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Helium as a major portion of the dark matter and the cell structure of the universe

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Helium as a major portion of the dark matter and the cell structure of the universe

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Abstract. One of the unsolved problems in physics is called dark matter. It should be called non-shining matter or invisible matter in order to include transparent matter. We will review the discovery of the dark matter and various explanations, some of which state that dark matter consists of baryons. In this article, we will discuss the possibility of ^4He as the transparent matter, including claims against and in favor of this idea and various implications, particularly on the evolution of galaxies, galaxy clusters, galaxy superclusters and the large cell structure of the universe. This necessitates a *few* paradigm shifts regarding the big bang, the black holes, rotation and more. We explain the contradictions in the paradigms accepted at present before deriving the new substitute paradigms suggested in this article. The big-bang theory is replaced with a relativistic expansion of the universe that increases the calculated time since the cosmic microwave background radiation about six times. Quasars and supermassive active galactic nuclei were and are additional factories that produce helium and disperse it in huge jets. Together these phenomena enable the production of helium in sufficient amounts to be the long time sought for transparent matter which is erroneously called dark matter.

As a result, new explanations are obtained for the cell structure of the universe, the structure of galaxies and galaxy clusters, and for their evolution.

1. Introduction and background

Dark matter is considered an unsolved problem in physics [1], [2], [3]. In the introduction we will review the discovery of dark matter and various previously suggested explanations, in particular some of which state that dark matter consists of baryons. We also mention and discuss previous suggestions usually not reviewed. This article details a possibility not suggested elsewhere to our knowledge.



Section 2 below discusses ^4He as invisible matter. Section 3 discusses transparent ^4He in various observed celestial bodies. Section 4 suggests the possible implications of ^4He on the evolution of galaxies, galaxy clusters, galaxy superclusters and the cell-structure of the universe. Section 5 discusses possible mechanisms of transparency of ^4He . Section 6 tells about the advantage of rough estimations in general. Section 7 concludes the article, including the classification of candidates for invisible matter and their relevant observations.

1.1. *Discovery of dark matter*

Oort (1932) [4] found that the Milky Way galaxy should include additional matter other than what was visible, because the velocity of the stars is higher than the escape velocity when considering only the visible mass. Rubin found in the 1970's [5], [6] that the rotation curves of the Andromeda galaxy and all the spiral galaxies whose rotation was measured pointed out the existence of a very large mass of rotating invisible halos around the visible spiral galaxies. Rubin et al. (1982) [7] reported the observation of the galaxy NGC3067 with the quasar QC232 in the background. The velocities measured in the galaxy were interpreted and found fitting to 94% of the mass of the galaxy to be beyond the optical radius of its visible light. This mass is made of invisible gas that cannot have a high temperature. Hydrogen clouds were not detected at the large halo of this galaxy.

The rotation curves of galaxies indicate a massive halo around the galaxies. The velocities of galaxies in *clusters* of galaxies are too high for the galaxies to be gravitationally held by the visible mass of the galaxies in the cluster (Zwicky (1933 [8], 1937 [9])). Apparently there exists *invisible* additional mass in both cases [10].

1.2. *Accepted beliefs of dark matter*

Neutrinos are considered too fast to be the additional mass in the halos of galaxies. The first candidate for the missing mass in halos of galaxies in Longair's list (1996) [11] is interstellar planets. If so, the missing mass consists of baryons, i.e., stars too small to ignite nuclear reaction within their core or brown dwarfs [12] or interstellar planets. Interstellar planets are also called free-floating planets or Jupiters or orphan Jupiters, and together with brown dwarfs are nicknamed MACHOs (Massive Astronomical Compact Halo Objects).

However, there are claims against the missing mass consisting of baryons, stating that the appropriate conditions to create baryons, which are known, lasted after the big bang during too short a time to enable the formation of so many baryons necessary to explain the missing mass. Raine and Thomas (2001) [13] mention research in nucleosynthesis after the big bang that found an upper limit on the amount of baryonic matter in the universe. They interpret this as meaning that most of the missing mass in the universe cannot be baryons and thus do not form atoms.

This missing mass is called dark matter. Its *assumed* features include:

- (i) It does not radiate light.
- (ii) It is attracted only gravitationally.
- (iii) They are neither neutrinos, nor photons, nor baryons.
- (iv) They could have been created during the limited time after the big bang.

1.3. Some other possibilities of dark matter

A few other possibilities were suggested. We mention a few:

- (i) Massive gravitational field: Xu and Wu (1997) [14] pointed out the similarity between properties of the dark matter and the gravitational field.
- (ii) Cooperstock and Tieu [15] [16] [17] [18], Cooperstock [19] and Cooperstock and Carrick [20] suggest that small relativistic effects accumulated during milliars of years yield the rotation curves observed in galaxies, as well as the observations of the high velocities of galaxies in their clusters.
- (iii) Recently, dark galaxies were detected near a quasar, presumably visible by reflecting the bright light of the close quasar (Cantalupo et al. [21]). These dark galaxies are made of gas [21], that is baryons. Ben-Amots [22] claims that it is reasonable to assume that such dark galaxies exist elsewhere in clusters of galaxies, but although they are able to reflect light, most of these dark galaxies are not near bright quasars and cannot *yet* be detected by astronomical observations.

These dark galaxies may be a significant fraction of the missing mass in *clusters* of galaxies [22]. Zwicky (1933 [8], 1937 [9]) first pointed out the missing mass in the Coma galaxy cluster.

- (iv) Recently, it was mentioned that extremely low-dense plasma of one electron or less in one cm^3 is fully transparent [23].
- (v) The 90 milliard years age of the universe after the Cosmic Microwave Background radiation (CMB) that Ben-Amots [22] found in his section 8-10-6 might allow sufficient time for the creation of additional huge amounts of baryonic dark matter in the form of dark galaxies, in addition to Jupiters in the halo around the galaxies. This result follows Ben-Amots's [24] [22] and chap. 11 in [25] derivation of a modified non-linear special relativistic Hubble law as follows:

1.4. *Contradictions in the accepted theories of expansion of the universe*

- The accepted definition of the Hubble constant is:

$$H(t) = \frac{[dA(t)/dt]}{A(t)} \quad (1)$$

where A is the expansion factor of the universe, t is the time and H is the Hubble constant. In this definition $H(t)$ is *not* constant in time. $A(t)$ is not constant in time, and is called the Hubble parameter, where the Hubble constant now is the Hubble parameter (at $t = 0$). If so, each small part of the universe, must *instantaneously* know by measuring or receiving information the value of $A(t)$, which may represent a very large value, up to the order of the radius or dimensions of the universe. This implies propagation velocity of information of $(universe's\ dimension)/(zero\ time)$, that is an infinite velocity of propagation of information. This is in contrast to the limitation of special relativity that the propagation velocity of information is always less than, or at most, equal to the velocity of light c . This is the crucial disadvantage of the accepted definition of Hubble constant (1).

Considering $A(t)$ as a parameter uniform over the entire universe while being time-dependent raises the question of how it instantaneously propagates over the entire universe to be evenly uniform. Such a propagation needs an infinite velocity, much larger than the speed of light c , which is again a crucial disadvantage.

The *linear* Hubble law

$$v = Hr \quad (2)$$

where v is the recession velocity and r is the distance implies definition of Hubble constant:

$$H = v/r \quad (3)$$

that also implies infinite velocity of propagation of the same information, that is the same crucial disadvantage.

- Based on Einstein equations, Alexander Friedmann (1922 [26], 1924 [27]) obtained the following equation (4), named after him as the relativistic Friedmann equation (See, i.e., [28], [29], [30] and in Section 7 of [31])

$$\left[\frac{(dA/dt)}{A} \right]^2 = \frac{8\pi G}{3c^2} u(t) - \frac{kc^2}{r_{c,0}^2} \frac{1}{[A(t)]^2} + \frac{\Lambda}{3} \quad (4)$$

where $A(t)$ is a time dependent parameter uniform over the entire universe, representing the "radius" or dimension of the universe, and $u(t)$ represents the time dependent energy density of the universe.

The accepted belief at present is that the Friedmann Equation (4) governs the expansion of the universe.

Einstein's equations are associated with the principle of equivalence, which is *local*. Therefore, the Friedmann Equation should be *local*. However, $A(t)$ and $u(t)$ in (4) are considered as local, but no explanation is given as to how these time dependent parameters can be uniform over the entire universe at all times. This again implies propagation velocity of information of (*universe's dimension*)/(zero time), that is an infinite velocity of propagation of information. This is again in contrast to the limitation of special relativity that the propagation velocity of information is always less than, or at most, equal to the speed of light c .

Furthermore, Hubble parameter A in (4) is taken from Formula (1) above, although Formula (1) has the same problem.

Friedmann's Equation (4) shows the dependence on instantaneous knowledge of the extremely large "radius" or dimension of the universe, and on $u(t)$ representing *non-local* energy density, and *instantaneous knowledge* of this information from the edge of the

universe. This contradicts the basis of Friedmann's Equation, which is based on Einstein's equations that are *local*, and also contradict special relativity that does not allow velocity faster than the speed of light c . Therefore, Friedmann's Equation is not valid for extremely large distances. Therefore Friedmann's Equation is inappropriate to describe the expansion of the universe.

- Robertson [32], [33], [34] and Walker [35] derived an expanding space represented by the line element:

$$ds^2 = c^2 dt^2 - A^2(t) \left[\frac{dr^2}{1 - k r^2} + r^2 (d\theta^2 + \sin^2 \theta d\phi^2) \right] \quad (5)$$

which is time dependent, where k equal to -1 or zero or +1, and $A(t)$ is a time dependent "universal" parameter representing the "radius" of the universe.

Like the Friedmann equation (4) it depends on the extremely large *non-local* radius of the universe or a parameter representing this extremely large non-local radius. This depends on *instantaneous knowledge* of this extremely large non-local radius. This also necessitates propagation of information much faster than the speed of light c , thus violating special relativity as well.

Therefore, the Robertson-Walker space, like the Friedmann equation, is also unqualified for extremely large distances.

1.5. Ben-Amots's theory of expansion of the universe

- Ben-Amots [22] defined Hubble constant as follows:

$$H = \frac{\frac{v(r+\Delta r) - v(r)}{1 - v(r+\Delta r)v(r)/c^2}}{\Delta r} \quad (6)$$

where c is the velocity of light in vacuum.

The information necessary to be known for definition (6) is the velocities at the edges of the *local* Δr and the value of Δr , where Δr may be infinitely small but not zero.

Equation (6) can be written [24]

$$H \Delta r = \frac{v(r + \Delta r) - v(r)}{1 - v(r + \Delta r)v(r)/c^2} \quad (7)$$

Going to infinitesimal $\Delta r \rightarrow dr$

$$H dr = \frac{dv}{1 - v^2/c^2} \quad (8)$$

that on integration leads to the special-relativistic *non-linear* Hubble law:

$$v(r) = c \tanh \frac{Hr}{c} \quad (9)$$

See Figure 1.

The integration assumes that at the same time the independent definition (6) of a *fixed* Hubble constant H is valid everywhere and any time, and independent of energy density that may vary in time. In this definition of Hubble constant (6), r is not written explicitly, but as Δr , and all the information is *local*. Therefore, according to Ben-Amots's [24] definition of Hubble constant (6), it does not impose a demand of infinite propagation of velocity of information. The *linear* definition $H = dv/dr$, leads to (3) and to the linear Hubble law $v = Hr$ (2). Comparing it to the modified definition (8), $H = dv/dr$ is actually (8) without the relativistic term $-v^2/c^2$ in the denominator. Therefore, the linear Hubble law (2) is eventually *Newtonian*, thus disregarding the *special relativistic* addition of velocities:

$$v = \frac{v_1 + v_2}{1 + v_1 v_2 / c^2} \quad (10)$$

In conclusion, the accepted definition of Hubble constant (1) *allows it to be variable in time*. Instead, Ben-Amots [22] [24] used the special relativistic addition law (10) to define a *constant in time and space* Hubble constant (6) and obtained a modified *special-relativistic* non-linear Hubble law (9) [22] [24].

See also [36], [37] and [38]. They obtained the same relativistic non-linear Hubble law (9) as well.

Solving r from (9) one gets

$$r = \frac{c}{H} \operatorname{arctanh} \frac{v}{c} \quad (11)$$

that is, the distance r of a remote point *can* approach infinity. See Figure 2.

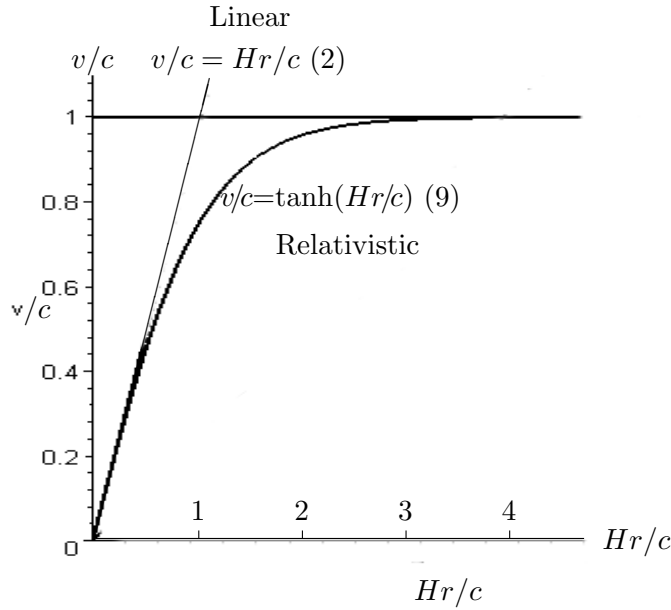


Figure 1. Comparing the linear Hubble law (2) with the relativistic non-linear Hubble law (9) in *velocity versus distance* graph. The velocity is normalized to v/c . The distance is normalized to Hr/c

- Using the special-relativistic non-linear Hubble law (9), Ben-Amots [22] obtained:

$$dt = \frac{dr}{c \tanh \frac{Hr}{c}} \quad (12)$$

Integrating

$$t = \int \frac{dr}{c \tanh \frac{Hr}{c}} \quad (13)$$

Because $\tanh \frac{Hr}{c} < 1$, one gets $1/\tanh \frac{Hr}{c} > 1$.

Integrating (13) Ben-Amots [22] obtained the non-linear expression

$$t = \frac{1}{H} \left[\ln \left(\sinh \frac{Hr}{c} \right) \right] \quad (14)$$

from which he got infinite $t|_0^R = t|_R^\infty = \infty$, that is the infinite age T of the universe, (past or future).

Solving r from (14) gives

$$r = \frac{c}{H} \operatorname{arcsinh}[\exp(Ht)] \quad (15)$$

See Figure 3.

Going backwards in time on the erroneous tilted straight line (Figure 3) leads to the singularity nicknamed "big bang." The straight line represents linear expansion of the universe. However, we explained above that linear expansion of the universe necessitates instantaneous propagation of information across the entire universe, which is much faster than the speed of light c .

However, a velocity faster than the speed of light c is impossible because it violates special relativity. Thus the "big bang" is a misinterpretation because it violates special relativity. Going backwards Friedmann's expansion is somewhat curved (not shown in Figure 3) and leads to another "big bang," but violates special relativity as well.

- Substituting the special-relativistic non-linear Hubble law (9) in the non-linear formula (16) for the redshift z of special relativity [39] [40]

$$z = \sqrt{\frac{c+v}{c-v}} - 1 \quad (16)$$

Ben-Amots [22] obtained

$$z = \sqrt{\frac{1 + \tanh(Hr/c)}{1 - \tanh(Hr/c)}} - 1 \quad (17)$$

or:

$$z = \exp\left(\frac{Hr}{c}\right) - 1 \quad (18)$$

from which he got the simple non-linear expression:

$$r = \frac{c}{H} \ln(z + 1) \quad (19)$$

Calculating the age of the universe since the CMB ($z=1089$) Ben-Amots obtained 90.8 milliard years [22]. See figures 3 and 4 below and Figure 5 in chapter 8 of [22]. The time *before* the CMB lasted much longer, enabling the production of sufficient baryons to be the major portion of the so-called dark matter.

- The relativistic non-linear expansion of the universe also means that in the far past the celestial bodies were closer to each other and fainter than expected. This is because their distances are larger than it was believed. These two effects were already observed for

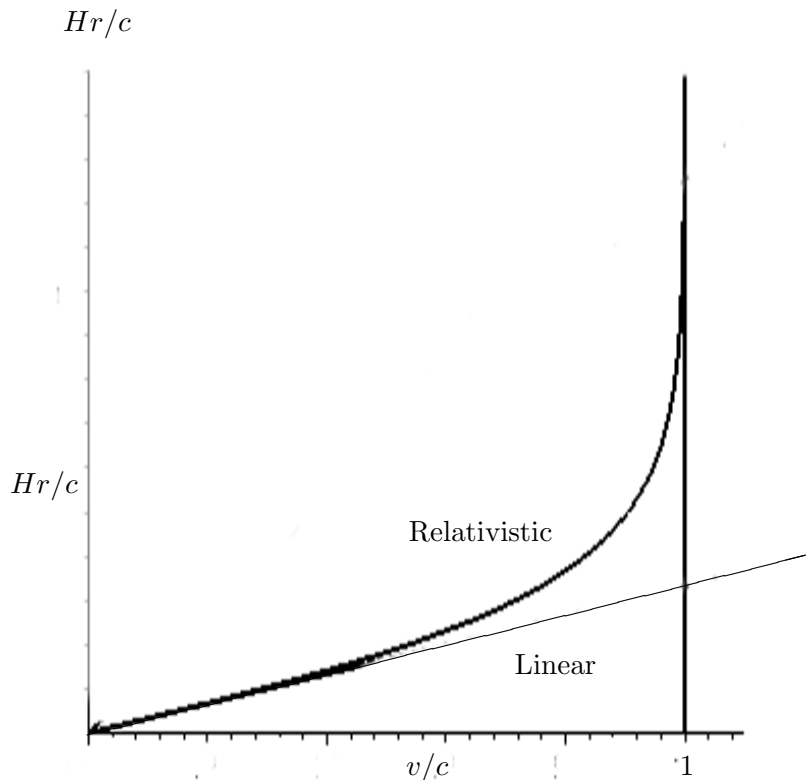


Figure 2. Comparing the linear Hubble law (2) with the relativistic non-linear Hubble law (9) in *distance versus velocity* graph. The velocity is normalized to v/c . The distance is normalized to Hr/c

remote galaxies, but were erroneously attributed to dark energy [22]. See also additional details in Chapter 8 of [22], Section 10.7.

- Reddish (1967) [42] deduced an explanation that fits the observations in *his* table 3: "... the formation of the galaxies has been going on for 10^{11} years. ...and have continued to do so at a declining rate, ..." and "the universe is expanding more quickly now than in the past..."

1.6. Additional possibilities suggested by Ben-Amots

- Zero-spin zero-electric-charge baryons:

Ben-Amots (chapter 5 in [22]) suggested twenty baryons that may have a spin of half *or* zero, nine of which have a zero electric charge (Figure 5). These nine zero-spin zero-electric-charge baryons may be constituents of dark matter. This is besides the other 36 baryons that may also have a zero spin. The baryon **UDS** (**u**p, **d**own,

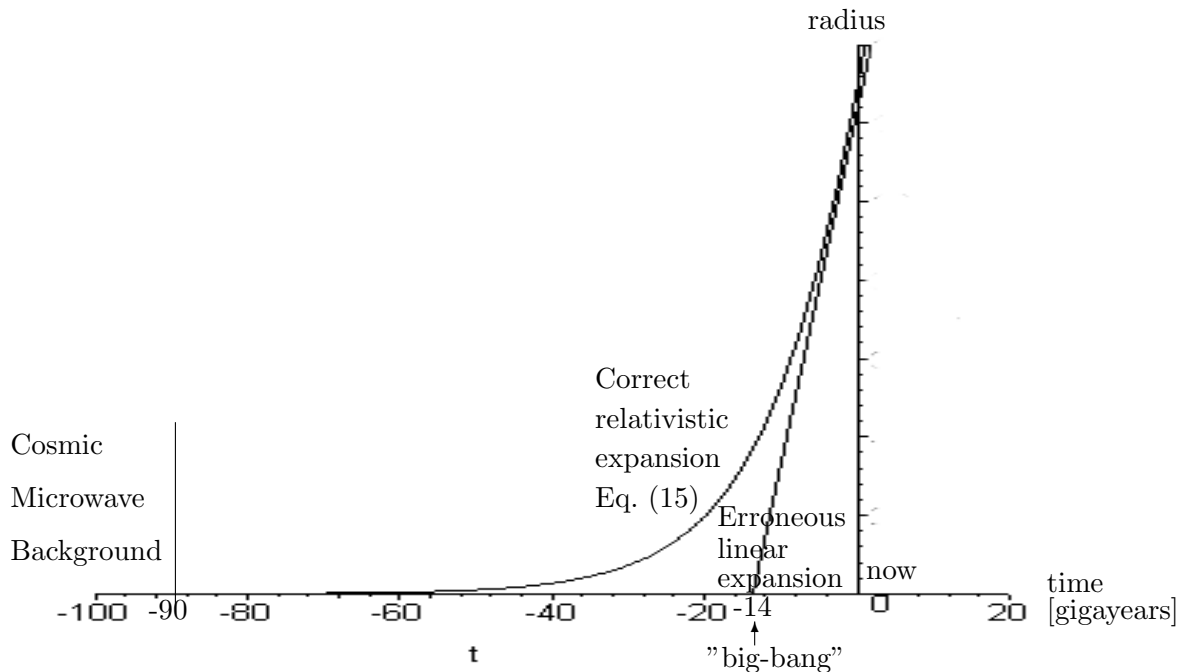


Figure 3. The history of the expansion of the Universe (schematic, according to Eq. (15)). The linear tilted line represents the expansion of the universe according to the linear Hubble Law $v = Hr$ (2). At -14 milliard years the intersection of the linear tilted line with the axis of time is a singularity nicknamed "big-bang". The curved line represents the expansion of the universe according to the correct non-linear relativistic Hubble Law $v = c \tanh(Hr/c)$ (9).

strange) is expected to be the most abundant among the twenty baryons with a zero spin [22]. The baryon **UDS** particle with spin $\frac{1}{2}$ is designated as the known *fermion* Λ^0 . It is unstable, and decays by the weak process with life time of about 2.6×10^{-10} seconds. Ref. [22] suggested additional **UDS bosonic baryon** particle with *zero spin* that *if stable* may be a portion of the so-called dark matter.

Here we suggest that a similar *zero-spin version of the neutron* (Figure 5) may be the most abundant among the other 36 baryons, nine of which also have a zero electric charge.

Here we also suggest that with zero spin and zero electric charge such baryons are *bosons* [41] that let photons, which are bosons, to pass through them as if they were transparent to photons. They may possess the features of dark matter provided that they are stable in cold temperatures, which is unknown.

- (vi) Ben-Amots [22] pointed out yet another possibility: In his section 8-10-6 his derivation showed that the age of the universe after CMB is 90 milliard years (see above). The time *before* CMB lasted much longer

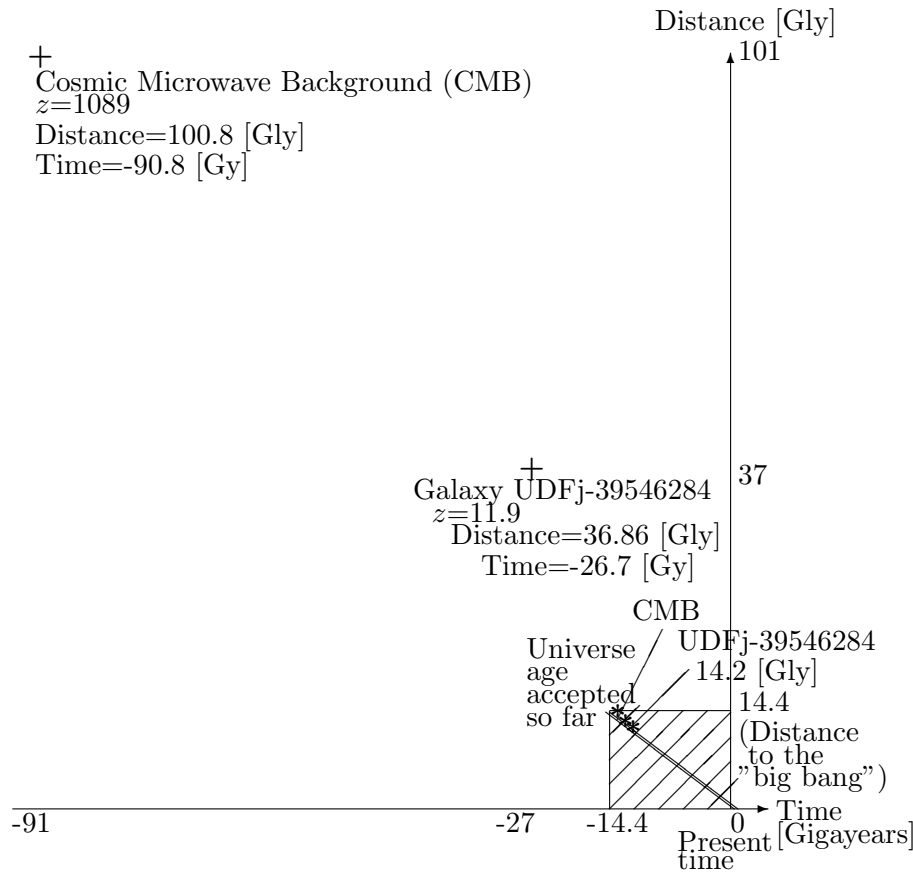


Figure 4. The time-distance of some events according to the linear expansion theory (*) and Ben-Amots's corrected theory (+). In Ben-Amots's theory the age of the universe *and* the distance to the big bang are increased from the values accepted so far to infinity. The tilted line shows the now *observable* values of the distances and age of the universe and other events according to the linear expansion assumption. The hashed area except the tilted line represents points before or after the time that events can be observed now according to the linear expansion assumption. Gly = Giga Light Years.

Note to Figure 4: The distance to the big bang according to the linear expansion universe is $r = c/H \approx 14.4\text{Gly}$. The distance to the big bang according to the Friedmann equation (calibrated) is larger. This distance according to [36] is larger: $r = \pi c/2H \approx 22.6\text{Gly}$. Each of these three occupies only a small part of the schematic description of the spacetime in Figure 4. The spacetime in Figure 4 considers the non-linear definition (16) of z , but the other three do not consider this non-linearity.

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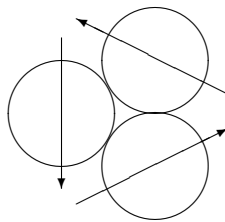


Figure 5. A baryon with zero total spin: In this configuration the resultant spin vector of the three half-spin quarks is zero [22]

(not shown in Figure 3), meaning that there is a much longer and sufficient time to create as many baryons as necessary to explain all the missing mass. These baryons might exist in the large necessary number of low-radiating orphan Jupiters, brown dwarfs [12] and dark galaxies [21], which may be a major constituent of dark matter within halos of all galaxies and of all the clusters of galaxies in the space between galaxies.

The non-linear special-relativistic Hubble law (9) [22] [24] enables this by invalidating the main claim against baryonic dark matter and greatly extending the age of the universe. This allows the universe to produce many more baryons than possible during the limited time after the so called the big bang. This is a paradigm shift compared to the big bang paradigm accepted at present.

- (vii) Ben-Amots ([43] and chapter 10 in [22]) analytically calculated the thick accretion disk around a central mass. In Section 3.1 we suggest that this thick accretion disk, after the ^1H was accreted and was exhausted, and after the remaining ^4He atoms have been cooled, the ^4He atoms might become the transparent halo around a galaxy or a cluster of galaxies, that is the so-called dark matter.

1.7. Additional possibilities of dark matter

The new trend in observational astronomy is infrared space telescopes that will capture images less distorted by obscuring dust in space. However, Jupiter-like bodies may emit very far infrared radiation that might be discovered by these infrared space telescopes in the future. If so, by this method we may discover a major constituent of today's unseen dark matter. In addition, Jupiter-like bodies and other non-exotic constituents of dark

matter may exist around most of the galaxies and galaxy clusters. This may contribute to the missing mass, but with little or no sufficient contribution to the infrared radiation, particularly when nobody suspects that this small radiation exists there.

Summing up the dark matter issue up to now, there was sufficient time for creation of the necessary amount of baryons [22]. Therefore, sufficient Jupiters, brown dwarfs [12] and dark galaxies [21] may exist and explain the astronomical observations without suggested non-baryonic dark matter particles, by being a significant constituent of the missing mass, but not necessarily the only one.

For *other*, non-baryonic suggestions the interested reader can see the detailed review [44] and references therein.

1.8. Sphericity of the halo of dark matter

It is accepted that the halo of dark matter around a galaxy is *spherical*, not like the luminous matter of a spiral galaxy, which takes the shape of a disk. We also accept this.

The accepted assumption to explain the sphericity of the dark matter, is that the *pressure* of the dark matter, together with its gravitational attraction, causes it to converge to a *sphere*, because the pressure opposes the gravitational attraction. On the other hand, the luminous matter is rotating, so that its *angular momentum* prevents it from falling to the center of the galaxy, causing it to converge to a *disk*. For this explanation to be valid, the dark matter must lack rotation. Because nothing is known about the dark matter, an assumption that its rotation is zero follows. All these accepted assumptions determine the feature of the sought-for particles assumed to be part of the dark matter, that is, particles that exert pressure.

However, there are types of rotations where the total angular momentum is indeed zero, but each particle conserves its own angular momentum of its orbital motion. A few famous examples are:

- Regarding the motion of stars in *elliptical* galaxies. Unlike in spiral galaxies, the stars in elliptical galaxies do not share the same direction of rotation, although each star conserves its own angular momentum of its orbital motion. In other words, the planes of the orbits of the stars

are not parallel to each other. All these planes pass through the center of the galaxy, thus the planes intersect through each other. These stars do not collide because of the vast distances between the stars, even in the rare case of collision between galaxies or galaxy clusters.

- Regarding the motion of galaxies in *clusters* of galaxies. The galaxies do not share the same direction of orbital motion, although each galaxy conserves its own angular momentum of its orbital motion. In other words, the planes of the orbits of the galaxies are not parallel to each other. All these planes pass through the center of the cluster, thus the planes intersect through each other. Because of the vast distances between the galaxies they rarely collide. In the rare cases of collision between galaxy clusters, the galaxies do not collide because of the vast distances between the galaxies.
- Likewise, globular clusters orbit around the spiral and elliptical galaxies. Each globular cluster conserves its own angular momentum, although the directions of rotation of the globular clusters around the centers of the galaxies are *different* for each globular cluster.

Unlike in these examples, in clouds of *usual* particles, a rotation of the particles in a different orbital direction for each particle should cause collisions between the particles, that would result in pressure, as is the accepted assumption for the dark matter.

However, dark matter is *collisionless*. Each particle of the dark matter has its own orbit, not in the same direction of the rotation orbits of other particles. Being collisionless, when particles of dark matter "collide," they pass through each other without any friction whatsoever, like the way photons pass through each other. Photons and particles of dark matter are *transparent* to each other. This way the particles of dark matter are able to make a spherical halo. The features of sought for particles of dark matter should fit the demand for transparency. Therefore, particles of dark matter:

- Cannot exert pressure, and apparently they are *bosons*.
- Their motion is in chaotic directions of rotation around the center of a galaxy or galaxy cluster.
- Each particle conserves its own angular momentum of its orbital motion around the center of the galaxy or galaxy cluster.

In this article, we use these features of the dark matter. See more details in Section 4 about the evolution that led to this type of rotation.

2. Helium as invisible matter

Section 2.1 discusses ^4He as possible transparent matter. Section 2.2 discusses whether ^4He may be a major portion of the invisible matter. Section 2.3 is about the absorption lines of ^4He . Section 2.4 explains and discusses the Lyman forest absorption lines issue.

2.1. Transparent matter

Still, a question remains: Is there a matter *transparent* to everything including photons, that possesses mass that attracts other masses, that is it obeys gravitation but not other forces? If so, it is what is called dark matter, but its correct name should be transparent matter, invisible matter or non-shining matter.

Many researchers called it dark matter, even long before Zwicky [8]. See [44]. However, Finzi [10] and a few others called it invisible matter. Many other expressions were used as well [44]. See a few examples in Table 1. Recently a few scientific journalists as well as responding readers mentioned transparency in the context of dark matter.

Let us look at the properties of *helium*.

The nuclei of ^4He atoms are called alpha particles. They behave like any particle during collisions. So are ^4He atoms. In the following discussion, we exclude ^3He and ^4He atoms that lost only one electron. Both ^4He atoms and ^4He nuclei apparently behave normally as an ideal gas at normal temperatures and at high temperatures respectively [45]. However, when ^4He is *ultracold* unexpected things occur. Below 2.1768 degrees Kelvin ^4He atoms become superfluid [46]. At these ultracold temperatures, ^4He atoms and ^4He nuclei behave like *bosons* [45] [41], exhibiting their *integer-spin* feature.

Bosons may be elementary particles like photons or composite particles like mesons [41]. Both types of particles possess an integer spin. Nuclei with an even number of nucleons are also bosons because their spin is an integer as well [41]. Boson nuclei include a deuterium nucleus and other nuclei with an even number of nucleons, including a ^4He nucleus that has four nucleons. ^4He atoms include six fermions and a zero electric charge.

Table 1. Partial selection of expressions describing dark matter before 1980

Expression	Author(s)	Year	Ref.
<u>Misleading expressions:</u>			
Dark mass	Secchi	1887	[47]
Dark structure	Ranyard	1894	[48]
Dark bodies	Kelvin	1904	[49]
Matiere obscure	Poincaré	1906	[50]
Dark matter	Poincaré	1906	[51]
Obscure stars	Poincaré	1911	[52]
	& Vergen		
Dark matter	Kapteyn	1922	[53]
Dark clouds	Lundmark	1930	[54]
Dark matter	Zwicky	1933	[8]
Dark matter	Zwicky	1933	[55]
Dark matter	Zwicky	1937	[9]
Dark material	Holmberg	1940	[56]
<u>Appropriate expressions:</u>			
Invisible stars	Bessel	1844	[57]
Unseen matter	Öpik	1915	[58]
Internebular material	Smith	1936	[59]
Clouds of low luminosity	Smith	1936	[59]
Internebular material	Hubble	1958	[60]
Invisible intergalactic material	Neyman et al.	1961	[61]
Invisible matter	Finzi	1963	[10]
Large amounts of undetected matter	Hodge	1966	[62]
Additional matter which is undetected	Freeman	1970	[63]
Low luminosity material	Rogstad & Shostak	1972	[64]
Hidden matter	Einasto	1974	[65]
Unseen matter	Einasto	1974	[65]
Large halo	Einasto	1974	[65]
Unrecognized massive population	Einasto	1974	[65]
Massive corona	Einasto	1974	[65]
Large amount of gas	Einasto	1974	[65]
Massive halo	Rubin et al.	1978	[66]
Invisible mass	Faber & Gallagher	1979	[67]
Nonluminous matter	Rubin et al.	1982	[7]

Therefore, due to their even number of fermions they are bosons as well [41]. Deuterium *atoms* are not bosons because they include three fermions.

Most photons pass through each other undisturbed (except for pair production of electron and positron in collisions of *very energetic* photons). Therefore most photons are transparent to most other photons. Is transparency to photons shared by other elementary bosons? Is this feature shared by composite bosons, particularly by ^4He atoms? If so, is this feature perfect, causing ^4He atoms to be *fully transparent*? Under what conditions? If so, are they transparent to photons, or to all elementary bosons, or to all the bosons including the composite bosons, particularly to other ^4He atoms? Or only to zero-spin bosonic atoms, including ^4He ? Maybe ^4He atoms are *almost transparent*? What are the implications in each case?

These questions will be discussed in Section 5. In this article, we will use our assumptions as answers to some of these questions.

We assume that photons, which are bosons, pass through single ^4He atom bosons as if the ^4He bosons are transparent. In other words, at *ultracold* temperatures ^4He behaves like photons, allowing photons to pass undisturbed through itself, like photons that usually allow other photons to pass undisturbed through themselves. We also assume that this quantum mechanical phenomenon is characteristic to all of the zero-electric-charge bosons, regardless of our limited ability to conceive this for *bosonic baryons*. This is a new paradigm. See also discussion in Section 5.

The bosonic behavior of ^4He is significant at very low temperatures of approximately 10 degrees Kelvin or below.

The average temperature of the surrounding space is known as approximately 2.725 degrees Kelvin, which is the average temperature of the CMB radiation [68]. When CMB photons collide with atoms in space, the temperature of the atoms gradually decreases and approaches the temperature of the CMB photons. However, at these cold temperatures, just 0.55 degree higher than the critical temperature of 2.1768 degrees Kelvin [46], ^4He is a boson [45]. It no longer responds to photons, but lets them pass undisturbed through itself.

We claim that this feature is exactly the desired property for the invisible matter: a particle with a mass that is transparent to radiation of photons and to collisions with particles of its own kind.

Furthermore, the temperature of the ^4He atoms in space decreases until it does not decrease anymore because the ^4He atoms already let the CMB photons pass undisturbed through themselves at a temperature somewhat larger than the CMB temperature. At this temperature, the ^4He atoms also let *any* photon pass through themselves undisturbed. Thus in the ultracold space the ^4He atoms may be transparent to any electromagnetic radiation.

Therefore, the ^4He bosonic gas may be the major portion of the missing transparent but massive so-called dark matter.

Transparent dark matter is a confusing expression. Therefore, the concept of dark matter was a misleading choice. It should be defined as *non-shining matter* or *invisible matter* in order to include the possibility of *transparent* matter.

2.2. Is helium part of the invisible matter?

Where is helium produced? An accepted process is the fusion of hydrogen nuclei in the core of stars. However, the rate of the production of ^4He by fusion in the core of stars is so slow that during the *assumed* age of the universe (which is accepted as approximately 14 milliard years) all the stars in the universe could not produce the amount of helium observed in the universe (Hoyle and Tayler 1964 [69]). Moreover, a significant portion of the helium produced in cores of stars is not dispersed, but is trapped in solitary helium white dwarfs because they neither explode nor disperse helium otherwise. The *assumed* solution is that most of the production of helium by the fusion of hydrogen nuclei occurred after the so-called big bang. However, the amount of the produced baryons after the so-called big bang seems to be limited [13]. This limitation *seems* to forbid baryons to be the dark matter [13]. However, no explanation is given as to how suggested alternatives of *assumed* non-baryonic dark matter particles with suggested names such as axions, ALPs (axion-like particles), charginos, cosmions, cosmic strings, d-star hexaquarks [70], darkinos, darkons, gluinos, gravitinos, higgsinos, monopoles, neutralinos, photinos, pyrgons, relaxions, saxions, sbottoms, selectrons, sleptons, sneutrinos, stauons, stops, winos, etc., (nicknamed WIMPs, that is Weakly Interacting Massive Particles), could be produced after the so-called big bang, because nothing is known about dark matter in the first place. Moreover, in spite

of extensive and sophisticated experimental searches during many years, not even one of any of these *assumed* particles was discovered [44].

Let us examine various possibilities in order to avoid this limitation of the big bang theory on the possible numbers of the existing baryons:

- (i) Margon (1980) [71] reported that the jets of the microquasar SS433 consists of hydrogen and *helium but no other components*. We suggest that ejecting *helium* in jets may occur in most of the other astronomical jets as well.
- (ii) Ben-Amots [22] [43] showed that quasars, active galactic nuclei and presumably other jet emitting celestial bodies *produce and expel* huge amounts of helium, either by jets or as enormous bubbles (called blobs [72]). The relevant processes are based on a theory that quasars and active galactic nuclei are not point-like black holes, but bodies with some dimensions, in spite of their enormous mass of up to millions of sun masses. This necessitates another paradigm shift, from black holes of general relativity to non-black-hole theory. See Ben-Amots [22], [73], [74], [75], [76], [24], [77], [43]. Collisions of black holes orbiting each other were already observed by LIGO [78] (Laser Interferometer Gravitational waves Observatory) and others. Such a collision is not possible between two point-like masses orbiting each other without contradicting the conservation of angular momentum, thus proving that black holes possess *physical radii*. The collisions show that these black holes possess *physical radii*. Otherwise a collision between pointlike bodies where the distance between them is zero necessitates circumferential velocity of the speed of light c in order to conserve the angular momentum. This would contradict special relativity that limits velocities of massive bodies to be smaller than the speed of light c .

The conservation of angular momentum

$$mvr = \frac{m_0vr}{(1 - v^2/c^2)^{\frac{1}{2}}} = \text{Constant} \quad (20)$$

Solving Eq. (20) for $v(r)$

$$v(r) = c \left[1 + \left(\frac{m_0rc}{\text{Constant}} \right)^2 \right]^{-\frac{1}{2}} \quad (21)$$

Collisions of pointlike bodies mean $r=0$ and consequently $v = c$ that

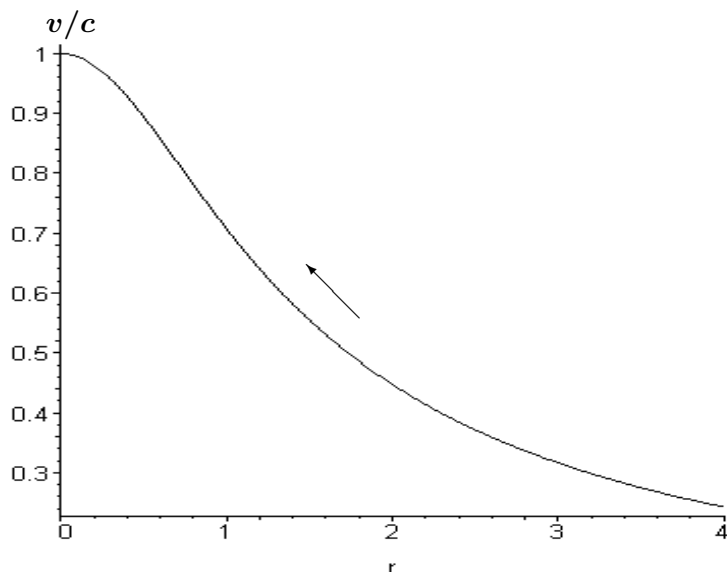


Figure 6. Circumferential velocity $v(r)$ (21) of two bodies orbiting each other and approaching towards a collision (schematic). The collision occurs when $r = r_1 + r_2$

is not allowed for massive bodies according to special relativity. See Fig. 6.

Therefore, a collision between two orbiting massive bodies means that they have a *physical* radius.

Indeed, the researchers of LIGO published the *physical radii* of the colliding "black holes," but did not mention that this is opposed to the prediction by general relativity that each of the black holes should have been imploded toward a pointlike singularity long before the collision.

- (iii) Ben-Amots (section 8-10-6 in [22]) calculated the age of the universe since the CMB as approximately 90 milliard years. This calculation shows that it is necessary to abandon the big bang theory. See details in [22], [24], chapter 11 in [25] and above in Section 1.6 in the introduction.

We claim that during 90 milliard years the quasars, active galactic nuclei and other jet emitting celestial bodies were capable of producing sufficient amounts of ^4He to explain its existence as approximately a quarter of the usual matter, and in addition as a major fraction of the transparent non-shining matter, erroneously called dark matter.

2.3. Absorption lines in the spectrum of helium

^4He absorption lines were discovered in the spectrum of the sun as early as 1868 [79]. See Figure 7. They also exist in the spectra of most stars,

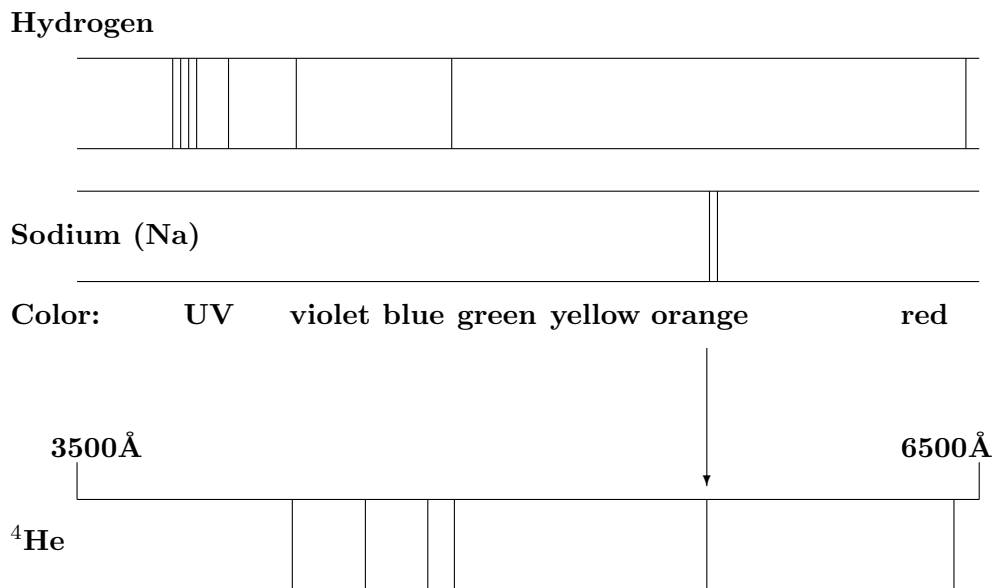


Figure 7. Absorption lines of hydrogen, sodium and ⁴He (schematic). The absorption line of helium marked with an arrow (this line was discovered in August and October 1868 [79] by Jules Janssen and separately by Norman Lockyer) is very close to the characteristic pair of absorption lines of sodium (Na) around 5890 Å, but has a somewhat shorter wavelength. Three other absorption lines of helium are close to three absorption lines of hydrogen. Strong absorption lines of hydrogen and sodium may mask these absorption lines of helium in a blurry or faint spectra. The UV (Ultra Violet) 584.33 Å, 537.03 Å and 304 Å absorption lines of helium are not shown here because they are too far to the left. Å denotes Angström = 10⁻¹⁰ meter

but the sun and stars are of course *not cold*. This means that the ultracold ⁴He in intergalactic space fails to absorb any light passing through itself. The missing absorption lines of ⁴He in space have a significant meaning: ⁴He is a *boson*. A cold ⁴He boson in space does not respond to photons, which are also bosons. Instead, the ultracold ⁴He in space is *transparent* to electromagnetic radiation and lets it pass undisturbed through itself.

According to the accepted belief, ⁴He should exist in intergalactic space at approximately a third of the amount of hydrogen in intergalactic space. However, we claim that cold ⁴He may exist in intergalactic space in a much larger amount than hydrogen. Actually, cold ⁴He bosons may be the most abundant element in intergalactic space, even many times more than the amount of hydrogen in the universe, and still not show any trace of itself in any observable spectrum.

This is exactly the feature of the long sought for so-called dark matter.

2.4. Helium in Lyman forest clouds

Examining the spectrum of each remote quasar one can see absorption lines of clouds of matter that exist along the milliards light years' line of sight. A typical spectrum of a quasar shows tens of Lyman groups of absorption lines, representing tens of clouds of hydrogen along the line of sight at different distances. Like the lines of spectra of galaxies, the absorption lines of an early hydrogen cloud are redshifted proportionally to the distance of the cloud from the Earth. These tens of redshifted Lyman groups of absorption lines of hydrogen clouds in every spectrum of a quasar are called Lyman forest, or Lyman α forest or Ly α forest. Before adopting these short names in the 1990's these absorption lines were called hydrogen Lyman alpha continuum of intergalactic matter at cosmological distances [80], a long name indeed.

There should also be tens of ^4He clouds along the milliards light years' line of sight for each of the quasars. However, the expected absorption lines of ^4He are not there. They are *missing* in the spectra of *most* quasars. What is the reason for this?

The Lyman forest is associated with hydrogen clouds on the line of sight to the quasars. Spectra of elements other than hydrogen were not detected in *most* of the hydrogen clouds. The accepted reasons are:

- (i) The Lyman forest of *most* quasars has hydrogen Lyman groups of tens of clouds with tens of redshifts that mask the spectra of all other elements.
- (ii) Technical limitations of observation equipment in space observatories prevent the detection of absorption lines of spectra in relatively close Lyman forest clouds of $z < 1$. The remote clouds available for observations are in the line of sight to even farther quasars. The remote quasars of course look fainter, thus blurring faint absorption lines.

However, the quasar HS1700+6416 is very bright and sufficiently far away ($z=2.72$) and its Lyman forest is just seven clouds on the line of sight to it. This enabled detection of absorption lines of non-hydrogen elements, including atoms of *helium*, in all of these seven clouds [80], [81]. These papers concluded that the small amounts of helium that they detected [80] in these Lyman forest clouds cannot be the dark matter.

Our explanation is that the Lyman forest clouds are *not cold*, so that their helium atoms may absorb photons.

Intergalactic Lyman forest clouds are abundant, but their total volume and mass are a tiny portion of the volume and mass of the dark matter in the intergalactic space and the universe.

^4He intergalactic *clouds* are discussed in Section 3.2 below.

3. Helium in observed celestial bodies

Section 3.1 points out the possibility that ^4He is the invisible matter or a major constituent of it in halos of galaxies, galaxy clusters and galaxy superclusters. Section 3.2 discusses the possibility of intergalactic clouds consisting of only cold ^4He . Section 3.3 suggests the existence of cold ^4He in *voids* in space. Section 3.4 explains the role of ^4He as the invisible matter in collisions between galaxies and in collisions between galaxy clusters as well. Section 3.5 deals with the coexistence of invisible matter and usual or plasma matter. Section 3.6 describes the production of the invisible matter.

3.1. Helium in halos

^4He atoms in intergalactic space between galaxy clusters and around them and in interstellar space in the halos of the galaxies, galaxy clusters and galaxy superclusters *are cold* and behave as *bosons*, thus allowing photons to pass undisturbed through them. They may be a significant portion of the so-called dark matter in the universe.

Still, a question arises: If ^4He atoms are the cold matter in *halos* around galaxies, galaxy clusters and galaxy superclusters they are attracted gravitationally to them like other atoms. What prevents them from accreting toward the centers of galaxies and galaxy clusters like the usual matter does in earlier stages of accretion disks during the formation of the galaxies and galaxy clusters?

The *usual matter* in accretion disks accretes to the central attracting masses *very slowly*, because it must first lose its kinetic energy and angular momentum by friction or viscosity that converts the kinetic energy into electromagnetic radiation [43] [22]. However, ultracold ^4He *cannot* lose kinetic energy or angular momentum for a few reasons:

- (i) Atoms of *cold* ^4He gas or liquid are *bosons*, and as such, they pass through each other and are *transparent to each other*. They are *not dissipative*. No friction or viscosity is available for them to decrease their kinetic energy and angular momentum.

- (ii) Ultracold helium *liquid* below the critical temperature of 2.1768 degrees Kelvin is *superfluid* without any dissipation, viscosity or friction whatsoever. No friction or viscosity is available to decrease the kinetic energy and angular momentum of the rotation of superfluid.
- (iii) Therefore, accretion disks of cold ^4He are orbiting around the central massive body in quasi-spherical halos *without losing their energy and angular momentum*.
- (iv) Dissipative dark matter would need an energy source to be stabilized in halos [82], otherwise the halos would accrete to the center of the galaxy or the galaxy cluster. However, since ultracold bosonic ^4He is *not dissipative*, it does not need a source of energy to be stable while orbiting in halos of galaxies and galaxy clusters. In this way the ultracold ^4He atoms are *stable in their orbits in the halos* and contribute only their mass and angular momentum to galaxies and clusters of galaxies, but no other properties. See Section 1.8 in the introduction to this article.
- (v) Moreover, gravitational tidal forces cause the massive matter that orbits in the halos to gain energy and angular momentum from the inner usual matter of the galaxy that orbits closer to the center of the galaxy. This *increases the distance of the halo* from the center of the galaxy. This effect is small because the halo is much more massive than the mass of the stellar inner parts of the galaxy. The influence of the gravitational tidal forces would be masked by the dissipation in the halo if dissipation existed in the halo. However, because ultracold ^4He is *not dissipative*, no dissipation exists in the halo. Thus the small gravitational tidal effect can accumulate during milliards of years and be significant, *increase* the distance of the halo from the center of the galaxy and *decrease* the distance of the usual matter from the center of the galaxy. Therefore it contributes to the *separation* between the halo and the inner parts of the galaxy. See a more detailed explanation in section 4 below.

Therefore, ultracold baryonic bosonic cold ^4He atoms as suggested in this article, (and perhaps also zero-spin zero-electric-charge baryons as suggested in chapter 5 of [22] and in Section 1.6 in the introduction above) are transparent to electromagnetic radiation. They also *cannot accrete* to galaxies and galaxy clusters like usual matter. As such they are *stable*

in their orbits in the halos, but not detectable by any electromagnetic radiation, even when they are very abundant. Therefore, the cold ${}^4\text{He}$ atom is the preferred candidate to be the so-called dark matter in the halos.

3.2. Cold clouds of helium

Are there intergalactic clouds consisting of cold ${}^4\text{He}$ alone? We find no reason why not. If so, cold ${}^4\text{He}$ clouds should be on the line of sight to remote quasars. However, their transparency leaves no absorption line traces as hydrogen Lyman forest absorption lines.

The strong gravitational attraction of large galaxies, galaxy clusters and galaxy superclusters bends the light that passes near them. In some cases, it produces Einstein rings [83], or double or multiple images of remote bright bodies like quasars. These phenomena are called gravitational lensing [84], which is attributed to Einstein, who was the first to calculate them. In many cases, the attracting galaxy or galaxy cluster is observed between the multiple images of the remote quasar [84].

However, in some cases, *nothing is seen* between the multiple images of the remote quasar. A suggested explanation for these cases attributed the gravitational lensing to unseen black holes, only because no other known phenomena could explain the lack of observation of the attracting mass between the multiple images.

Here we claim that the missing attracting mass may be a huge cloud consisting of only cold transparent bosonic ${}^4\text{He}$ gas. Such a cold ${}^4\text{He}$ cloud is *not accreting* because its *boson* ${}^4\text{He}$ particles pass through each other without any friction or viscosity, so that they are *not dissipative* and cannot get rid of their kinetic energy and angular momentum as is necessary for accretion. Therefore, such transparent cold ${}^4\text{He}$ clouds are *stable* and may be abundant and exist in many more cases than in those cases that are observed as gravitational lensing.

The lack of observed attracting mass between these multiple images of remote quasars may serve as proof of the existence of massive transparent cold ${}^4\text{He}$ clouds in intergalactic space as a portion of the so-called dark matter.

3.3. Helium in voids in space

Jaan Einasto pointed out in 1977 [85] that galaxies, galaxy clusters and galaxy superclusters are arranged in huge sheets surrounding what resembles empty cells between the sheets. Others called them voids in space [86]. The list of the largest voids [87] includes 38 voids with diameters between 326 millions of light years up to the largest, KBC Void, whose diameter is two milliards of light years. (KBC is named after Keenan, Barger and Cowie [88], [89]). These voids may be 150 million up to two milliards of light years in diameter [87]. Boötes void (called also the Great Void) was reported first in 1981 [90]. Its diameter is 330 millions of light years [91].

The universe resembles bubbles of soap. A soap bubble universe was suggested with empty bubbles of 150 millions of light years in diameter and larger. Similar to soap bubbles in the foam, the cell structure is random. No galaxy or any visible matter was observed within most of these bubbles of soap voids. Moreover, these voids are *transparent* and do not obscure astronomical objects beyond them. Only sixty galaxies were discovered in Boötes void instead of much more [91]. This means an average distance of 85 millions of light years between any two galaxies in Boötes void. Astronomers wonder whether these voids represent an ultimate vacuum or any mysterious matter. Apparently, these voids in space occupy a major portion of the *volume* of the entire universe. However, it is not even known whether these voids consist of pure vacuum or include mass.

The galaxies, galaxy clusters and galaxy superclusters are arranged in chains in the sheets or walls of the cells [85].

Here we suggest that these voids in space may consist of ultracold transparent bosonic ^4He . As such, these voids are *massive* and perhaps even more massive than all the rest of the matter in the universe, including the so-called dark matter. Therefore, voids may consist of much more ultracold ^4He invisible matter than the transparent matter in halos of galaxies, galaxy clusters and galaxy superclusters. The possibility of dark matter in voids in space was mentioned by Marc Davis in the '80s (See [92]), Geller and Hwang (2015) [93], and others (1995) [94] [95]. Transparent bosonic *helium* in voids in space is another new paradigm.

3.4. Collisions of galaxies and galaxy clusters

This section is based on reference [96] about the observed Bullet Cluster collision. See also references therein.

Galaxies may collide. Our Milky Way galaxy and Andromeda galaxy are moving towards each other and are expected to collide approximately 5 milliards of years from now. Two collisions between galaxy clusters are observed. Each of the collisions shows a collision between two galaxy clusters.

It is accepted that the distances between the stars are large so that during a collision of galaxies or galaxy clusters, collisions of stars will be very rare, if at all. However *interstellar and intergalactic hydrogen gas* may collide and be slowed down and heated and emit electromagnetic radiation that can be observed. Stars *and invisible matter* are expected to pass through without collisions or heating. Observations of the Bullet Cluster collision exhibits heating of the colliding gas up to millions of degrees Kelvin that emits observed electromagnetic radiation [96]. The slowing of the colliding gas, but not the stars and not the invisible matter results in a separation between the decelerating gas on one hand, and the shining stars and galaxies, together with the invisible matter on the other hand. The shining stars and galaxies, together with the invisible matter are slowed down slightly by gravitational forces only. The heated gas lags behind the shining galaxies. The back and forth motion may last a half milliard years and more after the first collision. The Bullet Cluster is observed moving back 150 million years after the first collision [96].

We claim that ultracold bosonic ${}^4\text{He}$ invisible matter atoms of each galaxy or galaxy cluster pass undisturbed through the second galaxy or galaxy cluster without heating. This is because apparently, the ultracold bosonic ${}^4\text{He}$ atoms are transparent to electromagnetic radiation *and to any matter* as well. They would slow down and be stopped and move back only because of the gravitational attraction of the other invisible halo.

However, they may be detected by their gravitational lensing [96] [84] influence on the electromagnetic radiations of remote galaxies and quasars that are beyond them.

Gravitational lensing analysis [84] [96] of observed collisions may be a way to learn about the role of transparent bosonic ${}^4\text{He}$ halos in collisions between galaxies, and in collisions between galaxy clusters as well. The

gravitational lensing analysis in the Bullet Cluster collision shows that the invisible matter is attached to the shining galaxies, not to the gas that lags behind the galaxies [96].

This observation proves that the invisible matter is transparent not only to photons and invisible matter but also *transparent to the usual gas*, while the usual gas is *not transparent to usual gas*. Therefore, dark matter is considered to be *collisionless*.

3.5. Hot matter and cold matter that do not mix

Between the galaxies in galaxy clusters there exists plasma. Its temperature is measured by the bremsstrahlung radiation that the electrons emit when accelerating and decelerating near ions and nuclei. The amount of the plasma is in the order of the mass of the shining galaxies [3]. Together with the shining matter, this means much more baryonic mass than could be produced during the limited time after the so-called big-bang, but still, a much larger mass is missing [3]. This missing mass is attributed to the so-called dark matter. So, can hot plasma, or at least warm plasma, exist together with *ultracold* ^4He transparent matter?

The gravitational lens research found that the invisible matter is transparent to any matter, whether invisible or usual [96]. Thus ultracold ^4He is transparent to plasma, as well as to the hot gas of colliding galaxies and galaxy clusters. That is, once a ^4He atom becomes ultracold and transparent, it remains transparent forever, disconnects itself from any reaction other than gravitational and becomes oblivious to any influence other than gravitation.

One may look at the tail of the Gaussian distribution of the velocity of atoms. Inside the sun and stars, the fusion occurs between two *nuclei* whose relative velocity is at the *high* tail/edge of the Gaussian distribution of the energy/relative velocities. However, at the vast space, the ^4He *atoms* at the *low* tail/edge of the Gaussian distribution of the temperature become sufficiently ultracold to become transparent forever and stop contributing to the pressure of the usual matter or gas. Other ^4He atoms "fill" the missing low tail, after colliding with the CMB photons (that are about a million times more abundant than all the other photons in the space [3]), and then also become transparent forever and so on. They remain ultracold and transparent even in a warm or hot environment. We are used to the fact that when we put together hot matter and cold matter they mix and

reach an average temperature. The coexistence of mixed hot and ultracold components of matter at the same time and place while each component retains its own temperature surprises us.

Furthermore, in this way ^4He atoms, after being produced and dispersed by quasars and supermassive bodies in the centers of galaxies [43], became transparent very slowly but surely and accumulated during the ninety milliard of years since CMB [22] to become the missing mass of the invisible matter. This is another new paradigm that states that the usual ^4He matter preceded the invisible matter, and the invisible matter was and is produced from the usual ^4He matter.

At a rough glance, it seems to be an exception to the second law of thermodynamics. However, this follows other relevant exceptions to the second law of thermodynamics such as the tendency of bosons to crowd, and Bose-Einstein statistics. Therefore, it is not an exception to the second law of thermodynamics, but simply a phenomenon subjected to the different statistics of Bose-Einstein, in which fermion-like ^4He is cooled and transformed to bosonic ^4He that obeys the different Bose-Einstein statistics.

3.6 Production of bosonic ultracold ^4He

The CMB radiation is black body radiation. It has a peak at 2.725 degrees Kelvin, and two slopes at higher and lower temperatures. Therefore, the lower slope includes a certain portion of the photons of CMB radiation at a temperature of 2.1768 degrees Kelvin and lower. Collisions of these ultracold photons with ^4He atoms transform a portion of the ^4He atoms that were produced by quasars and AGNs [43] into bosons. Once these ^4He atoms become bosons, they are transparent to any additional "collisions" and thus remain bosons forever. This transformation of ^4He atoms into bosons happened during milliards of years since the so-called recombination at a slowly increasing pace. During milliards of years the CMB radiation slowly cooled because of the expansion of the universe. The production of invisible bosonic ultracold ^4He atoms (so-called "dark matter") by this transformation continues to slowly occur at the present time and will continue in the future.

4. Helium, tides and evolution of galaxies and the universe

There are many kinds of galaxies [62] and each of them had its own evolution. There are a few types of evolutions that are believed to be shared by many kinds of galaxies.

Elliptical galaxies are believed to be the products of collisions between galaxies. If so, the evolution of spiral galaxies occurred prior to the evolution of elliptical galaxies.

It is suspected that quasars preceded spiral galaxies.

Another factor is the gravitational tides. Increasing the energy of a body orbiting a central massive body increases its distance r from the central body, thus *decreases* its circumferential velocity. See a detailed explanation below. The known example is Earth's Moon [97]. Earth is rotating once a day, much faster than the orbiting of the Moon around it once a month. Therefore, the bulge of the tide on Earth exerts a gravitational force on the Moon. The bulge of the tide on the fast rotating Earth transfers energy and angular momentum to the slow orbiting Moon. The Moon responds by *increasing* its distance from the Earth, which *slows* its circumferential velocity around the Earth. The Earth is losing angular momentum and slows its rotation. However, if the Earth were not almost solid, losing angular momentum would result in *decreasing* the radius of the Earth, and *increasing* its rotational velocity.

The stars in the galaxy orbit with about the same circumferential velocity v [5], [6]. Their angular velocity is $\omega = v/r$. Therefore the stars that are farther from the center of the galaxy have a smaller angular velocity than the angular velocity of stars closer to the center of the galaxy. Therefore, the stars that are farther away lag behind the closer stars. The stars attract gravitationally to each other. Therefore, the force that these closer stars exert on the stars that are farther away tries to accelerate them. In this way, it is increasing their energy. The opposite force that the stars that are farther away exert on the closer stars tries to decelerate them. In this way, it is decreasing their energy. Increasing the energy of a body orbiting a central massive body increases its distance r from the central body. This decreases its circumferential velocity. Decreasing the energy of a body orbiting a central massive body decreases its distance r from the central body. This increases its circumferential velocity. The net result is increasing the radial distance between stars close to the central body and

stars that are far from the central body, as in the well-measured example above of the Moon. The bodies that are far away may be the particles so-called dark matter.

In a galaxy *without invisible matter*, the inner parts should rotate *faster* than the outer parts according to Kepler's laws and exert gravitational tide forces on the slower outer parts. Therefore, the outer parts would gain angular momentum, and *increase* their distance from the center of the galaxy and *decrease* their circumferential velocity. The inner parts would lose angular momentum, *decrease* their distance from the center of the galaxy and *increase* their circumferential velocity.

Now we may apply this to the massive halo around the galaxy. This means that the outer halo gains energy and angular momentum from the inner stellar parts of the galaxy, and *increases* its distance from the center of the galaxy. The inner stellar parts of the galaxy lose energy and angular momentum and *decrease* their distance from the center of the galaxy, while *increasing* the angular velocity in their orbits around the center of the galaxy. In this way gravitational tidal forces *increase the separation* between the halo and the inner stellar parts of the galaxy.

As explained in section 3.1 above, this gravitational tidal effect might be smaller than the effect of dissipation in the halo to *decrease* the distance of the halo from the center of the galaxy. However, the halo consists of cold bosonic ^4He that is *not dissipative*. This means that the effect of the gravitational tidal forces is *not opposed* by dissipation. Therefore it accumulates during milliards of years and *increases* the distance of the halo from the center of the galaxy.

All the galaxies, galaxy clusters and galaxy superclusters should share and obey these *laws of dynamics* of nature.

Keeping the above conclusions in mind, the possible role of ^4He and gravitational tides in the possible evolution of galaxies may be the following:

- (i) Assuming that starting the accretion with rotation at ultracold temperatures, ^4He is bosonic, while most of the other matter behaves as usual fermions. The ultracold bosonic ^4He is not dissipative and cannot lose angular momentum. Other elements, particularly ^1H hydrogen are dissipative and lose angular momentum and consequently decrease their distance from the center of the galaxy. Once the separation starts,

the gravitational tidal forces increase the separation further, resulting in a halo of bosonic transparent ^4He surrounding the inner matter that behaves like fermions. Furthermore, the ultracold ^4He bosonic atoms orbit in ellipses whose focuses are at the central attraction *point*, even if their previous orbits when they were warm were circles around the *axis* of rotation. This is because as ultracold bosons they pass freely through each other instead of colliding. Then these bosonic ultracold ^4He atoms create a *spherical* halo. This halo conserves the total previous energy, but does not conserve the *resultant total* previous angular momentum. However, the angular momentum of each ^4He atom is conserved *separately*. See Section 1.8 in the introduction for a description of this type of rotation. Apparently, this is the situation in most of the galaxies, galaxy clusters and galaxy superclusters.

- (ii) Assuming that the accretion starts at a normal temperature, ^4He and the other matter are dissipative, lose angular momentum and consequently decrease their distance from the center. However, *buoyancy* will cause the light ^1H hydrogen to *float* above the heavier helium, in spite of slow rotation. Therefore, the heavier ^4He *sinks* inwards towards the center. The result is an external *curved* layer of a hydrogen-helium mixture that surrounds a central part consisting of ^4He . This produces a *cell* of ^4He with a *curved shell* consisting of a mixture of hydrogen and ^4He surrounding the ^4He matter.
- (iii) Therefore, the evolution may be according to the following scenario:
 - The universe started out hot and later on became cooler.
 - When the universe was hot, ^4He behaved like usual matter. Most of the rest of the matter included ^1H hydrogen. At a hot temperature, *buoyancy* took over, causing possibility (ii) (above) to occur. The heavier ^4He sank to the center of what we call voids in space [86] [87] [85], while buoyancy caused the ^1H hydrogen to *float* to the *curved* borders between the voids. This also explains the *curved sheets* that are the walls of the voids in space. The production of the cell structure surrounding voids filled with ^4He is a new paradigm.
 - For example, the Boötes void is surrounded by a few galaxy superclusters including Draco-Hercules Supercluster, Hercules Supercluster, Corona-Borealis Supercluster and Boötes Supercluster [91].
 - Later when the temperature of the universe decreased, the cold ^4He

in the voids became bosonic, causing the voids to be *transparent*. Then possibility (i) occurred: the mixture of cold bosonic ^4He and cold non-bosonic hydrogen in the sheets at the borders between the voids started to produce spiral galaxies, galaxy clusters and galaxy superclusters with ^4He halos according to possibility (i). Then separation of ^4He and hydrogen occurred, which was enhanced by gravitational tidal forces. In this way the transparent cold bosonic ^4He atoms were left at the halos of the spiral galaxies, galaxy clusters and galaxy superclusters.

- Much later, the spiral galaxies in clusters of galaxies were separated from the halos of cold bosonic ^4He surrounding the galaxy clusters by gravitational *tidal* forces, which caused the spiral galaxies to *crowd together* toward the center of the galaxy cluster. This is because the tidal forces between the inner galaxies that orbit the center of the galaxy cluster and the invisible matter that orbits the center of the galaxy cluster in orbits with a larger radius, exert gravitational forces on each other, that increase the radial separation between them. This is similar to the same effect between stars and invisible matter as explained above. This crowding of the spiral galaxies caused *collisions* between the spiral galaxies, which produced merging to elliptical galaxies. Later on each collision between elliptical galaxies or between spiral galaxies and elliptical galaxies produced merger and larger elliptical galaxies near the centers of the galaxy clusters.
- The evolution according to this theory might have taken more than 14 milliard years. Ben-Amots's calculation [22] suggested an available time of 90 milliards of years.
- The explanations in this section may guide researchers as to how to simulate the evolution of galaxies, galaxy clusters, galaxy superclusters and the cell structure of the universe. Without prior understanding, the results of numerical simulations may yield only a partial understanding or even confirm misleading conceptions.
- The description above is not complete: 60 galaxies were discovered in Boötes void [91]. Also, more than 150 dense globular clusters of stars [98] exist in the halo of the Milky Way, and much more, up to 13,000 globular clusters in the halo of M87 galaxy [99] exist in the

halos of other galaxies.

As for the debate as to whether the universe evolved top-down or down-top, the scenario described in this section suggests hot-to-cold, top-down evolution that explains the observed *curved sheets* of galaxies, galaxy clusters and galaxy superclusters around what seems as spherical-like voids and empty cells in space, and a few other astronomical observations of galaxies as well.

The scenario described above assumed that the universe started out hot. We may further consider that then the fusion of hydrogen to ${}^4\text{He}$ produced energy that heated the matter more, causing the observed expansion of the universe.

5. Almost transparent helium

So far this article discussed the implications assuming that *ultracold* ${}^4\text{He}$ atoms are *fully transparent* to photons and to other ${}^4\text{He}$ atoms. This is an extrapolation of the bosonic feature of photons that let them pass undisturbed through other photons. Is this assumption justified regarding ultracold ${}^4\text{He}$ bosons?

The behavior of photons with photons is not identical to the behavior of bosonic nuclei with bosonic nuclei.

Elementary bosons tend to crowd together, but nuclei have negative electric charges that cause the nuclei to repel each other, thus overcoming the bosonic tendency to crowd together according to Bose-Einstein statistics [41].

Quantum tunneling [100] allows a charged nucleus to tunnel through a high barrier electric potential. The fusion processes in cores of stars use this feature. The quantum tunneling is *not* transparent. Only a small fraction of the particles is tunneling through the barrier potential [100]. Quantum tunneling exhibits the possibility of a particle to pass through a barrier potential despite our expectations. However, quantum tunneling is *not* appropriate to justify *full* transparency or almost full transparency of bosonic cold ${}^4\text{He}$ atoms, that we suggested in this article so far.

We point out other suggestions and facts in favor of transparency:

- In this article, we suggest ultracold zero-charge ${}^4\text{He}$ *atoms* as the so-called dark matter.

- Transparency is not a surprising phenomenon. Most gaseous materials are transparent to most of the frequencies of electromagnetic radiation except the frequencies characteristic of each element. Thus elements let photons pass through themselves undisturbed when the elements are not ready to absorb the photons. This resembles the well known classical phenomenon of resonance.
Apparently ultracold bosonic ^4He atoms are not ready to absorb electromagnetic radiation of any frequency, including the characteristic frequencies of ^4He (Figure 7). Also, they are not ready to respond to other ultracold bosonic ^4He atoms, so they let them pass through undisturbed as well.
- All sorts of matter are almost transparent to neutrinos, which have a zero electric charge, although the neutrinos are fermions with a half spin. However, neutrinos move with the velocity of light c . Therefore, they are too fast to constitute the dark matter.
- Macgregor [101] [102] [103] [104] explained why scattering exhibits a much smaller diameter of particles than the real diameter. This means that most of the *volume* of a particle behaves as if it is transparent.
- Marmet [105] interpreted redshifts as caused by non-Doppler linear scattering of photons by ground state hydrogen molecules, which are considered to be dark matter. Marmet also suggested [105] that the same scattering simultaneously produced a scattered long wave of low frequency. Unlike quantum tunneling, Marmet's scattering allows *almost full transparency* where the electromagnetic radiation passes through with a slight weakening by redshifting.
- Macgregor's and Marmet's suggestions regarding scattering when applied on ^4He may explain the *almost transparency* of bosonic ultracold ^4He atoms to electromagnetic radiation, as well as to an almost undisturbed passage of other bosonic ultracold ^4He atoms.
- The *almost transparency* of bosonic ultracold ^4He atoms makes them *very weakly* dissipative. Energy and angular momentum needs to be supplied to make dissipative dark matter in halos stable [82]. The small effect of the gravitational tidal forces as explained in the previous section 4 may be sufficient for this. The energy and angular momentum is taken from the motion of the usual matter in inner orbits, slowly decreasing its distance from the central mass (stars in galaxies, and

galaxies in galaxy clusters, respectively).

- Maybe ultracold ^4He atoms are not ready to absorb or respond to any radiation or boson or even a fermion, because at ultracold temperatures the affinity of the two electrons of cold ^4He atoms to form a stable pair is stronger than it is at higher temperatures. (The hydrogen atom is a boson, but apparently the affinity of proton and electron to create a transparent pair is weaker than the affinity of pairs with two identical particles as the electrons in a cold ^4He atom).
- Ref. [106] describes the isolating/trapping of a single atom by David Wineland. Observation of the single atom showed that it blinked, nullifying its light a few times in a second for about a tenth of a second. This is an experimental observation. The explanation (by prediction of Bohr in 1913) is that the electrons reach a situation where the atom cannot absorb light, causing the atom to become invisible [106]. Isolating one ^4He atom and observing it may reveal relevant information.

In this article, we apply this phenomena of inability to absorb light to ultracold ^4He atoms.

- Extremely low-dense plasma of one electron or less in one cm^3 is fully transparent [23].
- Quantum phenomena exist and act without an explanation. We have a limited ability to understand them. Transparency of ultracold ^4He atoms to *all* bosons and frequencies may be such a phenomenon as well.

6. Remark

In addition to the well-established laws of dynamics like conservation of angular momentum, Kepler's laws and tidal dynamics, this article attributes the quantum feature of transparency to known ^4He atoms at ultracold temperatures. An assumption that uses a known particle seems more reasonable than assuming unknown WIMP particles with unknown features.

In this context we cite:

"Thumb's first postulate:

It is better to solve a problem with a crude approximation and know the truth, $\pm 10\%$, than to demand an exact solution and not know the truth at all." [107]

7. Conclusions

The known matter exists in various forms and kinds. It is implausible that the so-called dark matter, which is estimated to be many times more abundant than the visible matter, exists only in one unknown type. It is more reasonable to assume that there are a few kinds of so-called dark matter, most of which are baryons.

The concept of dark matter is misleading because the expression dark matter excludes transparent matter. The correct name should be *invisible matter* (Finzi [10]) in order to include the possibility of transparent matter. Invisible matter means matter that is attracted by gravitational forces and attracts masses by gravity, but does not shine light nor absorb light. This is in contrast to stars and quasars, which shine light in addition to possessing the feature of gravity.

In the following, we classify dark matter using the expressions *non-shining matter* or *invisible matter*. We avoid writing transparent dark matter or transparent invisible matter, but use the expression transparent non-shining matter.

So far the extensive experiments in order to find suggested WIMPs did not reveal any clue of an appropriate particle [44]. Excluding suggested WIMPs, we may classify *baryonic* and *non-baryonic* invisible matter.

The gravitational field is *not baryonic* but may possess mass, thus it may be a portion of the invisible so-called dark matter [14].

As for the *baryonic* invisible matter, extending the age of the universe to 90 milliard years after CMB by the modified non-linear relativistic Hubble law (9) (chapter 8 in [22], and in Section 1.5 in the introduction to this article) allows the production of many more baryons than was possible during the so-called big bang.

We may classify *non-transparent* baryonic invisible matter and *transparent* baryonic invisible matter. Transparent dark matter is a confusing expression.

A few possibilities of baryonic *non-transparent* invisible matter are:

- (i) Orphan interstellar planets [11] were already observed but called isolated brown dwarfs or free-floating planets or planetary-mass brown dwarfs [12].
- (ii) Thousands of brown dwarf stars were already observed. The first one was observed in 1994 [108]. See [12] for review.

(iii) Dark gas galaxies were already observed by Cantalupo et al. 2012 [21].

We may further classify *stable* baryonic *transparent* non-shining matter and *non-stable* baryonic *transparent* non-shining matter.

As for the possibly *non-stable* baryonic transparent non-shining matter, zero-spin zero-electric-charge baryons were proposed in chapter 5 of [22] and in Section 1.6 in the introduction of this article, but not yet discovered.

A few possibilities of *stable* baryonic transparent non-shining matter include *bosonic* cold ^4He :

- (i) Ben-Amots ([43] and chapter 10 in [22]) analytically calculated the thick accretion disk of usual matter at usual or hot temperatures around a central mass. In Section 3.1 in this article, we proposed that after being cooled it may be the transparent halo around a galaxy or a cluster of galaxies, that is invisible matter, in cases in which it consists of cold ^4He alone.
- (ii) We suggested in this article that ultracold ^4He atom bosons, which let photons pass undisturbed through themselves (that is, they are transparent to photons) are the major portion of the expected sought for invisible matter. The large amount of ^4He was produced during the 90 milliard years after CMB (Ben-Amots, chapter 8 in [22] and in Section 1.5 in the introduction to this article.)
- (iii) We also suggested that ultracold ^4He bosons may exist in *stable transparent halos* around galaxies, galaxy clusters and galaxy superclusters (Section 3.1 in this article) and in *stable transparent clouds* of ^4He only (Section 3.2 in this article).
- (iv) We further suggested that ultracold ^4He bosons may fill the *transparent voids* in space and as such may be the *most massive constituent* in the universe (Section 3.3 in this article).

The production of large amounts of ^4He occurred and occurs *inside* the quasars, active galactic nuclei, microquasars and other jet-producing celestial bodies *near* their center [43]. These large amounts of ^4He were and are *dispersed* by the ejected jets or ejected huge bubbles. Both possibilities were suggested by Ben-Amots in [43] and [22]. Helium was observed in the late 1970's in the spectra of jets ejected from microquasars [71]. Ejected huge astronomical bubbles were observed in the 1990's [72], and are called

blobs after they are expelled. This is in addition to the production of ${}^4\text{He}$ in the core of stars.

The lack of absorption lines of ${}^4\text{He}$ in the intergalactic *space* in the spectra of quasars may serve as proof that baryonic ${}^4\text{He}$ cold bosons are the long sought for invisible matter or its main constituent.

The inability of cold bosonic ${}^4\text{He}$ in spherical halos or in cold ${}^4\text{He}$ clouds to lose energy and angular momentum causes it to orbit forever in transparent spherical halos around galaxies, galaxy clusters and galaxy superclusters, or around the center of gravity in transparent cold ${}^4\text{He}$ clouds, respectively, as the invisible matter.

Section 3.2 above suggested that the lack of an observed attracting mass between the multiple images of remote quasars may serve as proof of the existence of transparent cold ${}^4\text{He}$ clouds in intergalactic space as a portion of the so-called dark matter.

In Section 4 we also suggested possibly appropriate scenarios of top-down evolution according to the following stages:

- (i) Hot universe and cooling,
- (ii) Producing baryons during a very long time,
- (iii) Cosmic Microwave Background radiation (CMB) finishes at $z=1089$ approximately 90 milliard years ago,
- (iv) ${}^4\text{He}$ -producing quasars,
- (v) Cells and ${}^4\text{He}$ -filled voids in space,
- (vi) Starting the transformation of usual ${}^4\text{He}$ to bosonic *cold* ${}^4\text{He}$ invisible matter,
- (vii) Galaxy superclusters,
- (viii) Galaxy clusters,
- (ix) Spiral galaxies,
- (x) Elliptical galaxies

in this order of evolution, using the transparency properties of ${}^4\text{He}$ as bosonic at cold temperatures.

The confusing traditional name dark matter misleads researchers from the obvious solution of the cold transparent ${}^4\text{He}$ non-shining matter, which also explains the structure of galaxies, galaxy clusters, galaxy superclusters and the large scale cell-structure of the universe and their evolution (Section 4).

The explanations in this article, particularly in Section 4, may guide researchers as to how to simulate the evolution of galaxies, galaxy clusters, galaxy superclusters and the cell structure of the universe. Without prior understanding as explained in this article the results of numerical simulations may yield only a partial understanding, or even confirm misleading conceptions or exhibit contradiction with the observations [109].

The *recent observations* [109] depart from *all* the computerized simulations of all the present theories up to now. Future computerized simulations of the theory presented here, may perhaps solve the factual discrepancy pointed out in [109].

Recent measurements are in favor of bosonic dark matter [110].

References

- [1] Wikipedia 2020 List of unsolved problems in physics (Retrieved 2020).
https://en.wikipedia.org/wiki/List_of_unsolved_problems_in_physics
- [2] Brooks M 2008, 13 things that don't make sense: The most intriguing scientific mysteries of our times, Profile, London, and Doubleday, New York. See Chapter 1. (Hebrew: 2012, Dvir, Israel)
- [3] Kolatt T 2004 The dark side of the universe, Mapa, Tel-Aviv, Israel. In Hebrew.
- [4] Oort J H 1932 The force exerted by stellar system in the direction perpendicular to the galactic plane and some related problems, *Bull. Astr. Inst. Netherlands* **6** 249-287
- [5] Rubin V C, Ford Jr. W K 1970 Rotation of the Andromeda Nebula from a spectroscopic survey of emission regions *Astroph. J.* **159** 379-403.
- [6] Rubin V C 1983 The rotation of spiral galaxies, *Science* **220** No. 4604 1339-44
- [7] Rubin V C, Thonnard N Y, Ford Jr. W K, March 1982 NGC 3067 - Additional evidence for nonluminous matter. *Astron. J.* **87** 477-85
- [8] Zwicky F 1933 Die Rotverschiebung von extragalaktischen Nebeln *Helvetica Physica Acta* **6** 110-27
- [9] Zwicky F 1937 On the masses of nebulae and of clusters of nebulae *Astrophys. J.* **86** 217-46
- [10] Finzi A 1963 On the validity of Newton's law at long distances *Mon. Not. R. Astron. Soc.* **127** 21-30
- [11] Longair M S 1996 *Our Evolving Universe* (Cambridge, UK: Univ. Pr.) p. 118
- [12] Wikipedia 2020 Brown dwarf (Retrieved 2020). https://en.wikipedia.org/wiki/Brown_dwarf
- [13] Raine D J, Thomas E G 2001 *An Introduction to the Science of Cosmology* (IOP Publ.) 30-32
- [14] Xu C M, Wu X 1998 The higher-order gravitational theory and its application in dark matter problem, in: Guendelman E L I ed.: *Proc. Int. Conf. Modern Modified Theories of Gravitation and Cosmology, held at Ben-Gurion Univ., Beer Sheva, Israel (29-30.6.1997)* published in: *Hadronic J.* **21** No. 2 (4.1998) 224-36. See p. 228
- [15] Cooperstock F I, Tieu S 2005 General relativity resolves galactic dynamics without exotic dark matter, (*Preprint astro-ph/0507619*)
- [16] Cooperstock F I, Tieu S 2005 Perspectives on galactic dynamics, (*Preprint astro-ph/0512048*)
- [17] Cooperstock F I, Tieu S 2006 Galactic dynamic via general relativity: A compilation and new developments *Int. J. Mod. Phys. A* **22** No. 13 2293-325 (*Preprint astro-ph/0610370*)
- [18] Cooperstock F I, Tieu S 2008 General relativistic velocity: The alternative to dark matter *Mod. Phys. Lett. A* **23** No. 21 1745-55 (*Preprint 0712.0019*)
- [19] Cooperstock F I 2009 *General Relativistic Dynamics: Extending Einstein's Legacy Throughout the Universe* (New Jersey, USA: Hackensack, World Scientific)
- [20] Cooperstock F I, 2010, Carrick J D 2010 General relativistic dynamics applied to the rotation curves of galaxies (*Preprint astro-ph.GA/1101.3324*)
- [21] Cantalupo S, Lilly S J, Haehnelt M G 9.2012 Detection of dark galaxies and circum-galactic filaments fluorescently illuminated by a quasar at $z=2.4$ *Mon. Not. Roy. Astron. Soc.* **425** 1992-2014

- [22] Ben-Amots N 2017 *Relativity, Gravitation, and Relativistic Rotation: Clarifying some Paradoxes of Relativity at the Extreme* (Bergenfield, New Jersey, USA: Technology Dynamics) chapters 10, 8, 4, 5. Details: <http://www.netsivi.org/book.htm> Order: email dillone.bookorder@gmail.com
- [23] Ben-Aryeh Y 31.12.2019 Transparency and stability of low density stellar plasma related to Boltzman statistic and to thermal bremsstrahlung *Sci. Rep.* **9** 20384 pp. 1-7
- [24] Ben-Amots N 2011 Relativistic radial expansion: Do we need dark energy? *J. Phys: Conf. Series* **330** 012018. <https://doi.org/10.1088/1742-7698/330/1/012018>
- [25] Ben-Amots N 2021 *Solving Seventeen Puzzling Scientific Mysteries: Tornado, Gyroscope, Supernova, Dark Matter, Astronomical Jets, Quasars, Origin of the Moon and More* A book in print (In English). See Chapter 10
- [26] Friedmann A 1922 Über die Krümmung des Raumes *Zeitschrift für Physik* **10**(1) 377-86
- English Translation:
Friedmann A 1999 On the curvature of space *Gen. Rel. Grav.* **31**(12) pp. 1991-2000
- [27] Friedmann A 1924 On the possibility of a world with constant negative curvature *Zeitschrift für Physik* **21** 326-32
- [28] Ryden B, Peterson B M 2010 *Foundations of astrophysics* (San Francisco, California, USA: Pearson Addison-Wesley) pp. 546-9. See p. 547
- [29] Mukhanov V 2005 *Physical foundations of cosmology*, (Cambridge University Press) See pp. 22-24, 27-36
- [30] Grøn Ø, Hervik S 2007 *Einstein's general theory of relativity with modern applications in cosmology* (New York: Springer). See pp. 294-6, 306-10, 321-5, 394-6
- [31] Gonzalo J A 2012 *Cosmic paradoxes* (World Scientific). See sections 7 and 11.
- [32] Robertson H P 1935 Kinematics and world structure *Astroph. J.* **82** 284-301
- [33] Robertson H P 1936 Kinematics and world structure II *Astroph. J.* **83** 187-201
- [34] Robertson H P 1936 Kinematics and world structure III *Astroph. J.* **83** 257-71
- [35] Walker A G 1937 On Milne's theory of world-structure, *Proc. London Math. Soc.* **2** **42**(1) 90-127
- [36] Grøn Ø 1978 Expansion of the universe and a hierarchical structure of the universe as solution of the dark night sky paradox, *Am. J. Phys.* **46** No. 9 923-7
- [37] Samuel S 2005 Comments on an expanding universe (*Preprint astro-ph/0512282*)
- [38] Abramowicz M A, Bajtlik S, Lasota J P, Moudens A 2007 Eppure si espande (*Preprint astro-ph/0612155*)
- [39] Wikipedia 2020 Hubble's law (Retrieved 2020). https://en.wikipedia.org/wiki/Hubble's_law
- [40] Wikipedia 2020 Redshift (Retrieved 2020). <https://en.wikipedia.org/wiki/Redshift>
- [41] Wikipedia 2020 Boson (Retrieved 2020). <https://en.wikipedia.org/wiki/Boson>
- [42] Reddish V C 1967 *Evolution of the galaxies*, Oliver & Boyd, Edinburgh and London, 109-10
- [43] Ben-Amots N 2019 How quasars with thick accretion disk eject relativistic jets, *J. Phys: Conf. Series* **1239** 012012 <https://doi.org/10.1088/1742-6596/1239/1/012012>
- [44] Bertone G, Hooper D 2018 History of dark matter *Rev. Mod. Phys.* **90**(4) 045002. arXiv:1605.04909
- [45] Wikipedia 2018 Bose-Einstein condensate (Retrieved 2018).
https://en.wikipedia.org/wiki/Bose-Einstein_condensate
- [46] Donnelly R J, Barenghi C F 1998 The observed properties of liquid helium at the saturated vapor pressure *J. Phys. Chem. Reference Data* **27**(6) 1217-74
- [47] Secchi A 1877 *L'Astronomia in Roma nel pontificato di Pio IX: memoria* (Roma: Tipografia della Pace)
- [48] Ranyard A 1894 Structure of the Milky Way *Knowledge* **17** 253
- [49] Kelvin B 1904 Baltimore lectures on molecular dynamics and the wave theory of light
<https://archive.org/details/baltimorelecture00kelviala>.
- [50] Poincaré H 1906 *L'Astronomie* **XX** 158
- [51] Poincaré H 1906 The Milky Way and the theory of gases *Popular Astronomy* **14** 475-88
- [52] Poincaré H, Vergne H 1911 Lecons sur les hypothèses cosmogoniques: professées à la Sorbonne (Paris: A. Hermann)
- [53] Kapteyn J C 1922 First attempt at a theory of the arrangement and motion of the sidereal system *Astrophys. J.* **55** 302-27
- [54] Lundmark K 1930 Meddelande frn Lunds astronomiska Observatorium (Message from Lund

- Astronomical Observatory). Translation from the German by Lars Bergström.
- [55] Zwicky F 1933 How far do cosmic rays travel? *Phys. Rev.* **43** 147
 - [56] Holmberg E 1940 On the clustering tendencies among the nebulae I *Astrophys. J.* **92** 200
 - [57] Bessel F W 1844 On the variations of the proper motions of Procyon and Sirius *Mon. Not. Roy. Astron. Soc.* **6** 136-41
 - [58] Öpik E 1915 *Bull de la Soc. Astr. de Russie* **21** 150
 - [59] Smith S 1936 The mass of the Virgo cluster *Astrophys. J.* **83** 23
 - [60] Hubble E P 1958 *The realm of the nebulae* (Dover) page 180
 - [61] Neyman J, Page T, Scott E 1961 Conf. on the instability of systems of galaxies, Santa Barbara, California, 10-12 May 1961: Summing of the conf. *Astron. J.* **66** 633
 - [62] Hodge P W 1966 *Galaxies and Cosmology* (New York, USA: McGraw-Hill)
 - [63] Freeman K C 1970 On the disks of spiral and S0 galaxies *Astrophys. J.* **160** 811-30
 - [64] Rogstad D H, Shostak G S 1972 Gross properties of five Scd galaxies as determined from 21-centimeter observations *Astrophys. J.* **176** 315
 - [65] Einasto J, Kaasik A, Saar E 1974 Dynamic evidence on massive coronas of galaxies, *Nature* (London) **250** 309-10
 - [66] Rubin V C, Thonnard N, Ford Jr. W K 1978 Extended rotation curves of high-luminosity spiral galaxies. IV - Systematic dynamical properties, SA through SC, *Astrophys. J.* **225** L107-11
 - [67] Faber S M, Gallagher J S 1979 Masses and mass-to-light ratios of galaxies, *Annu. Rev. Astron. Astrophys.* **17** 135-87
 - [68] Fixsen D J 2009 The temperature of the cosmic microwave background *Astrophys. J.* **707**(2) 916-20. (*preprint* 0911.1955)
 - [69] Hoyle F, Tayler R J 1964 The mystery of the cosmic helium abundance *Nature* **203** 1108-10
 - [70] Bashkanov M, Watts D P, February 2020 A new possibility for light-quark dark matter *J. Phys. G* **47** No. 3
 - [71] Margon B 1980 The bizarre spectrum of SS433 *Sci. Am.* **243**(4) 44-55
 - [72] Mirabel I F, Rodriguez L F 1994 A superluminal source in the galaxy *Nature* **371** 46-48. See figure on the front page of the issue.
 - [73] Ben-Amots N 2003 Basic aspect of relativistic rotation: Franklin rotation of a sphere *Found. Phys.* **33** 1369-72 <https://doi.org/10.1023/A:1025649529483>
 - [74] Ben-Amots N 2007 Relativistic exponential gravitation and exponential potential of electric charge *Found. Phys.* **37** 773-87 <https://doi.org/10.1007/s10701-007-9112-1>
 - [75] Ben-Amots N 2008 A new line element derived from the variable rest mass in gravitational field, (*Preprint* 0808.2609v1 [gen-ph])
 - [76] Ben-Amots N 2011 Some features and implications of exponential gravitation *J. Phys.: Conf. Series* **330** 012017 <https://doi.org/10.1088/1742-6596/330/1/012017>
 - [77] Ben-Amots N 2015 Energy accumulation in relativistic sub-Bohr orbitals, Franklins relativistic rotation of quarks and gravitational field bounceback as processes relevant to explosion of supernovae *J. Phys.: Conf. Series* **615** 012012 <https://doi.org/10.1088/1742-6596/615/1/012012>
 - [78] Abbott B P *et al* 2016 LIGO Scientific Collaboration and Virgo Collaboration: Observation of gravitational waves from a binary black hole merger *Phys. Rev. Lett.* **116**(6) 061102
 - [79] Kochhar R K 1991 French astronomers in India during the 17th - 19th centuries *J. Br. Astron. Assoc.* **101**(2) 95-100. See p. 99.
 - [80] Reimer D, Vogel S, Hagen H J, Engels D, Groote D, Wamsteker W, Clavel J, Rosa M R 1992 The O/C abundance ratio in absorbing gas clouds at high redshift *Nature* **360** 561-3
 - [81] Jakobson P 1995 Helium at high redshift, in: Crane P, ed.: *The Light Element Abundances* (Springer) pp. 75-84
 - [82] Foot R 2014 A dark matter scaling relation from mirror dark matter *Phys. Dark Universe* **5-6** 236-9
 - [83] Wikipedia 2020 Einstein ring (Retrieved 2020). https://en.wikipedia.org/wiki/Einstein_ring
 - [84] Wikipedia 2020 Gravitational lens (Retrieved 2020) https://en.wikipedia.org/wiki/Gravitational_lens
 - [85] Jõeveer M, Einasto J 1978 Has the universe the cell structure? in: Einasto J, and Longair M S, eds, *The Large Scale Structure of the Universe Symposium, Tallinn, Estonia, September 12-26, 1977, International Astronomical Union: Symposium 79* (Dordrecht-Boston: Reidel) 241-51. See p. 247.

- [86] Gregory S A, Thompson L A (March 1982) Superclusters and voids in the distribution of galaxies *Sci. Am.* **246** no. 3, 88-96
- [87] Wikipedia 2020 List of largest voids, in: Wikipedia, List of largest cosmic structures (Retrieved 2020). https://en.wikipedia.org/wiki/List_of_largest_cosmic_structures
- [88] Keenan R C, Barger A J, Cowie L L 2013 Evidence for a 300 Mpc scale under-density in the Local Galaxy distribution *Astroph. J.* **775** (2-13) 62 (16pp) (*Preprint astro-ph.CO/1304.2884*)
- [89] Wikipedia 2020 KBC Void (Retrieved 2020). https://en.wikipedia.org/wiki/KBC_Void
- [90] Kirshner A P, Oemler A J, Schechter P L, Shectman S A 1981 A million cubic megaparsec void in Bootes *Astrophys. J.* **248** L57-L60.
- [91] Wikipedia 2020 Boötes void (Retrieved December 2020). https://en.wikipedia.org/wiki/Boötes_void
- [92] Overbye D 1991 *Lonely Hearts of the Cosmos*, HarperCollins. - Hebrew translation: "Halevavot habodedim shel hakosmos", Zmora-Bitan, Tel-Aviv, Israel (1999), pp. 374, 401.
- [93] Geller M J, Hwang H S 2015 Schwarzschild Lecture 2014: HectoMAPping the Universe, arXiv:1507.06261v1 [astro-ph.CO] (22 Jul 2015)
- [94] Fong R, Doroshkevich A G, Turchaninov V I 1995 Dark matter in voids, AIP Conference Proceedings 336, 429 <https://doi.org/10.1063/1.48369>
- [95] Doroshkevich A G, Fong R, Gottlöber S, Mucket J P, Müller V, The formation and evolution of large- and superlarge-scale structure in the universe - I: General Theory, *Mon. Not. R. Astron. Soc.* (1995) <https://arxiv.org/pdf/astro-ph/9505088.pdf>
- [96] Wikipedia 2020 Bullet Cluster (Retrieved 2020). https://en.wikipedia.org/wiki/Bullet_Cluster
- [97] Wikipedia 2020 Tidal acceleration (Retrieved 2020) https://en.wikipedia.org/wiki/Tidal_acceleration
- [98] Wikipedia 2020 Globular cluster (Retrieved 2020). https://en.wikipedia.org/wiki/Globular_cluster
- [99] McLaughlin D A, Harris W E, Hanes D A 1994 The spatial structure of the M87 globular cluster system *Astrophys. J.* **422**(2) 486-507
- [100] Wikipedia 2020 Quantum tunnelling (Retrieved 2020) https://en.wikipedia.org/wiki/Quantum_tunnelling
- [101] MacGregor M H (June 17, 1987) UCRL 94777
- [102] MacGregor M H 1987 *Bull. Am. Phys. Soc.* **32** p. 31
- [103] MacGregor M H 1989 On the interpretation of the electron anomalous magnetic moment *Found. Phys. Lett.* **2** 577-89. See pp. 586-7
- [104] MacGregor M H 1990 An elementary particle constituent-quark model *Nuo. Cim. A* **103** 983-1052. See p. 1047.
- [105] Marmet P 1992 The cosmological constant and the red shift of quasars *IEEE Trans. on Plasma Sci.* **20** 958-64
- [106] Von-Baeyer H C 1992 *Taming the Atom: the Emergence of the Visible Microworld* (New York: Random House) p. xix. Hebrew translation: Iluf Ha'atom, Galileo, Israel (1996) pp. 1, 5
- [107] Nuclear News, August 1971 Thumb's first and second postulates *Nuclear News*
- [108] Rebolo R, Zapatero-Osorio M R, Martin E L (14th September 1995) Discovery of a brown dwarf in the Pleiades star cluster *Nature* **377** No. 6545, 129-31
- [109] Meneghetti et al. September 2020 An excess of small-scale gravitational lenses observed in galaxy clusters *Science* **369** No. 6509, 1347-51
- [110] B. Hoeneisen, Fermion or Boson Dark Matter? *Int. J. Astron. Astrophys.* 10 no. 3 (September 2020) 203-223.