Dark Matter Particles

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Abstract

Researchers have been able to infer the existence of Dark Matter (DM) only from the gravitational effect it seems to have on visible matter. DM seems to outweigh visible matter roughly six to one, making up about 27% of the universe. Here's a sobering fact: The matter we know and that makes up all stars and galaxies only accounts for 5% of the content of universe! But what is DM? [1]. Many experiments to detect and study Dark Matter Particles (DMPs) directly are being actively undertaken, but none have yet succeeded. Indirect detection experiments search for the products of the self-annihilation or decay of DMPs in outer space [2].

In the present paper, we discuss the main ideas of the developed Hypersphere World-Universe Model (WUM), introduce additional new DMP "XION" (boson) that is an analog of Axion, and consider a distribution of particles in the World including DMPs (four fermions and three bosons) and Ordinary particles (protons, electrons, photons, and neutrinos).

1. Introduction

Galaxy clusters are particularly important for DM studies since their masses can be estimated in two independent ways [2]:

- From the scatter in radial velocities of the galaxies within clusters;
- Gravitational lensing (usually of more distant galaxies) can measure cluster masses without relying on observations of dynamics (e.g., velocity).

In 2017, K. Freese has reviewed the Status of Dark Matter in the Universe [3]:

Most of the mass in the universe is in the form of an unknown type of dark matter. The need for dark matter has become more and more clear since the 1930s, with evidence from rotation curves, gravitational lensing, hot gas in clusters, the Bullet Cluster, structure formation, and the cosmic microwave background. A consensus picture has emerged, in which dark matter contributes 26% of the overall energy density of the universe. Its nature is still unknown. Dark matter searches for the best motivated candidates, ***axions*** *and* ***WIMPs****, are ongoing and promising over the next decade.*

In astrophysics and particle physics, Self-Interacting Dark Matter (SIDM) is an alternative class of Cold DM. SIDM particles have strong interactions, in contrast to the standard Cold DMPs [4]. On galactic scales, DM self-interaction leads to energy and momentum exchange between DMPs [5].

WIMPs, or Weakly Interacting Massive Particles, represent a favored class of DM candidates. Some WIMPs may mutually annihilate when pairs of them interact, a process expected to produce gamma rays [6]. A lightest neutralino of rest energy roughly ($10\ GeV \Leftrightarrow 10\ TeV$) is the leading WIMP DM candidate.

Axion is a hypothetical elementary particle postulated by the Peccei–Quinn theory to resolve the strong CP problem in quantum chromodynamics. With a rest energy $\gtrsim 10^{-11}$ times the electron rest energy about $5\ \mu eV$, axions could account for DM, and thus be both DM candidate and a solution to strong CP problem [7].

2. World-Universe Model vs Big Bang Model

WUM and Big Bang Model (BBM) are principally different Models:

- 1) Instead of the Initial Singularity with the infinite energy density and extremely rapid expansion of spacetime (Inflation) in BBM; in WUM, there was a Fluctuation (4D Nucleus of the World with an extrapolated radius equals to a basic size unit of a, see Section 3.2) in Eternal Universe with finite extrapolated energy density ($\sim 10^4$ less than nuclear density) and finite expansion of Nucleus in Its fourth spatial dimension with speed c that is a gravitodynamic constant;

- 2) Instead of alleged practically Infinite Homogeneous and Isotropic Universe around Initial Singularity in BBM; in WUM, 3D Finite Boundless World (Hypersphere of 4D Nucleus) presents Patchwork Quilt of various main Superclusters ($\gtrsim 10^3$) that emerged in different places of the World at different Cosmological times. The Medium of the World, consisting of protons, electrons, photons, neutrinos, and DMPs is Homogeneous and Isotropic. Distribution of Macroobjects is spatially Inhomogeneous and Anisotropic and temporally Non-simultaneous;
- 3) In our opinion, the most probable model is the one that built on the minimum number of parameters. BBM is based on six parameters (baryon density, dark matter density, dark energy density, scalar spectral index, curvature fluctuation amplitude, and reionization optical depth), the values of which are mostly not predicted by current theory. WUM is based on two parameters only: dimensionless Rydberg constant α (that later was named Fine-structure constant) and dimensionless quantity Q, which increases in time $Q \propto \tau$, and is, in fact, a measure of the Size and Age of the World.

Most direct observational evidence of validity of WUM are:

- 1) Microwave Background Radiation and Intergalactic Plasma speak in favor of existence of the **Medium**;
- 2) Laniakea Supercluster with binding mass $\sim 10^{17}\ M_{\odot}$ is home to the Milky Way galaxy and $\sim 10^5$ other nearby galaxies, which did not start their movement from Initial Singularity;
- 3) Milky Way is gravitationally bounded with the Virgo Supercluster (VSC) and has an Orbital **Angular Momentum** calculated based on distance of 65 Mly from VSC and orbital speed of $\sim 400\ km\ s^{-1}$, which far exceeds rotational angular momentum of Milky Way;
- 4) Mass-to-light ratio of VSC is ~ 300 times larger than that of Solar ratio. Similar ratios are obtained for other superclusters. These ratios are main arguments in favor of presence of significant amounts of **Dark Matter** in the World;
- 5) Astronomers discovered the most distant galaxy HD1 that is $\sim 13.5\ Bly$ away. WUM predicts discovery of galaxies with distance $\sim 13.8\ Bly$.

Medium of the World, Dark Matter, and Angular Momentum are main Three Pillars of WUM.

3. Multicomponent Dark Matter

3.1. Existent Models

DM is among the most important open problems in both cosmology and particle physics. There are three prominent hypotheses on nonbaryonic DM, namely Hot Dark Matter (HDM), Warm Dark Matter (WDM), and Cold Dark Matter (CDM).

The lightest **Neutralino** with the rest energy ($> 300\ GeV$) is an excellent candidate to form the universe's CDM [8]. The most widely discussed particles for nonbaryonic CDM are commonly assumed to be **WIMPs**. The Lee-Weinberg limit restricts their rest energy to >2 GeV [9].

It is known that a **Sterile Neutrino** with rest energy in $1.6 \Leftrightarrow 10\ keV$ range is a good WDM candidate [10].

HDM is a theoretical form of DM which consists of particles that travel with ultra-relativistic velocities. An example of a HDM particle is a **Neutrino** [11]. In WUM, the particles of HDM are **DMF4** (see Section 3.2).

The prospect that DMPs might be observed in Centers of Macroobjects has drawn many new researchers to the field in the last forty six years. Indirect effects in cosmic rays and gamma-ray background from the annihilation of CDM in the form of heavy stable neutral leptons in Galaxies were considered in pioneer articles [12]-[17].

Two-component DM system consisting of bosonic and fermionic components is proposed for the explanation of emission lines from the bulge of the Milky Way galaxy. C. Boehm, P. Fayet, and J. Silk analyze the possibility of two coannihilating neutral and stable DMPs: a heavy fermion for example, like the lightest neutralino (>100 GeV) and the other one a possibly light spin-0 particle (~100 MeV) [18].

Multicomponent DM models consisting of both bosonic and fermionic components were analyzed in literature (for example, see [19]-[25] and references therein). An article by G. Bertone and T. M. P. Tait [26] provides an excellent review of what we have learned about the nature of DM from past experiments, and the implications for planned DM searches in the next decade.

3.2. Basic Ideas

It is the main goal of WUM to develop a Model based on two dimensionless parameters only: the dimensionless Rydberg constant α and the time-varying parameter Q, which is a measure of the Size and Age of the World. In WUM, we often use well-known physical parameters, keeping in mind that all of them can be expressed through the Basic Units. Taking the relative values of physical parameters in terms of the Basic Units we can express all dimensionless parameters of the World through two parameters α and Q in various rational exponents, as well as small integer numbers and π [27].

In our view, there is no way to prevent an occurrence of the Initial Singularity in BBM. A **Finite World** must have gotten started in a principally different way – a **Fluctuation** in the Eternal Universe with an extrapolated finite size that equals to the basic size unit a [28]:

$$a = 1.7705641 \times 10^{-14}\, m$$

The size of this Fluctuation can increase with a finite speed c (gravitodynamic constant). Then, there is no need to introduce Cosmological Inflation. However, a question about the mechanism of Continuous Creation of Matter in the World arises [28].

In 1952, Y. Nambu proposed an empirical mass spectrum of elementary particles with a mass unit close to one quarter of the mass of a pion ($m_0/2 \cong 35\ MeV/c^2$) [29]. He noticed that meson masses are even multiplies of a mass unit $m_0/2$, baryon (and also unstable lepton) masses are odd multiplies, and mass differences among similar particles are quantized by $m_0 \cong 70\ MeV/c^2$. During many years M. H. Mac Gregor studied this property extensively [30]. In WUM we introduce a **Basic Energy Unit** E_0 that equals to:

$$E_0 = hc/a = 70.025252\ MeV$$

where h is the Planck constant. It is worth noting that the rest energy of electron E_e equals to: $E_e = \alpha E_0$ and the Rydberg unit of energy is: $Ry = hcR_\infty = 0.5\alpha^3 E_0 = 13.605692\ eV$ (R_∞ is the Rydberg constant).

According to WUM, the Eternal Universe is the Source of the World's DM. Ordinary Matter (7.2%) is a byproduct of DMPs self-annihilation. It means that rest energies of DMPs must be constant and proportional to the basic energy unit E_0 [28]. Considering the main goal of WUM – two dimensionless parameters only – the rest energies of DMPs should be proportional to constant α only.

Following the mechanism discussed by C. Boehm, P. Fayet, and J. Silk, we proposed multicomponent DM system consisting of two couples of co-annihilating DMPs: a heavy Dark Matter Fermion (DMF) – DMF1 (1.3 TeV) and a light spin-0 boson – DIRAC (70 MeV) that is a dipole of Dirac's monopoles with charge $\mu = e/2\alpha$ (e is the elementary charge); a heavy fermion – DMF2 (9.6 GeV) and a light spin-0 boson – ELOP (340 keV) that is a dipole of preons with electrical charge e/3. We also proposed a couple of co-annihilating DMPs: DMF3 (3.7 keV) and a spin-0 boson XION (10.6 μeV).

In frames of WUM, Dark Matter Particles DMF1, DMF2, and DMF3 have rest energies, which corresponds to the rest energies of Neutralinos, WIMPs, and Sterile Neutrinos discussed in literature (see Section 3.1).

DIRAC, which is a magnetic dipole of Dirac's monopoles, is introduced to explain the Dirac's quantization condition. The quantum theory of magnetic charge started with a paper by P. Dirac in 1931[31]. In this paper, Dirac showed that if any magnetic monopoles exist in the universe, then all electric charge in the universe must be quantized. The electric charge is, in fact, quantized, which is consistent with (but does not prove) the existence of monopoles. Since Dirac's paper, several systematic monopole searches have been performed but it remains an open question whether monopoles exist [32]. In our opinion, all electric charges are quantized due to existence of DIRACs – dipoles of Dirac's monopole, which are the smallest building blocks of the structure of constituent quarks and hadrons (mesons and baryons).

ELOP, which is an electric dipole of preons with the rest energy ($E_e/3 = 170.333\ keV$), is introduced to explain all subatomic particles with electrical charge $\propto e/3$. Preons are the smallest building blocks of the structure of quarks and leptons. According to I. A. D'Souza and C. S. Kalman "*In particle physics, preons are postulated "point-like" particles, conceived to be subcomponents of quarks and leptons* " [33].

S. Sukhoruchkin has this to say about "A Role of Hadronic effects in Particle Masses" [34]:

We discuss relations in particle mass spectrum and consider results of analysis of spacing distributions in nuclear spectra which show a distinguished character of intervals related to the electron mass and nucleon mass splitting. Systematic appearance of stable nuclear intervals rationally connected with particle mass splitting ***170****-340-510-1020 keV... was found in levels of different nuclei including low-spin levels observed in (γ, γ) and (n, γ) reactions. In this work we show such tuning effect in numerous levels from new compilation for light nuclei. Together with long-range correlations in nuclear binding energies they provide a support for the observed correlation between masses of hadrons and leptons (including masses of nucleons and* m_e *).*

We did not consider binding energies of DIRACs and ELOPs, and thus the values of their rest energies are approximate. They have negligible electrostatic and electromagnetic charges because the separation between charges is very small. They do however possess electrostatic and electromagnetic dipole momentum [35].

XION, which is introduced in the present paper for the first time, is an analog of Axion discussed in literature (see Introduction). It has the value of the rest energy $10.6\ \mu eV$ that is in reasonable agreement with the value of $\gtrsim 5\ \mu eV$ discussed in [7]. In WUM, XIONs have a high concentration in the World n_{XION} (see Section 4):

$$n_{XION} = 2.261364 \times 10^{13}\ m^{-3}$$

It means that a distance between XIONs is:

$$a_{XION} = 3.53625 \times 10^{-5}\ m$$

which is much smaller than the range of the Weak interaction R_W (see Section 3):

$$R_W = a \times Q^{1/4} = 1.65314 \times 10^{-4}\ m$$

Due to the Weak interaction, XIONs can collect into clouds with distances between particles smaller than R_W . As a result, clumps of XIONs will arise. Larger clumps will attract smaller clumps and DMPs and initiate a process of expanding DM clumps up to the Planck mass, which can interact each other gravitationally. As a result, they can generate Cosmic Gravitational Background that is very hard to observe (conjecture).

WUM also introduce self-annihilating fermions **DMF4** (0.2 eV), which are responsible for the Le Sage's mechanism of gravitation [28].

The reason for this multicomponent DM system was to explain:

- The diversity of Very High Energy gamma-ray sources in the World [36];
- The diversity of DM Cores of Macroobjects of the World (superclusters, galaxies, and extrasolar systems), which are Fermion Compact Objects and DM Reactors in WUM [28].

WUM postulates that rest energies of DMFs and bosons are proportional to the basic energy unit E_0 multiplied by different exponents of α and can be expressed with the following formulae:

DMF1 (fermion): $E_{DMF1} = \alpha^{-2} E_0 = 1.3149948\ TeV$

DMF2 (fermion): $E_{DMF2} = \alpha^{-1} E_0 = 9.5959804\ GeV$

DIRAC (boson): $E_{DIRAC} = \alpha^{0} E_0 = 70.025252\ MeV$

ELOP (boson): $E_{ELOP} = 2/3\alpha^{1} E_0 = 340.66596\ keV$

DMF3 (fermion): $E_{DMF3} = \alpha^{2} E_0 = 3.7289394\ keV$

DMF4 (fermion): $E_{DMF4} = \alpha^{4} E_0 = 0.19857107\ eV$

XION (boson) $E_{XION} = \alpha^{6} E_0 = 10.574179\ \mu eV$

We still do not have a direct confirmation of DMPs' rest energies, but we do have a number of indirect observations. The signatures of DMPs self-annihilation with expected rest energies of 1.3 TeV; 9.6 GeV; 70 MeV; 340 keV; 3.7 keV are found in spectra of the diffuse gamma-ray background and the emissions of various Macroobjects in the World [36]. We connect observed gamma-ray spectra with the structure of Macroobjects (nuclei and shells composition). Self-annihilation of those DMPs can give rise to any combination of gamma-ray lines. Thus, the diversity of Very High Energy gamma-ray sources in the World has a clear explanation.

In this regard, it is worth recalling a story about neutrinos: "*The neutrino was postulated first by W. Pauli in 1930 to explain how beta decay could conserve energy, momentum, and angular momentum (spin). But we still don't know the values of neutrino masses* ". Although we still cannot measure neutrinos' masses directly, no one doubts their existence.

Neutrons serve as another example. The mass of a neutron cannot be directly determined by mass spectrometry since it has no electric charge. But since the masses of a proton and of a deuteron can be measured with a mass spectrometer, the mass of a neutron can be deduced by subtracting proton mass from deuteron mass, with the difference being the mass of the neutron plus the binding energy of deuterium.

DMPs do not possess an electric charge. Their masses cannot be directly measured by mass spectrometry. Hence, they can be observed only indirectly due to their self-annihilation and irradiation of gamma-quants.

3.3. Weak Interaction

The widely discussed models for nonbaryonic DM are based on CDM hypothesis, and corresponding particles are commonly assumed to be WIMPs, *which interact via gravity and any other force (or forces), potentially not part of the standard model itself, which is as weak as or weaker than the weak nuclear force, but also, non-vanishing in its strength* [37]. It follows that a new weak force needs to exist, providing interaction between DMPs. The strength of this force exceeds that of gravity, and its range is considerably greater than that of the weak nuclear force.

According to WUM, strength of gravity is characterized by gravitational parameter:

$$G = G_0 \times Q^{-1}$$

where $G_0 = \frac{a^2 c^4}{8\pi hc}$ is an extrapolated value of G at the Beginning of the World ($Q=1$). Q in the present Epoch equals to: $Q = 0.759972 \times 10^{40}$. The range of the gravity equals to the size of the World R :

$$R = a \times Q = 1.34558 \times 10^{26}\ m$$

In WUM, weak interaction is characterized by the parameter G_W :

$$G_W = G_0 \times Q^{-1/4}$$

which is about 30 orders of magnitude greater than G . The range of the weak interaction R_W in the present Epoch equals to:

$$R_W = a \times Q^{1/4} = 1.65314 \times 10^{-4}\ m$$

that is much greater than the range of the weak nuclear force. The introduced principally new Weak Interaction between DMPs provide integrity of all Macroobjects' Cores, which are 3D fluid balls, made up of different fermions, with a very high viscosity and act as solid-state objects. In our view, weak interaction between particles DMF3 provides integrity of Fermi Bubbles [28].

We emphasize that DMPs do not interact via gravity. Two particles or microobjects will not exert gravity on one another when both of their masses are smaller than the Planck mass. Planck mass can then be viewed as the mass of the smallest macroobject capable of generating the gravitoelectromagnetic field and serves as a natural borderline between classical and quantum physics.

Incidentally, in his "Interpreting the Planck mass" article [38], B. Hammel showed that the Plank mass is *a lower bound on the regime of validity of General Relativity*.

In our opinion, cosmic dust particles with masses around Planck mass are the smallest building blocks of all macroobjects. The validity of this statement follows from the work of L. Spitzer [39] and A. M. Ignatov [40] who identified Le Sage's mechanism as a significant factor in the behavior of dust particles and dusty plasma.

In WUM, the gravitational parameter G is proportional to the Mediums' energy density. Gravitation is a result of simple interactions of DMF4 with Matter which work cooperatively to create a more complex interaction. DMF4 are responsible for the Le Sage's mechanism of gravitation [41].

To summarize:

- Le Sage's theory of gravitation defines Gravity as an emergent phenomenon;
- Gravity is not an interaction but a manifestation of the Medium;
- The proposed mechanism of Gravitation resembles Le Sage's theory.

4. Distribution of World's Energy Density

Our Model holds that the energy density of all types of self-annihilating DMPs is proportional to proton energy density in the Medium of the World ρ_p in all times that in the present Epoch equals to:

$$\rho_p = \frac{2\pi^2\alpha}{3}\ \rho_{cr} = 0.048014655\ \rho_{cr} = 239.1207\ MeV/m^3$$

where ρ_{cr} is the critical energy density of the World. In all, there are 6 different types of self-annihilating DMPs: DMF1, DMF2, DIRAC, ELOP, DMF3 and XION. Then the total energy density of DMPs ρ_{DM} is

$$\rho_{DM} = 6\ \rho_p = 0.28808793\ \rho_{cr}$$

that is in good agreement with the results in [1]. The total DMF4 energy density ρ_{DMF4} is

$$\rho_{DMF4} = 1.35\pi^2\ \rho_p = 0.63974563\ \rho_{cr}$$

The total baryonic energy density ρ_B is:

$$\rho_B = 1.5\ \rho_p$$

The sum of electron and Microwave Background Radiation energy densities ρ_{eMBR} equals to:

$$\rho_{eMBR} = 1.5\frac{m_e}{m_p}\ \rho_p + 2\frac{m_e}{m_p}\rho_p = 3.5\frac{m_e}{m_p}\ \rho_p$$

We take energy density of neutrinos ρ_ν to equal:

$$\rho_\nu = \rho_{MBR}$$

For Far-Infrared Background Radiation energy density ρ_{FIRB} we take

$$\rho_{FIRB} = \frac{1}{40}\frac{m_e}{m_p}\ \rho_p$$

Then the energy density of the World ρ_W equals to the theoretical critical energy density:

$$\rho_W = \left[1.35\pi^2 + 7.5 + (5.5 + 1/40)\frac{m_e}{m_p}\right]\rho_p = \rho_{cr}$$

From this equation we can calculate the value of $1/\alpha$ using electron-to-proton mass ratio m_e/m_p :

$$\frac{1}{\alpha} = \frac{\pi^2}{60}\left[54\pi^2 + 300 + (220 + 1)\frac{m_e}{m_p}\right] = 137.03600$$

which is in excellent agreement with the commonly adopted value of 137.035999. It follows that there is a direct correlation between constants α and m_e/m_p expressed by the obtained equation. As shown, m_e/m_p is not an independent constant but is instead derived from α [42].

As the conclusion:

- The World's energy density is inversely proportional to a dimensionless time-varying parameter $Q \propto \tau$ in all cosmological times;
- The particles relative energy densities are proportional to constant α .

5. Conclusion

Dark Matter is abundant [28]:

- 2.4 % of Ordinary Matter is in Superclusters, Galaxies, Stars, Planets, etc.
- 4.8 % of Ordinary Matter is in the Medium of the World;
- The remaining 92.8 % is DM.

Dark Matter is omnipresent:

- 2/3 of the total DM is in the Medium of the World;
- 1/3 of the total DM is in Macroobjects of the World;
- Cores of all Macroobjects of the World;
- DM Reactors in Cores of all gravitationally-rounded Macroobjects;
- Coronas of all Macroobjects of the World;
- Fermi Bubbles.

WUM predicts existence of DMPs with 1.3 TeV, 9.6 GeV, 70 MeV, 340 keV, 3.7 keV, 0.2 eV, and 10.6 μeV rest energies. We should concentrate our efforts on the observations of cosmic gamma-rays with spectral lines corresponding to the predicted values of DMP's rest energies.

In our view, great experimental results and observations achieved by Astronomy in the last decades should be analyzed through the prism of a New Paradigm based on WUM. Astronomers should plan new purposeful experiments based on the results of these analyses.

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