The discrepancy between the values of the Hubble constant and the effect of dark energy on baryonic matter

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Abstract

It seems clear that researchers have not yet fully appreciated the true implications of the discovery of dark energy for understanding evolutionary processes in the baryonic universe. Based on general physical considerations, we consider here the influence of dark energy on baryon objects at the level of atomic nuclei and elementary particles. For such an analysis, the concept is adopted, according to which the entire baryonic Universe interacts with dark energy on all cosmic scales. The consequences seem quite dramatic, since the accumulation of energy in the baryon world changes the energy balance and reduces the binding energy of all objects, including atomic nuclei. Consequently, the nuclear mass defect decreases, their mass increases, and both effects make the nuclei more and more unstable. This leads to the destabilization of all nuclei and their gradual transfer to the stage of radioactive decay, which increases over time the relative amount of light elements, including hydrogen. Evolution under the influence of dark energy, on the other hand, increases the masses of atomic nuclei. We have used this hypothetical effect to interpret the so-called "Hubble tension" paradox. This also makes it possible to estimate the growth of the proton mass due to dark energy.

Keywords: *Dark energy, baryon matter, interaction, energy exchange, Hubble constant: Hubble tension, evolution, mass growth, blueshift, metallicity*

1. Introduction.

The main paradigm, on the basis of which the model of the physical world is built in any field of science, is always consistent with the set of empirical data existing at a given stage in the development of science. When the accuracy of the data is not high enough, a more primitive or at least not perfect model of the physical processes under consideration can be used as the basis for the theoretical interpretation of these data. Therefore, any refinement of empirical data in a given field of science can often lead to paradoxical results if the main paradigm of this field is completely or partially erroneous.

Undoubtedly such was the world of Ptolemy - the geocentric system of the Universe. It was based on observational data on the movement of planets and stars, and at one time described the details of these movements quite well. But since the model was wrong, the accuracy was ensured by a set of free parameters, so the required accuracy could be provided only in a limited period of time. This is similar to polynomial approximation of an unknown function. In interpolation mode, the method works quite well, but it is worth going beyond the fixed values of the argument, and violent oscillations begin.

Modern cosmology is one of the most intensively researched and theoretically developed branches of science. It was built on the basis of observational data and some fundamental hypotheses, among which the central ones are the big bang hypothesis, as well as the Kant-Laplace hypothesis about the formation of cosmic objects (and their systems) from more rarefied matter. Any new phenomenon, observational fact, must be consistent with a number of such "absolute truths".

Today I wanted to dwell on one problem, refusing at the same time from the dictates of petrified ideas about the evolution of cosmic objects. Rather, taking into account new observational data, namely, the existence of dark energy, based on the analysis of physical processes, the idea is put forward that atomic nuclei and elementary particles also undergo secular evolutionary changes. Such a conclusion follows from the results of the self-consistent application of physical laws. And this result allows us to naturally interpret some paradoxes that do not have an unambiguous explanation to this day.

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We will focus here only on one of the mentioned dilemmas, which is associated with the existence of two different values of the Hubble constant and is known as the Hubble tension. This phenomenon is explained here by the fact that the determination of the ”early” value of the Hubble constant does not deal with real space objects and the properties of baryonic matter, while the ”later” value is determined by measurements of the velocities and distances of real galaxies.

We also know from the history of science and should carefully keep in the mind that researchers always try to keep all established ideas intact but not change any principal idea. They usually prefer to add new loose parameters to fit new observable facts or patterns to existing models and ideas. Major changes in comprehensive understanding of the physical world around that are highly valued by different paradigms take place not very frequent but very rarely and only when the inertia of the old type of thinking is reduced to a negligible level. Most probably this form of thinking underlies cognition through the human psyche. Of course, this is an issue, which has more philosophical than physical or astrophysical essence. However, when choosing a methodology for ongoing research, existing implicit trends should be taken into account.

2. Interaction between baryonic matter and the carrier of dark energy.

Obviously, the very fact of the discovery of dark energy (Perlmutter et al., 1999, Riess et al., 1998) through the fact of the acceleration of galaxies directly indicates the interaction of two substances, namely the baryon universe and the carrier of dark energy, whatever the latter may be. It is due to this interaction that energy is transferred to galaxies, which ensures the acceleration of the expansion of the Universe. It is clear that any interaction involves the exchange of energy between the interacting substances. This is what we know and usually interpret based directly on observational data. And all this applies to cosmological scales and cosmological objects as integral formations.

On the other hand, the contemporary science asserts that dark energy fills homogenously all spatial scales. If we also take into account that dark energy is purely positive, while all baryon objects and their systems have negative total energy (according to modern concepts), then it is obvious that the baryon world acquires energy during this kind of interaction and energy exchange at all scales. As one can notice, this conclusion has been arrived at using only the self-consistent physical approach, if the homogeneity of dark energy accepted by scientific community is true.

Let’s take the next step, relying on the general physical laws of interaction and energy transfer known to us. If we accept that dark energy fills all space on all scales, then we inevitably come to the conclusion that interaction with baryonic matter must also occur on all scales. And this, in turn, means that in a detailed study of the issue, we must take into account the exchange of energy and the consequences of this process for all scales, starting with the microcosm. The physical consequences thus obtained can be verified with the help of observational data relating to the corresponding objects.

Above we noted one essential circumstance about the energy state of baryonic objects common to the entire baryonic Universe. This is what any baryonic objects have, or are thought to have, negative energy. Therefore, when interacting with a carrier of dark energy, according to the known laws of physics, they must inevitably acquire additional energy. This applies both to gravitationally interacting or bound objects and systems, and to elementary particles and atomic nuclei. What happens at the level of atomic nuclei ultimately leaves its mark on the entire baryonic universe, and therefore must be accurately accounted for.

3. Atomic nuclei and dependence of baryons’ mass on physical conditions.

It is well known that atomic nuclei, as all baryonic objects, exist as integral entities only due to the binding energy of the nuclei, which is nothing but a lack of mass (mass defect). Each baryon in the nucleus exists, while having a smaller mass compared to the free state. This means that in order to completely divide the nucleus into the composing it baryons, one needs to give the nucleus the energy equivalent of the missing mass. There is another aspect of this situation that is not often noticed. It is that the missing mass for one baryon varies from nucleus to nucleus. A nucleon losses some part of its mass being bound in a nucleus and the same nucleon possesses different masses in different nuclei.

This fact can be interpreted as follows. Under the physical conditions of atomic nuclei, identical baryons, which are considered by modern physics absolutely indistinguishable from each other, can have different masses. It does mean that the same nucleon easily changes its mass being in different physical conditions

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and obey the conditions for existence. So, one can arrive at a conclusion that in principle, these baryons can have a different mass, if the physical conditions require it.

There are all prerequisites for such a phenomenon. Let’s discuss this briefly. If the interaction of baryonic objects with the carrier of dark energy really occurs at all scales, then it also takes place on the scales of atomic nuclei and elementary particles. Then the transfer of energy to the atomic nucleus reduces its nuclear binding energy. But this, on the other hand, means that the mass defect also decreases and, consequently, we will observe an increase in the mass of the nucleus and, accordingly, the mass of bound baryons.

Let’s emphasize that for this process doesn’t even matter what the density of dark energy is. However negligible the density would be, any non-zero value would increase the mass of the baryons. The fact is that energy is a cumulative type of substance, it can be accumulated and therefore the amount of energy will be integrated over time. In other words, over time the change in energy will reach the noticeable amount and have essential physical consequences, which we are going to discuss further in this report.

It is very important to find the “fingerprints” of the predictable changes occurred with the atomic nuclei. We can mention here several. First one, which provides an observable feature is the change in wavelengths of spectral lines. Indeed, let’s show it using the example of hydrogen-like atoms, line wavelength for which is given by the following relation:

$$\frac{1}{\lambda_{mn}} = Ry\frac{1}{hc}\frac{M_p}{M_p + m_e}\left(\frac{1}{m^2} - \frac{1}{n^2}\right), \tag{1}$$

where

$$Ry = \frac{m_e e^4}{8\varepsilon_0^2 h^2} \tag{2}$$

is the Rydberg constant. Instead of protons mass M_p one could write $M_n$for denoting hydrogen-like atoms consisted of several baryons. We see that the wavelengths of spectral lines depend inversely on the reduced mass of nucleus and electron

$$m_r = \frac{M_n m_e}{M_n + m_e}. \tag{3}$$

Obviously, when the masses of the nucleus and electron increase, spectral lines get blueshifted. This means that the more the object is affected by this mechanism, the more are its spectral lines blueshifted. On the other hand, one can conclude that the farther the object is, the bigger its spectral lines’ redshift due to the bigger nuclear binding energy. In other words, the objects located far away should possess some additional redshift not conditioned by the Hubble expansion of the Universe. This is due to the evolutionary process of atomic nuclei and elementary particles taking place because of interaction between the baryonic matter and the carrier of dark energy. This process is a universal mechanism converting dark energy into mass and increasing the mass of the baryonic universe simultaneously with its expansion. One of the most challenging problems is to find a method for quantitative separation of these two types of redshifts, if any.

The second feature, showing a kind of ”fingerprint”, is associated with a decrease in the binding energy of the nuclei, which obviously reduces the stability of all nuclei. On the basis of general physical considerations, it can be shown that the constant decrease in the binding energy of nuclei eventually transfers any given nucleus into the category of radioactively decaying. And this, in turn, means that after some time, instead of a given nucleus, there will be two (or more) lighter nuclei. From this we can draw several conclusions that radically change our understanding of the formation of chemical elements and the evolution of their abundance: a) Over time, the metallicity of all space objects and the universe as a whole decreases; b) In earlier epochs of the life of the universe, there were atomic nuclei consisting of a larger number of hadrons (with a large atomic number) with smaller masses and higher binding energy; c) With time, the half-life of radioactive atomic nuclei decreases.

4. The rate of evolution depending on the mass of the object.

None of these features can be observed directly. However, some of them could manifest themselves in an implicit form. In order to find possible ”fingerprints”, consider the following question. If indeed baryonic matter interacts with a carrier of dark energy on all scales, while receiving energy and, as a result, evolving, then it is interesting which objects are more easily subject to the influence of dark energy - massive or low-mass objects.

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To study this issue, we proceed from the following considerations. Any object exists due to its binding energy. For the objects bound through gravitation, this is the gravitational energy that can be calculated. The amount of dark energy is proportional to the volume of a given object, since dark energy is uniformly distributed. From a physical point of view, it is natural to assume that an object is the more subject to evolutionary changes, the greater the ratio of dark energy to binding energy, all other conditions being equal.

The gravitational energy of objects, as is known, is generally proportional to the square of the mass and inversely proportional to the size. In general, it depends on the density distribution and on the geometry of the object and each time must be calculated with exact consideration of the specified values. But in simple cases it is calculated analytically and the corresponding formulas are well known. For example, the homogeneous spherical object possesses of gravitational energy given by the following relation:

$$E_{gr} = kG\frac{M^2}{R} \tag{4}$$

where M is the mass of the object and R is its radius. Now one can introduce the amount od dark energy located in the same volume with the spherical object in this way

$$E_{de} = V\rho_{de}, \tag{5}$$

where

$$V = \frac{4\pi}{3}R^3 \tag{6}$$

is the volume of the object and ρ_{de} is the dark energy density. Then the ratio of "destroying" dark energy and "maintaining" gravitational energy for the given object will have the following form

$$\eta = \frac{E_{de}}{E_{gr}} = kG\frac{R}{M}\frac{\rho_{de}}{\rho_{bm}}, \tag{7}$$

where ρ_{bm} is the density of the baryonic mater within the object under consideration. As can be seen, in this purely model example, the introduced coefficient decreases with an increase in the mass of the object, provided that the density of objects of this family is unchanged. Naturally, this model does not actually work, and a more realistic case must be considered. However, our conclusion remains valid if the mass M grows faster than the radius R.

What conclusion can be drawn from the result obtained? Since the effect of dark energy is more effective where the introduced ratio is greater, this result can be interpreted as follows. The greater the mass of an object, the more difficult it is for evolutionary changes under the influence of dark energy. That is, all the effects that have been listed above occur more easily for low-mass objects and are more delayed in the case of more massive objects.

Let us now compare this result with well-known observational facts. Since the 1970s, the phenomenon of the dependence of the metallicity of galaxies on their luminosity has been studied in sufficient detail. A very large amount of evidence shows that the metallicity of massive galaxies is much higher than that of dwarf galaxies. Our results, combined with observational data, can be interpreted as follows. The process of evolution under the influence of dark energy goes in the direction of fragmentation of atomic nuclei and an increase in the relative number of light elements and, first of all, hydrogen. Then hydrogen is not the primary element from which the rest are synthesized, but the final product of evolution.

The paradoxical discoveries of recent decades related to the existence of "mature" galaxies on the very outskirts of the universe, heavy elements at the same distances, the amazing fact that it is galaxies and not quasars that have the largest redshifts, all the more strengthen the confidence in the correctness of our paradigm. But we will talk about these facts and their detailed analysis in another article. And here, after trying to substantiate this paradigm, we will focus on another paradox, which is known as the Hubble tension.

5. The new headache called "Hubble tension".

Since the discovery of the expansion of the Universe by Lemaitre and Hubble, much work has been devoted to improving methods for determining the main expansion parameter, which was once called the Hubble constant. Starting from a value of 500 − 600 km/s per Mpc, the refinement of this parameter over several decades led to a value of about 70 km/s per Mpc. From the very beginning, as one would expect,

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the scatter in the measured values of this quantity was large, but the researchers were sure that the scatter tends to zero as the accuracy of the measurements increases. This tendency is true and is observed in all empirical works.

But in the case of measuring the Hubble constant, such expectations were not justified. The refinement of the measurements led to the fact that for this constant two different values have been obtained, which differ from each other at the level of 4-6 sigma. One group of measurements, which uses data from the microwave background of the sky, gives a value of 67.4 ± 0.5 km/s per Mpc, while other methods, which use the measured distances of objects and their velocities, provide a value of 74.0 ± 1.5km/s per Mpc.

This is a very confusing result for astronomers and physicists, since any parameter can have only one value, measured by any methods, provided that all methods are correct and take into account all possible sources of error. This can happen when some effect is not taken into account or when they do not know about this effect.

Here, in our opinion, attention should be paid to the following circumstances. First, those methods that involve the use of background radiation do not deal with the physical properties of the baryonic universe. Second, the Hubble constant is larger precisely when it is measured using baryonic objects. This suggests that the reason may be hidden in the physical properties of baryonic matter. Let’s consider the question, which means that the Hubble constant in the case of measurements with baryonic objects turns out to be 6.6 km/sec per Mpc more. This means that for one Mpc, these methods from somewhere gain so much more decrease in speed. Decreasing speed in this language is nothing more than an extra blueshift. Where can it come from. But this is precisely what was discussed in the previous paragraph, namely, that due to interaction with a carrier of dark energy, the spectral lines of all elements move to the blue side of the spectrum. It remains to do some calculations in order to determine the rate of increase in the mass of atomic nuclei and elementary particles, at which we will get these additional 6.6 km/sec per Mpc. To do this, we first note that a distance of 1 Mpc in terms of time equals 3.26 million years. That is, we must proceed from the fact that these additional 6.6 km/sec per Mpc appear due to the increase in mass over 3.26 million years. Thus, we observe change of wavelengths on

$$\Delta z = \frac{\Delta v}{c} = \frac{6.6}{300000} = 2.2 \times 10^{-5} \tag{8}$$

for the time interval 3.26 million years. Using this one can calculate the annual growth of mass of the atomic nuclei and elementary particles. It is easy to find the analogous change for one year or for the distance of one light year. One should divide the spectral change on to the 3.26 million years. It gives for the blueshift per year

$$\Delta z_{year} = 6.7 \times 10^{-12}. \tag{9}$$

On the other hand, if using the expression (1) for expressing the change of blueshift by the mass growth, one finds

$$\Delta z = \frac{\Delta \lambda}{\lambda} = \frac{m_{r2} - m_{r1}}{m_{r2}} = \frac{\Delta m_r}{m_r}, \tag{10}$$

where m_{r1} and m_{r2} are the reduced masses of nucleus and electron, measured in a one-year difference. So, we can obtain from (9) and (10) the following expression

$$\frac{\Delta m_r}{m_r} = 6.67 \times 10^{-12}. \tag{11}$$

From this relation one can calculate the rate of the proton mass change. If the mass change takes place equally for protons and electrons, one can obtain from the relation (11) the following estimate

$$\frac{\Delta m_n}{m_n} \approx 6.6 \times 10^{-12}. \tag{12}$$

The same estimate is valid for any nuclei and, in a particular case, for the proton which possess of mass $M_p = 1.67262192369(51) \times 10^{-24}$ g.

The accuracy of determination of the proton mass, although very high, is about an order less than one needs to find its secular change, if any. Since according this paradigm the masses of elementary particles and atomic nuclei grow up constantly in the course of time, it seems not to be very difficult to check it empirically. However, to this end, new methods of measurement must be invented, since if the paradigm under consideration is correct, then mass standards, most probably, also change with time. One should overcome this difficulty to obtain really acceptable results.

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Which methods are applicable for such measurements, we cannot mention here. This problem, certainly, must be considered separately and very scrupulously to find any self-consistent method and corresponding solution.

6. Concluding remarks.

Obviously, we have not yet appreciated the true significance of the discovery of dark energy for understanding the processes of evolution in the baryonic universe. It is still perceived as another ordinary discovery, which slightly corrects our ideas about our world on a large scale. However, this is by no means the case. If we take into account the possibility of interaction between baryonic matter and the carrier of dark energy and all the consequences of this interaction for baryonic matter, then we inevitably come to the conclusion that all evolutionary processes in the baryonic world are controlled precisely by this influence.

If the paradigm we consider here is correct then one can find several ”fingerprints” of the corresponding physical processes. One of those signs is associated with the cosmic objects’ metallicity and its distribution. The point is that interaction between the baryonic matter and the carrier of dark energy leads ultimately to the fragmentation of atomic nuclei. It does mean that the relative number of light elements should increase over time. In other words, the longer evolution of object under the influence of dark energy, the lower the metallicity. This effect is know since 70s of the last century. That is the dependence of the metallicity of galaxies on the mass (luminosity).

We applied the results obtained on the secular growth of mass of atomic nuclei to explain the paradox called ”Hubble tension”. For this we have used the fact that atom’s spectral lines should be shifted to the blur end of spectrum if the mass of nucleus increases. This approach allows one to estimate the annual change of the mass of atomic nuclei including the proton mass (hydrogen atom’s nucleus).

A lot of observational facts fit our ideas following from the paradigm under consideration. It needs to have a comprehensive study of all possible ”fingerprints”, paying a special attention to ones, which, in their turn, predict new phenomena or provide a method to measure predicted changes in the objwcts’ characteristics.

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