4. PHYSICAL TRAVELS TO THE PAST AND FUTURE

The properties of physical time depend on the model that is used in its operational definition, whereas the model is chosen with respect to what objects we would like to consider and what properties of these objects we would like to take into consideration. For instance, the motion of the Space objects may be described with the Newtonian mechanics, Special relativity and other theories.

From mathematical point of view we cannot say which of the models is better since each of them presents just a system of coordinated relations which reflect the source physical assumptions (or hypotheses).

But from physical point of view we may say, for example, that the Special relativity is "more exact" than the Newtonian mechanics since the former takes into consideration more nuances than the latter, although this does not mean that we must use the former in everyday practice – on the contrary, it is more preferable to use the latter due to its simplicity and sufficient accuracy.

However, in definite situations we cannot say which of two physical theories is better due to a simple fact: we cannot perform an experiment which would resolve this problem. And this is a typical situation for the modern physical cosmology: we have a plenty of models that are based on quite reasonable hypotheses, but we have no possibility to verify neither the hypotheses, nor the theories (viz. models). As a result, a set of more or less reasonable assumptions are accepted to present a "standard" model, and after obtaining new observations this model is corrected.

Besides, it must be noted that these "standard" theories being developed for different objects may not correspond each other in a bound sphere (both mathematically and physically) as it takes place with the quantum physics and gravity (with an increase of the scale of phenomena the former does not transform in the latter, and vice versa), and the way out from this situation is not seen, except in proposing still new hypotheses. But they may give approximately the same numerical results; in this sense we should consider the mathematical models not as "describing" the reality, but as "approximating" it numerically – as we may approximate the temperature for the next day without knowing the essence of meteorology.

This prelude is aimed to show a reader that there are definite problems in verification of the existing physical theories pertaining to the evolution of the Universe, and, thus, the hypotheses that specify these theories also cannot be taken for gospel. In short, it may be stated as follows: the more general object the theory considers, the less reliable its conclusions.

Nevertheless, the existing physical theories, whether they are well supported by experiments and observations, or present just a good approximation for the observed processes, or merely based on a set of reasonable assumptions, in common provide us with a great and exciting canvas showing how the various processes develop in the Universe. Among them are the following keystone theories pertaining to Time and Space which we use in the below considerations while taking into account the aforesaid prelude.

The Special relativity (SR) quite exactly describes the phenomena pertaining to time and space, but for comparatively small regions of the Universe where the variation in gravity may be neglected.

The General relativity (GR), or another gravitation theory, allows to take into consideration the influence of the gravitation on time and space.

The model ΛCDM presents the standard cosmological model that allows to take into account even more general effect – the expansion of the Universe. тогда как

The SR and GR are the ***local models***. The former is applicable within the GR or ΛCDM model, but locally (in strict sense – in a point, viz. on the level of differential relations, practically – in a region where the gravitational potential changes, but negligibly). The latter describes the space-time with the use of the

system of differential equation, and for obtaining the properties of a region they are to be integrated; as far as such integration requires knowing the initial and bound conditions for the remote epochs and distant objects, for the real situation it may be performed but just *approximately*. Besides, these initial and bound conditions are frequently quite obscure when applied to a cosmological processes.

Meanwhile, the ΛCDM model is a ***global model*** in the sense that it allows to consider the expansion of the ***visible universe*** as a whole, although the description of this expansion is also obtained with the use of differential, viz. local models. The model of this expansion (viz. *motion*) provides the operational definition for ***the cosmological time***. An overview of the basic concepts relevant to this model are given in Sec. 4.2.

If not specified otherwise, the "***time***" in ***Secs. 4.1*** and ***4.2*** is understood in its ***physical*** meaning, and the "Universe" – as the observable universe, that is as that spatial domain which, at present, can be observed with the use of physical instruments; "That" in which it is contained is called, for distinctness, the Universe on the whole.

Comment 4.1.

The observable universe, formally, "consists of the galaxies and other matter that we can in principle observe from Earth in the present day … The word *observable* used in this sense does not depend on whether modern technology actually permits detection of radiation from an object in this region (or indeed on whether there is any radiation to detect)". However, as any attempt to determine a *primary concept* (time, space, etc.) this definition is actually inconsistent since the term "in principle" is too obscure and presumes a possibility to use any hypothesis relative to what and how we "observe". What sense would it make to discuss the properties of the object the time and spatial bounds of which remain absolutely unknown for us? What statement can be considered correct relative to such an obscure object?

An operational approach states that "In practice, we can see objects only as far as the surface of last scattering, before which the Universe was opaque to photons." But this definition also cannot be considered as correct because from the very beginning it ties the properties of the real world to the model of hypothetical Big Bang.

For these reasons we prefer to understand the term "observable universe" in its literal meaning – as the part of the Universe on the whole (whatever it presents) which we can observe at present and with the existing instruments. At least, in this case we will discuss the things of which we are aware.

4.1. Relativistic time dilation. Relocation and Travel to the future

Consider a model of motion that is described by the well known "twin paradox".

> In physics, the twin paradox is a thought experiment in special relativity, in which a twin makes a journey into space in a high-speed rocket and returns home to find he has aged less than his identical twin who stayed on Earth. This result appears puzzling because each twin sees the other twin as traveling, and so, according to a naive application of time dilation, each should paradoxically find the other to have aged more slowly. How the seeming contradiction is resolved, and how the absolute effect (one twin *really* aging less) can result from a relative motion, can be explained within the standard framework of special relativity. The effect has been verified experimentally using precise measurements of clocks flown in airplanes and satellites.

Let the first twin, "***resident***", remain on the Earth, and the second, "***pilot***", start the space journey through our Galaxy to some star **S** with the constant speed v being close to the speed of light c (viz. at a ***relativistic velocity***). By neglecting the proper velocities of the stars (in reality, they are by many orders less than the speed of light) for excluding the secondary effects we may consider them motionless in the reference frame $\Sigma = (x, t)$ associated with the Earth (that is with the resident), the spatial axis of which is aimed in the direction of the flight. Assign the pilot a reference frame $\Sigma' = (x', t')$ with the spatial axis x' pointed along the axis x. Imply for simplicity of calculations, that at the launch the origins of these coordinate systems coincide, viz. $x = x' = 0$, $t = t' = 0$, and, by neglecting the period of acceleration, that the flight starts with the velocity v, $v < c$. (In reality, the process of acceleration is principal for explanation of the twin paradox, but if the journey is long enough, the period of acceleration does not exert significant influence on the resulting time difference; neither it exerts influence on the effects that are observed during the motion with the constant speed). As well, we imply that the pilot and resident are supplied with the identical light etalons of time and length (that is with the similar "clocks" and "rulers").

From the resident's point of view (viz. in the system Σ) the pilot covers the distance $\boldsymbol{L}$ from the Earth to the star **S** at the speed v over the time $\boldsymbol{T} = L/c$. However, the SR states that the pilot's time t' as it is perceived by the resident flows slowly than t, either the pilot moves to the star, or returns to the Earth. For this reason, when the pilot returns to the Earth in the same fashion he founds himself to be younger than the resident, because not only the clock, but all processes in the rocket moving relative to the Earth are slowing down.

In analytical presentation this situation looks as follows.

***** When the resident's clock shows the time t, the pilot's clock shows the time being defined as follows

$$t' = \gamma \cdot (t - v \cdot l / c^2), \tag{4.1}$$

where the quantity

$$\gamma = \frac{1}{\sqrt{1 - v^2 / c^2}} > 1 \tag{4.2}$$

is Lorentz factor, and l – is the distance from Earth to pilot *measured in the system* Σ at the moment t. (Notice, that (4.1) presents a ***reference time function*** for the pilot' time relative to the time of resident).

Therefore, when the pilot reaches the star **S**, the resident concludes that the pilot has covered the distance $\boldsymbol{L}$ in time $\boldsymbol{T} = L/c$. However, by the clock of pilot he was ***traveling during the period***

$$\tau = \frac{T - vL/c^2}{\sqrt{1 - v^2/c^2}} = \frac{T - v \cdot (T \cdot v)/c^2}{\sqrt{1 - v^2/c^2}} = T\sqrt{1 - v^2/c^2} = \frac{1}{\gamma} T, \tag{4.3}$$

which is $\boldsymbol{\gamma}$ ***times less than the duration of the flight*** $\boldsymbol{T}$ ***in perception of the resident***.

Let Y be the Earth's year of departure. Then, in the same time scale the year of return makes $Y + 2T$, whereas by the pilot's clock – only $Y' = Y + 2\tau$. Therefore, after returning the pilot comes to the Earth's epoch which is $2 \cdot T$ years distant from the moment of departure and, thus, he turns out to be younger than resident by $\Delta_{v,L} = (2 \cdot T - 2 \cdot \tau)$ Earth's years (by the way, it was $\Delta_{v,L}$ years ago when the resident was in the same age as the pilot at the moment of arrival).

***Therefore**, **the** pilots returns, **but** in the future **of the** site of departure.*

* The distance L call the relocation distance, and the quantity

$$U = \frac{L}{\tau} = \frac{vT}{T\sqrt{1 - v^2/c^2}} = \gamma \cdot v \tag{4.4}$$

call the relocation velocity.

The former presents half of the "actual" distance that was covered by the pilot *as measured in the resident's frame*; it presents a distance to immovable space object as we perceive it from the Earth.

Formally, the quantity U presents a ***velocity*** as the **ratio** of ***distance covered in the system Σ*** (viz. actual distance in the stationary Galaxy) to ***proper time of travel in the system Σ'*** (viz. actual time of travel by the pilot's clock).

Physically, it presents the ***result of the travel for the pilot in his own perception***: after landing (whether he would know the Earth' age, or not) ***he estimates the distance to the star* S *as L*** and ***thus concludes*** that by his clock ***he*** covered the distance ***2L*** in time ***2τ***.

> This means that ***although the pilot was flying at a speed being lesser than the velocity of light v < c*** (in any of the systems), the result ***of his journey being estimated*** after ***landing*** – is transposing at a speed U that may exceed the velocity of light c.
>
> ***This effect is explained as follows***. The rate v defines the velocity of the pilot relative to the Earth, as well as the speed with which the Galaxy "flies by" relative to the pilot. But the nuance lies in ***contraction of the objects that move relative to the frame from which we observe them*** and which we consider "fixed": for the resident, the pilot is γ times contracted along the axis x, and vice versa – for the pilot ***the Galaxy, as all objects in it are γ times contracted along the axis x', but retain their sizes in the transverse directions***. This effect is the more pronounced the closer the velocity v to the speed of light. So, while he was moving, his path (as estimated from his bull's-eye) was shorter than after the landing, viz. after appearing in another frame of reference.

* Call ***the*** velocity ***of flight v_**** critical if the respective relocation velocity equals to the speed of light. For this case we obtain $c = \gamma \cdot v_*$, or

$$c = \frac{v}{\sqrt{1 - v^2/c^2}}. \tag{4.5}$$

from which the critical velocity makes

$$v_* = \alpha \cdot c, \quad \alpha = 1/\sqrt{2} \approx 0.707. \tag{4.6}$$

Hence, if a pilot flies at a speed v exceeding the critical value v_* (approximately *0.707 of speed of light)*, after returning to the Earth (viz. to the source frame of reference) he will discover that ha was traveling at a velocity (4.4) greater than the speed of light. And the faster he moves the more flattened the objects will be seen and to the more remote future (from the viewpoint of the Earth) he will return.

But ***neither*** these games with ***fast moving***, ***nor*** any ***other SR model*** gives a possibility to travel in the past.

In numbers this situation looks as is shown in Table 4.1, where the closeness of the velocity of flight to the speed of light is specified by the ratio $r = v/c$ which defines the contraction factor γ via (4.2) and the number of times the relocation velocity exceeds the speed of light:

$$U / c = \frac{\gamma v}{c} = \frac{r}{\sqrt{1 - r^2}}. \qquad (4.7)$$

Table 4.1. The influence the ratio of velocity of flight to the speed of light (r) exerts to the relocation velocity (in units of speed of light, U/c) and contraction factor for the Galactic objects (γ)

$r = v/c$	U / c (4.7)	γ (4.2)
$\alpha = 1/\sqrt{2} \approx 0.707$	1	$\sqrt{2} \approx 1.414$
0.9	*2.065*	*2.29*
0.99	*7.018*	*7.09*
0.999	*22.34*	*22.37*
0.999 9	*70.71*	*70.71*
0.999 99	*223.6*	*223.6*
0.999 999	*707.1*	*707.1*

As it is seen from this Table, for the ratios $r > 0.99$ the relocation velocity dozens of times exceeds the speed of light, and by hundreds of times – for the ratios exceeding the value *0.999 9*. ***On flying by the Earth*** with the ratio of $r = 0.999\ 999$ the pilot would ***see it as*** a "***pancake***" with the customary diameter of about 13 000 km, but ***contracted*** in the direction of his motion to a width of about ***18 km***! Inversely, if a large enough Celestial spherical body flies by the Earth, we would see it as a "pancake".

Accordingly, if a ***relativistic particle*** flies by the Earth, the latter presents to it almost flat object with flat beings, but in a "perception" of this particle all types of motion on this planet will be almost frozen since the Earth approaches it with a velocity close to speed of light.

So, within the SR scope of applicability the following physical effects are realizable, but expensive

1. ***It is theoretically possible to transpose in the*** future (of the source reference frame) as to the epoch being distant from the present ***by any, but fixed time interval***.

2. ***There is no theoretical possibility to transpose in the*** past (of the source reference frame), that is so that in the source frame the termination epoch precedes the epoch of the start.

> In other words, any motion relative to a fixed reference frame ***causes time dilation*** (takes farther in the future of this frame), but ***does not touch the proper time*** of the moving object. And as far as we ***do not know any "anti-motion"***, the SR gives no way for travels in the past.

3. ***It is theoretically possible*** to transpose over any fixed distance (measured in the source reference frame) and at a finite proper time (measured in the moving frame) so that after returning to the source frame the relocation velocity (as the ratio of that distance to the proper time) exceeds the speed of light.

4. When an ***object moves with a relativistic velocity***, it is ***perceived*** (by observer) ***contracted*** – up to a ***flat form in the limit case when it moves at the speed of light***. At that, all processes in the object are perceived the more decelerated, the faster it moves.

5. The ***sphere of practical applicability*** of these ***effects*** is ***bounded*** by ***extreme growth of power consumption*** required for accelerating an object to a relativistic velocity.

SR and General relativity

In a domain where the gravitational potential varies the SR not implying any restriction on a distance becomes not fully applicable because these variations themselves cause Gravitational time dilation: the clocks which are far from massive bodies run faster, and those which are closer – run slower.

6. In non-uniform gravitation field the ***time travels*** are ***possible without relativistic velocities***. In this case an analog of twin paradox may be illustrated as follows. Let ***Bob*** live on Pluto and ***decide*** to ***visit his girlfriend on Earth*** (where the Sun's and Earth gravity are greater). Suppose, for simplicity, that his travel requires much less time than the duration of his visit. Then, ***after returning to Pluto*** he will be in a state of the pilot from the twin paradox – ***he will be younger*** than his ***twin brother*** who remained on Pluto.

On the contrary, if his girlfriend had undertaken the same mission ***from Earth to Pluto***, ***after returning to*** the ***Earth*** she ***would be older than*** her ***twin sister*** since the clocks on Pluto ticks faster.

Although these effects may be neglected in the most applications, they must be allowed for in time count systems based on atomic time, and this actually is the case with the GPS.

The more the difference in gravitational potentials – the greater the time dilation. To this end the most extremal effects could be observed near the horizon of a black hole. But it is doubtful that somebody would be able to retell his feelings after such an experience, even if he had succeeded in getting that horizon.

7. However, as with the SR, so with the GR: ***any such travel*** cannot bring you to the past ***relative to the*** time ***and*** place ***from which the*** travel has started as well.

Expansion of the Universe

Even more unusual effects are caused by the expansion of the Universe (remind, that we consider just the ***observable Universe***); they cardinally change our understanding of Time and Space. One of the remarkable results is that the ***Earth*** becomes "***the centre of the Universe***", but "***visible*** ***one – as a region which neither we could leave, nor where something from outside could penetrate; as any other point of the Space presents the centre of the same kind of its own "visible*** ***Universe***.

But before considering the properties of the expanding Universe we must make clear some cosmological concepts since the diversity of terms in this sphere frequently cases confusion and improper conclusions.

4.2. Basic elements of the model of expanding Universe

4.2.1. Preface

The expansion of the Universe is the physical fact which is obtained from astronomical observations which states that the remote objects in the universe are moving apart with an acceleration. For obtaining a numerical description of this phenomenon these are put forward two principally different physical approaches.

The mainstream paradigm (for brief, call it ***M-paradigm***) proposes a system of concepts for description of both the process of ***expansion*** and its ***starting point***.
The so-to-say "non-mainstream" paradigm (for brief, call it ***NM-paradigm***) confines itself with considering of the process of ***expansion*** without attempting to explain how and when it had started .

For an overview and with respect to the distinctness of considered processes the ***M-paradigm*** may be presented as comprising the following two ***phases*** (for more detail See Timeline of the Big Bang):
1. The phase of Big Bang and cosmic inflation; the hypothetical moment of the Big Bang is taken for the origin of ***Cosmological time*** which defines the ***age of Universe***.
2. The phase of "Steady" expansion.

The ***Big Bang, inflationary and a series of subsequent epochs*** lasted ***less than a second***. It is assumed that the ***Singularity*** had "produced" some volume of primal substance of unknown physical nature that, via an unknown process, had transformed into "conventional" particles (baryonic matter).

During the ***inflation*** the volume occupied by the obtained matter had increased by dozens of orders. After then, during the Photon epoch and Dark ages the Universe was still expanding, but much slowly.

> Comment 4.2. In essence, the first phase is required basically for adjusting the "size" and "structure" of the universe to the results of modeling the expansion backwards, which show that *13.7* billion years ago it had to present a singularity. This age is very close to the Hubble's Time, and this correspondence is called "coincidence"; but there are physical reasons which make the latter the principal quantity, a proper value of time which reflects the rate of expansion so that it defines the farthest corners of the observable universe; it does not depend on the M-paradigm and probably this specific value had somehow engendered that "age of the universe". If the universe was expanding with roughly the current rate its age should be enlarged infinitely.

For the beginning of the second phase the epoch of Recombination ***may be taken*** when the hydrogen and helium *atoms* began to form; since that time the processes in the universe are more or less understandable. In figures, the ***M-paradigm*** describes this epoch as follows [Observable universe]:

> The Cosmic microwave background radiation (CMBR) ***that we see right now was emitted at the time of recombination, 379,000 years after the Big Bang, which occurred around 13.7 billion years ago.*** This radiation was emitted by matter that has, in the intervening time, mostly condensed into galaxies, and those galaxies are now calculated to be about 46 billion light-years from us.
>
> To estimate the distance to that matter at the time the light was emitted, a mathematical model of the expansion must be chosen and the scale factor, *a(t)*, calculated for the selected time since the Big Bang, *t*. For the observationally-favoured Lambda-CDM model, using data from the WMAP spacecraft, such a calculation yields a scale factor change of approximately 1292. ***This means the*** Universe has expanded ***to*** 1292 times ***the size it was when the*** CMBR photons were released.

Resume

By taking into account that an uncertainty in the estimate of the age of the Universe is quite close to the epoch of recombination, and that since that epoch the existing models describe the expansion of the universe as a more or less steady process with the use of the standard cosmological model without resorting to the Big Band hypothesis, as well as the models pertaining to ***NM-paradigm***, the moment of hypothetical Big Bang may be considered as a Benchmark epoch for the models that provide us with numerical estimates for the process of steady expansion of the universe; in this sense the cosmological time ***corresponds to that period of the expansion of the*** Universe ***during which it*** has expanded 1292 times.

So, the dubious hypotheses of Singularity and Big Bang not so much explain, as denote a possible variant of origination of the Universe. In this sense they rather reflect an attitude to obtaining distinct milestones.

Besides, these hypotheses engender a series of logical puzzles or contradictions relative to the place of the observable Universe in the Universe on the whole.

If the observable universe has appeared from a singularity (as from mathematical point, viz. ex nihilo), then what "volume" does it occupy in the "surrounding" Universe on the whole and how it is expanding?

If we reject these questions and consider a singularity as a finite volume within which the universe expands, we come to the accepted viewpoint that it is not the Universe which is expanding, but the metric. But in this case all components of the observable Universe should be contracting as the universe expands.

Obviously, we cannot answer any of these questions until we would know what does the "Universe on the whole" present.

Therefore, both the physical uncertainty of the first phases of the "Big Bang", and total vagueness of the "place" of the observable Universe in the surrounding Space does not allow us to consider the M-paradigm as a verifiable model.

To this end it is evidently more physical to use the ***NM-paradigm*** which considers the "observable Universe" as an integral part of indivisible single whole which could be *denoted* as the "Universe on the whole", employs the verifiable models and appeals to the observations. (***Note*** to this end, that it is the expansion itself which forms, so-to-say, an envelope of a sphere of "observable" Universe and the background radiation – See Sec. 4.3). In this way it agrees with the esoteric approach which considers the Universe as the ever existing and "breathing" (viz. contracting and expanding) entity which periodically comes into manifestation and dissolves in subtle matter and rejects any "creation ex nihilo"; meanwhile, it denies any considerations relative to the explicable essence of the Primal Cause and Universe on the whole.

Therefore, the ***age of the Universe*** being accepted to present the ***Cosmological time*** – is remaining just paying a homage to the ***M-paradigm***, or rather to the dubious hypotheses of Big Bang and Singularity, until these hypotheses would be acknowledged, if they would.

Meanwhile, the ***NM-paradigm*** allows us to make use of the most models that are used in the former and proposes the explanations for the ***CMBR*** without resorting to those hypotheses.

Resume

The author considers this prelude a necessary introduction to the following overview of the main concepts of the physical cosmology where the ***M-paradigm*** is frequently used or referred to, both explicitly and implicitly; but this does not necessarily mean that the Big Bang hypotheses make a basis for all of the referenced concepts and models; in most cases they are simply brought into correlation with the respective mainstream models. In this sense the ***Cosmological time*** does not present the age of the universe, but just ***one of possible time scales*** being coordinated with the expansion of the universe, although with a distinctive feature – ***in fact***, it defines the current cosmological time as being ***equal*** to the ***Hubble's Time***.

Therefore, with respect to the aforesaid, in the subsequent analysis (except of the below overview) we follow the NM-paradigm, that is we do not rely upon the hypotheses pertaining to the Big Bang and Singularity and thus consider the cosmological time not as the "age of the Universe", but as one of possible Time count systems being more or less exactly coordinated with the observed expansion of the Universe on the ground of the existing mathematical models on a time span during which it has expanded by 1300 times.

4.2.2. Metric expansion of space and Comoving coordinates

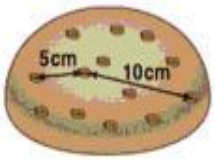
4.2.2.1. Metric expansion of space

The Metric expansion of space is the averaged increase of metric (i.e. measured distance) between distant objects in the universe with time. This is a key feature in description of the expansion of the Universe. It is modeled mathematically with the FLRW metric.

This model is valid in the present era only at relatively large scales (roughly the scale of galactic superclusters and above). ***It is presumed*** that ***at smaller scales the matter has clumped together*** under the influence of gravitational attraction ***and*** these ***clumps do not individually expand***, though they ***continue to recede from one another***. The expansion is due partly to inertia (that is, the matter in the universe is separating because it was separating in the past) and partly to a repulsive force of unknown nature, which may be a cosmological constant (viz. dark energy). Inertia dominated the expansion in the early universe, and according to the ΛCDM model the cosmological constant will dominate in the future. In the present era they contribute in roughly equal proportions.

> Comment 4.3. It should be noted that the above assumption, as a series of other ones, remains to be a suggestion and thus must be considered with a caution; e.g. it is not clear why a large-scale clump occupying a large region of Universe (their dimensions may be huge – up to billions of light years; See Sec. 4.5) should not expand together with the space containing this region. It is other thing that we cannot estimate the influence the expansion exert on a region depending on its size, since for this we have to take into consideration the *actual* distribution of both baryonic matter and dark matter and dark energy. As the observations show, ***unexplained gravitational effects*** take place even in our ***Solar system***:
>
> The **PIONEER ANOMALY** (or ***effect***) is the observed deviation from predicted trajectories and velocities of various unmanned spacecraft visiting the outer solar system, most notably Pioneer 10 and Pioneer 11. Both Pioneers are escaping from the solar system, and are slowing down under the influence of the Sun's gravity. Upon very close examination, however, they are ***slowing down*** slightly ***more than expected***. The effect can be modeled as a slight ***additional acceleration towards the Sun***.
>
> Thus, when all known forces acting on the spacecraft are taken into consideration, ***a very small but unexplained force remains***. It appears to cause a constant sunward acceleration of $(8.74 \pm 1.33) \times 10^{-10}$ m/s^2 for both spacecraft. The magnitude of the Pioneer effect a_p is ***numerically quite close*** to the ***product*** of the speed of light c and the Hubble constant H_0, ***hinting at a*** cosmological ***connection***, but the significance of this, if any, is unknown (It should be noted though that $a_p = H_0 \cdot c$ is the exact solution given from theoretical analysis by one of the proponents of ***new physics***.)
>
> The anomaly has ***no universally accepted explanation***. However, it is also ***possible*** that ***current physical theory does not correctly explain the behaviour of the craft relative to the sun***, since the ***gravitationally bound objects*** such as the solar system, or even the galaxy, ***are not supposed to partake of the expansion of the universe***, … although it ***does not necessarily interfere*** with the paths new physics can take. It is considered that new physics would take into consideration at least one of three possibilities: ***clock acceleration theory*** (it presumes that the increased gravitational potential accelerates cosmological time), a ***modification of the law of gravity***, or ***modified inertia***.
>
> (See also Flyby anomaly, Galaxy rotation problem, Unsolved problems in physics)

While special relativity constrains objects in the universe from moving faster than the speed of light with respect to each other, there is no such theoretical constraint when space itself is expanding. ***It is thus possible for two very distant objects to be moving away from each other at a speed greater than the speed of light*** (meaning that one cannot be observed from the other). However, this situation ***does not deny*** the ***SR***, but makes it ***applicable locally*** (more exactly – ***in differential equations***).



Example 4.1. The expansion of space is often illustrated with models. Thus, In the "raisin bread model" one imagines a loaf of raisin bread expanding in the oven. The ***loaf*** (space) ***expands as a whole***, but the ***raisins*** (gravitationally bound objects) do not expand; they merely ***grow farther away from each other***. (Animation shows that as the bread doubles in width (depth and length), the distances between raisins also double). This simple example would allows us to illustrate many important properties of the expanding Universe.

So, for describing the expansion we must specify how the distances between the objects change in time. In a static case (e.g. for the Earth's surface) we may find the distances with a map. But in the expanding space the situation becomes more complicated. Therefore, consider firstly the static case.

A metric defines how a distance can be measured between two *nearby* points in space, in terms of the coordinates of those points. A coordinate system locates points in a space (of whatever number of dimensions) by assigning unique numbers known as coordinates, to each point. The ***metric*** is then a ***formula*** which ***converts coordinates*** of two points ***into distance***.

Example 4.2. Metric for Earth's surface. Consider the measurement of distance between two places on the surface of the Earth. Because this surface is two-dimensional, points on the surface of the earth can be specified by two coordinates – for example, the latitude and longitude. Specification of a metric requires that one first specify the coordinates used. In this example we may choose any kind of coordinate system we wish, for example latitude and longitude, or X-Y-Z Cartesian coordinates. Once we have chosen a specific coordinate system, the numerical values of the co-ordinates of any two points are uniquely determined, and based upon the properties of the space being discussed, the appropriate metric is mathematically established too. On the curved surface of the Earth, we can see this effect in long-haul airline flights where the distance between two points is measured based upon a Great circle, and not along the straight line that passes through the Earth. While there is always an effect due to this curvature, ***at short distances the effect is so small as to be unnoticeable***.

4.2.2.2. Coordinates and metrics for the expanding Universe

Thus, in the expanding Universe a distance (or metric) between two points depends both on their spatial coordinates, and on time; besides, with respect to the GR the time itself is not a separate parameter and, this way, is spatially-dependent. For this reason various terms and approaches are used for defining a distance. But in the below consideration the latter dependence is neglected since for the large distances its contribution to the result is negligible if the considered points are not disposed in a close vicinities of super massive stars.

Besides, the fact that the Universe, in general, expands uniformly allows us to simplify the models for obtaining the qualitative results which illustrate analytically and numerically the effects that are caused by this expansion (in reality, all the existing models are approximate since they use various suggestions relative to the properties and numerical values of their parameters, and the more complicated the model the more difficulties we encounter in doing this).

So, the general idea of defining a metric for the expanding Universe consists in taking into consideration two kinds of frames and respective metrics. The first one (***comoving***) specifies the distances for a definite moment of time, as in a stationary case. The second (***proper***) – corrects them for the required moment of time with the use of ***scale factor*** reflecting the average measure of expansion. Consider this approach in more detail.

4.2.2.3. Comoving coordinates

While general relativity allows one to formulate the laws of physics using arbitrary coordinates, some coordinate choices are more natural; that is, easier to work with. Comoving coordinates are an example of such a natural coordinate choice. They assign **constant *spatial coordinate values*** to observers who perceive the universe as isotropic. Such observers are called "comoving" observers because they move along with the Hubble flow.

A ***comoving observer*** is the only observer that will perceive the universe, including the cosmic microwave background radiation (CMBR), to be isotropic. Non-comoving observers will see regions of the sky systematically blue-shifted or red-shifted. Thus isotropy, particularly isotropy of the CMBR, defines a special local ***frame of reference*** called the comoving frame. The velocity of an observer relative to the local comoving frame is called the peculiar velocity of the observer. Most large lumps of matter, such as galaxies, are nearly comoving, i.e., their peculiar velocities are low.

The comoving time coordinate is the elapsed time since the Big Bang according to a clock of a comoving observer and is a measure of cosmological time (for present, it makes about *13.7* billion year – See below: ***Age of the universe***). The ***comoving spatial coordinates*** tell us ***where*** an event occurs while ***cosmological time*** tells us ***when*** an ***event occurs***. Together, they form a complete ***coordinate system***, giving us both the location and time of an event.

Space in ***comoving coordinates*** is usually referred to as being "***static***", as most bodies are comoving, and comoving bodies have static, ***unchanging comoving coordinates***.

The expanding Universe has an increasing scale factor which ***explains how constantly comoving coordinates are reconciled with distances that increase with time***.

4.2.2.4. Comoving distance and Proper distance

Comoving distance is the distance between two points measured along a path defined at the present cosmological time. For objects moving with the Hubble flow, it is deemed to ***remain constant in time***. The comoving distance from an observer to a distant object (e.g. galaxy) can be computed as follows:

$$\chi = \int_{t_e}^{t} c \, \frac{\mathrm{d}t'}{a(t')}$$

where $a(t')$ is the ***scale factor*** (See §4.2.3.3), t_e is the time of emission of the photons detected by the observer, t is the present time, and c is the ***speed of light*** in vacuum. Despite being an integral over time, this does give the distance that *would* be measured by a hypothetical tape measure at *fixed* time t.

Comment 4.4. In standard cosmology, Comoving distance and Proper distance are two closely related distance measures used by cosmologists to define distances between objects. Most textbooks and research papers define the comoving distance between comoving observers to be a ***fixed*** unchanging quantity ***independent of time***, while calling the dynamic, ***changing distance*** between them proper distance. On this usage, comoving and proper distances are numerically equal at the current age of the universe, but will differ in the past and in the future. In the below consideration we follow this agreement.

However, this cosmological proper distance should not be confused with the similar, but more general ***relativistic*** proper distance.

Thus, in the Example 4.1 the ***raisins*** may be likened to ***comoving observers*** (by themselves, they do not expand, but just move apart), the ***shown distances*** between them ("***instantly***" measured before heating) – to the ***Comoving distances***, while the "***instantly***" ***measured distances*** at any ***subsequent moment*** (when the bread has increased its size) – to ***proper distances*** (***for that moment***). The ***ratio*** of proper and comoving distances for the same two raisins presents the ***scale factor*** (for that subsequent moment).

> Example 4.3. Let an ant move from raisin 1 to raisin 2 being l distant from the former (comoving distance) before the loaf is heated. With whatever small rate v he travels in a stationary case (viz. until the loaf is heated), in a finite time $t = l/v$ it will reach the raisin 2. Suppose now that the same ant is "heat-proof" and may still travel while the loaf is heated. Its rate, relative to a local point on the loaf remains the same, but the loaf expands. So, if the loaf expands faster than the ant moves, the latter would never reach the raisin 2. In other words, the result depends both on the distance l and on the rate of expansion;

if the rate is fixed, there exists such a limit comoving (viz. "initial") distance l^* which would never be passed by the ant in the sense that if $l > l^*$ then the proper distance between the current position of the ant and raisin 2 would ever increase. This is exactly what takes place with propagation of light in the expanding Universe: there are stars which we would never see since they are too far from us. In detail this situation, as the below definitions, are considered in Sec. 4.3, since for obtaining numerical estimates we must adopt the model of expansion.

Light travel time or ***lookback time***. This is the ***interval*** of ***cosmological time between*** the moments of ***emanation*** and ***reception*** of ***light*** (practically, this is how long ago light left an object of given redshift).

Light travel distance – is the ***light travel time*** *times* ***the speed of light***. In the expanding universe this distance is ***always less*** that the ***proper distance*** between the ***points of emanation and reception***.

In the Example 4.3 the latter presents the distance that was "actually" passed by the ant – as the length that could be measured *during the motion*, that is *locally* – "with a tape on the ground"; and it is always less than the "remoteness" of its position from the starting point (raisin 1) if measured globally – as a proper distance, because the passed way also expands. For this reason a ***light travel distance*** , in contrast to comoving and proper distances, at any moment ***cannot be presented geometrically***, although at any moment it ***presents*** the ***path*** that was ***actually passed*** by the ant (as measured by passometer).

For ***small values*** of ***light travel time*** the ***difference*** between the ***light travel distance*** and ***proper distance*** is ***negligible***, but with an increase of this time it becomes too great to be neglected. This is one more peculiarity that is to be taken into consideration in measuring distances in astronomy.

So, as far as the ***distances*** are estimated by observing the electromagnetic waves that propagate at the speed of light (locally, relative to the surrounding vicinity of the passed way) and present ***huge values*** comparing with the conventional terrestrial measures, these distances are ***specified*** in units of time relative to the ***speed of light***.

However, in this case the ***distance*** being ***equal*** to the product of this ***time*** by the ***velocity of light*** makes the ***light travel distance*** and, therefore, does not present ***neither a proper, nor a comoving distance***. One must remember that ***this distance may have no "direct" physical meaning***: due to expansion of the universe the light passes such length in lesser period; on the contrary, if this is a distance between two objects at present, the light emitted at one of them would reach the other in a longer interval. ***This is just a convenient unit for*** great values of light travel time and *indirectly* – for proper and comoving distances.

4.2.2.5. Light-year and the related units of length

As defined by the International Astronomical Union, a light-year (also light year or lightyear) is the distance that light travels in a vacuum in one Julian year; its approximate value is $\boldsymbol{9.5\times10^{12}}$ ***km***.

Parsec (pc) is defined as the distance at which an object will appear to move one arcsecond of parallax when the observer moves one astronomical unit perpendicular to the line of sight to the observer, and is equal to approximately ***3.26 light-years***.

More exactly, a light-year is ***equal to***:

exactly ***9,460,730,472,580.8 km*** (about 9.5 Pm)
about ***5,878,630,000,000 miles*** (about 6 trillion miles)
about ***63,241.1 astronomical units***
about ***0.306601 parsecs***

These figures are based on a Julian year of exactly ***365.25 days*** (exactly 86,400 SI seconds each) and a defined speed of light of ***299,792,458 m/s***. The DE405 value of astronomical unit is ***149,597,870,691 m***.

4.2.3. Lambda-CDM model

Lambda-CDM model is an abbreviation for ***Lambda-Cold Dark Matter*** (ΛCDM) ***model***. It is frequently referred to as the ***standard model*** of ***Big Bang cosmology***, since ***it attempts to explain*** the ***accelerating expansion of the universe***, the ***existence*** and ***structure*** of the ***CMBR***, the ***large scale structure*** of ***galaxy clusters***, and some other phenomena.

This ***model describes*** the ***evolution of the universe*** from a very uniform, hot, dense primordial state to its present state ***over a span of about 13.73 billion years*** of cosmological time; it is well understood theoretically and supported by high-precision astronomical observations such as WMAP.

In contrast, theories of the origin of the primordial state ***remain very speculative***.

Overview

* All modern cosmological models are based on the cosmological principle that our observational location in the universe is in no way unusual or special: on a large enough scale, the universe looks the same in all directions (isotropy) and from every location (homogeneity).

* ***The model includes*** an expansion of metric space that is ***well documented*** both as the red shift of prominent spectral absorption or emission lines in the light from distant galaxies and as the time dilation in the light decay of supernova luminosity curves. It also allows far distant galaxies to recede from each other at speeds greater than the speed of light.

* The model assumes a "flat" ***spatial geometry***, which means that the interior angles of a triangle defined by three beams of light will sum to 180°; space is defined by straight lines. (Alternative geometries include a spherical or "closed universe" in which the interior angles of a triangle would sum to more than 180°, and a hyperbolic or "open universe", in which the angles would sum to less than 180°.) The current ***values of key parameters imply*** that the ***universe*** is ***either flat or slightly open***, the universe will expand forever, and the expansion is accelerating.

* Λ (***Lambda***) stands for the cosmological constant which is currently associated with a vacuum energy or dark energy inherent in empty space that ***explains the current*** accelerating expansion ***of space*** against the attractive effects of gravity. The cosmological constant is ***denoted*** as Ω_Λ, which is ***interpreted as the fraction of the total mass-energy density of a flat universe*** that is ***attributed to*** dark energy. Currently, about 73% ***of the energy*** density ***of the present*** universe is estimated ***to be dark energy***.

* Cold dark matter is a ***form of matter*** necessary ***to account for*** gravitational effects observed in very large scale structures (anomalies in the rotation of galaxies, the gravitational lensing of light by galaxy clusters, enhanced clustering of galaxies) that ***cannot be accounted for by the quantity of*** observed matter. Dark matter is described as being cold (i.e. its velocity is non-relativistic [far below the speed of light] at the epoch of radiation-matter equality), ***possibly*** non-baryonic (consisting of matter ***other than protons and neutrons***), ***dissipationless*** (cannot cool by radiating photons) and ***collisionless*** (i.e., the dark matter particles interact with each other and other particles only through gravity). This component is currently estimated to ***constitute*** about 22% – 23% ***of the mass-energy*** density ***of the*** universe.

* ***The remaining*** 4% - 5% comprises all matter and energy observed as subatomic particles, chemical elements and electromagnetic radiation, the stuff of which visible planets, stars and galaxies are made (for distinctness, call these “conventional” forms of matter the baryonic, although it also comprises Leptons).

* The model includes a single originating event, the “Big Bang” or initial singularity, which was not an explosion but the abrupt appearance ***of expanding*** space-time containing radiation at temperatures of around 10^{15} K. This was immediately (within 10^{-29} second) followed by an exponential expansion of space by a scale multiplier of 10^{27} or more, known as cosmic inflation. The early universe remained hot (above 10,000 K) for several hundred thousand years, a state that is detectable as a residual cosmic microwave background or CMB, a very low energy radiation emanating from all parts of the sky.

* The model uses the FLRW metric, the Friedmann equations and the cosmological equations of state ***to describe the observable universe*** from ***right after the*** inflationary epoch ***to*** present and future.

The ΛCDM model foretells a future in which the metric expansion of space will carry all galaxies away from each other at speeds greater than light, and observers in each galaxy will see only their own galaxy in an otherwise empty universe.

* There is ***currently active research*** into ***many aspects of the ΛCDM model***, which is very likely to change as new information becomes available.

In particular, it is difficult to measure accurately the distance of very far galaxies or supernovae, so that ***distance related estimates*** (of stellar or galactic luminosities, or of ***key parameters*** such as the ***Hubble constant***) ***are still uncertain***.

What is much more important, this model can say nothing about the primordial states of the Universe which are called upon to ground the origination of the universe.

Besides, ΛCDM has ***no physical theory explaining the origin*** or ***physical nature*** neither for ***dark matter***, nor for ***dark energy***, nor for ***primordial curvature disturbances***.

Parameters

The ***ΛCDM model*** is ***based on six parameters*** (in various combinations) from which the remaining ones can be obtained. Among them are the ***Hubble constant*** (See Sec. 4.2.5) defining the rate of acceleration of the Universe and ***densities*** of aforesaid kinds of ***matter*** and ***energy*** (the baryon density presents the ratio of true density to critical, $\Omega_b = \rho_b / \rho_o$). Ω_m presents the baryon and dark matter density. Parameter values listed below are from the Five-Year WMAP temperature and polarization observations.

Parameter	Value	Description
t_0	$(13.72 \pm 0.12) \times 10^9$ years	Age of the universe
H_0	70.5 ± 1.3 km s^{-1} Mpc^{-1}	Hubble constant
Ω_b	0.0456 ± 0.0015	Baryon density
Ω_c	0.228 ± 0.013	Dark matter density
Ω_Λ	0.726 ± 0.015	Dark energy density
Ω_{tot}	$1.0050^{+0.0060}_{-0.0061}$	Total density

4.2.4. Age of the universe (Cosmological time)

The ***estimated*** age of the universe is 13.75 ± 0.17 billion years, ***the time since the Big Bang***. This value is accepted to present the cosmological time. The uncertainty range has been obtained by the agreement of a number of scientific research ***projects*** which include background radiation measurements and more ways to measure the expansion of the universe. The former give the ***cooling time*** of the universe since the Big Bang, whereas the latter measurements – accurate data to calculate the age of the universe.

Explanation. If one extrapolates the ΛCDM model backward from the earliest well-understood state, it quickly (within a small fraction of a second) reaches a singularity called the "Big Bang singularity". This ***singularity is not considered to have any physical significance***, ***but*** it ***is convenient to quote times measured*** "since the Big Bang", even though they do not correspond to a physically measurable time. For example, "10^{-6} second after the Big Bang" is a well-defined era in the universe's evolution. In one sense it would be more meaningful to refer to the same era as "13.7 billion years minus 10^{-6} seconds ago", but this is unworkable since the latter time interval is swamped by uncertainty in the former.

Though the universe might have a longer history, cosmologists presently use "***age of the universe***" to ***mean*** the ***duration of the Lambda-CDM expansion***, or equivalently the elapsed ***time since the Big Bang***.

The ***problem*** of determining the age of the universe ***is closely tied*** to the problem of ***determining*** the values of the ***cosmological parameters***. Today this is largely carried out in the context of the ΛCDM model, where the ***Universe is assumed to contain*** normal (***baryonic***) matter, cold dark matter, radiation (including both photons and neutrinos), and a cosmological constant. The fractional contribution of each to the current energy density of the Universe is given by the density parameters Ω_m, Ω_r, and Ω_Λ. The full ΛCDM model is described by a number of other parameters, but for the purpose of computing its age these three, ***along with*** the Hubble parameter H_0 ***are the most important***.

If one has accurate measurements of these parameters, then the age of the universe can be determined by using the Friedmann equation. This equation relates the rate of change in the scale factor ***a(t)*** to the matter content of the Universe. Turning this relation around, we can calculate the change in time per change in scale factor and thus calculate the total age of the universe by integrating this formula. The age t_0 is then given by an expression of the form

$$t_0 = \frac{1}{H_0} F(\Omega_r, \Omega_m, \Omega_\Lambda, ...) \tag{4.8}$$

where the ***function F depends only on the fractional contribution*** to the universe's ***energy content*** that comes from various components (the last observations show that the faraway galactic clusters have roughly the same proportion of dark matter to regular matter as the closer galaxy groups do).

The first observation that one can make from this formula is that it is the Hubble parameter (See Sec. 4.2.5) that controls that age of the universe, with a correction arising from the matter and energy content. So, a ROUGH ESTIMATE OF THE AGE OF THE UNIVERSE ***comes from*** THE INVERSE OF THE HUBBLE PARAMETER,

$$T_U \approx \frac{1}{H_0} = \left(\frac{H_0}{72 km/(s \cdot Mpc)} \right)^{-1} \times 13.6 \text{ billion years.}$$

To get a more accurate number, the correction factor F is to be computed numerically.

Observations

The Wilkinson Microwave Anisotropy Probe (WMAP) was instrumental in establishing an accurate age of the universe, though other measurements must be folded in to gain an accurate number. CMB measurements are very good at constraining the matter content Ω_m and curvature parameter Ω_k. It is not as sensitive to Ω_Λ directly, partly because the cosmological constant only becomes important at low redshift. The most accurate determinations of the Hubble parameter H_0 come from Type Ia supernovae. Combining these measurements leads to the generally accepted value for the age of the universe quoted above. The WMAP project ***estimates the age of the universe*** to be

(1.373 ± 0.012) × 10^{10} years, or ***13.73 Ga*** (billion years), ± ***120*** (million years) (4.9)

This is ***the value*** currently most ***quoted by astronomers***. However, this age is based on the assumption that the project's underlying model is correct; other methods of estimating the age of the universe could give different ages. Thus the age of universe based on the "best fit" to WMAP data "only" is ***13.69 ± 0.13*** Ga (the slightly higher number of ***13.73*** includes some other data mixed in).

Comment 4.5. Note, that the oldest event ***that was ever observed*** is a Gamma-ray burst that took place approximately ***13 billion years ago***; it was registered on April 23, 2009 (See Example 4.4 in §4.3.5)

4.2.5. the Hubble's law and Hubble constant (parameter)

4.2.5.1. The Hubble's law

Hubble's law describes the observation in physical cosmology that ***the velocity at which various galaxies are receding from the Earth is proportional to their distance from us***.

The law was first derived from the General Relativity equations by Georges Lemaître in 1927. Edwin Hubble derived it empirically in 1929 after nearly a decade of observations.

The law is often expressed by the equation

$$v = H_0 \cdot D \tag{4.10}$$

where

v is the recessional velocity typically expressed in km/s (viz. the derivative $v = dD/dt$); it defines the speed with which an object moves away (typically – from the Earth). As a rule, this term is used for the remote galaxies with respect to the redshift.

H_0 is Hubble's constant and corresponds to the value of H (often termed the Hubble parameter which is a value that is time dependent) in the Friedmann equations taken at the time of observation denoted by the subscript *0*. This value ***is the same throughout the universe*** for a given ***comoving time***.

D is the proper distance from the galaxy to the observer, measured in Mega parsecs (Mpc), in the 3-space defined by given ***cosmological time***.

Hubble's law is considered a fundamental relation between recessional velocity and distance.

It is considered the first observational basis for the expanding space paradigm and today serves as one of the pieces of evidence most often cited in support of the Big Bang model.

An observation stemming from this law is that seeing objects recede from us on Earth is not an indication that Earth is near to a center from which the expansion is occurring, but rather that *every* observer in an expanding universe will see objects receding from them.

4.2.5.2. Hubble constant H_0

The SI unit of H_0 is $\boldsymbol{s^{-1}}$ but it is most frequently quoted in ***(km/s)/Mpc***, thus giving the speed in km/s of a galaxy one Mega parsec away. The reciprocal of H_0 is the Hubble time (See below).

The most recent (2010) observational determination of the proportionality constant based upon measurements of gravitational lensing by using the Hubble Space Telescope yielded a value $H_0 = 70.6 \pm 3.1$ (km/sec)/Mpc. In 2009 also using the Hubble Space Telescope (HST) the measure was

$$H_0 = \boldsymbol{74.2 \pm 3.6} \text{ (km/s)/Mpc or } H_0 \sim \boldsymbol{2.29\times10^{-18}\ s^{-1}}. \tag{4.11}$$

The results agree closely with an earlier measurement of $H_0 = 72 \pm 8$ km/s/Mpc obtained in 2001 also by the HST In August 2006, a less-precise figure was obtained independently using data from NASA's Chandra X-ray Observatory: $H_0 = 77$ (km/s)/Mpc or about 2.5×10^{-18} s^{-1} with an uncertainty of ± *15*%. NASA summarizes existing data to indicate a constant of *70.8* ± *1.6* (km/s)/Mpc if space is assumed to be flat, or *70.8* ± *4.0* (km/s)/Mpc otherwise.

Comment 4.6. The value of the Hubble parameter ***during the*** phase of inflation is estimated as

$$10^{42}\ s^{-1} > H > 10^{36}\ s^{-1}, \tag{4.12}$$

which gigantically, by $\boldsymbol{10^{54} - 10^{60}}$ times, exceeds it current value $H_0 \sim 10^{-18}\ s^{-1}$.

4.2.5.3. Units derived from the Hubble constant

* Hubble time is defined as $1/H_0$ (remind, that the Hubble constant H_0 has units of inverse time). The value of Hubble time in the standard cosmological model makes

$$\boldsymbol{T_H} = 1/H_0 = 4.35\times10^{17} \text{ s} \approx \boldsymbol{13.8} \text{ billion years.} \quad (4.13)$$

The phrase "expansion timescale" means "Hubble time". Remind, that it quite exactly coincides with the age of the Universe (by the hypothesis of Big Bang).

* Hubble length or Hubble distance is a unit of distance in cosmology, defined as the speed of light multiplied by the Hubble time

$$r_H = \frac{c}{H_0} \approx \boldsymbol{4228} \textit{ million pc, or } \boldsymbol{13.8} \textit{ billion light years.} \quad (4.14)$$

So, its value in light years is, by definition, equal to that of the Hubble time in years.

* Hubble volume is defined as the volume of a sphere with comoving radius $\boldsymbol{r_H} = c/H_0$ (or sometimes – a cube of side r_H). This sphere, as the bound, is also called the Hubble limit.

Some cosmologists even use the term ***Hubble volume*** to refer to the volume of the observable universe, *although this has a radius approximately* ***three times larger***.

> Comment 4.7. If the value of H_0 were to stay constant, an interpretation of the Hubble time is that it is the time taken for the universe to increase in size by a factor of $e = 2.72$, because the solution of $dx/dt = xH_0$ is $x = s_0 \cdot exp(H_0 \cdot t)$, where s_0 is the size of some feature at some arbitrary initial condition $t = 0$. In this case we come to the contradiction with the hypothesis of the Big Bang, since it presumes that by that time the Universe presented a singularity. Instead, the current standard model states (See §4.2.1) that the universe has increased its size by ***1292*** times over the period of $T^* =$ ***13.7*** billion years, and before that it was expanding at a fantastic rate of – from a kind of mathematical point to that dimension being just 1300 times less than the current one.
>
> These variations in the value of the Hubble parameter over long periods are explained by the effects of general relativity, dark energy and other factors, but an inexplicable expansion from a singularity to a dimension comparable with the current one – by the inflation when the expansion was fantastically fast (4.12). By that time the Hubble length would make

$$r_{H,Infl} = \frac{c}{H} \approx \frac{3\times10^8 \ (m/s)}{10^{40} \ (s^{-1})} = 3\times10^{-32} \text{ (m).} \quad (4.15)$$

> And although this value is ***10^{17} times less than*** the proton ***charge radius*** (a measure of the size of an atomic nucleus) that makes 0.877×10^{-15} m, ***the significant part of the universe had to be "contained" in a sphere of this radius***. Such correlations leave us little hope to understand the assumed processes that took place during the Big Bang and inflation, if they actually had taken place.
>
> For this reason it is much more reasonable to consider just the models that describe the process of expansion of the Universe starting with the moment of T^* which may be thus called the reference expansion epoch. In this case the observable value of the Hubble parameter is actually changes, but very slowly and its average value over the period T^* makes roughly $7 \cdot H_0$.

4.2.5.4. Hubble constant and cosmological horizon

The ΛCDM model assumes that ***at a given moment of time*** the ***Hubble constant*** has ***the same value throughout the Universe***; to this end the ***subscript*** "***0***" indicates the value of the ***Hubble constant today***.

Therefore, it is only a constant in space, not in time, and the radius of the Hubble sphere may, in principle, increase or decrease over various time intervals. However, in order to explain the main effects that are associated with the Hubble sphere, ***suppose the Hubble parameter*** to ***remain unchanged*** for a long enough period of time (e.g. comparable with the Hubble time). Note, that this suggestion is ***more sensible than*** (4.12) and its sequent (4.15), the more so that ***it is difficult to imagine*** **physically** ***how it could quickly change throughout the Universe***.

For distinctness, consider this sphere to be centered at the Earth.

The Hubble constant, or its derivatives – Hubble length, etc., presents the key parameter defining the regions of "visibility" the bounds of which are called horizons. Their main types are as follows.

The cosmological horizon is ***the maximum distance from which particles could have traveled to the observer in the age of the universe***. It represents the boundary between the observable and the unobservable regions of the universe. The existence, properties, and significance of a cosmological horizon depend on the particular cosmological model being discussed.

Particle horizon represents ***the largest comoving distance from which light could have reached the observer*** by a specific time.

Event horizon is ***the largest comoving distance from which light emitted now can*** **ever** ***reach the observer***.

4.2.5.5. Hubble parameter and scale factor

The scale factor is a function of time $a(t)$ which represents the relative expansion of the universe. It is also called the ***cosmic scale factor parameter*** of Friedmann equations, or Robertson-Walker scale factor.

For an ***expanding universe*** this factor ***relates*** the ***proper distances*** $D(t)$ at epoch t with the ***comoving distances*** $D(t_0)$ at a ***reference time*** t_0 arbitrarily taken to be the ***present*** (for convenience):

$$D(t) = D(t_0) \times a(t). \tag{4.16}$$

In this case the current value of the scale factor is $a(t_0) = 1$. The time t is counted from the birth of the universe and t_0 is the present age of the universe, 13.7 ± 0.2 Gyr.

The evolution of the scale factor is a dynamical question, determined by the equations of general relativity, which are presented in the case of a locally isotropic, locally homogeneous universe by the Friedmann equations. In other words, the scale factor increases as the universe expands in a manner that depends upon the cosmological model selected. Its meaning is that all measured (viz. proper) distances $D(t)$ between co-moving points increase, with respect to the comoving distance at the reference epoch, proportionally to a, if $t > t_p$, and decrease if $t < t_p$ (the co-moving points are not moving relative to each other except as a result of the expansion of space).

The relation (4.16) may also be presented as follows

$$\frac{D(t)}{D(t_0)} = \frac{a(t)}{a(t_0)}. \tag{4.17}$$

Suppose a galaxy is at distance D, and this distance changes with time at a rate dD/dt. This rate of recession is called the "recession velocity" v_r

$$v_r = \frac{dD(t)}{dt} = \frac{\dot{a}}{a} \times D(t_0)$$

By this quantity the Hubble *parameter* is defined ***as follows***

$$H \equiv \frac{\dot{a}}{a}, \tag{4.18}$$

where the dot represents a time derivative. So, we come to the Hubble law

$$v_r = H \times D \tag{4.19}$$

which, for present time, takes the form

$$v_r = H_0 \times D(t_0)$$

H_0 is the Hubble *constant* – the ***current value*** of the ***Hubble parameter H(t),*** and $D(t_0)$ – the current distance to the galaxy.

Comment 4.8. Within the Friedmann equation the Hubble parameter (4.18) is associated with the most important cosmological parameters as well:

$$H^2 \equiv \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}\rho - \frac{kc^2}{a^2} + \frac{\Lambda c^2}{3},$$

where G is the gravitational constant, k is the normalized spatial curvature of the universe and equal to -1, 0, or +1, c is the speed of light,and Λ is the cosmological constant.

4.2.5.6. Hubble's law and redshift

If light is emitted from a galaxy at time t_e and received by us at t_0, it is redshift *due to* the ***expansion of space***, and this redshift ***z*** is simply:

$$z = \frac{a(t_0)}{a(t_e)} - 1. \tag{4.20}$$

This law can be related to redshift z approximately by making a Taylor series expansion:

$$z \approx \frac{a(t_0)}{a(t_0)\cdot(1+(t_e - t_0)\cdot H(t_0))} - 1 \approx (t_0 - t_e)\cdot H(t_0),$$

If the distance is not too large, all other complications of the model become small corrections and the time interval is simply the distance divided by the speed of light:

$$z \approx (t_0 - t_e)\cdot H(t_0) \approx \frac{D}{c} H(t_0) \tag{4.21}$$

or

$$c \cdot z \approx D \cdot H(t_0) = v_r. \tag{4.22}$$

Strictly speaking, neither v nor D in the formula are directly observable, because they are properties *now* of a galaxy, whereas our observations refer to the galaxy in the past, at the time that the light we currently see left it.

For relatively nearby galaxies (redshift ***z much less than unity***), v and D will not have changed much, and v can be estimated using the formula

$$c \cdot z \approx v_r.$$

This gives the empirical relation found by Hubble.

For distant galaxies, *v* (or *D*) cannot be calculated from *z* without specifying a detailed model for how *H* changes with time. The redshift is not even directly related to the recession velocity at the time the light set out, but it does have a simple interpretation: *(1+z)* is the factor by which the universe has expanded while the photon was traveling towards the observer.

> From the perspective of (4.19) and (4.20) – (4.22) the Hubble's law is a fundamental relation between (i) the recessional velocity contributed by the expansion of space and (ii) the distance to an object; the connection between redshift and distance is a crutch used to connect Hubble's law with observations.

However, in using Hubble's law to determine distances, only the velocity due to the expansion of the Universe can be used. Since gravitationally interacting galaxies move relative to each other independent of the expansion of the universe, these peculiar velocities need to be accounted for in the application of this law.

4.2.5.7. Estimates for the Hubble parameter

Deceleration parameter estimates

The age and ultimate fate of the universe can be determined by ***measuring the Hubble constant*** today and extrapolating with the observed value of the deceleration parameter, uniquely characterized by values of density parameters (Ω_M and Ω_Λ).

A "closed universe" with $\Omega_M > 1$ and $\Omega_\Lambda = 0$ comes to an end in a Big Crunch and is considerably younger than its Hubble age.

An "open universe" with $\Omega_M \leq 1$ and $\Omega_\Lambda = 0$ expands forever and has an age that is closer to its Hubble age.

> For the accelerating universe with ***nonzero*** Ω_Λ that we inhabit, ***the age of the universe is coincidentally very close to the Hubble age***.

The value of the Hubble parameter changes over time either increasing or decreasing depending on the sign of the so-called deceleration parameter q which is defined by

$$q = -\left(1 + \frac{\dot{H}}{H^2}\right). \tag{4.23}$$

In a universe with a deceleration parameter equal to zero, it follows that $H = 1/t$, where t is the time since the Big Bang; that is we obtain (4.13).

A non-zero, time-dependent value of q simply requires integration of the Friedmann equations backwards from the present time to the time when the comoving horizon size was ***zero***.

It was long thought that q was positive, indicating that the expansion is slowing down due to gravitational attraction. This would imply an age of the universe less than $1/H$ (which is about 14 billion years). For instance, a value for q of 1/2 (once favoured by most theorists) would give the age of the universe as $2/(3H)$. The ***discovery in 1998*** that q is apparently negative ***means*** that the ***universe could actually be older than 1/H.*** However, ***estimates of the*** age of the universe ***are very close to 1/H.***

Numerical estimates

The value of the Hubble constant is estimated by measuring the ***redshift*** of distant galaxies and then determining the distances to the same galaxies ***by some other method*** than Hubble's law. Uncertainties in the physical assumptions used to determine these distances have caused varying estimates of the Hubble constant. For most of the second half of the 20th century the value of H_0 was estimated to be between 50 and 90 (km/s)/Mpc. Other aspects of obtaining of these estimates are considered above.

4.3. "Observable" Universe: Scanning of the Past

4.3.1. Analytical model for the expanding Universe. General aspects

In this section we develop the analytical models describing the motion of light and physical bodies in the expanding Universe, and study their main properties.

For convenience, we imply the following.

* A physical body (star, for short) has ***no peculiar velocity*** and moves away ***from the Earth*** due to the ***expansion of the Universe*** only.

* For distinctness, the process of emanation, propagation, and reception of ***light*** is considered on an example of a ***separate*** photon.

* If not specified otherwise, the ***motion*** is considered along the axis ***Ol***, the Earth's l-coordinate is 0.

* The ***motion*** is considered in comoving time t that starts ($t = 0$) with the beginning of motion, thus differing from the cosmological time just by the shift in the origin.

* Since we are interested, first of all, in obtaining the qualitative picture of the considered processes, we make use of the ***analytical model of expansion*** in a differential form of Hubble's law

$$\frac{dl}{dt} = H \cdot l \tag{4.24}$$

with the Hubble constant $\boldsymbol{H}$, where the length l at the starting moment presents the comoving, and at any subsequent moment – the proper distance. The respective Hubble time denote $\boldsymbol{T_H} = 1/H$.

* On the ground of (4.24) we obtain the analytical expressions for time and distance directly – by integration of the respective model equation, without use of scale factor.

* For calculations, the numerical value of the Hubble constant $H = \boldsymbol{2.29\times10^{-18}\ s^{-1}}$ is taken from (4.11).

4.3.2. Model 1: Proper distance to a star as a function of time

Due to the expansion of the Universe a star $\boldsymbol{S}$ moves along the axis l from the Earth ⊕ (Fig. 4.1) by following the Hubble law (4.24). At the starting moment $t_o = 0$ the star S is l_o distant from the Earth (this is comoving distance); its proper distance at the moment $t = T$ denote L. ***Find the dependence between the parameters T and L.***

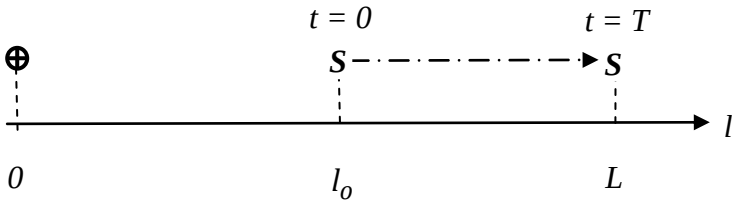


Fig. 4.1. Model 1: Growth of the proper length to a star due to the expansion of the Universe

Integration of (4.24) in these conditions yields $ln\, l\Big|_{l=l_0}^{l=L} = H \cdot t\Big|_{t=0}^{t=T}$. Hence, for the known time T (distance L) the distance L (time T, respectively) makes

$$L = l_o \times e^{HT} = l_o \times e^{T/T_H}, \tag{4.25}$$

$$T = \frac{1}{H} \times ln\frac{L}{l_o} = T_H \times ln\frac{L}{l_o}. \tag{4.26}$$

4.3.3. Model 2: Propagation of light to terrestrial observer: comoving distance to a star as a function of light travel time

At the moment $t_o = 0$ a star ***S*** emits photon ***F*** in the direction of the Earth (Fig. 4.2) when it is L distant from the Earth. At a moment $t = T$ the photon reaches the Earth. ***Find the dependence between the parameters T and L*** (in this case the time T presents the aforesaid Light travel time for the photon)

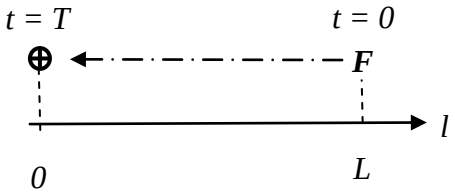


Fig. 4.2. Model 2: Photon moves towards the Earth by "overcoming" the expansion of the Universe

Let at a moment t the photon be l distant from the Earth. Since locally the light propagates as described by the special relativity, during an elementary time interval dt the photon approaches the Earth by $c \cdot dt$ due to its own velocity c, but the remaining distance to the Earth, due to the expansion of the space, according to Hubble's law is increased by $H \cdot l \cdot dt$. So, if these elementary distances satisfy the inequality $H \cdot l \cdot dt < c \cdot dt$, during this time interval the distance l between photon and Earth decreases and photon approaches the Earth; otherwise, its distance increases and will be increasing still further.

This means that the photon could reach the Earth only if the initial distance L satisfies the inequality

$$L < r_H, \tag{4.27}$$

where $r_H = c / H$ – is the ***Hubble distance*** (4.14).

Geometrically, the condition

$$L = r_H \tag{4.28}$$

defines a Hubble sphere around the Earth – a static structure specifying a mathematical horizon with the ***permanent radius*** r_H that divides the Universe into inner and outer parts, and it ***does not expand***.

Physically it specifies the Hubble limit; and although it ***does not present any*** "***bound***" that could be detected locally, the ***objects*** disposed in the ***inner*** and ***outer*** parts ***differ*** in their ***physical manifestations but relative to the Earth***: the light of only those could reach the Earth which lie in the inner part; as the Universe expands the objects lying close to this limit from the inner part continuously pass it outwards and, since then, their light would never reach the Earth since they remove from the Earth at the rates more and more exceeding the velocity of light.

So, ***in compliance with the cosmological definitions*** (See § 4.2.5.4):

– the sphere ***around the Earth with the*** radius $L < r_H$ ***presents*** the particle horizon (for the Earth) for the given time ***T*** since this radius defines "***the largest comoving distance from which light could have reached the observer*** by a specific time". Meanwhile,

– the Hubble sphere ***around the Earth with the radius*** equal to ***Hubble distance*** r_H defines the event horizon (for the Earth) since it is "***the largest comoving distance from which light emitted now can*** ever ***reach the observer*** ". For its origin and for uniformity, call it the Hubble horizon.

Comment 4.9. This "***geocentrism***" reflects just the isotropy in expansion of the Universe ***without any suggestion relative to the Big Bang***, and it would be manifested ***in the same way*** in ***any other point*** in the Universe had it been taken for the centre of observation. And if the Earth approaches such a limit of a planet X, all our current processes would be perceived by the observers of that planet eternally – as more and more delayed; and vice versa: since that planet is also approaching the limit, but with respect to the Earth. Meanwhile, in cosmological time (which may be likened to our civil time) both we and they would continue to live "synchronously".

In case of (4.27) the equation for the motion of photon takes the form

$$dl = H \cdot l \cdot dt - c \cdot dt \ . \tag{4.29}$$

Integration of (4.29) in these conditions yields

$$ln\,(-H \cdot l + c)\Big|_{l=L}^{l=0} = H \cdot t\Big|_{t=0}^{t=T} ,$$

that is

$$1 - \frac{H \cdot L}{c} = e^{-HT} , \tag{4.30}$$

or

$$L = r_H \left(1 - e^{-T/T_H}\right). \tag{4.31}$$

From this relation we obtain the Light travel time for the photon

$$T = -T_H \times ln\left(1 - \frac{L}{r_H}\right),\ L < r_H , \tag{4.32}$$

that is the ***interval*** of ***cosmological time between*** the moments of ***emanation*** and ***reception*** of ***light.*** Directly, it defines the Light travel distance $L_T = T \cdot c$ (as the *light travel time* times *the speed of light*) for the photon, but this ***is not*** the ***comoving distance*** L: the value L_T shows the path that photon has actually "walked" if it was measuring the passed distance in a local vicinity of his position. In the expanding universe the distance L_T is ***always greater*** that the ***proper distance*** L between the ***points of emanation and reception***, because the impending path of the photon is expanding continually.

The practical importance of the Light travel time is that it ***may be estimated by the*** redshift z of the received radiation.

The Hubble sphere as a "mirror" everlastingly reflecting the passed by sources of radiation

If we normalize time and length units by the respective Hubble values, in these relative units the relations (4.31), (4.32) take the form

$$1 - \lambda = e^{-\tau} , \quad \text{or} \quad \tau = -ln(1 - \lambda) . \tag{4.33}$$

where $\lambda = L / r_H$, $\tau = T / T_H$.

Thus, if time τ is small enough (viz. $l << r_H$), we obtain an approximation $\lambda \approx \tau$, viz. $L / r_H \approx T / T_H$, or $LH / c = TH$, which coincides with the well known classical and relativistic formula for the distance that the light passes in the given time:

$$L = c \cdot T . \tag{4.34}$$

In other words, for small time intervals ($\tau < 0.1$), or distances, the ***light travel distance*** $L_T = T \cdot c$ is ***close*** to the ***comoving distance*** L. But for $\tau \approx 0.5$ the error of this approximation increases to *28* %, and ***reaches the value of Hubble time*** when the distance makes the ***Golden section of the Hubble length***

(viz. at $\lambda = \varphi = 0.618\ldots$). As the distance L, where the photon is emanated, approaches the Hubble limit the exponential growth of the light travel time becomes explosive (approximately with the value $\lambda = 0.9$) with an increase of the initial comoving distance L.

In other words, when the point of emanation of photon approaches the Hubble limit, a small increase in comoving length L results in an enormous growth of light travel time (and distance), and the closer this point to the limit, the greater the effect. This situation is illustrated by Graph 4.1 and Table 4.2.

However, although the distance depends on time non-linearly (4.31), it retains to be monotonic, since the greater value of time presents the greater value of distance.

Graph 4.1.
Light travel time τ
as a function of
comoving distance λ

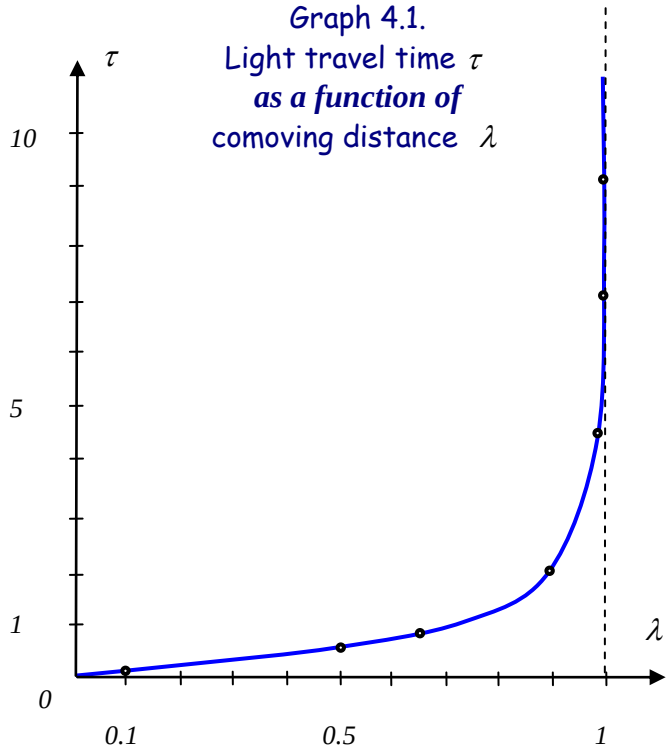


Table 4.2.

$\lambda = L/R_H$	$\tau = T/T_H$	δ
0.001	0.0010005	0.05 %
0.01	0.010050	0.5 %
0.1	0.105361	5 %
0.5	0.693	28 %
φ=0.618…	0.962 ≈ 1	
0.9	2.3	
0.99	4.6	
0.999	6.9	
0.9999	9.2	
0.99999	11.5	

$\lambda = L/R_H$ – normalized comoving distance (in relative unit of Hubble length)

$\tau = T/T_H$ – normalized light travel time (in relative unit of Hubble time)

δ – error of approximation $L = c \cdot T$

These illustrations show that the light emitted when a star approaches the Hubble limit may travel to the Earth any amount of time: the closer it is emanated to this event horizon, the greater the light travel time τ. When a photon is emitted on the horizon itself, viz. at the comoving distance r_H, it theoretically remains on it forever; a photon issued at the next moment already moves away from the Earth (Fig. 4.3.b).

This situation may be likened to watching a videotape recorder. Suppose, you are fond of some episode with a passing car which you have just photographed, and you would like to see it as long as possible, but without iterations; for this, each minute you decrease the speed of the film by two times. The action will be more and more slowed down (exponentially), but you would be able to see the film infinitely, although the car has already moved away and you would never see it once again.

So, the expanding inner region of the Universe on the whole continuously moves “outwards”, towards the immovable Hubble sphere with the fixed radius. As an object has reached this limit, for a terrestrial observer it disappears forever, since starting with this moment we will be unable to receive any information from this body, but we still would receive a slowed down prehistory of his approaching the Hubble limit. After then, new stars approach the horizon thus forming a steady process of stars falling “outwards” through the immovable horizon, the process that is caused by expansion of the Universe. In essence, this horizon does not differ from the black hole horizon except of philosophical disagreements relative to what is “inside”, and what is “outside”.

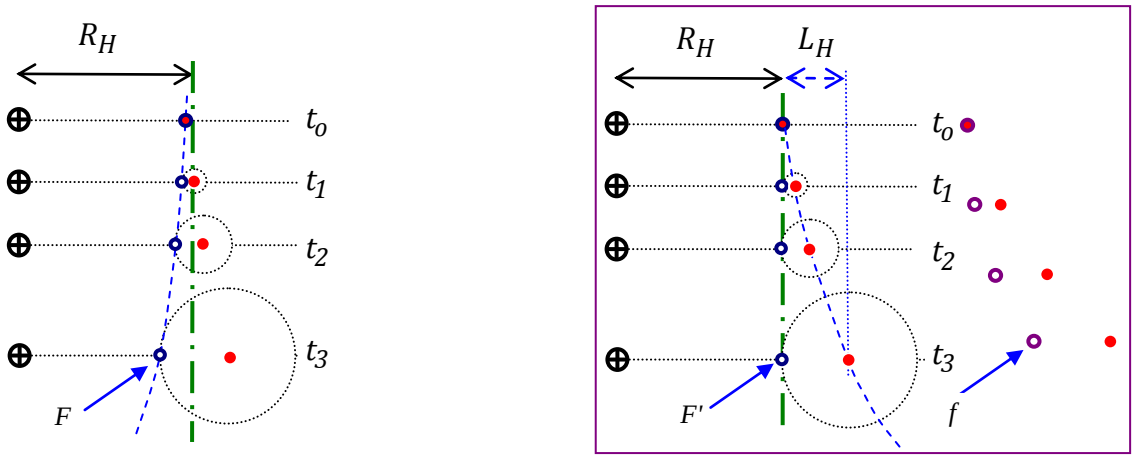


Fig. 4.3. Photon F position ∘ on the wave front ◌ with respect to the Hubble horizon — · — at the moment t_o it is emanated by star • and at the subsequent equally spaced moments of time t_1, t_2, t_3

a) Photon (F) ∘ emanated directly before the horizon (Hubble sphere of radius r_H) approaches the Earth with an acceleration being caused by non-linearity of function (4.32) presented in Graph 4.1.
b) Photon (F') ∘ emanated directly on the horizon remains on the Hubble sphere (at any interval of time its own motion towards the Earth is compensated by the expansion of the space);

Photon (f) ∘, emanated directly after the horizon moves "away from the Earth" (for the terrestrial observer) with an acceleration: as in the case of ***relocation***, but due to ***another cause***, it may withdraw at a super-light velocity.

For these reasons the ***light travel time,*** viz. the time T, may be considered as a measure of remoteness of the space objects, but this quantity ***is not connected with a geometrical distance L directly***: for obtaining this ***comoving distance*** for the moment of emanation it is ***required to transform*** the time T as specified ***by*** (4.31).

Moreover, for the remote objects (with a significant values of redshift) namely this quantity is used, not the ***light travel distance***. Firstly because it ***could be measured by redshift***; secondly, because the relation (4.31) presumes that the ***Hubble parameter*** retains its current value (viz. Hubble constant) whereas in general it is supposed that it ***changes in time***. For taking these changes into account it is required to accept a unified cosmological model and make the integration of this quantity as a function. As far as the result of all these ***manipulations is dubious***, the ***light travel distance*** is ***still used for the measure of distance with the aforesaid reservation.***

Meanwhile, as far as the exponential distortion may exceed the error caused by approximation of Hubble parameter with its current value by many orders, the relation (4.31) may give more adequate result if the light travel time becomes comparable or greater than the Hubble time. However, ***the most*** "***ancient***" ***signal*** that has been ***ever registered*** is characterized by a ***light travel time of approximately 13 billion years***, which even ***less*** that the ***Hubble time*** (See the Example 4.4)

4.3.4. Model 3: Light travel time for a star that crosses the Hubble horizon

Model 3. A star ***S*** being x distant from the Earth emits a photon ***F*** at the moment $t = 0$ (Fig. 4.4). At the moment $t = y$ photon reaches the Earth, and the star passes the Hubble horizon.
Find the critical values $r_* = x$ and $T_* = y$.

In fact, the solution to this problem specifies that ***unique situation*** when we ***register the light*** of a ***star*** moving with the Hubble flow at ***the very moment*** of cosmological time ***it passes the horizon***. The value r_* specifies the ***comoving distance*** at which the light was emanated, and T_* – the ***Light travel time***.

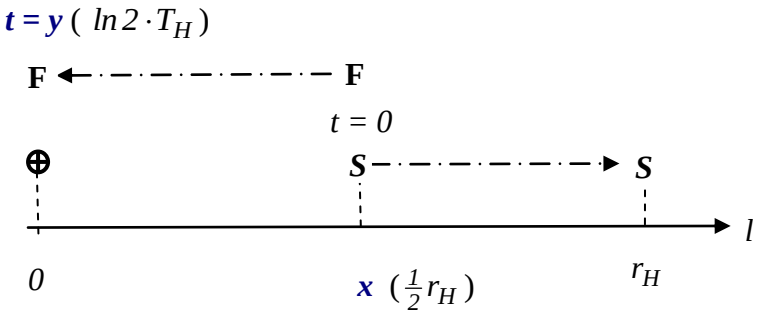


Fig. 4.4. Model 3: Observing a light of star (photon F) that crosses the Hubble horizon

For solving this problem consider the models 1 and 2. Then, with these notations from (4.25) и (4.31) we obtain the following system of equations

$$\begin{cases} r_H = x \cdot e^{y/T_H}, \\ 1 - \dfrac{x}{r_H} = e^{-y/T_H}. \end{cases} \tag{4.35}$$

The unique solution to this system for the accepted value of the Hubble constant is as follows:

$$r_* = x = \tfrac{1}{2} r_H \approx 13.8 / 2 = \mathbf{6.9} \text{ (Billion light years).} \tag{4.36}$$

$$T_* = y = \ln 2 \cdot T_H \approx 0.693 \times 13.8 \approx \mathbf{9.6} \text{ (Billion light years).} \tag{4.37}$$

4.3.5. Model 4: Proper distance to a star as a function of Light travel time

Model 4. Before crossing the Hubble horizon, at the moment $t = 0$ a star ***S*** emits a photon ***F*** which reaches the Earth in time T. ***Find the proper distance*** between the ***Earth*** and ***star*** at the ***moment T***.

Let l be the comoving distance to the star on emanation of the light, and L – the proper distance on reception of the photon. Then, from (4.31) it follows that

$$l = r_H (1 - e^{-T/T_H}).$$

By inserting this value in (4.25)we obtain the searched quantity

$$L = l \cdot e^{T/T_H} = r_H (e^{T/T_H} - 1). \tag{4.38}$$

Example 4.4. The oldest event ***that was ever observed*** is a Gamma-ray burst that took place approximately ***13 billion years ago***; it was registered on April 23, 2009 ("it is assumed to be disposed on the opposite side of the observable Universe"). This means that the light travel time for it makes $T = 13$ billion light years (***bly***) and according to (4.31) the ***burst took place*** when the ***comoving distance*** to that object was

$$l = r_H (1 - e^{-13/13.7}) \approx 0.613 \cdot r_H \approx 8.4 \text{ (bly).} \tag{4.39}$$

If the respective "object" had survived that event (its nature is still not clearly understood), it continued to move with the Hubble flow (viz. away from the Earth by the expanding Universe). Anyhow, the light from this burst was moving towards the Earth; as its travel time equals to T, the proper distance to this object at present (if it still exists) with respect to (4.38) makes

$$L = r_h (e^{13/13.7} - 1) \approx 1.58 \cdot r_H \approx 21.7 \text{ (bly).}$$

As far as this distance exceeds the Hubble length (*13.8* bly), the light which it emits at present, if it still alive, would never reach the Earth.

4.3.6. The Scannable Universe and the Resident world

Thus, if at definite moment the distance to a star is less than the Hubble length r_H, the light emitted at this moment would reach the Earth in a finite time. But if at the moment of radiation this distance exceeds the Hubble length r_H, the emitted light would never reach the Earth because at distances $D > r_H$ the objects recede at a rate faster than the speed of light.

So, the Hubble limit, as a sphere with centre at the Earth and radius r_H, presents a "thought" surface for the given moment *t* which divides the Universe (but "mathematically", not physically!) into two regions with respect to whether or not the light (or any other type of electromagnetic radiation) that is emitted at this moment could ever reach the Earth. There are no objections implied by the expansion of the universe for the light emitted by any object residing in the inner region to reach the Earth, except the conventional effects like dissipation, damping, etc. On the contrary, the light emitted by any object residing in the outer region would never reach the Earth since the space expands faster, than the light propagates (still with the same fixed speed relative to the local environment it passes).

Some time later, the expansion of the Universe would increase the distance to the former star to a value r_H; starting with this moment we would never see the light of this star that was issued outside the Hubble limit, since by passing the Hubble sphere it transfers to the outer sphere. But we will still "observe" the light that was issued before crossing this sphere!

And what is important – a star passes this bound (due to expansion of the Universe) in a finite and relatively small period of time, but the light emitted during this period will be "reflected" everlastingly. At that, seeing objects recede from Earth is not an indication that Earth is near to a center from which the expansion is occurring, but rather that *every* observer in an expanding universe sees objects receding from him.

In this sense the Hubble sphere S_{r_H} with the ***radius*** equal to the ***Hubble constant*** r_H ***presents*** an "***immovable***" horizon ***for the Earth*** which, for any given moment of cosmological time *t*, "separates" the stars into two groups: *potentially* "***scannable***", disposed in the inner region, and "***non-scannable***" disposed in the outer region.

In other words, this sphere ***divides*** the Universe on the whole into two regions (Fig. 4.5.a); the inner one, presenting the ball of ***Hubble volume***, call the Scannable Universe, and the outer one – the Non-scannable Universe (it presents the ***Universe on the whole with the "punctured" scannable region*** , or ball of the Hubble volume).

The light of ***any object*** residing in the inner region that is ***emitted at present*** could ***reach the Earth*** in future; for this reason it is called **SCANNABLE UNIVERSE**; it should rather be called "***observable***", but this term is reserved for the greater region including the Hubble volume, that contains the objects the light of which we see now, but their present state would remain unknown for us forever.

The outer region contains the ***objects*** about which we ***cannot obtain any information*** (at least in a form of electromagnetic radiation) ***pertaining to their*** current state - neither at present nor in future. For this reason it is called **NON-SCANNABLE UNIVERSE**.

Meanwhile, the **OBSERVABLE UNIVERSE** comprises the ***scannable universe*** and a ***spherical hoop*** (Fig. 4.5.b) that surrounds it; the "***inner***" ***bound*** radius of this spherical hoop remains ***fixed*** and well defined since that bound is formed by the ***Hubble sphere***, but the "***outer***" ***bound*** (dashed pink circle), with respect to the definition of the observable universe, expands with the space and is "formed" by the most distant "pieces" of matter that formed during the Big Bang.

So, although the received light had to be emitted while its source was residing in the ***scannable universe***, at the moment of receiving this source could be in any of these regions. In particular, if the light was issued near the horizon, we will observe it everlastingly – mathematically, but during a finite period – practically (due to damping of radiation), even if this object collapsed long ago – it will be the light still issued

from the inner region! We would never know what happened with it after it had crossed the horizon. And all such objects (if they are still alive) reside **now** in this hoop, as the gamma-bursts from Example 4.4.

However, neither the diameter of this "outer bound", nor the state of the matter in its vicinity are known, although there are the estimates for this quantity which are based on the use of existing models and observations of remote light sources and considered as the "***diameter of (observable) universe***"

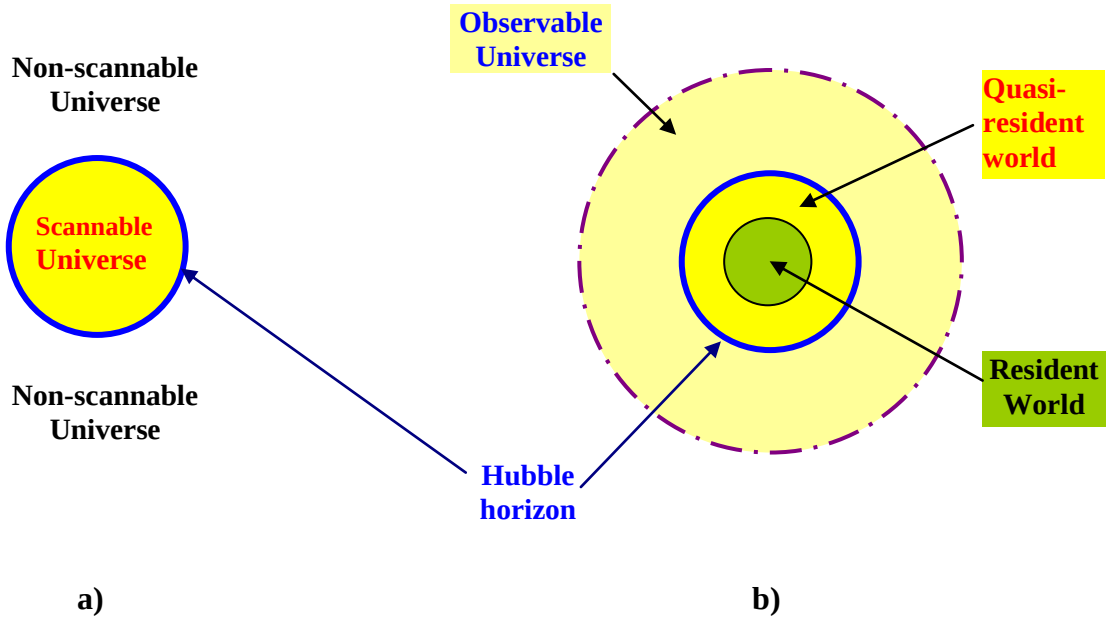


Fig. 4.5. Scannable vs. Observable universe
(***Universe on the whole*** is *reflected* by the ***plane as a whole***)

a) The Hubble horizon (blue circle) divides the ***Universe on the whole*** into two regions: ***Scannable Universe*** (yellow ring) and ***Non-scannable Universe*** (the plane with the punctured yellow ring).

b) The ball of ***Resident world*** (green) and the hoop of ***quasi-Resident world*** (bright yellow) form the ball of ***Scannable universe*** that is bounded by the Hubble sphere (blue circle). The latter lies within the ***Observable universe*** (dark yellow) the bound of which (dashed pink circle) is defined according to a cosmological model based on the Big Bang hypothesis.

Therefore, an ***object*** from the "scannable" part of the Universe (whether we see it at present, or could see it later or never) ***differs qualitatively*** from that which has passed this horizon, but, with respect to the existing terminology, is considered still residing in the "observable Universe", like the gamma-burst in the Example 4.4.

Therefore, although the term "***observable Universe***" is adopted in cosmology, it may be misleading relative to those ***objects*** or regions that ***passed the Hubble horizon***: we may ***observe*** now, or in a distant future, but ***only*** the ***delayed past*** that ***has nothing in common*** with ***what happens*** with the ***object*** neither in the past (when it approached the horizon), nor at ***present***, nor in ***future***.

Comment 4.10. When we consider the scannable universe, no problems arise relative to its bound ***in contrast to*** the "observable" universe that is defined as a part of the Universe on the whole that was ***engendered by the Big Bang***; in the latter case a series of unsolvable problems arises relative to its bound: what is it, how it interacts with the Universe on the whole, etc.

Further on, let the sphere S_{r_*}, with the ***critical radius*** $r_* = ½ r_H$ of (4.36) ***divide*** the Scannable Universe into two regions (See fig. 4.5.b). The inner ball region call the resident world, and the spherical layer enclosed by the spheres S_{r_*} and S_{r_H} – the quasi-resident world. The light emitted by an object residing in any of these worlds can reach the Earth if its source is quite powerful, but:

– if the ***object*** resides in the **RESIDENT WORLD**, viz. its comoving distance l is less than r_*, the light reaches the Earth ***before*** the object would ***leave*** the ***Scannable Universe***; when we receive its light we know that it continues to reside in the ***Scannable Universe***.

– if the ***object*** resides in the **QUASI-RESIDENT WORLD**, viz. its comoving distance l complies with inequalities $r_* < l < r_H$, the light reaches the Earth ***after*** the object has ***left*** the ***Scannable Universe***; when we receive its light we know that it no more resides in the ***Scannable Universe*** as it already transferred to the Non-scannable Universe.

Example 4.5. Sunset analogy. The "resident" position of the Sun corresponds to the solar day period: its apparent position more or less exactly corresponds to its true position (in this example we neglect the relativistic effects). But at the sunset the Sun is in the "quasi-resident" position: after the Sun has descended below the horizon, due to the refraction we still observe its *image* above the horizon for several minutes more.

Comment 4.11. The ***Hubble parameter***, whatever fixed value we would assign it, ***satisfies*** the following ***analytical*** (viz. mathematically accurate) or quite ***accurate numerical*** relations which ***associate*** it with the ***principal mathematical constants***: 2, e, π, and Φ.

1. The ***resident sphere radius*** makes ***exactly ½*** of the ***Hubble distance***.
2. The ***light travel time*** for the ***light crossing the Hubble horizon*** (model 3) makes ***exactly ln2*** times the ***Hubble time***.
3. In Hubble units (viz. in a proper sense), the ***sum*** (1.*942695…*) of ***light*** $T_*/T_H = 1/\ln 2$ and ***proper*** $r_*/r_H = ½$ ***distances*** for the ***light crossing the Hubble horizon*** (model 3) with a ***high precision*** (*0.06* %) ***presents*** the ***ratio*** (*1.941611…*) of ***mathematical constants*** $\pi = 3.14159…$ and ***Golden section*** $\Phi = 1.61833…$, that is

$$\frac{1}{2} + \frac{1}{\ln 2} \approx \frac{\pi}{\Phi} \ (\delta \cong 0.06\%),$$

that may be converted to the form

$$e\sqrt{2} = 2^{\pi/\Phi}, \qquad \text{or} \qquad e = 2^{\pi\cdot\varphi - 1/2}, \tag{4.40}$$

where $\varphi = 1/\Phi = 0.61833$ – is another presentation of the Golden section number.

Therefore, the resident world presents a ***critical object*** not only with respect to the ***physical properties*** of the Universe, but relative to ***mathematics as well***: its formal definition with a high ***accuracy*** (***0.06%***) specifies the sum of ***two main critical distances*** (presented in a proper units) through ***three*** main mathematical constants – e, π, and Φ, in a simple expression.

Note to this end, that probably the only artifact that ***co-relates these constants*** is the Great pyramid of Egypt [24], and this accuracy corresponds to the most exact relations between periods in the ***ATS*** [16].

4.3.7. Conjugate oscillator distances for the light emanation and reception moments

One more remarkable property of the ***system of equations*** (4.25) and (4.31) relative to ***Model 4*** is that it ***engenders*** a ***system of critical points*** specified by the ***Golden section*** and ***harmonic series*** in which the moments of emanation and reception of photon are synchronized. Thus, find the points being distant from the Earth at the comoving distances l and L which form the Golden section ratios with the Hubble length:

$$l / r_H = \varphi, \quad \text{or } l = \varphi \cdot r_H, \tag{4.41}$$

$$L / r_H = \Phi, \quad \text{or } L = \Phi \cdot r_H. \tag{4.42}$$

It turns out that ***these points*** are time conjugated: within the ***frame of Model 4*** for the ***same time T*** they ***satisfy*** the following ***system of equations***

$$\begin{cases} l / r_H = 1 - e^{-T/T_H} = \varphi, \\ L / r_H = e^{T/T_H} - 1 = \Phi. \end{cases} \tag{4.43}$$

Indeed, denote $e^{T/T_H} = a$. Then, the system (4.43) takes the form

$$\begin{cases} 1 - \dfrac{1}{a} = \varphi, \\ a - 1 = \Phi. \end{cases} \tag{4.44}$$

By allowing for the equality $1 - \varphi = 1/\Phi^2$, the fist equation is converted to the form $a = \Phi^2$. In a similar way, the second equation may be reduced to the form $a = 1 + \Phi = \Phi^2$; this means that the system (4.44) remains compatible for any non-zero a. So, by implying $e^{T/T_H} = \Phi^2$ we obtain the following scenario: If a star has issued a photon at the distance $l_2 = \varphi \cdot r_H$ (from the Earth), then, after elapsing of the time

$$T_2 = 2 \cdot \ln \Phi \cdot T_H \tag{4.45}$$

two events take place synchronously: this photon is received on the Earth and the proper distance to the star makes the value $L_2 = \Phi \cdot r_H$. The analogous conjugate points appear if we apply the Golden section to the distance $l_2 = \varphi \cdot r_H$ as well. In this case they satisfy the system (4.43) with the following parameters

$$\begin{cases} l / r_H = 1 - e^{-T/T_H} = \varphi^2, \\ L / r_H = e^{T/T_H} - 1 = \varphi. \end{cases} \tag{4.46}$$

As with (4.44), it may be converted to a form

$$\begin{cases} 1 - \dfrac{1}{a} = \varphi^2, \\ a - 1 = \varphi. \end{cases} \tag{4.47}$$

Its compatibility results from the following transformations of the first and second equations:

$$a = 1/(1 - \varphi^2) = \Phi^2/(\Phi^2 - 1) = \Phi^2/(1 + \Phi - 1) = \Phi, \text{ viz. } e^{T/T_H} = \Phi;$$

$$a = 1 + \varphi = \Phi.$$

For the respective distances $l_1 = \varphi^2 \cdot r_H$ and $L_1 = \varphi \cdot r_H$ the transition time makes

$$T_G = \ln \Phi \cdot T_H, \tag{4.48}$$

that is ***exactly two times less*** than the ***value*** T_2 for (4.45). Therefore, a photon that is issued at a distance $r_1 = \varphi^2 \cdot r_H$ from the Earth reaches it in time $T_G = \ln \Phi \cdot T_H$ and at the same moment when the distance from Earth to the star has increased Φ (viz. Golden section) times – up to the value $r_2 = r_1 \cdot \Phi = \varphi \cdot r_H$ that specifies the Golden section of the Hubble sphere radius (Fig. 4.6).

Further on, a photon that is issued at a distance r_2 reaches the Earth in time $T_2 = 2 \cdot T_G = 2 \cdot \ln \Phi \cdot T_H$ and at the same moment when the star passes the conjugate point $r_3 = \Phi \cdot r_H$ (the second Golden section point of the Hubble sphere).

So, the spheres with radii $r_1 - r_3$ may be called the Golden section spheres of the ***Hubble Universe***; the first two of them belong to the scannable Universe and lie in the ***resident*** and ***quasi-resident worlds***, respectively, whereas the last one resides in the ***non-scannable Universe***

Therefore, as far as the ***most distant Space objects*** are registered with the ***light travel time*** slightly exceeding ***13 Gy***, and the ***light travel time*** for the ***objects*** disposed ***near the second Golden section sphere*** (See (4.39)) ***makes*** $2T_G = 2 \cdot \ln \Phi \cdot T_H \approx 0.96 \cdot T_H = 0.96 \cdot 13.8 \approx$***=13.3 Gy***, we may conclude that the Golden section spheres present not only mathematical interest, but physical as well.

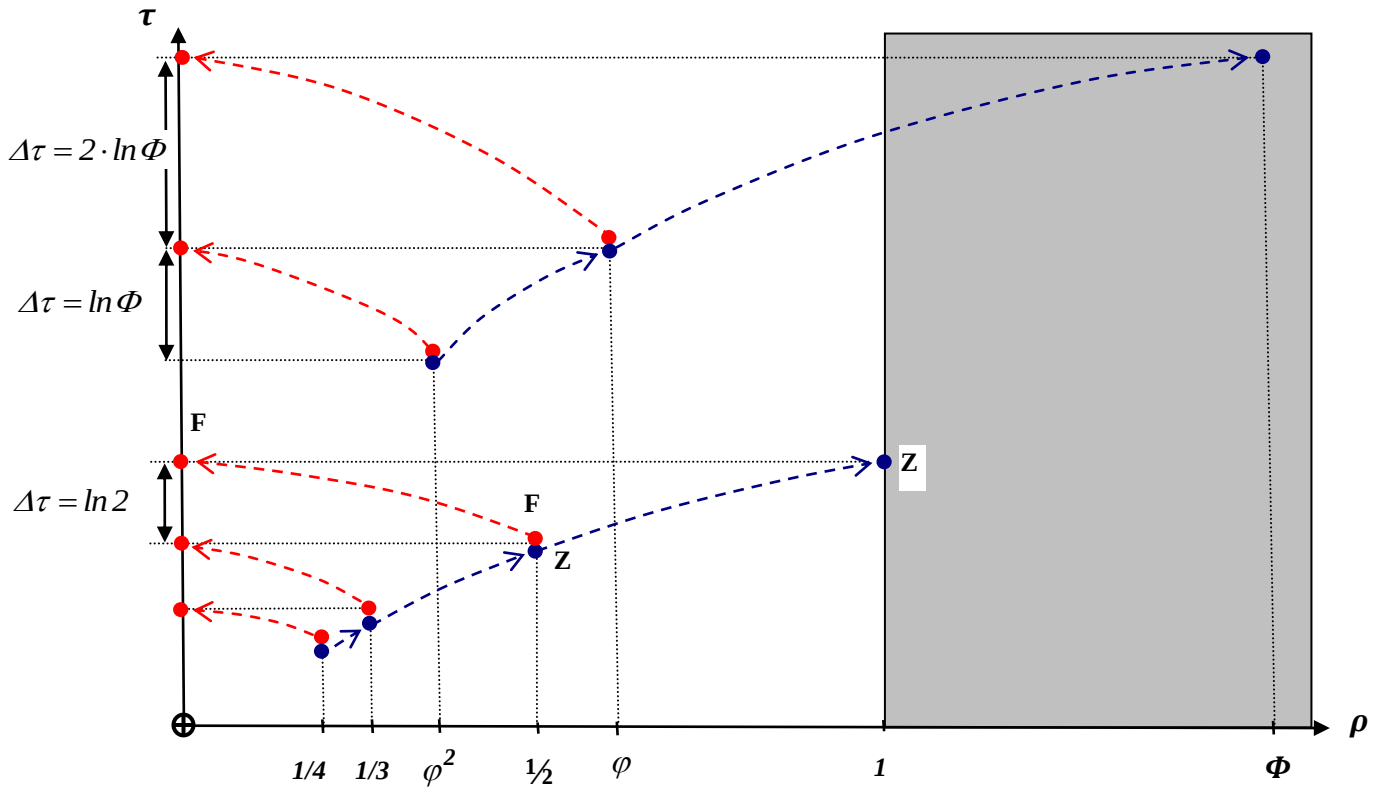


Fig. 4.6. Conjugate points of emanation and reception of light (photon F) relative to Earth-centered scannable Universe. These points present the Golden section and harmonic solutions to the system of equations (4.46) specifying the expansion of the Universe and relativistic propagation of light

$\rho = l / r_H$ – proper distance from the centre of the scannable Universe in units of Hubble length;

$\tau = T / T_H$ – comoving time (or time spans $\Delta\tau$) in units of Hubble time.

● – ***photon***; ● – ***emitting object***; *grey background* – ***non-scannable Universe***.

After the object **Z** has emitted a photon **F** at the distance ½ (viz. $\frac{1}{2} r_H$) from the Earth, it continues to move with the Hubble flow (that is due to the expansion of the universe); at the moment the photon reaches the Earth, the object **Z** is already ***1*** (viz. r_H) distant from it. In the comoving time this process of object's transfer from point ***½*** to the conjugate point ***1*** occupies $\Delta\tau = \ln 2$ units of Hubble time, that is $\ln 2 \cdot T_H$ units of comoving time. The light emitted in the point ***1*** would never reach the Earth.

The same synchronization of the emanation and reception moments also takes place in the pairs of coordinates {*1/2, 1/3*}, {*1/3, 1/4*} … which form a harmonic sequence of conjugate points (§4.3.8), as well as in the conjugate coordinate pairs $\{\Phi, \varphi\}$, $\{\varphi, \varphi^2\}$ specified by the Golden section partitioning of the Hubble sphere.

4.3.8. Harmonic series of conjugate distances

In general case, call the distances ***x*** and ***y*** conjugate if they define the distances to the object for the moments of emanation and reception of light issued by this object. With respect to obtaining the system (4.47), a pair of quantities x and y specify the conjugate distances if they comply with the inequalities $0 < x < 1$, $0 < y$ which reflect their physical meaning (x must lie in the scannable Universe) and satisfy the system

$$\begin{cases} 1 - \dfrac{1}{a} = x, \\ a - 1 = y, \end{cases} \tag{4.49}$$

from which we obtain that the ***conjugate distances*** ***x*** and ***y*** must satisfy the following equality

$$y + 1 = \frac{1}{1 - x}, \tag{4.50}$$

or

$$x = 1 - \frac{1}{1 + y}. \tag{4.51}$$

From (4.51) it follows that for any $y > 0$ there exists $x < 1$, that is for any position of light emitting object, whether in scannable or non-scannable part Universe, there is the conjugate distance x that is disposed in the scannable Universe. Now, ***present*** (4.51) ***as*** a recurrent formula

$$x_n = 1 - \frac{1}{1 + y_n}, \tag{4.52}$$

which any value $y_n > 0$ assigns the conjugate distance x_n. Then, ***starting with an arbitrary*** $y_0 > 0$ we obtain a series of numbers being uniquely defined by the initial value y_0, each sequential pair of which presents the conjugate distances. If we combine these numbers in pairs, this series may be presented as a sequence of pairs of conjugate distances

$$\Pi(y_0) = \langle \{ x_k, y_k \} \rangle_{k=1,\infty} \tag{4.53}$$

with the following values that are obtained by the initial value y_0

$\{ x_0, y_0 \}$, where y_0, $x_0 = 1 - 1/(1 + y_0)$;
$\{ x_1, y_1 \}$, where $y_1 = x_0$, $x_0 = 1 - 1/(1 + y_0)$;
$\{ x_2, y_2 \}$, where $y_2 = x_1$, $x_2 = 1 - 1/(1 + y_2)$;
$\{ x_3, y_3 \}$, where $y_3 = x_2$, $x_3 = 1 - 1/(1 + y_3)$; etc.

where each subsequent point is nearer to the Earth than the preceding one:

$$y_0 > x_0 \equiv y_1 > x_1 \equiv y_2 > x_2 \ ...$$

As far as the initial value y_0 may be chosen arbitrarily, there is an ***infinite number of series like*** (4.53). But the most interest stimulate those of them which are expressed with the use of natural scale (apart from mathematical constants, like the aforesaid conjugate points defined by the Golden section) and include the critical points of the scannable Universe.

It turns out that the ***both these conditions*** are satisfied for the harmonic series

$$\Gamma = \{ 1/k \}_{k=1,\infty} = 1/1,\ 1/2,\ 1/3,\ 1/4, ... \ . \tag{4.54}$$

that presents great importance in physics in ***many aspects***, and especially – in ***time series***, as they define the main ***resonant harmonics*** (viz. fraction of the main period).

Indeed, by inserting the value $y_k = 1/k$ (from Γ) in (4.52) we obtain

$$1 - \frac{1}{1 + y_k} = 1 - \frac{1}{1 + 1/k} = \frac{k + 1 - k}{k + 1} = \frac{1}{k + 1} \equiv x_k .$$

Therefore, in ***units of Hubble length the harmonic series*** Γ ***forms the series of conjugate distances***, the ***initial term*** of which, $y_0 = 1$, specifies the ***radius*** of sphere of the ***scannable Universe***, and the ***second term***, ½, – the ***radius*** of sphere of the ***resident world***.

In other words, the series (4.54) defines the unique sequence of ***conjugate distances*** that ***specifies*** the ***radii*** of the ***both critical spheres*** of the ***scannable Universe***.

Note, however, that the ***actual process of emanation and reception of light*** via the conjugate points develops ***in the order inverse*** to the growth of ***indices***. For the first four distances (1, ½ , 1/3, and ¼) of the series (4.54) this process is described in Fig. 4.6.

The comoving time T_k of transition $x_k \rightarrow y_k$ (it also presents the light travel time for the photon emitted at x_k) may be obtained from the equation $e^{T/T_H} = a$ and (4.49):

$$\begin{cases} e^{T_k/T_H} = a_k \\ a_k = y_k + 1 \end{cases},$$

thus giving

$$T_k = T_H \times ln\left(1 + \frac{1}{k}\right) \quad . \tag{4.55}$$

Notice, that for the situation considered in §4.3.4 ($x = ½$, $y = 1$), at $k = 1$ we come to the previously obtained relation (4.37) for Hubble sphere: $T_* = ln\,2 \cdot T_H$.

The time (4.55) may also be presented in a form $T_k = T_H \times [\, ln(k+1) - ln\,k\,]$, but more interesting result yields a one term expansion (4.56) of logarithm from (4.55) in a series, in the vicinity of *1*; for comparison, a two term expansion is also presented (4.57):

$$ln(1+\alpha) \approx \alpha\,, \tag{4.56}$$

$$ln(1+\alpha) \approx \alpha - \alpha^2/2\,. \tag{4.57}$$

Making use of expansions (4.56), (4.57) for time T_k of (4.55) gives the following approximations

$$T'_k = T_H \times \frac{1}{k}\,, \text{ or } \tau_k = \frac{1}{k} \text{ (in units of Hubble time)}, \tag{4.58}$$

$$T''_k = T_H \times \left(\frac{1}{k} - \frac{1}{2 \cdot k^2}\right), \text{ or } \tau'_k = \frac{1}{k} - \frac{1}{2 \cdot k^2} \text{ (in units of Hubble time)}. \tag{4.59}$$

As it follows from Table 4.3, the accuracy of approximation (4.58) grows quickly enough with an increase in index *k*.

Therefore, the harmonic series $\Gamma = \{\, y_k \,\}_{k=1,\infty}$, $y_k = 1/k$, in units of Hubble length (r_H) defines the sequence of conjugate distances that starts with the radii of scannable Universe and Resident world spheres, whereas (4.55) specifies the time required for the light emitting object to displace from position $x_k = 1/(k+1)$ to $y_k = 1/k$. Moreover, the duration of this displacement is approximated (4.58) by the same harmonic $\tau_k = 1/(k+1)$ (in units of Hubble time) with a relatively low error, if *k* is large enough.

Table 4.3. Error of harmonic approximation for the time of displacement in the conjugate point

k	y_k	$ln(1+1/k)$	$1/k$	δ %	$1/k - 1(2k^2)$	δ %
1	1	0.693	1	30%	0.5	27%
2	1/2	0.405	0.5	19%	0.375	7%
3	1/3	0.29	0.33	13%	0.278	3%
10	1/10	0.0953	0.1	5%	0.095	0.3%
50	1/50	0.019803	0.02	1%	0.0198	0.01%
100	1/100	0.0099503	0.01	0.5%	0.00995	0.003%

4.3.9. Cosmological radiation damping

Thus, if a space object emits light before it crosses the Hubble horizon, this light could reach the Earth, although the light travel time may attain, with respect to (4.32), whatever large value – the greater the closer to the horizon it was emitted. But, evidently, the intensity of this radiation must decrease: both due to the redshift caused by the expanding space that diminishes the photon energy, and due to diminution of the flux density caused by increase of the wave front (energy conservation law).

With the aim to illustrate the second effect consider the propagation of the front wave in the frame of emitting object. So, let the object S emit photon in the point $x = 0$ at the moment $t = 0$. Then, it is required to find the proper distance of photon at the moment $t = T$.

Since the Universe is expanding symmetrically, in the frame of the emitting object this distance would specify the radius r of sphere presenting the front wave of the light emanated at the initial moment. Then, with respect to the models 1 and 2 this distance r increases due to the expansion of the space and proper velocity of light so that

$$dr = r \cdot H \cdot dt + c \cdot dt. \tag{4.60}$$

With the given initial conditions integration of this equation yields

$$ln\,(H \cdot r + c)\Big|_{r=0}^{r=R} = H \cdot t\Big|_{t=0}^{t=T},$$

that is

$$R = r_H \cdot \left(e^{T/T_H} - 1\right). \tag{4.61}$$

Therefore, the front wave radius R increases exponentially with time T, that is avalanche-like.

Model 5. Exponential growth of redshift

However, the ***distance*** (4.61) defines ***how far the photon is*** disposed ***relative to the source object***; the actual ***distance*** it "***walked***" with respect to its local vicinity at any moment of its motion is ***defined by the light travel distance***, that is by the *light travel time T times the speed of light c*:

$$\rho = c \cdot T = -c \times T_H \times ln\left(1 - \frac{L}{r_H}\right), \tag{4.62}$$

where L is the distance from the Earth to the emitting object at the initial moment. In this case the ***redshift z*** , with respect to (4.16), (4.21), is specified by expansion of the Universe during the time T, that is

$$z = \frac{R(T)}{R(t_o)} - 1 \approx \frac{L \cdot e^{T/T_H}}{L} - 1 = e^{T/T_H} - 1, \tag{4.63}$$

which also grows with time infinitely and exponentially.

Model 6. Loss of power of radiation

Let the ***electromagnetic radiation power*** of the source S be ***W***. Then, the power flux of the spherical wave front with radius r (relative to the source) makes

$$p = \frac{W}{4\pi r^2}, \tag{4.64}$$

that is it ***decreases quadratically***.

Besides, since the ***cosmological redshift*** decreases the proper photon energy (due to increase in the wave length), the ***numerator*** of (4.64) is ***to be decreased*** to some value $W_r < W$.

Moreover, the power W_r ***has to decrease in time exponentially*** or even ***hyperbolically*** since the ***total energy output*** of the source, that was emitted before it crossed the Hubble horizon, is ***finite*** and, thus, ***could not retain a finite value infinitely***.

On the other hand, there are many factors which define the minimal level of radiation power that could be registered. Thus, any recording instrument is characterized by definite sensitivity p_o that roughly may be explained as a minimal radiation power which it is capable to detect. Besides, it is difficult to imagine an instrument which can register separate photons in any waveband. As well, we must take into account the noise ratio, since there are many sources that emit in the same bands. Furthermore, if W in (4.64) is proportional to the number of photons emitted per unit of time, with the growth of distance the moment comes when the wave front photon density becomes so small that the probability of receiving a photon becomes negligible for an antenna of any reasonable size.

Therefore, the radiation of a source S could only be registered on the Earth if its power flux p exceeds a finite value of the threshold power flux $p_o > 0$ reflecting the current state-of-the-art in radionics. In common with W_r it defines the maximal ***distance*** r at which a light emitting object ***could be detected***:

$$r_{**} = \sqrt{\frac{W_r}{4\pi\, p_o}}\,. \tag{4.65}$$

With the use of (4.61) the maximal ***light travel time*** for a light emitting object ***to be detected*** makes

$$T_{**} = T_H \times ln\left(\frac{r_{**}}{r_H} + 1\right) \text{ (light years).} \tag{4.66}$$

Hence, with the given level of radionics the maximal distance, at which a light emitting ***object could be detected***, is dominantly ***specified*** by the logarithm of its energy output. Note also that the light travel time (4.66) presents ***greater interest*** than the ***distance*** (4.65) since the former could be estimated with the use of the *observable* value – by the redshift of the received radiation (the uncertainties in time/distance correlations were considered above).

So, the cosmological radiation damping defines a threshold ***light travel time*** $T_{**} = T_{**}(W_r)$ as a function of energy output W_r: if the ***light travel time*** for some object exceeds this value, its light could reach the Earth (if it was emitted in the scannable Universe), but would not be detected.

Resume. For the object with energy output W_r the ***threshold light travel time*** T_{**} is corresponded by the finite comoving distance $D(T_{**})$ at which the light was emitted before the source had crossed the Hubble horizon. Therefore, this distance is less than the Hubble distance and thus, as radius of the sphere, specifies ***within the scannable Universe*** the horizon and region ***of*** *practical* observability in the sense that only the light that was emitted within this region could practically ***be detected*** on the Earth.

By the energy output these ***regions*** and ***horizons*** may be ***categorized*** into 5 classes, each class comprising the Space ***objects*** and ***light emitting events*** with ***commensurable energy outputs*** (See §4.4).

The very fact of the ***expansion of Universe***, ***without any assumption*** relative to its starting point (***Big Bang*** or the like), ***engenders a steady isotropic radiation damping*** being ***accompanied*** by a ***pronounced redshift***, whereas the ***detection*** of the resulting radiation is ***cut down*** by the ***radionic threshold***.

This radiation is caused by the sources that approach the Hubble horizon, but it ***continues*** forever, being gradually damping, ***even after they had passed that horizon and already exploded there***, since it is ***caused*** not by new emanation of light but by the ***former emitting*** that was "***delayed***" with its coming to the Earth ***by the expansion of the Universe***. And from considerations of symmetry this process is to be ***isotropic***. For these reasons this damped and redshifted radiation ***must form*** an isotropic background radiation that fills the Universe and is perceived as such for any comoving point of the Universe. ***These aspects of the Hubble horizon*** "mirror" almost exactly ***reflects*** the general properties of the Cosmic microwave background radiation (CMBR, or relic radiation) ***except*** that in this work we have not discussed the ***spectrum*** of the former, but that is another problem which requires us to analyze the dynamics of Hubble parameter and other factors.

4.3.10. Evaluation of adequacy of the considered models

1. Steady period of Expansion of the universe

By taking into account that an uncertainty in the estimate of the age of the Universe is quite close to the epoch of recombination, and that since that epoch the existing models describe the expansion of the universe as a more or less steady process with the use of the standard cosmological model without resorting to the Big Band hypothesis, as well as the models pertaining to ***NM-paradigm***, the moment of hypothetical Big Bang may be considered simply as a Reference epoch for the models that provide us with numerical estimates for the process of steady expansion of the universe; in this sense the cosmological time ***corresponds to that steady period of the expansion of the*** Universe ***during which it*** has expanded 1292 times.

2. Hubble parameter

The Hubble parameter is an important factor of different models describing the preceding, current and future trends in expansion of the Universe. However, there is no generally adopted and verified theory that could describe how this parameter changes in time. Meanwhile, the trends of this parameter are estimated with various models and numerically – by integrating the respective differential equations in the past.

ΛCDM model. Within this model the value of the Hubble parameter (during the ***steady period***) changes over time either increasing or decreasing depending on the observed value of density parameters which determine the deceleration parameter q. Before the discovery of dark energy, it was believed that the universe was matter dominated; it was long thought that q was positive, indicating that the expansion is slowing down due to gravitational attraction. This would imply an age of the universe less than $1/H$. The discovery in 1998 that q is negative has surprised many astronomers with the implication that the expansion of the universe is currently "accelerating", although the Hubble parameter is still decreasing with time; this means that the universe could actually be older than $1/H$. However, estimates of the age of the universe are very close to $1/H$.

There is currently active research into many aspects of the ΛCDM model, which is very likely to change as new information becomes available. In particular, it is difficult to measure accurately the distance of very far galaxies or supernovae, so that distance related estimates are still uncertain. In addition, ΛCDM has no explicit physical theory for the origin or physical nature of dark matter or dark energy; the nearly scale-invariant spectrum of the CMB perturbations, and their image across the celestial sphere, are believed to result from very small thermal and acoustic irregularities at the point of recombination.

A de Sitter universe is a cosmological solution to Einstein's equations of General Relativity. It models the ***universe as spatially flat*** and neglects ordinary matter, so the dynamics of the universe are dominated by the cosmological constant, thought to correspond to dark energy in our universe or the inflaton field in the early universe. Relative to inflation models and observations of the accelerating universe, the concordance models are converging on a consistent model where our universe was best described as a de Sitter universe at about a time $t = 10^{-33}$ seconds after the fiducial ***Big Bang singularity***, and far into the ***future***.

In de Sitter universe cosmological constant $\Lambda > 0$ sets the expansion rate so that a larger cosmological constant leads to a larger expansion rate. It is common to describe a patch of this solution as an expanding universe of the FLRW form where the scale factor describing the expansion of physical spatial distances is given by $a(t) = e^{Ht}$, where the constant H is the ***Hubble expansion rate*** and t is time. Unique to universes described by the FLRW metric, a de Sitter universe has a Hubble Law which is not only ***consistent*** through all space, but also through all time (since the deceleration parameter is equal to $q = -1$), thus satisfying the perfect cosmological principle that assumes isotropy and homogeneity throughout space and time.

Our universe is becoming like de Sitter universe:

Because our Universe entered the Dark Energy Dominated Era a few billion years ago, our universe is probably approaching a de Sitter universe in the infinite future. If the current acceleration of our universe is due to a cosmological constant then as the universe continues to expand all of the matter and radiation will be diluted. Eventually there will be almost nothing left but the cosmological constant, and our universe will have become a de Sitter universe.

Numerical estimates

With respect to the ***de Sitter model*** the expansion of the Universe is described by Hubble constant with the existing value for a few billion years and still would remain this trend.
If this value was the same in the preceding era as well, or changed slowly, with respect to the Hubble law the scale factor for the ***Steady period of Expansion of the universe*** makes $a = e^{H_0 \cdot T_U} \approx e^{H_0 / H_0} = e^1 \approx 2.7$, where H_0 - is the present value of the Hubble constant being close to the inverse value of the age of the universe T_U. In other words, with this model the scale factor of the Universe over the period of cosmological time of 13.7 billion years approximately makes ***2.7***; that is ***at the epoch of the hypothetical Big Bang the distances between the remote space objects were only 2.7 times less than at present***.

On the other hand, for the observationally-favoured ***ΛCDM model***, using data from the WMAP spacecraft, the calculation yields a ***scale factor change*** of approximately ***1292***. ***This means the*** Universe has expanded to 1292 times ***the size it was*** when the CMBR photons were released, that is ***during*** the Steady period of Expansion of the universe of 13.7 billion years (although this result of integration in the far past should not be considered as accurate with all its 4 digits, since it does not take into account many factors and even the current value of the Hubble constant is several orders less exact). If so, an average value of the Hubble parameter $\overline{H}$ for this period may be estimated by the Hubble law $a = e^{\overline{H} \cdot T_U}$ with these values of the scale factor $a = 1292$ and time interval $T_U = 13.7$ billion years. From this equation we obtain $\overline{H} = \ln a / T_U \approx 7 \cdot H_U$, where H_0 - is the present value of the Hubble constant close to the inverse value of T_U.

3. The Cosmic microwave background radiation

In the ***ΛCDM model*** the Cosmic microwave background radiation that we ***see right now*** is considered to be ***emitted in epoch of recombination, 379,000 years after the*** Big Bang (around ***13.7 billion years ago***).

Meanwhile, there are ***other models*** which ***explain*** the ***origin of this radiation*** without ***a hypothesis of the Big Bang***. In particular, the above models show that at all existing estimates of the Hubble parameter the background radiation *should appear* as the ***result of the very*** expansion of the Universe, and the time ***variations of Hubble parameter***, if they exist, must modulate this ***radiation*** due to the respective variations in the ***rate of expansion*** and ***radius of the Hubble sphere***. But the detailed analysis of the effects of these variations exceed the bounds of this work.

Resume

Hence, even if the Hubble parameter was actually changing during the Steady period of Expansion of the Universe, the total variation of its value had not exceed, in average, one order of magnitude. This means that the above considered models present more or less exact approximations for the Hubble time interval.

But even if the Hubble parameter was actually decreasing gradually, its inverse value – the Hubble time and Hubble distance – were increasing, also gradually; in this sense the bound of the scannable Universe also expands and presently has the "maximal" radius. Hence, at any moment the Hubble horizon, whatever size it has, acts qualitatively as described in the aforesaid models, including generation of the background radiation. If the Hubble parameter remains its value, these models become more exact, but still should be considered as approximations since we do not know how this parameter was actually changed.

Therefore, the presented models could seemingly be considered as rather adequate, not so in numbers, but as qualitative description of that how the expansion of the Universe influences the process of light emanation and reception, as well as radiation damping without resorting to the Big Bang hypothesis. We see also that the Big Bang hypothesis is apparently not more necessary for explaining the observed expansion of the Universe and CMBR than it is useful is description of the primordial state of the Universe, for which it was proposed and which it still unable to explain.

4.4. Classification of Space objects and events by their energy output

W1. Maximal energy output one-time events

GAMMA RAY BURSTS (GRBs) are flashes of gamma rays associated with extremely energetic explosions in distant galaxies. They are both the most luminous electromagnetic events known to occur in the universe (e.g. GRB 080319B), and the most distant (GRB 090423) objects in the universe that were ever observed. New developments recognize the short gamma-ray bursts as a ***separate class.***

Bursts ***can last*** from ***milliseconds to several minutes***, although a ***typical burst lasts a few seconds***. The initial burst is usually followed by a longer-lived "***afterglow***" emitted at longer wavelengths (X-ray, ultraviolet, optical, infrared and radio).

The sources of ***most GRBs*** are billions of light years away ***from Earth***, implying that the explosions are both extremely energetic (a ***typical burst releases as much energy in a few seconds as the Sun will in its entire 10 billion year lifetime***) and extremely rare: although ***currently*** orbiting ***satellites detect*** an average of about ***one gamma-ray burst per day***, only ***few GRBs*** take place ***per galaxy per million years***.

All observed GRBs have ***originated*** from outside the Milky Way galaxy, although a related class of phenomena, soft gamma repeater flares, are associated with magnetars within the Milky Way. Although it is unclear if any star in the ***Milky Way*** has the appropriate characteristics to produce a gamma-ray burst, it has been hypothesized that a gamma-ray burst in the Milky Way could cause a mass extinction on Earth.

The ***means by which gamma-ray bursts convert energy into radiation remains poorly understood***, and as of 2010 there was still ***no generally accepted model*** for how this process occurs. In particular, while most astronomical transient sources have simple and consistent time structures, the light curves of gamma-ray bursts are extremely diverse and complex. No two gamma-ray burst light curves are identical, with large variation observed in almost every property. The nature of the ***longer-wavelength afterglow*** emission that follows GRB is ***better understood***.

Gamma-ray bursts are very bright as observed from Earth despite typical immense distances. An average long GRB has comparable bolometric flux to a bright Galactic star despite a distance of billions of light years (compared to a few tens of light years for most stars). Most of this energy is released in gamma rays, although some GRBs have extremely luminous optical counterparts as well

This combination of brightness and distance ***requires an extremely energetic source***. Assuming the gamma-ray explosion to be spherical, ***the energy output*** of GRB 080319B would be ***within a factor of two*** of the ***rest-mass energy*** of the ***Sun*** (the energy which would be released were the Sun to be converted entirely into radiation.)

No known process in the Universe can produce this much energy in such a short time. However, gamma-ray bursts are thought to be ***highly focused explosions***, with most of the explosion energy collimated into a narrow jet ***traveling at speeds exceeding 99.995% of the*** speed of light. Observations suggest significant variation in the jet angle from ***between 2 and 20 degrees***. Because their energy is strongly beamed, the gamma rays emitted by most bursts are expected to miss the Earth and never be detected. When a gamma-ray burst is pointed ***towards Earth***, the focusing of its energy along a ***relatively narrow beam*** causes the ***burst to appear much brighter than it would have been were its energy emitted spherically***. When this effect is taken into account, typical gamma-ray bursts are observed to have a ***true energy release*** of about 10^{44} J, or about ***1/2000 of a Solar mass energy equivalent***.

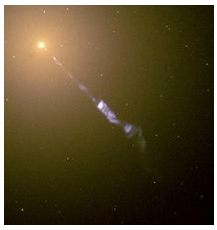
Most observed GRBs are believed to be ***a narrow beam of intense radiation*** released during a supernova event, as a rapidly rotating, high-mass star collapses to form a black hole.

The "***short" bursts*** appear to originate from a different process, possibly the merger of binary neutron stars. There is strong evidence that some short-duration gamma-ray bursts occur in systems with no star formation and where no massive stars are present, such as galaxy halos and intergalactic space.

The aforesaid GRB 090423 was registered on April 23, 2009. At a redshift of $z = 8.2$, the burst is the current ***record holder for the most distant known object of any kind***. It is also the oldest known object in the Universe, as the light from the burst took approximately 13 billion years to reach Earth (light travel time).

W2. Maximal energy output sources with continual manifestation

An ACTIVE GALACTIC NUCLEUS (AGN) is a compact region at the centre of a galaxy that has a much higher than normal luminosity over at least some portion, and possibly all, of the electromagnetic spectrum. Such excess emission has been observed in the radio, infrared, optical, ultra-violet, X-ray and gamma ray wavebands. A galaxy hosting an AGN is called an ACTIVE GALAXY. AGN are ***the most luminous* persistent *sources*** of ***electromagnetic radiation*** in the ***universe***, and as such can be used as a means of discovering distant objects; their evolution as a function of cosmic time also provides constraints on models of the cosmos.



Hubble Space Telescope image of a 5000 light-year long jet being ejected from the active nucleus of the active galaxy M87, a radio galaxy. The blue synchrotron radiation of the jet contrasts with the yellow starlight from the host galaxy.

The radiation from AGN is believed to be a result of accretion of mass by the supermassive black hole at the centre of the host galaxy. Central supermassive black holes are now believed to exist in the centers of most or all massive galaxies

There is no single observational signature of an AGN. It is ***convenient*** to ***divide AGN*** into ***two classes***, conventionally called ***radio-quiet*** and ***radio-loud***. In the radio-loud objects a contribution from the jet(s) and the lobes they inflate dominates the luminosity of the AGN, at least at radio wavelengths but possibly at some or all others. Radio-quiet objects are simpler since jet and jet-related emission can be neglected.

AGN terminology is often confusing, since the distinctions between different types of AGN sometimes reflect historical differences in how objects were discovered or initially classified, rather than real physical differences. ***Unified models of AGN*** unite two or more ***classes*** of objects, based on the traditional observational classifications, by proposing that ***they are really a single type of physical object observed under different conditions***. The currently favoured unified models propose that the apparent differences between different types of objects arise simply because of their different orientations to the observer.

The most notable types of AGNs are as follows.

A QUASAR (quasi-stellar radio source) is a very energetic and distant galaxy with an AGN. They are ***the most luminous, powerful, and energetic objects known in the universe***, and can be detected over the entire observable electromagnetic spectrum including radio, infrared, optical, ultraviolet, X-ray and gamma rays. Quasars were first identified as being ***high redshift sources*** of electromagnetic energy, including radio waves and visible light, that were point-like, similar to stars, rather than extended sources similar to galaxies.

Most quasars are known to be farther than three billion light-years away. Although quasars appear faint when viewed from Earth, the fact that they are visible from so far away means that quasars are the ***most luminous objects*** in the known universe. The quasar that appears brightest in the sky is 3C 273 in the constellation of Virgo. ***From a distance of about 33 light-years, this object would shine in the sky about as brightly as our sun***. This quasar's luminosity is, therefore, about 2 trillion (2×10^{12}) times that of our sun, or about ***100 times that of the total light of average giant galaxies*** like our Milky Way. However, this assumes the quasar is radiating energy in all directions. An AGN can be associated with a ***powerful jet of matter and energy***; ***it need not be radiating in all directions***.

More than 200,000 quasars are known. All observed quasar spectra have ***redshifts between 0.06*** and ***6.5***. Applying Hubble's law to these redshifts, it can be shown that they are ***between 780 million*** and ***28 billion light-years away*** (in terms of comoving distance).

Quasars are found to ***vary in luminosity*** on a variety of time scales. This means that ***quasars*** generate and ***emit*** their ***energy*** from a ***very small region***. The ***emission of large amounts of power*** from a small region ***requires a power source far more efficient than the nuclear fusion which powers stars***. The ***release of gravitational energy by matter falling towards a massive black hole is the only process known that can produce such high power continuously*** (this process can convert on the order of 10% of the mass of an object into energy as compared to 0.7% for the p-p chain nuclear fusion process that dominates the energy production in sun-like stars; ***GRB*** can do so, but only for a short time span.

Quasars have all the same properties as active galaxies, but are more powerful, and some are observed to ***also have*** jets and lobes like those of radio galaxies that also carry significant (but poorly known) amounts of energy in the form of ***high energy*** (relativistic) ***particles***. A minority of quasars show ***strong radio emission***, which originates ***from jets*** of matter moving close to the speed of light. When looked at down the jet, these ***appear as a*** blazar. There is a consensus that in many cases it is simply the viewing angle that distinguishes ***quasars*** from other classes, such as ***blazars*** and ***radio galaxies***.

A BLAZAR (blazing quasi-stellar object) is a ***very compact quasar*** associated with a presumed ***supermassive black hole*** at the center of an active, giant elliptical galaxy.

Blazars are thought to be AGN, with relativistic jets oriented close to the line of sight with the observer.

The observed emission from a Blazar is greatly enhanced by relativistic effects in the jet, a process termed relativistic beaming. The bulk speed of the plasma that constitutes the jet can be in the range of 95%–99% of the speed of light. The special jet orientation explains the general peculiar characteristics: high observed luminosity, very rapid variation, high polarization, and the apparent superluminal motions.

RADIO GALAXIES are types of active galaxy that are very luminous at radio wavelengths (up to 10^{39} W between 10 MHz and 100 GHz). They are almost universally found hosted by elliptical galaxies.

The observed structure in radio emission is determined by the interaction between twin jets and the external medium, modified by the effects of relativistic beaming. *Radio-loud* active galaxies are interesting not only in themselves, but also because they can be detected at large distances, making them valuable tools for observational cosmology.

Radio galaxies display a wide range of structures in radio maps. The most common large-scale structures are called ***lobes***: these are double, often fairly symmetrical, roughly ellipsoidal structures placed on either side of the active nucleus. Some radio galaxies show one or two long narrow features known as ***jets*** coming directly from the nucleus and going to the lobes. Since the 1970s, the most widely accepted model has been that the lobes or plumes are powered by *beams* of high-energy particles and magnetic field coming from close to the active nucleus. The jets are believed to be the visible manifestations of the beams, and often the term *jet* is used to refer both to the observable feature and to the underlying flow. The largest radio galaxies have ***lobes*** or plumes extending to megaparsec scales, implying a ***timescale*** for growth of the order of ***tens to hundreds of millions of years***. This means that, except in the case of very small, very young sources, we cannot observe radio source dynamics directly.

W3. Especially powerful one-time events

A SUPERNOVA is a stellar explosion that is more energetic than a nova. *Nova* means "new" in Latin, referring to what appears to be a very bright new star shining in the celestial sphere.

Supernovae are extremely luminous and cause a burst of radiation that often briefly outshines an entire galaxy, before fading from view over several weeks or months. ***During this short interval a supernova can radiate as much energy as the Sun is expected to emit over its entire life span***. The explosion expels much or all of a star's material at a velocity of up to 30,000 km/s (10% of the speed of light), driving a shock wave into the surrounding interstellar medium. This shock wave sweeps up an expanding shell of gas and dust called a supernova remnant.

Although no supernova has been observed unquestionably in the Milky Way since 1604, on average ***supernovae occur about once every 50 years in a galaxy the size of the Milky Way***. They play a significant role in enriching the interstellar medium with higher mass elements. The earliest recorded supernova, SN 185, was viewed by Chinese astronomers in 185 AD. The brightest recorded supernova was the SN 1006, which was described in detail by Chinese and Islamic astronomers. The widely observed supernova SN 1054 produced the Crab Nebula. Supernovae SN 1572 and SN 1604, the last to be observed with the naked eye in the Milky Way galaxy, had notable effects on the development of astronomy in Europe because they were used to argue against the Aristotelian idea that the universe beyond the Moon and planets was immutable.

Supernovae provide ***important information on cosmological distances***. In the 1960s astronomers found that the maximum intensities of supernova explosions could be used as standard candles, hence

indicators of astronomical distances. Some of the most ***distant*** supernovae recently observed appeared ***dimmer than expected***. This ***supports the view*** that the expansion of the universe is accelerating.

Several large stars within the Milky Way have been suggested as possible supernovae within the next million years; among them is Eta Carinae; its cycle of activity is synchronous with the Solar cycles [16].

HYPERNOVA refers to an exceptionally large star that collapses at the end of its lifespan. Until the 1990s, it referred specifically to an explosion with an energy of over 100 supernovae (10^{46} joules); such explosions are believed to be the origin of long-duration gamma ray bursts.

After the 1990s, the term came to be used to describe the supernovae of the most massive stars, the hypergiants, which have masses from 100 to over 300 times that of the Sun (e.g. Eta Carinae).

The radiation output of a nearby hypernova could cause serious harm to Earth. A group led by Brian Thomas, an astrophysicist at Washburn University in Kansas, has conjectured that a hypernova may have caused a mass extinction on Earth 440 million years ago, but there is no unambiguous evidence of it.

W4. Especially powerful sources with continual manifestation

A MAGNETAR is a type of neutron star with an extremely powerful magnetic field, the decay of which powers an intense high-energy electromagnetic radiation, particularly X-rays and gamma rays.

Little is known about the physical structure of a magnetar because none are close to Earth. Magnetars are around 20 kilometres in diameter but are more massive than our Sun. The density of a magnetar is such that a thimbleful of its substance, sometimes referred to as neutronium, would have a mass of over 100 million tons. Magnetars also rotate rapidly, with most magnetars completing a rotation once every one to ten seconds. The active life of a magnetar is short. Their strong magnetic fields decay after about 10,000 years, after which activity and strong X-ray emission cease. Given the number of magnetars observable today, one estimate puts the number of inactive magnetars in the Milky Way at 30 million or more.

Quakes triggered on the surface of the magnetar cause great volatility in the star and the magnetic field which encompasses it, often leading to extremely powerful gamma ray flare emissions which have been recorded on Earth in 1979, 1998 and 2004.

Magnetars are primarily characterized by their extremely powerful magnetic field, which can often reach the order of ten gigateslas. As of 2010, they are the most magnetic objects ever detected in the universe. A magnetic field of 10 gigateslas is enormous relative to magnetic fields typically encountered on Earth. Earth has a geomagnetic field of 30–60 microteslas, and a neodymium based rare earth magnet has a field of about 1 tesla, with a magnetic energy density of 4.0×10^5 J/m^3. A 10 gigatesla field, by contrast, has an energy density of 4.0×10^{25} J/m^3, with an E/c^2 mass density $>10^4$ times that of lead. The magnetic field of a magnetar would be lethal even at a distance of 1000 km, tearing tissues due to the diamagnetism of water. At a distance halfway to the moon, a magnetar could strip information from all credit cards on Earth. As described in the February 2003 *Scientific American* cover story, remarkable things happen within a magnetic field of magnetar strength. "X-ray photons readily split in two or merge together. The vacuum itself is polarized, becoming strongly birefringent, like a calcite crystal. Atoms are deformed into long cylinders thinner than the quantum-relativistic wavelength of an electron." In a field of about 10^5 teslas atomic orbitals deform into rod shapes. At 10^{10} teslas, a hydrogen atom becomes a spindle 200 times narrower than its normal diameter.

A HYPERGIANT (luminosity class 0) is a star with a tremendous mass and luminosity, showing signs of a very high rate of mass loss. The most massive stars are considered to be hypergiants, and can have masses ranging up to 100–265 solar masses. Because of their high masses, the lifetime of a hypergiant is very short in astronomical timescales, only a few million years compared to around 10 billion years for stars like the Sun. Because of this, hypergiants are extremely rare and only a handful are known today.

Hypergiants are very luminous stars, up to millions of solar luminosities, and have temperatures varying widely between 3,500 K and 35,000 K. Almost all hypergiants exhibit variations in luminosity over time due to instabilities within their interiors.

As luminosity of stars increases greatly with mass, the luminosity of hypergiants often lies very close to the Eddington limit, above which the star would generate so much radiation that parts of its outer layers

would be thrown off in massive outbursts; this would effectively restrict the star from shining at higher luminosities for longer periods. A good candidate for hosting a continuum driven wind is ***Eta Carinae***, one of the most massive and luminous stars ever observed. With an estimated mass of around 130 solar masses and a luminosity four million times that of the Sun, astrophysicists speculate that Eta Carinae may occasionally exceed the Eddington limit. The last time might have been a series of outbursts in 1840-1860, reaching mass loss rates much higher than our current understanding of what ***stellar winds*** would allow.

SUPERGIANTS are among the most massive stars. They occupy the top region of the Hertzsprung-Russell diagram. They typically have bolometric absolute magnitudes between -5 and -12. The most luminous supergiants are often classified as ***hypergiants of class 0***.Supergiants can have masses from 10 to 70 solar masses and brightness from 30,000 up to hundreds of thousands times the solar luminosity. They vary greatly in radius, usually from 30 to 500, or even in excess of 1,000 solar radii.
Because of their extreme masses they have short lifespans of 30 million years down to a few hundred thousand years (by the calculation $M^{-2.5} \times 10^{10}$ where M = mass in sols). They are mainly observed in young galactic structures such as open clusters, the arms of spiral galaxies, and in irregular galaxies. They are less abundant in spiral galaxy bulges, and are rarely observed in elliptical galaxies, or globular clusters, which are believed to be composed of old stars.
Most type II supernova progenitors are thought to be red supergiants. However, the progenitor for Supernova 1987A was a blue supergiant. It is believed that it was a red supergiant before losing its outer layers to its strong stellar wind.

PULSARS are ***highly magnetized***, ***rotating neutron stars*** that ***emit a beam of electromagnetic radiation***. The radiation can only be observed when the beam of emission is pointing towards the Earth. This is called the ***lighthouse effect*** and gives rise to the ***pulsed nature*** that gives pulsars their name. Because neutron stars are very dense objects, the rotation period and thus the ***interval between observed pulses is very regular***. For some pulsars, the regularity of pulsation is ***as precise as an atomic clock***. The observed periods of their pulses range from 1.4 milliseconds to 8 s (to date, the slowest observed pulsar has a period of 8 seconds). A few pulsars are known to have planets orbiting them, such as PSR B1257+12. Werner Becker of the Max Planck Institute for Extraterrestrial Physics said in 2006, "***The theory of how pulsars emit their radiation is still in its infancy, even after nearly forty years of work***."
The events leading to the ***formation of a pulsar*** begin when the core of a massive star is compressed ***during*** a ***supernova***, which ***collapses into a neutron star***. The neutron star retains most of its angular momentum, and since it has only a tiny fraction of its progenitor's radius (and therefore its moment of inertia is sharply reduced), it is formed with ***very high rotation speed***. A ***beam of radiation*** is emitted ***along the magnetic axis*** of the pulsar, which spins along with the rotation of the neutron star. The magnetic axis of the pulsar determines the direction of the electromagnetic beam, with the ***magnetic axis not necessarily being the same as its rotational axis***. This misalignment causes the beam to be seen once for every rotation of the neutron star, which leads to the "***pulsed***" ***nature of its appearance***. The beam originates from the rotational energy of the neutron star, which generates an electrical field from the movement of the very strong magnetic field, resulting in the acceleration of protons and electrons on the star surface and the creation of an electromagnetic beam emanating from the poles of the magnetic field. This rotation slows down over time as electromagnetic power is emitted. When a pulsar's spin period slows down sufficiently, the radio pulsar mechanism is believed to turn off (the so-called "death line"). This ***turn-off*** seems to take place ***after*** about ***10-100 million years***, which means of all the neutron stars in the 13.6 billion year age of the universe, around 99% no longer pulsate.
Three distinct classes of pulsars are currently known to astronomers, according to the source of the power of the electromagnetic radiation: Rotation-powered pulsars, Accretion-powered pulsars and Magnetars.

W5. The stars of the Main sequence

W6. The dwarfs (White, Red, Brown, Black) and other objects with faint luminosity

W7. The objects seen in the reflected light (planets, comets, etc.)

4.5. The main cosmological models and their esoteric analogs

Occam's Razor : "Entia non sunt multiplicanda sine necessitate"
("entities must not be multiplied beyond necessity" William of Ockham)

4.5.1. Incompleteness of the Big Bang hypothesis

When a model of natural process is developed one has to solve two principal problems which are called the structural and parametric identification.

The former, in general, assumes construction of mathematical model presenting a mathematical description of the considered process in terms of a set of chosen parameters; what is important, this model is always based on a set of hypotheses (or assumptions) that, in common, reflect our general understanding of the main aspects of the process and premises which we imply to represent the fundamental laws.

The latter assumes adjusting the values for the chosen parameters with the aim to "tune" the model to the observed data.

If a model foretells the result of an experiment but erroneously, it should be modified. However, with cosmology we encounter the most complicated situation when it is almost impossible to make an experiment. In this case we may have several models which *numerically* describe the same observations with the same accuracy, but are based on different, if not antagonistic hypotheses. In these circumstances we cannot say definitely which of the models is correct in essence.

As well, we must remember that making use of proper premises, while dealing with several concepts, may result in improper conclusion, and vice versa.

Therefore, if a model provides us with a more or less exact numerical description of a process for the current moment, this gives no guarantee neither that all its premises are valid, nor that its predictions (for past or future) reflect the reality correctly. To a full extent this statement is applicable to the cosmological models which, with respect to the level of their verifiability, we have divided into two groups: those which use the Big Bang hypothesis as the keystone for explaining the "initial" evolution of the observable Universe (***the phase of Big Bang and Inflation***), and those which may refer to this hypothesis, but do not essentially ground on it for explaining the ***phase of Expansion of Universe***.

THE EXPANSION OF UNIVERSE is an observational fact that is described by various theories (viz. models), but none of them could be considered complete, even the mainstream ones (ΛCDM etc.), because the basic objects they deal with remain a mystery; first of all, these are the dark matter and dark energy. It is not meant as a reproach, but as a matter of fact: although these subjects explain many phenomena we observe in the Universe and thus seemingly present new aspects of the reality, it is still almost nothing known about their physical nature. Besides, none of these theories can explain the Large-scale structure of the universe (See below) since they deal with averaged distribution of matter, not with separate objects.

BIG BANG, SINGULARITY AND INFLATION. The minority of cosmological models does not consider the starting point of expansion of the universe in describing this process and Cosmic microwave background radiation (CMBR). However, the mainstream theories come to this since backward modeling of the expansion of the Universe shows that approximately 13.7 billion years ago a more or less steady expansion (roughly by 1300 times) was preceded by a fantastic ***inflation*** from a ***singularity*** that took place ***within a second***.

This was the reason why the ***physical hypotheses*** of the Big Bang and Singularity were put forward, although there exists no physical explanation for these initial states of the "Universe"; moreover, those states even contradict all the existing physical laws (and philosophy as well, since appearing of the Universe from ***Singularity*** (viz. form "nothing", or mathematical point) was always objected: "***Ex nihilo nihil***", and since the ancient times: the old sages had maintained that "***Nature abhorred vacuum*** {as void – SS}"[SD1-495].

Besides, it must be noted that the set of the mainstream theories (from quantum physics to gravitation) do not form a "unitary" approach: neither in transition from one to another, at their bound, nor in modeling the past, present and future of the universe.

Meanwhile, such a situation is typical for most ***mathematical approximations***: the accuracy of an approximation is "guaranteed" just within the interval of observations: if a function *f(x)* quite exactly approximates the trend observed on an interval, say *[100, 105]*, in any way this does not mean that the same function would be appropriate for extrapolation – that is for describing the trend of the same quantity on an interval, say *[0, 1]*. Moreover, in many cases the situation changes drastically outside of the approximation interval – even in a close vicinity (e.g. this is typical for the polynomials: the more points are taken in the interval for approximation, the greater the oscillations around the interval). The behavior of the approximating function could become much more instable and unpredictable if even small errors take place in a model which, as in the case of cosmological models, requires integration of differential equations (backwards in time).

LARGE SCALE STRUCTURE OF THE UNIVERSE. Offering the explanation for ***forming of the Large scale structure of the Universe*** is one more ***principal problem*** that stands before the hypothesis of the Big Bang. It demands an explanation, ***how*** from a ***chaotic state*** of matter, during Inflation or even before it, in a negligible ***fraction of second*** the observed ***ordered structure of the Universe had been formed***.

Sky surveys have yielded much information on the content and character of the Large-scale structure of the Universe which ***follows*** a hierarchical ***model***. The Observable universe contains about 3 to 7×10^{22} stars which are organized into galaxies, which, in their turn, form clusters and superclusters that are separated by immense voids, thus creating a vast ***foam-like structure*** sometimes called the "cosmic web".

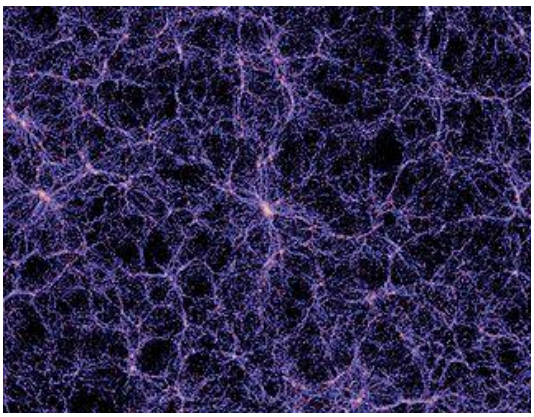


Fig. 4.7. Distribution of galaxies in the Universe (a slice of 3D computer image)

Prior to 1989, it was commonly assumed that galaxy clusters were the largest structures in existence, and that they were distributed more or less uniformly throughout the universe in every direction. However, the recent studies show that the Universe ***is composed largely of giant bubble-like*** voids separated by sheets and filaments of galaxies which have an intricate web-like structure, with the ***superclusters*** appearing as ***occasional*** relatively dense nodes.

Filaments (of galaxies) are the largest known structures in the Universe, ***thread-like structures*** with a typical length of 50 to 80 Mpc that form the boundaries between large ***voids*** in the Universe. Filaments consist of gravitationally-bound ***galaxies***; parts where a large number of galaxies are very close to each other are called superclusters.

Hyperclusters (***clusters*** of ***superclusters***) are even greater formations:

In 1987 R. Brent Tully identified what he called the Pisces-Cetus Supercluster Complex, a structure ***one billion light years long and 150 million light years across***.

In 1989 the Great Wall was discovered – a sheet of galaxies more than ***500 million light-years long and 200 million wide***, but ***only 15 million light-years thick***.

In 2003, the Sloan Great Wall was discovered – the largest structure in the universe known to date.

In 2006 ***another indicator*** of ***large-scale structure*** was found – the "Lyman alpha forest"; it presents three filaments aligned to form the largest structure known to humanity, composed of ***densely-packed galaxies*** and ***enormous blobs of gas***.

Voids are the "empty" spaces (their densities might be as low as one tenth the cosmological mean) between ***filaments***, the largest-scale structures in the Universe, that contain ***very few, or no, galaxies.*** Voids typically have a diameter of 11 to 150 Mpc; particularly large voids, defined by the absence of rich superclusters, are sometimes called supervoids.

In 2007, a possible supervoid was detected in the constellation Eridanus. It ***coincides*** with the "WMAP Cold Spot", a cold region in the microwave sky that is ***highly improbable under the currently favored cosmological model***. This supervoid could cause the cold spot, but to do so it would have to be ***improbably big***, possibly a ***billion light-years across***.

At the centre of Hydra supercluster there is a gravitational anomaly, known as the Great Attractor, which affects the motion of galaxies over a region ***hundreds of millions of light-years across***. It denotes the existence of a concentration of ***mass*** equivalent to ***tens of thousands of galaxies***.

BIG BANG AND FORMATION OF THE LARGE SCALE STRUCTURE OF THE UNIVERSE. The study of Galaxy formation and evolution is concerned with the processes that formed a ***heterogeneous universe*** **from** a ***homogeneous beginning***, the formation of the first galaxies, the way galaxies change over time, and the processes that have generated the variety of observed structures.

Galaxy formation is hypothesized to occur, from structure formation theories, as a result of tiny quantum fluctuations ***in the aftermath of the*** Big Bang.

After the Big Bang, the Universe, for a time, was remarkably homogeneous. There was little-to-no structure in the universe, and thus no galaxies. ***Thus we must ask how the smoothly distributed universe of the CMB became the clumpy universe we see today***.

The most accepted theory of how these structures came to be is that all the structure we observe today was formed as a consequence of the growth ***of the*** primordial fluctuations, which are ***small changes in the density of the universe*** in a confined region. As the universe cooled clumps of dark matter began to condense, and within them gas began to condense. The primordial fluctuations gravitationally attracted gas and dark matter to the denser areas, and thus the seeds that would later become galaxies were formed. These structures constituted the first galaxies.

While the simulations appear to ***agree broadly*** with ***observations***, their ***interpretation is complicated*** by the understanding of how dense accumulations of ***dark matter*** spur galaxy formation. A ***paradoxical aspect of structure formation*** is that while ***dark matter*** greatly accelerates the formation of dense haloes, because dark matter does not have radiation pressure, the formation of smaller structures from dark matter is impossible because dark matter cannot dissipate angular momentum, whereas ordinary baryonic matter can collapse to form dense objects

Despite its many successes, this picture is not sufficient to explain the variety of structure we see ***in galaxies***. Galaxies come in a variety of shapes, from round featureless elliptical galaxies to the pancake-flat spiral galaxies. Some notable observed features of galaxy structure that astronomers wish to explain with galactic formation theories include (but are certainly not limited to) the following:

* ***Spiral galaxies*** and the ***Galactic disk*** are quite thin, dense, and ***rotate very fast***. The Milky Way disk is 100 times longer than it is thick.

* ***The majority of mass in galaxies*** is made up of ***dark matter***, a substance which is not directly observable, and does not interact through any means except gravity.

Resume

So we see, that ***the existing explanations*** as to forming of the large-scale structure of the Universe resemble not a physical theory, but ***rather a plausible reasoning*** which could have led us to any desirable conclusion, since apart from an assumption that those were the primordial fluctuations that had formed the structure of the Universe, no model was proposed neither for this process, nor for the role the dark matter and dark energy (comprising *96 %* of matter-energy) was playing in it. Without arguments presented in a form of mathematical model they ***more likely present*** a one more ***hypothesis*** pertaining to the series of other ones which are ***engendering by the*** Big Bang paradigm.

With respect to the large scale structure of the Universe it is significant to note that almost a century before this structure was reveled by astronomers, in her letters, that were inspired by Mahatmas, Helen Roerich wrote [9]: "The Universe on the whole ***is as an*** infinite web in which the ***multiple*** spiders, or ***conscious beings*** of various levels, ***tat in*** new patterns." This idea was also explicitly expressed by Mahatmas (See the epigraph to Sec. 2.2).

Indeed, it is almost as difficult to believe that a random process has formed the existing structure of the Universe, as in sporadic transformation of an ape in a human being (the Secret Doctrine explains that in reality the modern apes present the descendants of illegal and condemned copulation of the humans of the former Root Races with the animals: "Moreover, the "ancestor" of the present anthropoid animal, the ape, is the direct production of the yet mindless Man, who desecrated his human dignity by putting himself physically on the level of an animal." [SD2-187])

However, by this we do not appeal to belief, but emphasize the fact that the greater the number of hypotheses that are required to support a paradigm, the lesser the confidence in its validity.

Therefore, the Big Bang hypothesis including the concept of Singularity and first phases that follow it are to be considered not a physical model, but rather as a result of extrapolation of the mathematical models in the past. In this sense the state of the Universe called Singularity presents not a physical reality, but just the feature of the existing mathematical models which may have nothing in common with the reality.

Therefore, both the physical uncertainty of the first phases of the "Big Bang", and total vagueness of the "place" of the observable Universe in the surrounding Space does not allow us to consider the Big Bang paradigm as a grounded model.

It rather resembles the wonder-working Biblical Creation of Earth and man in several days, since like the latter it affirms creation of matter from unknown substance and through unknown process in negligibly small part of second. To this end it is more misleading than physical; and if the Big Ban hypothesis does not explains the *origination* of the Universe, a question arises: whether it is so indispensable? Probably it would be much wiser not to concentrate our efforts on the mystery of the *origination* of the Universe; the more so since there are physical grounds for describing the existing processes in the Universe without resorting to a series of dubious hypotheses.

From this point of view the Theosophical Doctrine is much more "scientific" since it states that the matter, in unity of all its forms, is eternal and periodically transforms from a subtle state to a denser one, and inversely. For comparison, consider its concepts in more detail.

4.5.2. Esoteric paradigm of Cyclic manifestations of the universe in a non-singular Space region

4.5.2.1 Manifestation and breathing of the Universe

The Secret Doctrine denies an “emptiness” in the Universe and creation from “nothing”, but affirms the eternal motion with cyclic transformation of matter, in particular – from the subtle planes into “observable” state of physical matter, and backwards.

However, it is impossible in this overview to explain even the revealed aspects of the Theosophical paradigm of Cosmogenesis [2] that was imparted by Mahatmas, but we hope that it is possible to give a set of hints that could form a general understanding of the processes that define the evolutionary changes. At the same time it must be noted that Mahatmas (as the Higher Beings Who are in charge for the Earth, in the infinite Hierarchy of Creative Beings) should not be considered omniscient since the level of Their knowledge is also bounded, although by much more extensive spheres than ours [2].

Thus, the Secret Doctrine describes the observable Universe as a state of definite area of the Space (or Universe on the whole) in which it periodically manifests itself, without emanating from a dimensionless singularity.

STANZA III. (Continued).

10. FATHER-MOTHER SPIN A WEB WHOSE UPPER END IS FASTENED TO SPIRIT (Purusha), THE LIGHT OF THE ONE DARKNESS, AND THE LOWER ONE TO MATTER (Prakriti) ITS (the Spirit's) SHADOWY END; AND THIS WEB IS THE UNIVERSE SPUN OUT OF THE TWO SUBSTANCES MADE IN ONE, WHICH IS SWABHAVAT (a).

11. IT (the Web) EXPANDS WHEN THE BREATH OF FIRE (the Father) IS UPON IT; IT CONTRACTS WHEN THE BREATH OF THE MOTHER (the root of Matter) TOUCHES IT. THEN THE SONS (the Elements with their respective Powers, or Intelligences) DISSOCIATE AND SCATTER, TO RETURN INTO THEIR MOTHER'S BOSOM AT THE END OF THE "GREAT DAY" AND REBECOME ONE WITH HER (a). WHEN IT (the Web) IS COOLING, IT BECOMES RADIANT, ITS SONS EXPAND AND CONTRACT THROUGH THEIR OWN SELVES AND HEARTS; THEY EMBRACE INFINITUDE. (b)

The expanding of the Universe under the breath of FIRE is very suggestive in the light of the "Fire mist" period of which modern science speaks so much, and knows in reality so little.

Great heat breaks up the compound elements and resolves the heavenly bodies into their primeval one element, explains the commentary.

“Once disintegrated ***into its*** primal constituent by getting within the attraction and reach of a focus, or centre of heat (***energy***), ***of which many are carried about to and fro in space***, a body, whether alive or dead, will be vapourised ***and*** held ***in*** “***the bosom of the Mother***” – until Fohat, gathering a few of the clusters of Cosmic matter (nebulae) will, ***by giving it an impulse***, set it in motion anew, develop the required heat, and then leave it ***to follow its own new growth***”.

The ***expanding*** and ***contracting*** of the ***Web*** – i.e., the world stuff or atoms – ***expresses*** here the ***pulsatory movement***; for it is the regular contraction and expansion of the infinite and shoreless Ocean of that which we may call the noumenon of matter emanated by Swabhavat, which causes the universal vibration of atoms. But it is also suggestive of something else. ***It shows that the ancients were acquainted with that which is now the puzzle of many scientists and especially of astronomers: the cause of the first ignition of matter or the world-stuff, the paradox of the heat produced by the refrigerative contraction and other such Cosmic riddles. For it points unmistakeably to a knowledge by the ancients of such phenomena***. [SD1 – 83, 84]

An Archaic Manuscript – a collection of palm leaves made impermeable to water, fire, and air, by some specific unknown process – is before the writer's eye. On the first page is an immaculate white disk within a dull black ground. On the following page, the same disk, ***but*** with a central point. The ***first***, the student knows to represent ***Kosmos in Eternity***, before the re-awakening of still slumbering Energy, the emanation of the Word in later systems.

The ***point*** in the hitherto immaculate Disk, ***Space and Eternity in Pralaya***, denotes the ***dawn of differentiation***. It is the ***Point in the Mundane Egg*** (see Part II., "The Mundane Egg"), the germ within the latter which ***will become the Universe***, the ALL, the boundless, periodical Kosmos, this germ being ***latent*** and ***active***, ***periodically*** and by turns. The one circle is divine Unity, from which all proceeds, whither all returns. Its circumference – a forcibly limited ***symbol***, in view of the limitation of the human mind – indicates the abstract, ever ***incognisable PRESENCE***, and its plane, the Universal Soul, although the two are one.

Only the face of the Disk ***being*** white and the ground ***all around*** black, shows clearly that ***its*** plane ***is the*** only knowledge, dim and hazy though it still is, that is attainable by man. It is ***on this*** plane that ***the Manvantaric manifestations begin***; for it is in this SOUL that slumbers, during the Pralaya, the Divine Thought, wherein lies concealed the plan of every future Cosmogony and Theogony. [SD1-1]

… the point being the LOGOS… This Point is the First Cause, but THAT from which it emanates, or of which, rather, it is the expression, the Logos, is passed over in silence. In its turn, the universal symbol, the point ***within the circle***, was not yet the Architect, but the cause ***of that Architect***; and the latter stood to it in precisely the same relation as the point itself stood to the circumference of the Circle, which cannot be defined, according to Hermes Trismegistus. [SD1-426]

Meanwhile, as it is ***directly specified*** below, the point (within a circle) – as a symbol – ***does not signifies creation*** "from" a ***geometrical*** point: the Universe is already specified by the white interior, and it is this "interior" which comes to physical manifestation under the influence of the forces that are symbolized by the central point.

Therefore, the "last vibration of the Seventh Eternity" was "fore-ordained" – by no God in particular, but occurred in virtue of the eternal and changeless LAW which causes the ***great periods*** of Activity and Rest, called so graphically, and at the same time so poetically, the "Days and Nights of Brahma.

The expansion "FROM WITHIN WITHOUT" of the Mother, called elsewhere the "Waters of Space," "Universal Matrix," etc., DOES NOT ALLUDE TO AN EXPANSION FROM A SMALL CENTRE OR FOCUS, but, without reference to size or limitation or area, means the development of limitless subjectivity into as limitless objectivity.

"The ***ever*** (to us) ***invisible*** and ***immaterial Substance*** present in eternity, ***threw its periodical shadow*** from its own plane ***into*** the lap of Maya." It implies that THIS EXPANSION, not being an increase in size – ***for infinite extension admits of no enlargement*** – was a change of condition.

It "***expanded like the bud of the Lotus***"; for the Lotus plant exists not only as a miniature embryo in its seed (a physical characteristic), but its prototype is present in an ideal form in the Astral Light from "Dawn" to "Night" during the Manvantaric period, like everything else, as a matter of fact, in this objective Universe; from man down to mite, from giant trees down to the tiniest blades of grass. [SD1-62]

"Butter milking gives the ***best illustration*** to the ***process*** of ***physical creation of the worlds***" [10]; or as the saline causes the development of film or photography, so Fohat causes the Spirit-Matter being distributed over the Universe to manifest itself physically.

The solitary ray dropping into the ***mother deep*** may be taken as meaning ***Divine Thought*** or ***Intelligence, impregnating chaos***. This, however, occurs on the plane of metaphysical abstraction, or rather the plane whereon that which we call a metaphysical abstraction is a reality. The ***Virgin-egg*** being in one sense abstract Egg-ness, or the power of ***becoming developed through fecundation***, is ***eternal*** and for ***ever the same***. And just as the fecundation of an egg takes place before it is dropped; so the non-eternal periodical germ which becomes later in symbolism the mundane egg, contains in itself, when it emerges from the said symbol, "the promise and potency" of all the Universe. Though the idea per se is, of course, an abstraction, a symbolical mode of expression, it is a ***symbol truly***, as it suggests the ***idea of infinity as*** an ***endless circle***.

It brings before the mind's eye ***the picture of Kosmos emerging from and in boundless space***, a Universe as shoreless in magnitude if not as endless in its objective manifestation. The simile of an ***egg also expresses*** the ***fact taught in Occultism*** that the primordial form of ***everything manifested***, from atom to globe, from man to angel, is ***spheroidal***, the sphere having been with ***all nations*** the emblem ***of*** eternity ***and infinity*** – a serpent swallowing its tail.

To ***realize the meaning***, however, the **SPHERE MUST BE THOUGHT OF AS SEEN FROM ITS CENTRE**. The field of vision or of thought is like a sphere whose radii proceed from one's self in every direction, and extend out into space, opening up boundless vistas all around.

It is ***the symbolical*** **CIRCLE OF PASCAL** and the **KABALISTS**, "**WHOSE CENTRE IS EVERYWHERE AND CIRCUMFERENCE NOWHERE**," a conception which enters into the compound idea of this emblem.

The "Mundane Egg" is, perhaps, one of the ***most universally adopted symbols***, highly suggestive as it is, equally in the spiritual, physiological, and cosmological ***sense***. Therefore, ***it is found in every world-theogony***, where it is largely ***associated*** with the serpent symbol; the latter being everywhere, in philosophy as in religious symbolism, an emblem of ***eternity***, ***infinitude***, ***regeneration***, and ***rejuvenation***, as well as of ***wisdom***. (See Part II. "Tree and Serpent and Crocodile Worship.") The mystery of apparent self-generation and evolution through its own creative power repeating in miniature the process of Cosmic evolution in the egg, both being due to heat and moisture under the efflux of the unseen creative spirit, justified fully the selection of this graphic symbol. The "***Virgin Egg***" is the microcosmic symbol of the macrocosmic prototype – the "***Virgin Mother***" – ***Chaos*** or the ***Primeval Deep***. The ***male Creator*** (***under whatever name***) springs forth from the Virgin female, the immaculate root fructified by the Ray. [SD1-64]

Jesus accepted the serpent as a synonym of Wisdom, and this formed part of his teaching: "***Be ye wise as serpents***," he says. "In the beginning, before Mother became Father-Mother, the fiery Dragon moved in the infinitudes alone" (Book of Sarparajni.) The Aitareya Brahmana calls the Earth Sarparajni, "the Serpent Queen," and "the Mother of all that moves."

Before our globe ***became egg-shaped*** (and the Universe also) "***a*** long trail of Cosmic dust ***(or*** fire mist***)*** moved and writhed like ***a*** serpent ***in*** Space." The "***Spirit of God moving on Chaos***" was ***symbolized*** by ***every nation*** in the shape of a ***fiery serpent breathing fire*** and ***light upon the*** primordial waters, until ***it had*** incubated cosmic matter and made it assume the ***annular shape of a serpent with its tail in its mouth*** – which symbolizes not only Eternity and Infinitude, but also the ***globular shape*** of all the bodies ***formed*** within the Universe ***from that fiery mist***.

The Universe, as well as the Earth and Man, ***cast off periodically***, ***serpent-like***, their ***old skins***, to assume ***new ones after a time of rest***. The serpent is, surely, a not less graceful or a more unpoetical image than the caterpillar and chrysalis from which springs the butterfly, the Greek emblem of Psyche, the human soul. The "***Dragon***" was also the symbol of the Logos with the ***Egyptians***, as with the ***Gnostics***. [SD1-74]

4.5.2.2. The centre and circumference of the Cosmic Circle in Hermetic philosophy

The "observed Universe" is understood as a spherical part of the Universe on the whole, with the centre at the Earth, where the objects reside (if they are still "alive") the light from which has reached the Earth, or could reach in the future. The Hubble sphere with the same centre divides it into two parts; the inner spherical part – the scannable Universe that is bounded by the Hubble sphere – contains the objects the light of which, if issued now, could reach the Earth if they are powerful enough. The outer part contains the objects the light of which, if issued now, would never reach the Earth – we may observe only that light which was emitted before they passed the Hubble sphere; for this reason we will never know their state at present, but still may observe their light infinitely (until it is energetic enough to be detected); in this sense this part of the Universe is non-scannable (or non-observable): we continue to observe the more and more slowed down prehistory of approaching the Hubble horizon.

This situation is not connected with the Big Bang hypothesis, but is engendered by the very expansion of the Universe. Within the Hubble sphere presenting the Scannable Universe the Universe is isotropic and filled with the background radiation engendered by those objects that approach or passed the Hubble horizon. At the same time, if analyzed locally, this horizon, in itself, has no physical properties – it presents a mathematical sphere relative to its centre, and its centre could be taken anywhere in the Universe. After this centre is fixed, all the above properties (the scannable and outer parts of the Universe, etc.) will be specified with respect to this centre.

Therefore, for any point in the Universe on the whole it is defined the finite spherical region with the centre at this point – the scannable Universe (its radius remains unchanged as long as the Hubble constant does) which is bounded by the Hubble sphere. And this is the only part of the Universe on the whole, the present state of which is accessible for our observations in electromagnetic radiation (although the light emitted now could reach the Earth at a distant future).

With the astonishing exactness this modern physical understanding of the scannable Universe, that is actually "observable" Space, is reflected in the ancient Hermetic formula:

"THE CENTRE OF THE COSMIC CIRCLE IS EVERYWHERE AND THE CIRCUMFERENCE NOWHERE"

Therefore, returning to Eliphas Levi and the Zohar, we answer for the Eastern Occultists and say that, applying practice to principle, they agree entirely with Pascal, who says that "***God is a circle, the centre of which is everywhere and the circumference nowhere***," whereas the Kabalists say the reverse, and maintain it solely out of their desire to veil their doctrine. By the way, the definition of Deity by the Circle is not Pascal's at all, as E. Levi thought. It was ***borrowed by the French philosopher from*** either Mercury Trismegistus or Cardinal Cusa's Latin work, ***De Docta Ignorantia***, in which he makes use of it. It is, moreover, disfigured by ***Pascal***, who **replaces *the words*** "Cosmic Circle," which stand ***symbolically in the original inscription***, by the word Theos. With the ancients both words were synonymous. [SD2-545]

4.5.2.3 Dark matter and dark energy vs. dissolution and manifestation of the Universe

The contemporary physical models and observations (WMAP) state that the bulk of mass-energy of the Universe consists of ***dark matter*** (***23%***) and ***dark energy*** (***72%***), and only about ***4%*** are allotted to "conventional" ***baryonic*** matter (stars, planets, comets, and interstellar gas and dust).

Therefore, the ***dark matter*** and ***dark energy*** comprise about ***96% of the Universe***. And although the physical nature of these forms of matter remains unknown, making use of these subjects in cosmological models explains a series of principal phenomena that could not otherwise be explained; in particular, the current process of expansion of the Universe, the dynamics of motion of Galaxy spiral arms, etc.

Remind, that dark matter ***does not interact in any way with electromagnetic fields***, but ***shows its presence just*** in ***gravitational interactions*** (hence, it may also ***influence*** the ***flow of time***). The dark energy ***counteract the gravity*** in the sense that it ***promotes a repulsion and, thus, the expansion*** of the Universe.

It is amazing that these two basic forms of matter have the direct analogs in the ***Secret Doctrine*** as well. But remind firstly the main physical concepts pertaining to these subjects.

0. PHYSICAL MATTER AND STRUCTURE OF THE UNIVERSE.

* Physical matter. With respect to the standard cosmological model, the physical matter appeared from unknown type of matter, which, in its turn had appeared from Singularity presenting a kind of mathematical point in an unknown state of space-time (in more detail these concepts are considered above).

* The FLRW metric giving an exact solution of Einstein's field equations of general relativity describes a simply connected, homogeneous, isotropic expanding or contracting universe. The respective equations present the basis of the standard ***Big Bang*** cosmological model including the current ***ΛCDM*** model. However, as far as the FLRW model assumes homogeneity, it does not directly account neither for the observed lumpiness of the universe, nor for its structure.

* Lumpiness of the matter. In a strictly ***FLRW model***, there are no clusters of galaxies, stars or people, since it ***deals with*** the ***average distribution of different types of matter*** in the universe. In this sense the ***FLRW model is used as a first approximation*** for the evolution of the real, lumpy universe, and models which calculate the lumpiness in the universe are added onto the FLRW models as extensions. Most cosmologists agree that the observable Universe is well approximated by an *almost FLRW model*, i.e., a model which follows the FLRW metric ***apart from*** primordial fluctuations.

* Structure of the Universe. A physical explanation of the observed structure of the Universe relies upon a series of assumptions, some of which deal with uncertain states of physical matter and dubious hypotheses. In essence it postulates that the ***observed structure*** was ***engendered*** in the first second of the Big Bang by the primordial fluctuations – density variations in the early universe which are considered the seeds of all structure in the universe. Currently, the most widely accepted explanation for their origin is in the context of cosmic inflation. According to the inflationary paradigm, the exponential growth of the scale factor during inflation caused quantum fluctuations of the hypothetical inflaton field to be stretched to macroscopic scales, and, upon leaving the horizon, to "freeze in". At the later stages of radiation- and matter-domination, these fluctuations re-entered the horizon, and thus set the initial conditions for structure formation.

* Rotation of the Space objects presents one more puzzle that is to be explained by physics.

1. DARK ENERGY. The "***negative gravitation***" ***feature*** of ***dark energy*** corresponds to the esoteric concept affirming that gravitation ***should be understood*** as a manifestation of ***the forces*** of attraction and repulsion.

> But Kepler gave a pretty fair ***description*** of ***cosmic magnetism***. ***That such magnetism exists in nature, is as certain as that gravitation does not***; not at any rate, in the way in which it is taught by Science, which never took into consideration the different modes in which the dual Force – that Occultism calls attraction and repulsion – may ***act within our solar system***, the ***earth's atmosphere***, and ***beyond in the Kosmos***.
>
> …***There are many phenomena*** in our Solar system, which he {Newton} confessed his inability to explain by the law of gravitation… "These adjustments," we are told, "Newton, in his general Scholium, pronounces to be '***the work of an intelligent and all-powerful Being***'." Intelligent that "Being" may be; as to "all-powerful" there would be every reason to doubt the claim [SD1-497]

To this end we may add that such ***inexplicable phenomena pertaining to gravitation still puzzle the physicists*** (e.g. the Pioneer effect – See Comment 4.3).

2. DARK MATTER AND SUBTLE PLANES. By reasoning from the esoterical paradigm that in the evolutionary process the worlds (as the "regions" of the Universe on the whole) periodically "***manifests***" into physical existence, during a Day of Brahma, and, then "***dissolve***", during a Night of Brahma, we may assume that that enigmatic state in which the physical matter transforms on dissolving is just what is understood as the dark matter, thus presenting the ***matter of subtle planes***:

> The period of passivity ends, the night of mind ceases, the ***solar system*** awakes and ***re-emerges into manifestation*** and ***existence***, and everything throughout it is once more as it was when the night set in. Though a ***period inconceivable to human minds has passed***, it has passed but as a sound and dreamless sleep. The law of activity comes again into operation, the centre of evolution resumes its work, the fount of being commences to flow again…
>
> *When the hour strikes the cosmic atoms already in a differentiated state remain status quo, as well as globes and everything else in the process of formation…*
>
> In the still passive portion of the Universe in which, and interpenetrated by which, hangs the remanifested solar system; ***in the non-being where subsists the eternal mechanical motion***, its uncreated cause, a ***vortex is formed*** which in its ***ceaseless rotation perpetually ejects into the polarized active manifested conscious Universe***, the ***unpolarised passive unmanifested and unconscious Universal element***.
>
> Call it ***motion***, ***cosmic matter***, ***duration*** or ***space***, for it is all these and yet one, this the Universe manifested ***and*** unmanifested and ***there is nothing else in the Universe***. But ***the moment it passes out of passivity*** (or non-being) ***into activity*** (or being), ***it begins to change its state and differentiate***, ***from contact with what had formerly changed***, and so the eternal wheel rolls on, the effect of to-day becoming the cause of tomorrow for ever and ever. But it must ever be remembered that the non-being – the ***passive, is the eternal, the real***; the being – the ***active, the transitory and the unreal***. For longer or shorter as its career may be according to the impulses it receives, ***sooner or later the manifested disintegrates into the unmanifested***, and ***being fades into non-being***. [7]

All over the Universe, from galaxies and large scale structures like walls to voids the ***baryonic matter***, ***dark matter*** and ***dark energy*** co-exist, and – on average – ***in the same proportion***, although only *0.4*% of all kinds of matter is concentrated in the in compact baryonic objects (planets, stars, etc.), whereas the remaining part of baryonic matter (about *3.6* %) composes the gas and dust clouds and nebulae.

In the light of these physical data the suggestion that during a ***dissolution*** the ***physical matter transforms*** into ***dark matter*** representing some ***subtle planes***, and during an ***obscuration*** (a letup of evolution without dissolving of physical matter) – into a ***gas-dust state*** quite clearly explains ***where*** (in Space) and in what (in form) ***the physical matter*** "***disappear***" in these periods, and ***from where*** it "***appears***":

> ***There is but*** One Universal Element, which is ***infinite, unborn, and undying***, and that all the rest – as in the world of phenomena – ***are but so many various differentiated aspects*** and transformations (correlations, they are now called) of that One, from Cosmical down to microcosmical effects, from super-human down to human and sub-human beings, the totality, in short, of objective existence …
>
> All the Kabalists and Occultists, Eastern and Western, recognize (a) the ***identity of*** "***Father-Mother***" with ***primordial AEther*** or ***Akasa***, (***Astral Light***). [SD1-75]

> Intra-Cosmic motion is ***eternal and ceaseless***; cosmic motion (the ***visible***, or that which is ***subject to perception***) ***is finite and periodical***. [SD1-3]

The epactal amount of dark matter also explains from where a "new" "constructional material" can be taken for "building" the physical worlds, the "building sites" for which is granted due to the expansion of the Universe.

Note also that Hawking radiation, quantum fluctuation and some other physical models may possibly present models that describe a transfer of dark matter (or energy) into physical manifestation.

3. DARK ENERGY AND FOHAT. As to the dark energy, which according to ΛCDM model ***assists in expanding the Space***, we may assume that in some way and probably ***in common*** with the ***electromagnetism*** it ***contributes*** to ***getting physical matter*** into manifestation (viz. coming into physical existence) and forming the structures ***in the Universe*** by monitoring the gravity ***with*** expanding the space and putting the matter into rotation.

> ***Upon inaugurating an active period***, says the Secret Doctrine, an ***expansion of this Divine essence from without inwardly*** and ***from within outwardly***, occurs in obedience to eternal and immutable law, and the ***phenomenal or*** visible universe is ***the ultimate result of the long chain of cosmical forces*** thus ***progressively set in motion***.
> In like manner, when the passive condition is resumed, a ***contraction of the Divine essence takes place***, and the ***previous work of creation*** is ***gradually*** and ***progressively undone***. The visible universe ***becomes disintegrated***, its ***material dispersed***; and '***darkness'*** solitary and alone, broods once more over the face of the '***deep***.'
> To use a Metaphor from the Secret Books, which will convey the idea still more clearly, "***an outbreathing of the 'unknown essence' produces the world; and an inhalation causes it to disappear. This process has been going on from all eternity, and our present universe is but one of an infinite series, which had no beginning and will have no end***." [SD1-4]

And this is the activity of Fohat – the ***Cosmic energy*** being symbolically described as ***gliding of Spirit over the*** "***deep***" (or "***Waters of Space***") – which ***causes*** the ***subtle plane*** matter to "crystallize" ***into*** physical matter, to lump, to structure, and to rotate. To this end it is worth to remind the physical explanation of these effects.

> All the Kabalists and Occultists, Eastern and Western, recognize (a) the identity of "Father-Mother" with primordial AEther or Akasa, (Astral Light); and (b) its homogeneity before the evolution of the "Son," cosmically Fohat, for ***it is Cosmic Electricity***. "Fohat hardens and scatters the seven brothers"; which means that the primordial Electric Entity – for the ***Eastern Occultists insist*** that Electricity ***is an Entity*** – ***electrifies into life, and separates*** primordial stuff or pregenetic matter into atoms, themselves the source of all life and consciousness. "***There exists*** an universal agent ***unique of all forms and of life***, that is called Od, Ob, and Aour, active and passive, positive and negative, like day and night: it is the first light in Creation" (Eliphas Levi's Kabala): – the first Light of the primordial Elohim – the Adam, "male and female" – or (scientifically) ELECTRICITY AND LIFE.
> (c) The ***ancients represented it*** by a serpent, for 'Fohat hisses as he glides hither and thither" (in zigzags). The ***Kabala*** figures it with the Hebrew letter Teth, whose symbol is the ***serpent*** which played such a prominent part in the Mysteries. ***Its universal value*** is nine, for it is the ninth letter of the alphabet and the ninth door of the fifty portals or gateways that lead to the concealed mysteries of being. It is the magical agent par excellence, and designates ***in Hermetic philosophy*** "***Life infused into primordial matter***," the essence that ***composes all things***, and the spirit that ***determines*** their ***form***. [SD1-76]

Note to this end the use of number Nine ***in the Cabbalistic Swastika*** (See §3.8.3.2) ***in connection with*** the evolutionary cycles.

> ***Great heat*** breaks up the compound elements and ***resolves the heavenly bodies*** into their ***primeval one element***, explains the commentary. "Once disintegrated into its primal constituent by getting within the attraction and reach of a focus, or centre of heat (energy), of which many are carried about to and fro in space, a body, ***whether alive or dead***, will be vapourised and held in "the bosom of the Mother" ***until*** Fohat, ***gathering a few of the clusters of Cosmic matter*** (nebulae) will, ***by giving it an impulse***, set it in motion anew, develop the required heat, ***and then*** leave it to follow its own new growth."[SD1-84]

Note that the Cosmic magnetism as a ***phenomenon*** (Solar wind, Cosmic rays, etc.) and as a ***factor which exerts*** great ***influence to the Earth*** [17, 29] was ***discovered*** just by the ***end of the 20th century***.

4. FOHAT AND ROTATIONAL MOTION IN THE SPACE. The Secret Doctrine states that these are ***not the fluctuations of Fohat*** which ***cause*** the ***subtle matter to develop into physical worlds*** (viz. to manifest itself physically), ***but*** a deliberate and spiral motion, and this type of motion ***is observed practically*** in all Space objects, both ***separate*** and planetary and stellar ***systems***, thus attributing them with the angular momentum.

However, the cause of ***appearing*** of these rotations (or rather – ***momentums***) in such ***totality*** remains a puzzle: ***within*** the ***existing*** physical theories such a ***mass "self-generation" of rotation*** does not find an explanation (in particular, due to the laws of conservation).

Meanwhile, the esoteric explanation, in general, follows the physical law of conservation of angular momentum:

> "Fohat ***sets in motion*** the ***primordial World-germs***, or the aggregation of ***Cosmic atoms*** and ***matter***, some one way, some another, ***in the*** opposite direction" - looks orthodox and Scientific enough…
>
> Fohat ***turns*** with his two hands in contrary directions the "seed" and "the curds," or ***Cosmic matter***; is turning, in clearer language, particles in a highly attenuated condition, and nebulae.
>
> Outside the boundaries of the solar system, it is other Suns, and especially the mysterious "central Sun" (the "Abode of the invisible deity" as some reverend gentlemen have called it) that ***determines the motion of bodies and their direction***. That motion serves also to differentiate the homogeneous matter, round and between the several bodies, ***into elements*** and sub-elements unknown to our earth, which are regarded by modern Science as distinct individual elements, whereas they are merely temporary appearances, ***changing with every small cycle*** within the Manvantara, some Esoteric works calling them "Kalpic Masks." [SD1-672]

But in different cultures this concept was hidden under various mythological images:

> Since the esoteric ***teachings*** in ***Egypt*** and ***India*** were identical. And, therefore, the personification of Fohat synthesizing all the manifesting forces in nature is a legitimate result. Moreover, as will be shown {below} the real and Occult forces in nature only now begin to be known [SD1-672]
>
> Fohat is the ***key in Occultism*** which ***opens*** and unriddles the multiform symbols and respective allegories in the so-called ***mythology of every nation***; demonstrating the wonderful philosophy and the deep insight into the mysteries of nature, in the ***Egyptian*** and ***Chaldean*** as well as in the ***Aryan*** religions. Fohat, shown in his true character, proves how deeply versed were all those prehistoric nations in every science of nature, now called physical and chemical branches of natural philosophy.
>
> In India, Fohat is the scientific aspect of both Vishnu and Indra, the latter older and more important in the Rig Veda than his sectarian successor; while in ***Egypt*** Fohat was ***known*** as ***Toum*** issued of ***Noot***, or ***Osiris*** in his character of a primordial god, creator of heaven and of beings (see chapter xvii., "Book of the Dead"). For Toum is spoken of as the Protean god who generates other gods and gives himself the form he likes; the "***master of life***" "giving their vigour to the gods" (chapter lxxix.) He is the overseer of the gods, and he "***who creates spirits and gives them shape and life***"; … and finally the "***Setting Sun of Life***," or the ***vital electric force*** that ***leaves the body at death,*** wherefore the defunct begs that Toum should give him the breath from his right nostril (positive electricity) that he might live in his second form. Both the hieroglyph, and the text of chapter LXII in the "Book of the Dead," show the ***identity*** of Toum ***with*** Fohat. [SD1-673]

5. MATTER AND ENERGY. ***From physical point of view*** there is no clear-cut distinction between a matter, as "palpable" substance, radiation and energy; in particular, due to relativistic equivalence of mass and energy. Therefore, if ***energy*** may change the property of "palpable" matter (e.g. applying of energy accelerates a body and thus increases its mass), it ***should also be considered as matter***, ***as well as the dark matter*** participating in gravitational interactions ***and dark energy*** influencing the dynamics of Universe, or otherwise a series of logical contradictions would appear. In this respect the concept of "matter" is evidently to be considered ***indefinable in physics***, at least because we cannot define an object if the essence of its components (like dark matter and energy) remains unclear.

In esotery the matter is ***understood in not less broad sense***, but it is considered ***as*** a "***condensation***" (or "crystallization") of the Spirit presenting the ***opposite*** "***pole***" of the single whole; it may be manifested on different levels of "density", viz. planes of existence, among which the familiar to us physical plane presents the lowest. With a few strokes these concepts could be portrayed as follows [8, 9, 10]:

> In all ancient Eastern Teachings the Matter and Spirit present a single whole, since ***any one cannot exist without the other***. For this reason ***all exoteric deities*** have their ***wives*** who ***personify Matter*** and their Power. Thus Parabrahmam (Spirit) is ***inconceivable*** and ***has no manifestations without*** throwing over Him a ***thinnest veil*** of Mulaprakriti (Matter).
>
> The Spirit ***being devoid of*** Matter ***has no manifestation***, in other words – ***does not exist***. Truly, in thoughts and actions, we cannot separate from the Matter.
>
> There is a ***definition*** that the Matter ***is the crystallized*** Spirit. After all, Spirit ***is*** energy, and we know that ***whatever energy cannot become apparent out of Matter***. The very ***visible light*** presents a ***subtle matter in motion***. {That is why any kind of ***matter***, ***if*** taken ***in itself*** or as the "***objective***" ***essence***, is considered as ***illusion*** – S.S.}
>
> The Spirit and Matter are ***two facets*** of Incognizable unity, and their apparently opposite ***aspects depend on*** (a) the level of ***differentiation of Matter*** and (b) on the ***level of conscience*** that has been ***attained by a man himself***.
>
> Should we consider the seven principles as ***all-matter and all-spirit unity***, with the Spirit, so to speak, at the ***one pole*** and matter – at the ***other***? Yes, namely so.

However, if at present we are unable to measure the properties of the subtle planes this does not mean that they are non-existent: this only means that these planes do not exist for the contemporary physics which deals with the objects of physical plane, although in cosmology and quantum physics it probably has started to analyze the effects pertaining to the subtle planes. Meanwhile, the esotery considers the connection between the Matter and Energy by taking into account their properties at the subtle planes as well:

> Matter, energy and motion is the trinity of ***physical objects*** of Nature.
>
> Energy is ***the only*** existing ***reality*** … All perceptions of senses are exclusively the consequences of energies. Energy and Matter – are the ***equivalent terms***; and ***Matter*** is ***energy*** since none of them exists without the other one.
>
> The primordial energy in the whole ***manifested world*** is ***the same,*** but its ***properties differ***. By combining with the elements, it engenders the apparent diversity: each ***new combination*** results in ***transmutation*** of ***energy*** and ***element***.
>
> Under some ***rays*** the psychic (mental) energy takes the ***property of*** matter.
>
> The basic element of Fire presents a connecting origin, and its combinations with different properties of the primordial energy engenders an infinite multiplicity of elements. In this sense the ***diversity of elements*** (electrons, isotopes, ions, etc.) and ***kinds of energy*** are just the ***different qualities*** of the ***same energy***.
>
> The Matter, in the long run, ***is*** the electricity.

In particular, the processes of coming into manifestation are allotted with the following properties:

> ***{The matter} has descended*** from the Primordial Element. And this element is considered as the Divine Origin, triple in its manifestation…
>
> Undoubtedly, the elements ***known to us***, as they are understood and defined at present, ***are not*** and ***cannot be*** the primordial elements. Those ***primordial elements*** were ***formed from*** the "***lumps of cooled Radiant Matte***r" and from the "***fiery seeds of the Flaming Father***", which are unitary, or primal. These elements were engendered in the depths of the Primordial Fiery Mist, in the masses of scorching steam of insoluble nebula.
>
> The Matter is ***eternal*** and becomes atomic, but ***just periodically***. The Matter is ***eternal***, and an Atom is ***periodical***. That, what is at present called Spirit and Matter, presents the Eternal Single Whole as the immutable cause, and is neither Spirit, nor Matter – but all THAT which was, is and will be, all THAT which a human imagination could conjure.
>
> ***Infinite divisibility*** of Atom is the ***Cosmic law***, but the ***essence*** confined in ***its nucleus***, or its psycho-life, is ***elusive*** on the ***physical plane***.

Regarding the modern state of the Earth, the following esoteric concepts [8, 9, 10] present importance as correlates to that influence the Solar activity and Cosmic rays exert to our planet [17, 22, 29, 26].

> The Cosmic ray ***embodies*** in itself ***all elements and energies*** which exist ***in our Solar system***. It focuses in our Sun, and ***the latter*** transmutes all the energies it receives from the distant spheres and transfers ***them*** further on – to the planets of our Solar system {physically – via the radiation and Solar wind –S. S.}.
>
> Inversely, the Sun ***receives back*** the ***spent energies*** of the planets disposed in the Solar system. The Sun ***transmute these energies*** in its ***Fiery Hearth*** and, after ***then***, ***sends them back*** to the planets being gravitationally connected with the Sun.
>
> Thus, we have an important scientific corroboration for one of our ***fundamental dogmas*** – namely, that (a) the Sun ***is the store-house*** of ***Vital Force***, which ***is the*** Noumenon of Electricity; and (b) that it is ***from its mysterious, never-to-be-fathomed depths***, that issue those life currents which thrill through Space, as through the organisms of every living thing on Earth. [SD1-531]
>
> An ***exertion of the rays of heavenly bodies*** may ***speed up*** the motion and cause a shift of the Magnetic Pole. The ***shift*** of the ***Magnetic Pole*** coincides with the ***set up term*** for an event in Russia.

Regarding the rate and periodicity of evolutionary processes the following esoteric concepts present undoubted significance.

> These laws are immutable; but the motion of all the bodies, which motion is diverse and alters with every minor Kalpa – is regulated ***by the Movers***, the Intelligences within the Cosmic Soul.[SD1-530]
>
> … everything in the universe, as well as the ***universe itself***, is formed (created) during its periodical manifestations – by accelerated **MOTION** set into activity by the BREATH of the ever-to-be-unknown power (unknown to present mankind, at any rate) within the phenomenal world. [SD2-551]
>
> But ***there are certainly*** "designers," though these are neither omnipotent nor omniscient in the absolute sense of the term. They are ***simply Builders***, or Masons, ***working under the impulse*** given them ***by*** the ***ever-to-be-unknown*** (on our plane) ***Master Mason*** – the **ONE LIFE** and Law ... ***they*** work in cycles and on a ***strictly*** geometrical and mathematical scale ***of*** progression [SD2-732]

CONCLUSIONS

1. Physical relocation in the future is possible, even a *relocation* with an over-light velocity, but it is impossible to return or transpose in the past

* From the viewpoint of ***Special relativity*** it is ***possible to physically transpose in the*** future (relative to the reference frame *S* associated with the space-time point of start of the travel) – to the epoch being distant from the "present" (viz. starting moment in the frame *S*) ***by any, but fixed time interval***; at that, the spatial ***end point*** of the travel ***may or may not coincide with the starting point*** – by a choice of the traveler.

* Moreover, the traveler may relocate with a ***speed exceeding the velocity of light***; this means that the relocation velocity as the ***ratio*** of the ***distance*** the traveler passed ***in the frame S*** and travel ***time*** measured ***in the traveler's frame*** may ***exceed*** the ***velocity of light***. During this journey the traveler would see all the flied by objects contracted.

* However, neither the Special relativity, nor any other mainstream physical theory provides a possibility to travel in the past – so that the time of returning to the starting point precedes the time of departure. So, ***one*** may ***arrive*** in the ***future***, but ***cannot return*** to a more or less close vicinity of the time of departure.

* The ***sphere of practical applicability*** of these ***effects*** is ***bounded*** by ***extreme growth of power consumption*** required for accelerating an object to a relativistic velocity.

* In the expanding Universe, or in a vicinity of super massive object the ***similar results*** could be achieved with much lower velocities – but due to the very ***expansion*** of the universe or ***immense gravity***; however, the ***realization*** of these effects is also ***doubtful*** due to ***huge distances*** and ***enormous power consumption***.

2. Observation of the past of the Universe is partly possible in the electromagnetic radiation

* In the ***expanding Universe*** we live in, it is ***possible to observe*** the ***past as*** the ***electromagnetic radiation*** the ***objects emitted***, but ***not farther than at the Hubble distance***. However, ***as with the subtle planes***, we may ***only observe*** it and cannot exert influence to those objects.

* At the same time, if an ***object*** was emitting light ***before*** and ***during crossing*** of the ***Hubble sphere***, we would ***observe this light***, in theory, ***everlastingly***, ***even if that object had exploded*** just after passing of that limit. But ***this*** phantom light, which ***continuously attributes to the*** background radiation, would have ***nothing in common with the actual state of the object***; in this sense the term "***observable Universe***" ***does not reflect the situation quite correctly*** since in reality we ***cannot observe anything behind the Hubble sphere*** – we may ***only extrapolate*** where the objects that passed the Hubble sphere reside.

* Meanwhile, ***our possibility to observe*** the ***radiation*** of ***distant objects*** is ***confined*** by the ***very expansion of the Universe***, apart from ordinary physical factors. As a matter of fact, the ***light travel time*** to the ***most distant source of radiation*** (***gamma burst***) ever registered makes about ***13 billion years***, which is ***close*** to the ***Hubble time***. This means that approximately 95% of Hubble distance (viz. radius of the Hubble sphere) present the current limit of observation, from the outside of which the light emitted by even the most powerful source could not be received on the Earth.

3. There are no sound grounds for assuming the existence of Wormholes and "Time tunnels"

* There are ***theoretical models*** that ***allow*** a possibility of ***time travels via*** the ***highly curved spacetime***; for example – through a Wormhole which is understood as ***hypothetical topological feature*** of ***spacetime*** that would be, fundamentally, a "shortcut" through spacetime. However, the observations ***coordinated with the*** standard cosmological model ***show*** that to within a negligible error the Universe is flat (in a sense of its curvature) with the ***exception*** of ***close vicinity*** of very peculiar objects like black holes.

Therefore, ***there are no observational grounds***, neither indirect evidences, to assume that in the ***bulk volume of the Universe*** (except of vicinities of the black holes) ***something like*** Wormhole ***could be met*** – which would allow to travel to the future and back, to the past. On the other hand, the theories that assume the existence of ***Wormholes*** still present the hypothetical models which may or may not be valid.

4. The Hubble's bound of the Scannable Universe and its ancient Theosophical analog

* The Hubble horizon is a mathematical object that is defined by a Hubble sphere with the centre in an arbitrary point in the Universe and unchanging radius being equal to Hubble constant. It presents the ***event horizon*** for the chosen point (in our case – this is Earth) which, in itself, does not show any physical property pertaining to the presence of the Earth. It defines how the processes in the Universe are perceived when seen from the Earth and limits the scope of the expanding Universe from which the radiation could reach the Earth. Since the radius remains the same value, with expanding of the Universe the light emitting objects approach this sphere and those of them that crossed it would transfer to "unknown" because we would not be able to receive their light (although that part of the Universe on the whole is called "observable"). So, the ***Hubble horizon*** presents, in essence, a ***cosmological limit surface*** for the Earth.

* With respect to the effects of time dilation (relative to the objects approaching the horizon) and loss of information (relative to the objects that has passed the horizon), the ***Hubble horizon*** could ***roughly*** be ***likened*** to the ***black hole horizon***: the closer an object approaches the horizon, the more time is delayed (as perceived via the emanated light), and this process continuous infinitely, although in reality (in cosmological or proper time, respectively) the object passes the horizon without any delay – as quickly as the space expands between the Earth and this object. The difference is that the Hubble horizon we perceive from "within", whereas the black hole horizon – from "outside", and the former remains a mathematical sphere without peculiarities pertaining to the Earth.

* So, for the Terrestrial observer our planet becomes the "Centre" of homogeneous and expanding Universe which "occupies" a limited volume of the Universe on the whole, that is bounded by the Hubble sphere, which defines the scannable region of the Universe on the whole, scannable in a sense that for the present moment of cosmological time it contains all those and only those objects an information from which could reach the Earth. An information pertaining to any object residing outside of this sphere would never reach us, and vice versa – the new Earth's movies for this object would be lost forever (although its humanity would still be able to watch the old ones, but more and more delayed).

* In these circumstances the ***finitude*** and ***geometrical structure*** of the Scannable Universe bounded by Hubble horizon **directly corresponds** to the ***ancient esoteric concept*** relative to the ***finitude*** and ***geometry*** of the perceivable Universe, whereas the Hubble sphere may seemingly present the boundary of the great circle of "Pass not" [SD1-90] – the bound that could not have been "seen" (or "reveled"), but exists!

* Besides, this physical understanding of the scannable Universe (being "visible" in a sense that its current state is actually perceivable) is **directly described** by the ***ancient esoteric(Hermetical) concept:***

"THE CENTRE OF THE COSMIC CIRCLE IS EVERYWHERE AND THE CIRCUMFERENCE NOWHERE"

5. Big Bang and Singularity – the facts or degenerate solutions to mathematical models?

* The Expansion of Universe and Big Bang concepts are different in their essence. The former is described by models based on Einstein and Friedmann equations that fit the observations, whereas the latter presents a mathematical singularity being obtained, in essence, as degenerate solution to the problem of extrapolating a long-term trend in expansion of Universe in the past with the use of the chosen models and assumptions relative to the qualitative and quantitative properties of the Universe in the past.

In essence, the Big Bang hypothesis including the phases of Singularity and Inflation is called upon to support the consistency of accepted cosmological models for the distant past, for which they predict an abrupt, in parts of a second, expanding of the Singularity from a "point" to a observable Universe commensurable with its current dimensions. It reflects the mainstream paradigm of the modern physical cosmology, although there are other theories which do not rely upon the Big Bang hypothesis in explaining the expansion of the Universe and Cosmic microwave background radiation.

In engineering practice, such degenerate solutions, as a rule, testify to inadequacy of the design formulas or rather to incompleteness of an approximation model for a long-term trend. However, the Big Bang and Singularity were assigned a cosmological significance, although none of them has gained any physical meaning; moreover, these are the states which do not fit any physical law; for these reasons they remain non-verifiable hypotheses which bear no physical sense.

* One more principal problem facing the Big Ban hypothesis requires to explain how the observed large scale structure of the Universe comprising the ***filamentary web*** of ***galaxy clusters*** and interior ***Voids*** was formed in the first second of the Big Bang. ***The plausible explanations***, which reduce the forming of this structure to random quantum fluctuations of primordial matter with actually unknown properties, ***constitute*** rather ***one more dubious hypothesis*** than ***a physically grounded*** and/or ***validated theory***.

Therefore, by its scientific validity (or rather vagueness) the Big Bang hypothesis including the state of Singularity in some way is equivalent to that pertaining to the Biblical Creation of Earth and man, since like the latter it affirms creation of matter from unknown substance and through unknown process in negligibly small part of second; in fact, they equally give no explanation to the "creation". For this reason much more confidence deserve those physical theories which do not rely on this hypothesis.

* In the Secret Doctrine we also do not find a support to the Big Bang hypothesis attempting to curtail the evolution to an explosive creation from a point disposed in unknown during a finite period. The esotery rejects a "once" creation; on the contrary, it affirms the cyclic evolution that develops infinitely, in sequential transmutations (manifestations and dissolutions) of matter that is accompanied by expansion and contraction of Space, but definitely not to (or from) a state of singularity.

6. Cosmological time and age of the Universe

* The age of the Universe is understood as the cosmological (comoving) time that elapsed ***since the hypothetical*** Big Bang. For the presented above reasons the ***moment of the hypothetical*** Big Bang should ***rather be considered*** as an arbitrary reference point, and the singularity ***from which the Universe as if developed*** – as a non-verifiable hypothesis which ***bears*** no physical sense.

* That the age of the Universe ***practically coincides*** with the Hubble time that is defined by the observed value of Hubble constant (that is why, in itself, it is not associated with any age) and present important physical parameter describing the observed properties of the expanding Universe is rather an evidence of tuning the cosmological model parameters to the observations than to the frequently mentioned "coincidence" of these values.

* As well, the comoving time ***is not directly associated with the Big Bang***, neither with any other age, since its operational definition is based on the observed properties of the Universe, although for the retrograde extrapolation it uses approximating models and thus reflects the properties and assumptions pertaining to the chosen models and their parameters; but this way may be misleading because the adequacy of these suggestions could be tested in the experiments, but in the exceptional cases.

7. Dark matter and dark energy and their esoteric analogs

* The dark energy which as "negative" gravitation assisting in expansion of the Universe ***corresponds*** to the ***Theosophical concept*** that the gravitation should be ***understood as manifestation*** of opposite forces of ***attraction*** and ***repulsion*** (to this end we may add that the dark matter assists in attraction). It may also present that "instrument" which esoteric Fohat uses ***for putting the matter*** into ***rotary motion***.

* By reasoning ***from the esoteric paradigm***, which states that the worlds (as regions of the Universe on the whole) cyclically develop into physical "reality" and dissolve back, into the subtle planes, we may ***assume*** that the ***state in which the physical matter transmutes*** on ***dissolving*** (during a Night of Brahma) just ***correspond*** to the dark matter (as a form of ***subtle planes***), whereas during the ***obscurations*** (let-up of evolution without a dissolution) – transforms to a ***gas-dust state***. It is possible also that the that ***Hawking radiation***, ***quantum fluctuation*** and some other effects present those models that describe a ***transmutation of dark matter (or energy) into physical substance***.

* The ***epactal amount*** of dark matter also explains from where a "new" "constructional material" can be taken for "building" physical worlds, the "building sites" for which is granted due to the expansion of the Universe.