 [Gy]
CMBR particle horizon =13,893 [Gly]
CMBR luminosity distance = 75,714 [Gly]
Aspect ratio = $75{,}714/13{,}893 = 5{,}45$

However the fundamental questions we asked previously all pertain to the future, i.e. to the event horizon, then we will concentrate our efforts on the analysis of the related problems. Whereas Davis and Lineweaver always define the horizon as a distance, in our cosmological model it is possible to define it as a distance or as a separation angle, which equals the colatitude of the observed star with respect to the observation point, assumed to be the universe North Pole.

We will start considering the horizon from the distance viewpoint. As time passes, the distance between the observer and the light emitted by a celestial body changes, due to two opposite reasons: the propagation of light, which causes a decrease of the distance, and the expansion of the universe, which causes a distance increase. When these variations are equal, the distance keeps unchanged; if the distance covered by light is constantly in excess of the distance increase due to universe expansion, the light emitted by the celestial body will finally reach the observer, so that we can say that the celestial body is observable; if, viceversa, the distance covered by light is constantly smaller than the distance increase due to universe expansion, the light emitted by the celestial body will never reach the observer, so that we can say that the celestial body is unobservable. But the increase of the distance due to universe expansion is proportional to the distance itself; it would seem, therefore, that a break-even distance exists, such that celestial bodies located within this distance from the observer will be observable, whereas the ones located beyond this distance will be unobservable. Have we already found the correct definition of the *event horizon*? We will show shortly that this constraint to guarantee that the star light reaches the observer is much more stringent than necessary, and must be considered only a sufficient constraint. We will however develop the calculations concerning this bound, and obtain interesting results.

Be now:
- α = star-observer separation angle;
- $R_u(T_i) = R_{u,i}$ = universe radius at time T_i;
- $R_u(T_{i+1}) = R_{u,i+1}$ = universe radius at time $T_{i+1} = T_i + \Delta T_i$;
- ΔT_i (variable quantity) = time difference between $T_{i+1}$and T_i;
- ΔR_u (constant quantity) = variation of the universe radius in the time interval ΔT_i;
- $v_u(T_i) = v_{u,i} = \Delta R_u / \Delta T_i$ = radial expansion velocity of the universe at time T_i;
- $v_u(T_{i+1}) = v_{u,i+1} = \Delta R_u / \Delta T_{i+1}$ = radial expansion velocity of the universe at time T_{i+1};
- c = velocity of light;
- $c \cdot \Delta T_i$ = distance covered by light in the time interval ΔT_i;
- $\alpha \cdot R_{u,i}$ = physical distance between the star and the observer at the light emission time T_i;
- $\alpha \cdot R_{u,i+1}$ = physical distance between the star and the observer at time T_{i+1};
- $\alpha \cdot \Delta R_u$ = distance increase due to the expansion of the universe in the time interval ΔT_i.

At time T_i the physical distance between the star and the observer is $\alpha \cdot R_{u,i}$, and light is emitted by the star. During the time interval ΔT_i the light covers the distance $c \cdot \Delta T_i$, and the universe expands with radial velocity $v_{u,i}$, so that at time T_{i+1} the star-observer distance is:

$$D(T_{i+1}) = D_{i+1} = \alpha \cdot R_{u,i} + \alpha \cdot \Delta R_u - \mathrm{c} \cdot \Delta T_i \qquad (44)$$

The distance *D* keeps unchanged (break-even condition) if $\alpha \cdot \Delta R_u - c \cdot \Delta T_i = 0$, i.e. if:

$$\alpha = c \cdot \left({}^{\Delta T_i}\!/_{\Delta R_u} \right) = {}^{c}\!/_{v_{u,i}}$$

and this gives us the break-even value of the separation angle:

$$\alpha_{BE,i}[\text{radians}] = {}^{c}\!/_{v_{u,i}} \qquad (45)$$

Multiplying by the universe radius we obtain the break-even distance:

$$D_{BE,i} = {}^{c \cdot R_{u,i}}\!/_{v_{u,i}} \qquad (46)$$

We still hesitate to call this value "horizon", and this prudence will shortly appear well justified. But, for the time being, we want to better define this break-even curve.

At present the universe radius is 10,170 billion light-years and the radial expansion velocity is 221.498.952 m/s. The present value of the break-even separation angle is therefore:

$${}^{299.792.458}\!/_{221.498.952} = 1{,}35347 \text{ [rad]} = 77{,}548°$$

When R_u goes to infinity, the radial expansion velocity tends asymptotically to $0{,}74112 \cdot c$, which corresponds to a break-even separation angle:

$${}^{1}\!/_{0{,}74112} = 1{,}34931 \text{ [rad]} = 77{,}31°$$

Going back in time, both radius and expansion velocity decrease, reaching the minimum values at the Big Bang. In our cosmological model, at the beginning the radius of the universe equals the Schwarzschild radius of the white hole R_s, and the radial velocity is zero; as a consequence, the increase of the distance between any two points in the universe is negligible with respect to the distance covered by light, and all points in the universe are in physical relation; in this situation an equalization process can take place, and homogeneity and isotropy can be guaranteed. As time passes, however, the radial velocity increases, and the break-even separation angle gradually decreases: when the increase of the distance between two antipodal points equals the light-covered distance, the break-even angle is exactly π. Immediately after that moment, the increase of distance between two antipodal points exceeds the light-covered distance, and the break-even angle becomes smaller than π. The universe radius for which the break-even angle is π can be found imposing ${}^{v_u}/{}_{c} = {}^{1}/{}_{\pi}$ in equation (29). The linear equation so derived can be easily solved obtaining:

$$(R_u)_{\alpha=\pi} = 1{,}150 \cdot R_s$$

This result is independent of the white hole dimension. With our assumptions the Schwarzschild radius is 100 [Mly], so $(R_u)_{\alpha=\pi} = 115$ [Mly], a value which was reached after about 71 million years of universe life.

The break-even curve is shown in figs. 8 and 9. It can be easily verified that the geodesic lines cross the break-even curve ($\alpha = \alpha_{BE}$) for redshift z ~ 1,8 (see Table 4). This result seems to match very well a statement by Davis and Lineweaver: "……Most observationally viable cosmological models have event horizons and in the ΛCDM model of fig. 1 galaxies with redshift ~ 1,8 are currently crossing our event horizon. These are the most distant objects from which we will ever be able to receive information about the present day. …." (Davis and Lineweaver, page 4).

Table 4 - Redshift value when light geodesic crosses the Break-Even curve

Epoch E [Gy] (Time in the past)	**$\alpha=\alpha_{BE}$ [deg]**	**Time after Big Bang [My]**	**R_u [Mly]**	**Redshift evaluated at epoch E**	**today**
0 (today)	77,97	5159,4	3730	1,7265	1,7265
-2	78,08	4419,5	3187	1,7276	2,191
-4	78,25	3677,5	2643,5	1,7298	2,847
-6	78,5	2935,5	2101	1,733	3,84
-8	78,94	2191,2	1559	1,7383	5,52
-10	79,9	1441,5	1017,5	1,7518	9
-12	83,5	678	479	1,8017	20,31
-13	98,3	256,5	204,5	2,065	48,72
-13,5	No crossing	No crossing	No cr.	No cr.	No cr.

But we can now ask ourselves: “Why reception from objects with z > 1,8, which was possible in the past, should become impossible in the future?”. For a deeper discussion of this problem, let us show first that $\alpha \leq \alpha_{BE}$ is just a sufficient condition of convergence; as a matter of fact, it is possible to receive information also when the separation angle is larger than $\alpha_{BE} = \alpha_{suf}$; in fact, be this the value of the separation angle at time T_i (we will call it α_i), let check which is the value of the separation angle at times T_{i+1} and T_{i-1}:

$$D(T_i) = D_i = \alpha_{i-1} \cdot R_{u,i-1} + \alpha_{i-1} \cdot \Delta R_u - \mathrm{c} \cdot \Delta T_{i-1} \qquad (47)$$

$$D(T_{i+1}) = D_{i+1} = \alpha_i \cdot R_{u,i} + \alpha_i \cdot \Delta R_u - \mathrm{c} \cdot \Delta T_i = \alpha_i \cdot R_{u,i} \qquad (48)$$

$$D(T_{i+2}) = D_{i+2} = \alpha_{i+1} \cdot R_{u,i+1} + \alpha_{i+1} \cdot \Delta R_u - \mathrm{c} \cdot \Delta T_{i+1} \qquad (49)$$

where:

$$\alpha_{i+1} = \frac{\alpha_i \cdot R_{u,i}}{R_{u,i+1}} = \alpha_i \cdot \frac{R_{u,i}}{R_{u,i} + \Delta R_u} \sim \alpha_i \cdot \left(1 - \frac{\Delta R_u}{R_{u,i}}\right)$$

and for simmetry:

$$\alpha_{i-1} \sim \alpha_i \cdot \left(1 + \frac{\Delta R_u}{R_{u,i}}\right) > \alpha_i = \alpha_{BE}$$

and substituting in (47):

$$D_i \sim \alpha_i \cdot \left(1 + \frac{\Delta R_u}{R_{u,i}}\right) \cdot \left(R_{u,i-1} + \Delta R_u\right) - \mathrm{c} \cdot \Delta T_{i-1} \qquad (47a)$$

$$D_i = \alpha_i \cdot R_{u,i} + \alpha_i \cdot \Delta R_u - \mathrm{c} \cdot \Delta T_{i-1}$$

and since:

$$\Delta T_{i-1} = \Delta T_i \cdot \frac{v_{u,i}}{v_{u,i-1}} > \Delta T_i$$

we obtain:

$$D_i < D_{i+1} = \alpha_i \cdot R_{u,i} = D_{BE,i}$$

We have shown that, for objects located beyond the break-even separation angle, although the distance increases, the separation angle decreases; this means that information can be received also from objects located beyond $\alpha_{BE,i}$. But we must still answer the questions: “Does an horizon exist? In the affirmative, which is the value of the horizon?”.

Since there are two conflicting causes of variation of the distance between the radiating object and the observer, the analysis of the evolution of the distance brought us to the determination of a break-even value for the distance; the value of the separation angle corresponding to this distance is not, however, a break-even value, since the separation angle decreases monotonically also when crossing this value. A strong danger of confusing horizon and break-even distance exists, as a consequence, if we analyze the problem from the distance viewpoint, but not necessarily if we analyze it from the viewpoint of the separation angle. As a matter of fact, the light propagation causes the separation angle to decrease, but the expansion of space does not produce any increase of the separation angle; therefore, the two actions are not conflicting and a break-even value will not exist for the separation angle. The separation angle will decrease monotonically, step by step, and the only question is: "The sum of potentially infinite steps will be finite or infinite? In case of finite sum, the value will be sufficient to cover the distance between the object and the observer or not?".

The reduction of the separation angle in the time needed to increase by 1 [Mly] the universe radius is:

$$\Delta\alpha_i = \frac{c \cdot \Delta T_i}{R_{u,i}} = \frac{c}{v_{u,i}} \cdot \frac{\Delta R_u}{R_{u,i}}$$

Today the universe radius is 10,170 billion light-years, and the radial expansion velocity is 221.498.952 [m/s]. The reduction of the separation angle is therefore:

$$\Delta\alpha_i = {}^{1,35437}/_{10.170}\ \text{[rad]} = 1,33085 \cdot 10^{-4} \cdot {}^{180}/_{\pi}\ \text{[deg]} = 7,62 \cdot 10^{-3}\ \text{[deg]}$$

The present value of the radial velocity is rather close to the limit value for $i \to \infty$; assuming $v_{u,i} = \text{constant} = v_{u,\infty} = 0,74112 \cdot c$, we obtain a value of $\Delta\alpha_i$ which is slightly underestimated:

$$\Delta\alpha_\infty = {}^{1,34931}/_{10.170}\ \text{[rad]} = 1,32675 \cdot 10^{-4} \cdot {}^{180}/_{\pi}\ \text{[deg]} = 7,602 \cdot 10^{-3}\ \text{[deg]}$$

Let now define:

$$i = (K - 1) \cdot 100$$

so that for $K = 1,01$ we obtain $i = 1$, and, whereas K changes step 0,01, i will change step 1. The value $R_u = 10.170$ is obtained for $K = 101,7$ and correspondingly $i = 10070$.

To study the event horizon problem we must compute the total variation of the separation angle from today to infinity:

$$\Delta\alpha_{total} = \Delta\alpha_{10070} + \Delta\alpha_{10071} + \Delta\alpha_{10072} + \ldots..$$

$$\Delta\alpha_{total} = 1,34931 \cdot \sum_{10070}^{\infty} \frac{1}{100 + i}$$

Since the sum of the harmonic series diverges, we find the important result that the light emitted by the star will always reach the observer at some time in the future, whichever the values of R_u and α.

CONCLUSIONS

The proposed cosmological model agrees very well with the present knowledge about the universe; in particular, the agreement looks practically perfect as concerns age of the universe, Hubble constant, mass budget, value of the redshift at the break-even curve. The model also allows to compute luminosity distances starting from redshift measurements (which are much more precise), but, admittedly, the agreement with measured data is much less accurate in this case, and more work is required, perhaps on both sides.

The model reduces strongly the matter/antimatter unbalance and makes superfluous the inflation hypothesis; in addition, the dark side of reality reduces from 96% to 26%. This is true, however, only if the considerations are limited to our universe; the multiverse option remains on the table, and could be strongly supported by our model.

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THE ROAD TO TRUTH

“Truth is not in a single dream, but in many dreams”

(from *The Book of One Thousand and One Nights*)

“God hath spoken once; twice have I heard this; that power belongeth unto God.”

(King James Bible, Psalm 62, 11)

“[……..] Now it will be necessary for you to investigate everything,
both the eternal heart of the perfect truth,
and the opinions of the deadly humans, which do not deserve full confidence.
However you will also understand this: how it was necessary in the reality
the existence of the opinions, which exist in all possible ways with respect to everything.”

(Parmenides, *About Nature*, Fragment 1, 28-32)

A <u>very</u> free translation gives what we may call the *Gospel according to Parmenides*:

“You shall love Truth with all your heart, all your soul, all your mind;
you shall love the opinion of your neighbour as your own opinion.”

“At that season Jesus answered and said, I thank thee, O Father, Lord of heaven and earth, that thou didst hide these things from the wise and understanding, and didst reveal them unto babes: yea, Father, for so it was well-pleasing in thy sight.”

(World English Bible, *The Gospel According to St. Matthew*, 11, 25-26)

“It is not pretentiousness to publish a book about Jesus at the age of thirty: it is pretentiousness hesitating to publish, because a theology book is not published when perfection is reached, but to make available to the others what we were given, with the hope to be surpassed by those who will do better than us. In this way, only in this way, I could publish all my books.”

(Henry de Lubac to Bruno Forte, from *La sfida di Dio = The Challenge of God*, Mondadori 2001, page 135)

“We are like dwarfs perched on the shoulders of giants. We see more and farther than our predecessors, not because we have keener vision or greater height, but because we are lifted up and borne aloft on their gigantic stature.”

(Bernard of Chartres, quoted by John of Salisbury in his *Metalogicon*)