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DID CDM PARTICLES OF MASS 2.47 x 10^{-3}eV INTERACT WITH PRECURSOR BIOPOLYMERS AND NUCLEIC ACIDS TO INITIATE AND BOOST LIFEFORMS ON EARTH?

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Abstract. Recent observations and theoretical studies have shown that non-baryonic Cold Dark Matter (CDM), which constitutes about 84% of all matter in the Universe, may feature a complex-scalar-field that carries particles of mass $m \cong 2.47 \times 10^{-3} eV$ with the associated Compton range $m^{-1} \cong 8.02 \times 10^{-3} cm$, a distance on the scale of extended bionucleic acids and living cells. Such a complex-scalar-field can enter a weak-isospin Lorentz-invariant interaction that generates the flow of right-handed electrons and induces a chirality-imbued quantum chemistry on the m^{-1} scale. A phenomenological Volterra-type equation is proposed for the CDM-impacted time development of *N*, the number of base pairs in the most advanced organism at Earth-age t. The solution to this equation suggests that the boosts in *N* at $t \cong 1.1$ Gyr (advent of the first living prokaryotic cells), at $t \cong 2.9$ Gyr (advent of eukaryotic single-celled organisms) and finally at $t \cong 4.0$ Gyr (the Cambrian explosion) may be associated with three multi-Myr-duration cosmic showers of the complex-scalar-field CDM particles. If so, the signature of the particles may be detectible in Cambrian rocks.

Keywords. Cold Dark Matter (CDM), particles with Compton range $m^{-1} \cong 8.02 \times 10^{-3} cm$, chirality-producing interaction, enlargement of DNA, evidence in Cambrian rocks

1. Introduction

It has been conjectured by numerous authors that Cold Dark Matter (CDM), which constitutes about 84% of all matter in the Universe, may play a central role in the origin of precursor biopolymers, bioactive nucleic acids and living cells. Various Earth-restricted (terrestrial-biochemistry) scenarios for the origin of the latter are plagued by intransigent difficulties associated with chemical reaction pathways and rates (Shapiro, 1986; Mattioli and Wood, 1986; Raulin-Cerceau, Maurel and Schneider, 1998). Thus authors have been led to conclude that an astrophysical scenario occurred, one which would naturally accommodate the early view of Schrödinger (1944) that “living matter, while not eluding the laws of physics as established to date, is likely to involve other laws of physics hitherto unknown” to account for its origin. In light of the current experimental program (CDMS II Collaboration, 2010) to detect and measure the properties of CDM particles, considerable interest is attached to how CDM particles may relate in theory to the origin of prebiotic and biological entities.

CDM astrophysics is primarily relevant because of homochirality, a unifying structural characteristic of the biopolymers and a likely prerequisite for their origin (for a comphrensive review: Borchers, Davis and Gershwin, 2004). Natural DNA is right-handed (in the 5’ to 3’ helical sense) and living cells use left-handed L-amino acids and right-handed D-sugars almost exclusively. Of the three established fundamental interactions, the strong, the electroweak and the gravitational, only the electroweak can impart homochirality. Circularly polarized electromagnetic radiation can produce a rather nominal enantiomeric excess in special racemic

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substances. More potently, electrons with definite spin-momentum helicities $\vec{\boldsymbol{\sigma}} \cdot \vec{\boldsymbol{p}} / |\boldsymbol{p}| = \mp 1$, for left-handed and right-handed electrons e_L and e_R respectively, can produce molecular homochirality in a pronounced manner through electromagnetic interactions (Hegstrom, 1982; Rosen, 2002). Such electrons with definite helicities are quanta of the fields $\Psi_L \equiv \frac{1}{2}(1-\gamma_5)\Psi$ and $\Psi_R \equiv \frac{1}{2}(1+\gamma_5)\Psi$ that arise in weak interactions, where Ψ_L is the companion of the electron neutrino field in a weak-isospin doublet and Ψ_R stands alone as a weak-isospin singlet [see, *e.g.*, Raffelt (1996)]. However, owing to the smallness of the Fermi constant G_F, the past and present small terrestrial Ψ_L and Ψ_R fluxes are not likely to have instigated homochirality during the formation of precursor biopolymers , bioactive nucleic acids and living cells on Earth (Mason, 2000), thereby requiring a significant form of augmentation. Such an augmentation for an effective chiral quantum chemistry may derive from CDM particles associated with a complex-scalar-field, as described in the following.

2. Homochirality-producing Mechanism Based on a CDM Complex-scalar-field

Recent astrophysical observations and refined estimates (Fabris and Jardim, 2010) support a complex-scalar-field model for CDM based on the Lagrangian density (Rosen, 2010)

$$\mathcal{L}_{DM} = (-g^{\mu\nu}\phi^*_{,\mu}\phi_{,\nu} + (\lambda-1)m^2\phi^*\phi - ½\lambda(\phi^*\phi)^2)\ \sqrt{-g} \tag{1}$$

In (1), $\phi = \phi(x)$ is the complex-valued CDM scalar-field, λ and m are constants with the physical values dictated by cosmological observations

$$\lambda \cong 3.5 \quad \text{and} \quad m \cong 2.47 \times 10^{-3} eV \tag{2}$$

and physical units are such that $\hbar = c = 1$ [which implies that $1\ cm \cong (1.98 \times 10^{-5}\boldsymbol{eV})^{-1}$]. Notwithstanding the cubic nonlinear term that results from the Higgs-type quartic term in (1), the associated field equation for ϕ admits the particle density flux four-vector

$$f^{\mu} \equiv -\frac{i}{2} g^{\mu\nu} \sqrt{-g}\, (\phi^* \phi_{,\nu} - \phi^*{}_{,\nu}\phi), \tag{3}$$

that satisfies the conservation equation

$$f^{\mu}{}_{,\mu} = 0 \tag{4}$$

as a direct implication of ϕ field equation. Hence, the ϕ field may couple naturally, in a Lorentz-invariant and weak-isospin invariant manner, to the right-handed electrons of ordinary matter through the interaction Lagrangian density

$$\mathcal{L}_{\text{int}} = G_F f^{\mu} \overline{\Psi}_R \gamma_{\mu} \Psi_R \sqrt{-g} \tag{5}$$

in which $G_F \cong 4.57 \times 10^{-33} cm^2$ is the Fermi constant for weak-interaction Lorentz-invariant current-current coupling. Note that the right-handed weak-isospin singlet Ψ_R enters with exclusion of the weak isospin doublet component Ψ_L in (5), thereby making the right side of (5) manifestly invariant with respect to both Lorentz spacetime-coordinate and weak-isospin unitary transformations. The essential biophysical consequence of the interaction (5) is to cause the right-handed electron flow-vector $\overline{\Psi}_R \gamma \Psi_R$ to align parallel to the CDM flow-vector $\boldsymbol{f} = (f^1, f^2, f^3)$ in order to minimize the groundstate energy of molecules (Rosen, 2002). It has been established experimentally (Hegstrom, 1982; Borchers, Davis and Gershwin, 2004) that such a right-handed electron flow is conducive to reaction pathways in an intrinsically chiral quantum chemistry. However, for this to follow from (5), the CDM flow vector must be large in magnitude, with $|\boldsymbol{f}| \gtrsim 1.0 \times 10^7\, cm^{-3}$, at least three orders of magnitude greater than the detectible CDM cosmic flux to Earth at the present time. With $|\boldsymbol{f}|$ sufficiently large during certain intervals of Earth's history, the interaction (5) on precursor biopolymers and bioactive nucleic acids on the m^{-1} scale is expected to generate alterations and fusions of DNA segments and supportive protein enzymes for adaptively larger DNA (e.g., topoisomerases). Indeed, the fact that only about 15% of DNA is active in advanced organisms suggests that DNA enlargements have been followed by survival-fitness selection in the evolution of lifeforms.

3. Phenomenological Volterra-type equation for the CDM-induced development of DNA

Let $N = N(t)$ denote the number of base pairs in the most advanced organism at time t, with the Earth forming at $t = 0$ and $t \cong 4.54\ Gyr$ at present. The development of life on Earth has been characterized by broad periods of stasis punctuated by very brief periods in which new higher phyla, with order-of-magnitude larger N, made their abrupt appearance, as described approximately by (*e.g.*, Valentine, 2004):

$$\log_{10} N \cong \begin{cases} \sim 0 & \text{for} \quad t \lesssim 1.1\ Gyr \\ 6.5 & \text{for} \quad 1.1\ Gyr \lesssim t \lesssim 2.9\ Gyr \\ 7.0 & \text{for} \quad 2.9\ Gyr \lesssim t \lesssim 4.0\ Gyr \\ 9.5 & \text{for} \quad 4.0\ Gyr \lesssim t \lesssim 4.54\ Gyr \end{cases} \qquad (6)$$

The relatively short-duration ($\lesssim 100\ Myr$) increases in $\log_{10}N$ at $t \cong 1.1\ Gyr$ (the advent of the first single-celled prokaryotic organisms), at $t \cong 2.9\ Gyr$ (the advent of single-celled eukaryotic organisms, and finally at $t \cong 4.0\ Gyr$ (the Cambrian explosion, with the simultaneous appearance of all higher phyla), can be described phenomenologically by a Volterra-type equation of the simple form

$$\frac{dN}{dt} = G_F\, |\boldsymbol{f}| N \qquad (7)$$

in which the Fermi constant has been inherited directly from (5). For a time interval from t to $t + \Delta t$, the change in $\log_{10}N$ follows from (7) as

$$\Delta(\log_{10} N) \equiv \log_{10}(N(t+\Delta t)/N(t)) = (2.3026)^{-1} G_F \int_{t}^{t+\Delta t} |\boldsymbol{f}| dt \qquad (8)$$

where the numerical prefactor in the final member of (8) converts from the natural logarithm to $\log_{10}$. Finally, by letting $\langle |\boldsymbol{f}| \rangle_t$ denote the average of $|\boldsymbol{f}|_t$ from t to (t + Δt) and transforming units, we obtain

$$\Delta(\log_{10} N) \cong (1.88 \times 10^{-8} cm^3) \langle |\boldsymbol{f}| \rangle_t \, (\Delta t / 10 Myr) \qquad (9)$$

Thus, if the three boosts in (6) to higher phyla were caused by CDM cosmic showers of the same average intensity, say $\langle |\boldsymbol{f}| \rangle_t \cong 4.0 \times 10^7 (cm)^{-3}$, then (9) implies the three Δt duration intervals:

$$\langle |\boldsymbol{f}| \rangle_t \cong 4.0 \times 10^7 (cm)^{-3} \text{ for } \begin{array}{lll} \Delta t \cong 86 \, Myr & \text{at about} & t \cong 1.1 \, Gyr \\ \Delta t \cong 6.6 \, Myr & \text{at about} & t \cong 2.9 \, Gyr \\ \Delta t \cong 33 \, Myr & \text{at about} & t \cong 4.0 \, Gyr \end{array}$$

$$\langle |\boldsymbol{f}| \rangle_t = 0 \quad \text{otherwise} \qquad (10)$$

In order to attain the CDM flow vector magnitudes that yield $\langle |\boldsymbol{f}| \rangle_t \cong 4.0 \times 10^7 (cm)^{-3}$ during the cosmic shower intervals, it can be shown that the particles must be ultrarelativistic with an average relativistic momentum somewhat greater than 20*m*. Hence, if the conjectural scenario described here is in essence correct, then the microscopic etched signature of such CDM particles should be detectible in the $\Delta t \cong 33 \, Myr$ layers of Cambrian rocks. Perhaps the "bizarre etching" generally attributed to graptolites may in part contain the CDM particle signature; experiments in progress by the CDMS II Collaboration may elucidate the CDM particle signature, and thereby provide criteria for the possible detection of their signature in Cambrian rocks.

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