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5D World-Universe Model. Multicomponent Dark Matter

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Abstract

5D World-Universe Model (WUM) is based on the decisive role of the Medium of the World composed of massive particles: protons, electrons, photons, neutrinos, and Dark Matter Particles (DMP). The model forecasts the masses of DMP, discusses the possibility of all macroobject cores consisting of DMP (galaxy clusters, galaxies, star clusters, extrasolar systems, and planets), and explains the diffuse cosmic gamma-ray background radiation as the sum of contributions of multicomponent dark matter annihilation. The signatures of DMP annihilation with expected masses of 1.3 TeV, 9.6 GeV, 70 MeV, 340 keV, and 3.7 keV, are found in spectra of the diffuse gamma-ray background and the emission of various macroobjects in the World. The correlation between different emission lines in spectra of macroobjects is connected to their structure, which depends on the composition of the cores and surrounding shells made up of DMP. Consequently, the diversity of Very High Energy (VHE) gamma-ray sources in the World has a clear explanation.

Keywords

5D World-Universe Model, Medium of the World, Dark Matter Particles, Cores of Macroobjects, Gamma-Ray Background Radiation, Pioneer Anomaly

1. Introduction

We can't solve problems by using the same kind of thinking we used when we created them.
Albert Einstein

In the World-Universe Model (WUM), we introduce the basic unit of mass m_0 that equals to

$$m_0 = \frac{h}{ac} = 70.025267\ \mathrm{MeV}/\mathrm{c}^2$$

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where h is Planck constant, c is the electrodynamic constant, $a = 2\pi a_0$, and a_0 is the classical electron radius. m_0 plays a key role when the masses of Dark Matter Particles (DMP) are discussed in the next Section.

The Fine-structure constant (FSC) α is a fundamental physical constant that has several physical interpretations. α is the rest mass of an electron m_e measured in terms of basic unit m_0. FSC plays a central role in WUM.

According to WUM, all stable particles are created in the 3-sphere World due to the surface energy of the 4-ball Nucleus of the World provided by the 4-dimensional Universe. The World consists of the Medium (protons, electrons, photons, neutrinos, and DMP) and Macroobjects (Galaxy clusters, Galaxies, Star clusters, Extrasolar systems, planets, etc.) made of these particles. There is no empty space or dark energy in WUM. The role of the Intergalactic plasma consisting of protons, electrons, and photons as part of the Medium of the World is analyzed in [1].

This paper discusses the Multicomponent Dark Matter and its decisive role in the Medium and Macroobjects of the World. DMP includes three Majorana fermions (Neutralinos, WIMPs, and Sterile neutrinos) with spin of 1/2 and two spin-0 bosons (named DIRACs and ELOPs in the World-Universe Model), as detailed below. Multicomponent dark matter models consisting of both bosonic and fermionic components were analyzed in literature (for example, see [2]-[10] and references therein).

2. Dark Matter Particles

Dark Matter (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).

A neutralino with mass m_N in $100 \Leftrightarrow 10000\ \mathrm{GeV/c^2}$ range is the leading CDM candidate. Light DMP that are heavier than WDM and HDM but lighter than neutralinos is DM candidates too. Subsequently, we will refer to the light DMP as WIMPs. Their mass m_{WIMP} falls into $1 \Leftrightarrow 10\ \mathrm{GeV/c^2}$ range. It is known that a sterile neutrino with mass m_{ν_s} in $1 \Leftrightarrow 10\ \mathrm{keV/c^2}$ range is a good WDM candidate. In our opinion, a tauonic neutrino is a good HDM candidate.

In addition to fermions discussed above, we offer another type of DMP—spin-0 bosons, consisting of two fermions each. There exist two types of DM bosons which we called DIRACs and ELOPS.

DIRACs are magnetic dipoles with mass m_0, consisting of two Dirac monopoles with mass $\frac{m_0}{2}$ and charge $\mu = \frac{e}{2\alpha}$, where e is an electron charge. Dissociated DIRACs can only exist at nuclear densities or at high temperatures. In our opinion, Dirac monopoles are the smallest building blocks of constituent quarks and hadrons (mesons and baryons).

The second spin-0 boson is the ELOP (named by analogy to an **EL**ectron-nortis**OP** dipole). ELOP weighs $\frac{2}{3}m_e$ and consists of two preons with mass $m_{pr} = \frac{1}{3}m_e$ and charge $e_{pr} = \frac{1}{3}e$. ELOPs break into two preons at nuclear densities or at high temperatures. In particle physics, preons are postulated to be "point-like" particles, conceived to be subcomponents of quarks and leptons [11].

We did not take into account the binding energies of DIRACs and ELOPs, and thus the values of the masses of monopoles and preons are approximate. They have negligible electrostatic and electromagnetic charges because the separation between charges is very small. The signatures of these bosons' annihilation in gamma-ray spectra will be discussed in Section 6.

WUM postulates that masses of DMP are proportional to m_0 multiplied by different exponents of α and can be expressed with the following formulae:

CDM particles (neutralinos and WIMPs):

$$m_N = \alpha^{-2} m_0 = 1.3149950\ \mathrm{TeV/c^2} \quad (2.1)$$

$$m_{\mathrm{WIMP}} = \alpha^{-1} m_0 = 9.5959823\ \mathrm{GeV/c^2} \quad (2.2)$$

DIRACs:

$$m_{\mathrm{DIRAC}} = 2\alpha^0 \frac{m_0}{2} = 70.025267\ \mathrm{MeV}/\mathrm{c}^2 \tag{2.3}$$

ELOPs:

$$m_{\mathrm{ELOP}} = 2\alpha^1 \frac{m_0}{3} = 340.66606\ \mathrm{keV}/\mathrm{c}^2 \tag{2.4}$$

WDM particles (sterile neutrinos):

$$m_{\nu_s} = \alpha^2 m_0 = 3.7289402\ \mathrm{keV}/\mathrm{c}^2 \tag{2.5}$$

These values fall into the ranges estimated in literature. The roles of those particles in macroobject cores built up from fermionic dark matter, in gamma-ray spectra of the diffuse gamma-ray background, and the emission of various macroobjects in the World will be discussed in Sections 3, 4 and 6 respectively.

Our Model holds that the energy densities of all types of DMP are proportional to the proton energy density ρ_p in the World's Medium [1]:

$$\rho_p = \frac{2\pi^2\alpha}{3}\rho_{cr} \tag{2.6}$$

where ρ_{cr} is a critical energy density of the World:

$$\rho_{cr} = 3\rho_0 \times Q^{-1} \tag{2.7}$$

$$\rho_0 = \frac{hc}{a^4} \tag{2.8}$$

ρ_0 is a basic unit of energy density and a dimensionless time-varying quantity Q equals to the ratio of the size of the World R at cosmological time τ to the Worlds' size a at the beginning:

$$Q = \frac{R}{a} \tag{2.9}$$

In all, there are 5 different types of DMP. Then the total energy density of DM is

$$\rho_{DM} = 5\rho_p = 0.24007327\rho_{cr} \tag{2.10}$$

which is close to the measured DM energy density: $\rho_{DM} \cong 0.268\rho_{cr}$ [12]. Note that one of outstanding puzzles in particle physics and cosmology relates to so-called cosmic coincidence: the ratio of dark matter density in the World to baryonic matter density in the Medium of the World $\cong 5$ [10] [13].

Neutralinos, WIMPs, and sterile neutrinos are Majorana fermions, which partake in the annihilation interaction with strength equals to α^{-2}, α^{-1}, and α^2 respectively (see Section 3). The signatures of DMP annihilation with expected masses of 1.3 TeV, 9.6 GeV, 70 MeV, 340 keV, and 3.7 keV are found in spectra of the diffuse gamma-ray background and the emission of various macroobjects in the World (see Section 6).

3. Macroobject Cores Built up from Fermionic Dark Matter

In this section, we discuss the possibility of all macroobject cores consisting of DMP introduced in Section 2. The first phase of stellar evolution in the history of the World may be dark stars, powered by Dark Matter heating rather than fusion. Neutralinos and WIMPs, which are their own antiparticles, can annihilate and provide an important heat source for the stars and planets in the World.

In our view, all macroobjects of the World (including galaxy clusters, galaxies, star clusters, extrasolar systems, and planets) possess the following properties:

- Macroobject cores are made up of DMP;
- Macroobjects consist of all particles under consideration, in the same proportion as they exist in the World's Medium;
- Macroobjects contain other particles, including DM and baryonic matter, in shells surrounding the cores.

Taking into account the main principle of the World-Universe Model (all physical parameters can be expressed in terms of α, Q, small integer numbers, and π) we modify the published theory of Fermionic Compact Stars

(FCS) developed by G. Narain, *et al*. [14] as follows. We take a scaling solution for a free Fermi gas consisting of fermions with mass m_f in accordance with following equations:

Maximum mass:

$$M_{\max} = A_1 M_F \tag{3.1}$$

Minimum radius:

$$R_{\min} = A_2 R_F \tag{3.2}$$

Maximum density:

$$\rho_{\max} = A_3 \rho_0 \tag{3.3}$$

where

$$M_F = \frac{M_P^3}{m_f^2}; \quad R_F = \frac{M_P}{m_f}\frac{L_{Cf}}{2\pi}; \quad \rho_0 = \frac{hc}{a^4} \tag{3.4}$$

and M_P is Planck mass, L_{Cf} is a Compton length of the fermion. A_1, A_2, and A_3 are parameters. Let us choose π as the value of A_2 (instead of $A_2 = 3.367$ taken by G. Narain, *et al*. [14]). Then diameter of FCS is proportional to the fermion Compton length L_{Cf}. We use $\pi/6$ as the value of A_1 (instead of $A_1 = 0.384$ taken by G. Narain, *et al*. [14]). Then A_3 will equal to

$$A_3 = \left(\frac{m_f}{m_0}\right)^4 \tag{3.5}$$

Table 1 summarizes the parameter values for FCS made up of various fermions:

Table 1. Parameter values of Compact Stars built up from fermionic dark matter particles.

Fermion	Fermion relative mass m_f/m_0	Macroobject relative mass $M_{\max}/M_0$	Macroobject relative radius $R_{\min}/L_g$	Macroobject relative density $\rho_{\max}/\rho_0$
Sterile neutrino	α^2	α^{-4}	α^{-4}	α^8
Preon	$3^{-1}\alpha^1$	$3^2\alpha^{-2}$	$3^2\alpha^{-2}$	$3^{-4}\alpha^4$
Electron-proton (white dwarf)	α^1, β	β^{-2}	$(\alpha\beta)^{-1}$	$\alpha^3\beta$
Monopole	2^{-1}	2^2	2^2	2^{-4}
WIMP	α^{-1}	α^2	α^2	α^{-4}
Neutralino	α^{-2}	α^4	α^4	α^{-8}
Interacting WIMPs	α^{-1}	β^{-2}	β^{-2}	β^4
Interacting neutralinos	α^{-2}	β^{-2}	β^{-2}	β^4
Neutron (star)	$\approx\beta$	β^{-2}	β^{-2}	β^4

where

$$M_0 = \frac{4\pi m_0}{3} \times Q^{3/2} \tag{3.6}$$

$$L_g = a \times Q^{1/2} \tag{3.7}$$

$$\beta = \frac{m_p}{m_0} \tag{3.8}$$

and m_p is the mass of a proton. A maximum density of neutron stars equals to the nuclear density:

$$\rho_{max} = \beta^4 \rho_0 \tag{3.9}$$

which is the maximum possible density of any macroobject in the World.

A Compact Star made up of heavier particles—WIMPs and neutralinos—could in principle have a much higher density. In order for such a star to remain stable and not exceed the nuclear density, WIMPs and neutralinos must partake in an annihilation interaction whose strength equals to α^{-1} and α^{-2} respectively.

Scaling solution for interacting WIMPs can also be described with Equations (3.1), (3.2), (3.3) and the following values of A_1, A_2 and A_3:

$$A_{1\max} = \frac{\pi}{6}(\alpha\beta)^{-2} \tag{3.10}$$

$$A_{2\min} = \pi(\alpha\beta)^{-2} \tag{3.11}$$

$$A_{3\max} = \beta^4 \tag{3.12}$$

The maximum mass and minimum radius increase about two orders of magnitude each and the maximum density equals to the nuclear density. Note that parameters of a FCS made up of strongly interacting WIMPs are identical to those of neutron stars.

In accordance with the paper by G. Narain, *et al*. [14], the most attractive feature of the strongly interacting Fermi gas of WIMPs is practically constant value of FCS minimum radius in the large range of masses M_{WIMP} from

$$M_{\text{WIMPmax}} = \frac{\pi}{6}(\alpha\beta)^{-2} M_F = \frac{1}{\beta^2} M_0 \tag{3.13}$$

down to

$$M_{\text{WIMPmin}} = \alpha^4 M_{\text{WIMPmax}} \tag{3.14}$$

M_{WIMPmin} is more than eight orders of magnitude smaller than M_{WIMPmax}. It makes strongly interacting WIMPs good candidates for stellar and planetary cores of extrasolar systems with Red stars (see Section 4).

When the mass of a FCS made up of WIMPs is much smaller than the maximum mass, the scaling solution yields the following equation for parameters A_1 and A_2:

$$A_1 A_2^3 = \pi^4 \tag{3.15}$$

Compare $\pi^4 \cong 97.4$ with the value of 91 used by G. Narain, *et al*. [14].

Minimum mass and maximum radiuses take on the following values:

$$A_{1\min} = \frac{\pi}{6}\sqrt{6}(\alpha\beta)^2 \tag{3.16}$$

$$A_{2\max} = \pi\sqrt[6]{6}(\alpha\beta)^{-2/3} \tag{3.17}$$

It follows that the range of FCS masses $(A_{1\min} \Leftrightarrow A_{1\max})$ spans about three orders of magnitude, and the range of FCS core radii $(A_{2\min} \Leftrightarrow A_{2\max})$—one order of magnitude. It makes WIMPs good candidates for brown dwarf cores too (see Section 4).

Scaling solution for interacting neutralinos can be described with the same Equations (3.1), (3.2), (3.3) and the following values of A_1^*, A_2^* and A_3^*:

$$A_{1\max}^* = \frac{\pi}{6}(\alpha^2\beta)^{-2} \tag{3.18}$$

$$A_{2\min}^* = \pi(\alpha^2\beta)^{-2} \tag{3.19}$$

$$A_{3\max}^* = \beta^4 \tag{3.20}$$

In this case, the maximum mass and minimum radius increase about four orders of magnitude each and the maximum density equals to the nuclear density. Note that parameters of a FCS made up of strongly interacting neutralinos are identical to those of neutron stars.

Practically constant value of FCS minimum radius takes place in the huge range of masses M_N from

$$M_{N\max} = \frac{\pi}{6}(\alpha\beta)^{-2}\alpha^2 M_F = \frac{1}{\beta^2}M_0 \quad (3.21)$$

down to

$$M_{N\min} = \alpha^8 M_{N\max} \quad (3.22)$$

$M_{N\min}$ is more than seventeen orders of magnitude smaller than $M_{N\max}$. It makes strongly interacting neutralinos good candidates for stellar and planetary cores of extrasolar systems with Main-sequence stars (see Section 4).

When the mass of a FCS made up of neutralinos is much smaller than the maximum mass, the scaling solution yields the following equation for parameters A_1^* and A_2^*:

$$A_1^* A_2^{*3} = \pi^4 \quad (3.23)$$

Minimum mass and maximum radiuses take on the following values:

$$A_{1\min}^* = \frac{\pi}{6}\sqrt{6}\left(\alpha^2\beta\right)^2 \quad (3.24)$$

$$A_{2\max}^* = \pi\sqrt[6]{6}\left(\alpha^2\beta\right)^{-2/3} \quad (3.25)$$

It means that the range of FCS masses $\left(A_{1\min}^* \Leftrightarrow A_{1\max}^*\right)$ is about twelve orders of magnitude, and the range of FCS core radiuses $\left(A_{2\min}^* \Leftrightarrow A_{2\max}^*\right)$ is about four orders of magnitude. The numerical values for FCS masses and radii will be given in Section 4.

Fermionic Compact Stars have the following properties:

- The maximum potential of interaction $U_{\max}$ between any particle or macroobject and FCS made up of any fermions

$$U_{\max} = \frac{GM_{\max}}{R_{\min}} = \frac{c^2}{6} \quad (3.26)$$

does not depend on the nature of fermions;

- The minimum radius of FCS made of any fermion

$$R_{\min} = 3R_{SH} \quad (3.27)$$

equals to three Schwarzschild radii and does not depend on the nature of the fermion;

- FCS density does not depend on $M_{\max}$ and $R_{\min}$ and does not change in time while $M_{\max} \propto \tau^{3/2}$ and $R_{\min} \propto \tau^{1/2}$.

4. Macroobjects of the World

According to WUM, all macroobjects of the World (galaxies, stars, planets) possess cores consisting of DMP. The theory of fermion compact stars made up of DMP is well developed. Scaling solutions are derived for a free and an interacting Fermi gas in Section 3. **Table 2** describes the numerical values for masses and radii of FCS made up of different fermions:

The calculated parameters of FCS show that

- White Dwarf Shells (WDS) around the nuclei made of strongly interacting WIMPs or neutralinos compose cores of stars in extrasolar systems;
- Shells of dissociated DIRACs to monopoles around the nuclei made of strongly interacting WIMPs or neutralinos form cores of globular clusters;
- Shells of dissociated ELOPs to preons around the nuclei made of strongly interacting WIMPs or neutralinos constitute cores of galaxies;

Table 2. Numerical values for parameters of Compact Stars built up from fermionic dark matter particles.

Fermion	Fermion mass m_f, MeV/c^2	Macroobject mass M_{max}, kg	Macroobject radius R_{min}, m	Macroobject density ρ_{max}, kg/m^3
Sterile neutrino	3.73×10^{-3}	1.2×10^{41}	5.4×10^{14}	1.8×10^{-4}
Preon	≥0.17	5.9×10^{37}	2.6×10^{11}	7.8×10^{2}
Monopole	≥35	1.4×10^{33}	6.2×10^{6}	1.4×10^{12}
Interacting WIMPs	9596	1.9×10^{30}	8.6×10^{3}	7.2×10^{17}
Interacting neutralinos	1315×10^{3}	1.9×10^{30}	8.6×10^{3}	7.2×10^{17}
Electron; proton (white dwarf)	0.511; 938.3	1.9×10^{30}	1.6×10^{7}	1.2×10^{8}
Neutron (star)	939.6	1.9×10^{30}	8.6×10^{3}	7.2×10^{17}

- Shells of sterile neutrinos around the nuclei made of strongly interacting WIMPs or neutralinos make up cores of galaxy clusters.

Although there are no free Dirac's monopoles and preons in the World, they can arise in the cores of FCS as the result of DIRACs and ELOPs gravitational collapse with density increasing up to the nuclear density $\left(\sim 10^{17}\ \text{kg/m}^3\right)$ and/or at high temperatures, with subsequent dissociation of dipoles to monopoles and preons.

4.1. Galaxies and Galaxy Clusters

A number of non-traditional models explaining the supermassive dark objects observed in galaxies and galaxy clusters, formed by self-gravitating non-baryonic matter composed of fermions and bosons, are widely discussed in literature [2]-[10].

Dark matter can be, in principle, achieved also through extended theories of gravity. It has been shown, for example, that in the framework of R^{2}gravity and in the linearized approach, it is possible to obtain spherically symmetric and stationary galaxy states which can be interpreted like an approximated solution of the Dark Matter problem [15] [16].

According to WUM, the heaviest macroobjects include a high-density preon plasma shell around their cores:

- Macroobjects with a cold preon shell emit strong radio waves. Such objects are good candidates for the compact astronomical radio sources at centers of galaxies like Sagittarius A* in the Milky Way Galaxy;
- Red Giants are macroobjects with hot preon shells;
- Blazars are members of a larger group of active galaxies that host active galactic nuclei (AGN). They are macroobjects with hot preon and sterile neutrinos shells;
- Quasars are the most energetic and distant members of AGN. They are macroobjects with very hot preon and sterile neutrinos shells;
- Seyfert galaxies are one of the two largest groups of AGN, along with quasars. They have quasar-like nuclei, but unlike quasars, their host galaxies are clearly detectable. Seyfert galaxies account for about 10% of all galaxies.

Note that the temperature of the preon and sterile neutrinos shells depends on the composition of the macroobject core. Macroobjects whose cores are made up of WIMPs and preons remain cold. Macroobjects with cores made up of WIMPs and WDS produce hot preon and sterile neutrino shells. Macroobjects whose cores consist of neutralinos and WDS have very hot preon and sterile neutrino shells.

The mass of an AGN is about 7-11 orders of magnitude larger than the mass of the Sun. The radius of an AGN is about 4 - 7 orders of magnitude larger than the radius of WDS (see **Table 2**). The area of the closed spherical surface around the AGN is 8 - 14 orders of magnitude greater than the surface area of WDS. Luminosity of the AGN is then 8 - 14 orders of magnitude higher than the luminosity of the largest star. This take on AGNs explains the fact that the most luminous quasars radiate at a rate that can exceed the output of average galaxies, equivalent to two trillion suns.

To summarize, macroobjects of the World have cores made up of DM particles. The cores are surrounded by shells made up of DM and baryonic matter. Every macroobject consists of all particles under consideration that are present in the same proportion as they exist in the World's Medium. No compact stars are made up solely of fermionic DMP, for instance.

4.2. Extrasolar Systems

There are two primary types of stars: main-sequence stars and red stars. They differ in their surface temperatures and radii:

- Red stars have cool surface temperatures: 3500 ⇔ 4500 K for Hypergiants, Supergiants, Giants, lower for Red dwarfs (2300 ⇔ 3800 K), and significantly lower for Brown dwarfs (300 ⇔ 1000 K). These stars have enormous range of radii: from $1650R_{\text{Sun}}$ for Hypergiants down to $0.08R_{\text{Sun}}$ for Red dwarfs, and lower still for Brown dwarfs.
- Main-sequence stars have surface temperatures in the range of 3000 ⇔ 45,500 K, and radii in the range from $35R_{\text{Sun}}$ for the most massive known star R136a1 down to $0.1R_{\text{Sun}}$ for least heavy stars.

In our opinion, the difference between main-sequence stars and red stars lies in composition of stellar cores. Main-sequence stars cores are made up of neutralinos, while red star cores consist of WIMPs. As we have shown in Section 3, in both cases the cores' maximum mass and minimum radius equals to that of a neutron star. The fermions, however, have drastically different interaction strength of annihilation: α^{-1} in case of WIMPs and α^{-2} in case of neutralinos.

The Core temperature is therefore much higher in main-sequence stars whose cores are made up of neutralinos. Ignition of proton-proton chain reaction with the interaction strength equal to $\beta \approx 13.4$ developing in the surrounding WDS happens much more efficiently in these stars.

The developed star model explains the very low power production density produced by fusion inside of the Sun. Wikipedia humorously notes that the power output of the Sun *more nearly approximates reptile metabolism than a thermonuclear bomb*. In our Model, the core made up of strongly interacting neutralinos is the supplier of proton-electron pairs into WDS and igniter of the proton-proton chain reaction developing in the surrounding WDS with small interaction strength $\beta \cong 13.4$.

New neutralinos freely penetrate through the entire stellar envelope, get absorbed into the core and support neutralino annihilation and proton fusion in the WDS. An important consequence for Solar system, and in fact for all other stars in the World, is that they will never burn their "fuel" out. On the contrary, stars accumulate more fuel with time, and output more power.

Enormous radii of Hypergiants (up to $1650R_{\text{Sun}} \cong 10^{12}$ m) and huge luminosity of giant stars can be explained by an additional shell of preons—particles whose charge equals to $\frac{1}{3}e$. They compose hot high-density plasma with surface temperature in the range of 3500 ⇔ 4500 K. The minimum radius of preon shell $R_{\min} \cong 2.6\times10^{11}$ m (see **Table 2**).

Brown dwarfs are sub-stellar objects whose masses range from 13 to 80 Jupiter masses. In our opinion, Brown dwarfs differ from red stars in that the density of their cores is smaller than nuclear density. Consequently, WIMPs annihilation takes place less efficiently.

4.3. Extrasolar System Formation

The Nebular Hypothesis is the most widely accepted model of planetary formation. It holds that 4.6 Billion years ago, the Solar System was formed during a gravitation collapse of a giant molecular cloud, some light years across. The most significant criticism of the hypothesis is its inability to explain the Sun's relative lack of angular momentum when compared to the planets [17].

According to WUM, extrasolar systems arise from clouds of all particles under consideration with mass M_{Cl}. As a result of gravitational instability, gravitational collapse takes place and one third of M_{Cl} is concentrating at the center of the cloud, increasing the density of the core up to the nuclear density.

The heaviest particles—neutralinos or WIMPs are the first in this stream of matter. When their density achieves the nuclear density, self-annihilation process ignites. As the result, the Stellar Nucleus (SN) grows up to 10^4 for neutralinos and 10^2 times for WIMPs taking additional mass of neutralinos and WIMPs from oncoming stream.

The next heaviest particles—protons, joined by electrons—will follow neutralinos or WIMPs during the gravitational collapse, and form the White Dwarf Shell (WDS) around the SN made of strongly interacting WIMPs or neutralinos.

Expansion of the hot Stellar Core (SC), consisting of SN with WDS, is progressing. Drops of the SC are ejected from the equatorial bulges of an overspinning SC (outward centrifugal forces exceed the inward gravitational force) and give birth to the cores of planets.

The following facts support the creation picture of extrasolar systems outlined above:

- The analysis of a mass-radius ratio for compact stars made of strongly interacting fermions shows that the radius remains approximately constant for a wide range of compact stars masses;
- The analysis of a mass-radius ratio for the lowest mass white dwarfs shows the same behavior—radius does not depend on mass. It happens because at the low mass end the Coulomb pressure (which is characterized by constant density $\propto M/r^3$ and thus $r \propto M^{1/3}$) starts to compensate the degeneracy: $r \propto M^{-1/3}$. The two effects nearly cancel each other out, so $r \propto M^0$—no dependency at all;
- Recent analysis of the Solar and Heliospheric Observatory (SOHO) mission data favors a faster rotation rate in the solar core (below 0.2 solar radius) than in the rest of the radiative zone [18];
- By analyzing the minute changes in travel times and wave shapes for earthquake doublets, the researchers of [19] concluded that the Earth's inner core is rotating faster than its surface by about 0.3 - 0.5 degrees per year;
- The authors of [20] found that Earth's inner core, made up of solid iron, "superrotates" in an eastward direction—meaning it spins faster than the rest of the planet—while the outer core, comprising mainly molten iron, spins westwards at a slower pace.

In our opinion, the Earth's inner core is made up of neutralinos, while the outer core is the WDS. The cores of the Sun and the planets comprising the Solar System are not rotating with the same speed as their surfaces. When analyzing the angular momentum distribution of the entire Solar System, one must consider these additional angular momentums. Moreover, the remainder of the original particle cloud weighing $\frac{2}{3}M_{Cl}$ may possess additional angular momentum.

As discussed above, the minimum radius of the hot neutralinos and WIMPs core $R_{\min} \cong 8.6\ \text{km}$, and it remains essentially constant whether the core belongs to a star or to a planet. The masses of planets formed around red stars and main-sequence stars differ:

- The smallest possible mass of planets formed around red stars is 8 orders of magnitude smaller than maximum star mass M_0;
- Planets formed around main-sequence stars may be 17 orders of magnitude lighter than the maximum star mass.

Consequently, all round objects in hydrostatic equilibrium, down to Mimas in Solar system, contain hot neutralinos cores with WDS and should be considered planets. Planets can arise only around main sequence and red stars. Due to the less violent nature of their formation, brown dwarfs do not create planets.

4.4. Pioneer Anomaly

According to WUM, the macroobject energy E_{MO} enclosed in surface S_{MO} is proportional to the area of that surface:

$$E_{MO} = \sigma_0 S_{MO} \tag{4.4.1}$$

where σ_0 is the basic unit of surface energy density: $\sigma_0 = \rho_0 a$. It is natural to define surface S_{MO} as the boundary between macroobject and surrounding environment. In case of our Solar system, such a surface is named Heliosphere. We will refer to such a surface as Macroobject Boundary (MOB). According to the developed Model, Macroobjects have cores made up of fermionic DMP possessing minimum radii $R_{\min}$ described in **Table 1** and **Table 2**. In case of extrasolar systems, the cores are made up of interacting neutralinos or WIMPs surrounded with White Dwarf Shells (WDS).

The cores are surrounded by the transitional region. In this region, the density decreases rapidly to the point of the zero level of the fractal structure [21] characterized by radius R_f and energy density ρ_f that satisfy the following equation for $r \ge R_f$:

$$\rho(r) = \frac{\rho_f R_f}{r} \tag{4.4.2}$$

According to Yu. Baryshev: *For a structure with fractal dimension D* = 2 *the constant* $\rho_f R_f$ *may be actual-*

ly viewed as a new fundamental physical constant [21]. In our Model, it is natural to connect this constant with the constant σ_0:

$$\rho_f R_f = 4\sigma_0 \tag{4.4.3}$$

The value of 4 above follows from the ratio for all Macroobjects of the World: 1/3 of the total energy is in the central macroobject (for example, star in extrasolar system) and 2/3 of the total energy is in the fractal structure around it. Taking the radius of a Macroobject Boundary R_{MOB} we find the macroobject energy:

$$E_{MO} = 4\pi R_{MOB}^2 \sigma_0 \tag{4.4.4}$$

The energy in the fractal structure E_{FS} at $R_{MOB} \gg R_f$ is:

$$E_{FS} = \int_{R_f}^{R_{MOB}} \frac{4\sigma_0}{r} \times 4\pi r^2 \mathrm{d}r \approx 8\pi R_{MOB}^2 \sigma_0 \tag{4.4.5}$$

and the total energy E_{tot} equals to: $E_{tot} = 12\pi R_{MOB}^2 \sigma_0$.

It allows us to explain the so-called "Pioneer anomaly". Wikipedia describes this effect the following way: *The Pioneer anomaly is the observed deviation from predicted accelerations of the Pioneer* 10 *and Pioneer* 11 *spacecraft after they passed about* 20 *astronomical units* $\left(3\times10^9\ \text{km}; 2\times10^9\ \text{mi}\right)$ *on their trajectories out of the Solar System. An unexplained force appeared to cause an approximately constant sunward acceleration of* $a_P = 8.74 \pm 1.33\times10^{-10}\ \text{m/s}^2$ *for both spacecraft. The magnitude of the Pioneer effect* a_P *is numerically quite close to the product of the speed of light c and the Hubble constant* H_0 *hinting at cosmological connection.*

Let us calculate a deceleration a_P at the distance $r_P \gg R_f$ due to the additional mass of the fractal structure $M_{FS}\left(r_P\right) \propto r_P^2$ with the following equation for the gravitational parameter *G* [1]:

$$G = \frac{c^4}{8\pi\sigma_0 R_0} \tag{4.4.6}$$

$$a_P = \frac{GM_{FS}}{r_P^2} = \frac{c^4}{8\pi\sigma_0 R_0} \times \frac{8\pi\sigma_0}{c^2} = \frac{c^2}{R_0} = cH_0 = 6.68\times10^{-10}\ \text{m/s}^2 \tag{4.4.7}$$

which is in good agreement with the experimentally measured value (R_0 and H_0 are the values of the World's size *R* and Hubble's parameter *H* at the current time *t*). It is important to notice that the calculated deceleration does not depend on r_P and equals to cH_0 for all objects around the macroobject at the distance $r > R_f$.

Mass of the fractal structure around Sun M_V at distances $R_V \gg R_f$ is

$$M_V = 8\pi R_V^2 \sigma_0 / c^2 \tag{4.4.8}$$

At distance $R_V = 1.8\times10^{13}\ \text{m}$ away from the Sun (approximate distance to Voyager 1 [22]),

$$M_V \cong 3.3\times10^{27}\ \text{kg} \tag{4.4.9}$$

that is $\sim 0.15\% M_{\text{Sun}}$. Note that the distances traveled by Voyagers are much smaller than the radius of the MOB: $R_V \ll R_{MOB} \sim 10^{15}\ \text{m}$.

5. X Rays and Gamma Rays

All "elementary" particles of the World are fermions and they possess masses. Bosons such as photons, X-quants, and Gamma-quants are composite particles and consist of two fermions. Gamma rays are usually distinguished from X rays by their origin: X rays are emitted by electrons outside the nucleus, while gamma rays are emitted by the nucleus. A better way to distinguish the two, in our opinion, is the type of fermions composing the core of X-quants and Gamma-quants.

Super-soft X rays possess energies in the 0.09 ⇔ 2.5 keV range, whereas soft Gamma rays have energies in the 10 ⇔ 5000 keV range. We assume that X-quants are composed of two interacting neutrinos. New Physics with the dineutrinos in the Rare Decay $B \to K\nu\bar{\nu}$ is actively discussed in literature in recent years (for example, see [23] [24]).

Soft Gamma-quants are composed of two sterile neutrinos (3.7 keV each). Hard and super-hard Gamma-quants may be composed of two preons ($\gtrsim$ 0.17 MeV each), which are ELOPs in our Model, two Dirac monopoles ($\gtrsim$ 35 MeV each) which are, in fact, DIRACs.

We propose that Super-soft gamma rays (<10 keV) can arise as the result of sterile neutrino annihilation in the low energy case. Two or three super-soft gamma-quants with the energy < 3.7 keV are created. Similarly,

- ELOP annihilation produces hard gamma rays with energies < 340 keV;
- DIRAC annihilation produces hard gamma rays with energies < 70 MeV;
- WIMP annihilation produces super-hard gamma rays with energies < 9.6 GeV;
- Neutralino annihilation produces super-hard gamma rays with energies < 1.3 TeV.

Diffuse cosmic gamma-ray background is the sum of the contributions of the multicomponent self-interacting dark matter annihilation.

6. Dark Matter Signatures in Gamma-Ray Spectra

Large number of papers has been published in the field of X-ray and gamma-ray astronomy. The X-ray and gamma-ray background from $\lesssim$ 0.1 keV to $\gtrsim$ 10 TeV has been studied using high spectral and spatial resolution data from different spectrometers. Numerous papers were dedicated to Dark Matter searches with astroparticle data (see reviews [25]-[34] and references therein). Dark Matter annihilation is proportional to the square of the DM density and is especially efficient in places of highest concentration of dark matter, such as compact stars built up from fermionic dark matter particles (see Section 3).

The models of DM annihilation and decay for various types of macroobjects (galaxy clusters, blazars, quasars, Seyfert galaxies) are well-developed. Physicists working in the field X-ray and gamma-ray astronomy attempt to determine masses of DM particles that would fit the experimental results with the developed models.

Recall that no macroobjects are made up of just a single type of DM particles, since other DM particles as well as baryonic matter are present in the shells. It follows that macroobjects cannot irradiate gamma rays in a single spectral range. On the contrary, they irradiate gamma-quants in different spectral ranges with ratios of fluxes depending on structure of a given macroobject.

WUM forecasts existence of DM particles with 1.3 TeV, 9.6 GeV, 70 MeV, 340 keV, and 3.7 keV masses. We will look for signs of annihilation of these particles in the observed gamma-ray spectra. We connect gamma-ray spectra with the structure of macroobjects (core and shells composition).

C. Boehm, P. Fayet, and J. Silk have this to say about Light and Heavy Dark Matter Particles:

It has recently (2003) *been pointed out that the* 511 keV *emission line detected by Integral/SPI from the bulge of our galaxy could be explained by annihilations of light Dark Matter particles into* e^+e^-. *If such a signature is confirmed, then one might expect a conflict with the interpretation of very high energy gamma rays if they also turn out to be due to Dark Matter annihilations*.

They proposed a way *to reconcile the low and high energy signatures*, *even if both of them turn out to be due to Dark Matter annihilations*. *One would be a heavy fermion*, *for example*, *the lightest neutralino* (>100 GeV) *and the other one a possibly light spin*-0 *particle* (~100 MeV). *Both of them would be neutral and also stable as a result of two discrete symmetries (say R and M-parities)* [9] [35].

According to our Model, the two couples of co-annihilating DMP are: a heavy fermion—neutralino with mass 1.3 TeV and a light spin-0 boson—DIRAC with mass 70 MeV; a heavy fermion—WIMP with mass 9.6 GeV and a light spin-0 boson–ELOP with mass 340 keV.

6.1. Neutralino 1.3 TeV

J. Holder has this to say about TeV Gamma-ray Astronomy: *In leptonic scenarios*, *a population of electrons is accelerated to TeV energies*, *typically through Fermi acceleration by shocks in the AGN jet*. *These electrons then cool by radiating X-ray synchrotron photons*. *TeV emission results from inverse Compton interactions of the electrons with either their self-generated synchrotron photons*, *or an external photon field*. *The strong correlation between X-ray and TeV emission which is often observed provides evidence for a common origin such as this*, *although counter examples do exist* [36].

In our opinion, the TeV blazar emission should be classified as extremely-hard X rays and not gamma rays, since by definition: X rays are emitted by electrons outside the nucleus, while gamma rays are emitted by the nucleus.

R.C.G. Chaves, *et al.* have found that a significant fraction of the Galactic VHE (Very High Energy) gamma-ray sources (from the observed approximately 100 VHE γ-ray sources [38]-[42]) do not appear to have obvious counterparts at other wavelengths [37].

This correlation between keV emission and TeV emission can be easily explained by the annihilation of the sterile neutrinos (3.7 keV) in the shell around the core of AGN made of neutralinos (1.3 TeV). Lack of the counterpart in gamma-ray spectra means the absence of sterile neutrino shell.

A detailed global analysis on the interpretation of the latest data of PAMELA, Fermi-LAT, AMS-02, H.E.S.S, and other collaborations in terms of dark matter annihilation and decay in various propagation models showed that for the Fermi-LAT and H.E.S.S. data favor DMP mass is $m_\chi \approx 1.3\,\text{TeV}$ [43]-[46]. The obtained data in [47]-[55] require DM mass m_χ to be around 1 to 1.5 TeV which is in good agreement with the predicted mass of a neutralino (1.3 TeV). Pulsars are the most natural candidates for such sources [41].

The presence of spectral break at 1.3 TeV in VHE spectra was measured for different blazars [56]-[58]. Some nearby sources, e.g. Vela, Cygnus Loop, and Monogem Supernova Remnant (SNR) have unique signatures in the electron energy spectrum in the TeV region: broken power-law at ~1.3 TeV [59]. The DM interpretations of the $e^\pm$ excesses observed by PAMELA, Fermi and ATIC suggest the DMP mass of 1.3 TeV [60].

As we mentioned above, pulsars are the most natural candidates for such VHE gamma-ray sources. According to WUM, FCS made up of strongly interacting neutralinos and WIMPs have maximum mass and minimum size which is exactly equal to parameters of neutron stars (see **Table 1** and **Table 2**). It follows that pulsars might be in fact rotating Neutralino stars and WIMP stars with different shells around them.

The cores of such pulsars may also be made up of the mixture of neutralinos (1.3 TeV) and WIMPs (9.6 GeV) surrounded by shells composed of the other DMP: DIRACs (70 MeV), ELOPs (340 keV), and sterile neutrinos (3.7 keV). Annihilation of those DMP can give rise to any combination of gamma-ray lines. Thus the diversity of VHE gamma-ray sources in the World has a clear explanation in frames of the World-Universe Model.

In our opinion, results obtained by the CALET program are the closest to the ultimate discovery of the first confirmed dark matter particle—neutralino with mass 1.3 TeV [59].

6.2. WIMP 9.6 GeV

Dan Hooper summarized and discussed the body of evidence which has accumulated in favor of dark matter in the form of approximately 10 GeV particles, including *the spectrum and angular distribution of gamma rays from the Galactic Center*, *the synchrotron emission from the Milky Way's radio filaments*, *the diffuse synchrotron emission from the Inner Galaxy (the "WMAP Haze") and low-energy signals from the direct detection experiments DAMA/LIBRA*, *CoGeNT and CRESST-II*. Dan Hooper finds that *gamma-ray signal observed from the Galactic Center is consistent with* 7 - 12 GeV *dark matter particles annihilating mostly to leptons* [61] [62].

Based on EGRET observations, P. Sreekumar, *et al.* attribute the high-energy gamma ray emissions to blazars: *Most of the measured spectra of individual blazars only extend to several GeV and none extend above* 10 *GeV*, *simply because the intensity is too weak to have a significant number of photons to measure* [63]. WUM proposes that cores of blazars are composed of annihilating WIMPs (9.6 GeV), explaining why no observed radiation extends above 10 GeV. The results of gamma-ray emission between 100 MeV to 10 GeV detected from 18 globular clusters in our Galaxy are also in a good correlation with the predicted mass of WIMPs [64] [65].

The DAMA/LIBRA, CoGeNT, CRESST-II, CDMS-II collaborations conduct direct detections of DMP by nuclear recoils due to the elastic scattering of DMP. An 8.6 GeV DMP is deemed most probable [66].

Based on its core assumptions, WUM analytically predicts WIMPs to possess the mass of 9.6 GeV. A large number of experimental results seem to converge to a number in the neighborhood of 10 GeV, providing additional support to WUM.

6.3. DIRAC 70 MeV

S. D. Hunter, *et al.* discuss a peak at 67.5 MeV: *Below about* 100 MeV, *gamma rays produced via electron bremsstrahlung are the dominant component of the observed spectrum, whereas, above about* 100 MeV, *the gamma-rays from* π^0 *decay, which form the broad "pion bump" centered at* 67.5 MeV, *are the dominant component of the spectrum*. *The "pion bump", clearly visible in this spectrum, is the only spectral feature in the diffuse gamma ray emission in the EGRET energy range* [67].

70 MeV peak in EGRET data was discussed by Golubkov and Khlopov [68]. They explained this peak by the

decay of π^0 -mesons, produced in nuclear reactions. B. Wolfe, *et al*. said that gamma rays at 70 MeV are notably detectable by GLAST and EGRET [69]. R. Yamazaki, *et al*. attribute the 70 MeV peak in the emission spectrum from an old supernova remnant (SNR) to π^0 -decay [70] [71].

Note that whenever the 70 MeV peak appears in gamma-ray spectra, it is always attributed to pion decay. We claim that π^0 decay produces a 67.5 MeV peak, while DIRAC annihilation is responsible for 70 MeV peak. To find out the source of the observed broad peak about 70 MeV, we suggest utilization of exponentially cutoff power-law for analysis of experimental data for gamma-ray energies < 70 MeV. A better fit of experimental data will be evidence of DIRACs annihilation.

In our opinion, the DIRAC may indeed be the so-called U boson, target of intense search by the scientific community. Note that the mass of DIRAC proposed by WUM—0.07 GeV/c^2—falls into the mass range of U boson: $M_U = 0.02 \text{ - } 0.1\,\text{GeV}/\text{c}^2$ [72]-[77].

6.4. ELOP 340 keV

An ELOP is a spin-0 boson with 340 keV mass. Existence of DMP of similar masses $\left(m_\chi < 0.42\,\text{MeV}\right)$ has been discussed by Y. Rasera, *et al*. [78]. The experimental 100 - 400 keV "bump" [79] is in good agreement with the theoretical analysis in [78] and with annihilating ELOPs with mass 340 keV proposed in our Model.

D. E. Gruber, *et al*. describes a wide gamma-ray extragalactic background spectrum between 1 keV and 10 GeV: *Above* 60 keV *selected data sets included the HEAO* 1 A-4 (*LED and MED*), *balloon*, *COMPTEL*, *and EGRET data*. *The fit required the sum of three power laws* [80].

According to our Model, the fit of the total diffuse spectrum in the range between 3 keV and 10 GeV should be performed based on three exponentially cutoff power-laws with injection spectral $J(E) \propto E^{-\gamma} \exp\left\{-E/E_{cut}\right\}$ with the spectral index γ and E_{cut} being the cutoff energy of the source spectra. For values of E_{cut}, we should use

- 9.6 GeV (annihilating WIMPs) in the 9.6 GeV - 70 MeV range;
- 70 MeV (annihilating DIRACs) in the 70 MeV - 340 keV range;
- 340 keV (annihilating ELOPs) in the 340 keV - 3.7 keV range.

The fit in the range between 9.6 GeV and 1.3 TeV should be done with $E_{cut} = 1.3\,\text{TeV}$, which equals to the mass of a neutralino.

6.5. Sterile Neutrino 3.7 keV

The very first signature of the emission around 3.7 keV was found in 1967 by P. Gorenstein, R. Giacconi, and H. Gursky. They analyzed the counting rate in the 2 - 5 keV range and found that *the sources GX*-10.7, +9.1, +13.5, *and* +16.7 *are qualitatively different from Sco* X-1, *Cyg* X-1 *or Cyg* X-2 *in that the highest number of net counts is recorded in the bin centered at* 3.75 keV [81].

An important result was obtained by S. Safi-Harb and H. Ogelman in 1997. They reported that *the observations of the X-ray lobes of the large Galactic source* W50 *[are] associated with the two-sided jets source SS* 433. *A broken power-law model gives the best fit*. *The power-law indices are* 1.9 *and* 3.6, *with the break occurring at* 3.7 *keV* [82].

T. Itoh analyzed the broad-band (3.0 - 50 keV) spectra of NGC 4388 and found line-like residual around 3.7 keV at the high confidence level [83].

A. Bykov, *et al*. investigated *the nature of the extended hard X-ray source* XMMU J061804.3 + 222732 *and its surroundings using XMM-Newton*, *Chandra*, *and Spitzer observations*. *The X-ray emission consists of a number of bright clumps embedded in an extended structured non-thermal X-ray nebula larger than* 30″ *in size*. *Some clumps show evidence for line emission at* ~1.9 keV *and* ~3.7 keV *at the* 99% *confidence level*. *A feature at* 3.7 keV *was found in the X-ray spectrum of Src* 3 *at the* 99% *confidence level* [84].

In our opinion, the line emission ~3.7 keV corresponds to the annihilation of sterile neutrinos and the line ~1.9 keV corresponds to their decay.

R. Fukuoka, *et al*. observed the South End of the Radio Arc and found the line-like residual at ~3.7 keV with ~3σ significance [85]. In 2012, A. Moretti, *et al*. measured the diffuse gamma-ray emission at the deepest level and with the best accuracy available today. An emission line around 3.7 keV is clearly visible in the obtained spectrum [86].

6.6. Conclusions

- Emission lines of 1.3 TeV, 9.6 GeV, 70 MeV, 340 keV, and 3.7 keV, can be found in spectra of the diffuse gamma-ray background radiation and various macroobjects of the World in different combinations depending on their structure.
- The diffuse cosmic gamma-ray background radiation in the <1.3 TeV range is the sum of the contributions of multicomponent dark matter annihilation.
- The total cosmic-ray radiation consists of gamma-ray background radiation plus X-ray radiation from the different highly ionized chemical elements in the hot areas of the World and is due to various electron processes such as synchrotron radiation, electron bremsstrahlung, and inverse Compton scattering.

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