IS THERE A FIELD-THEORETIC EXPLANATION FOR PRECURSOR BIOPOLYMERS?

GERALD ROSEN
Department of Physics, Drexel University, Philadelphia, Pennsylvania 19104; present address: 415 Charles Lane, Wynnewood, Pennsylvania 19096

(Received 12 March 2001; Accepted in revised form 5 March 2002)

Abstract. A Hu-Barkana-Gruzinov cold dark matter scalar field ϕ may enter a weak isospin invariant derivative interaction that causes the flow of right-handed electrons to align parallel to $(\vec{\nabla}\phi)$. Hence, in the outer regions of galaxies where $(\vec{\nabla}\phi)$ is large, as in galactic halos, the derivative interaction may induce a chirality-imbued quantum chemistry. Such a chirality-imbued chemistry would in turn be conducive to the formation of abundant precursor biopolymers on interstellar dust grains, comets and meteors in galactic halo regions, with subsequent delivery to planets in the inner galactic regions where ϕ and $(\vec{\nabla}\phi)$ are concomitantly near zero and left-right symmetric terrestrial quantum chemistry prevails.

Keywords: chirality-producing interaction, cold dark matter, precursor biopolymers

1. Introduction

Recent developments of cold dark matter (CDM) models (Spergel and Steinhardt, 2000; Kamionkowski and Liddle, 2000; Hu, Barkana and Gruzinov, 2000; Matos, Guzmán and Nuñez, 2000) may have an important bearing on the origin of the biopolymers that were precursors to living cells. Various Earth-bound spontaneous generation scenarios for the origin of such precursor biopolymers are plagued by intransigent difficulties associated with chemical reaction pathways and rates (Shapiro, 1986; Mattioli and Wood, 1986; Dick, 1996; Raulin-Cerceau, Maurel and Schneider, 1998). Thus authors have been led to conclude that precursor biopolymers are most probably of extraterrestrial origin and were delivered to Earth by interplanetary dust particles, comets or meteors (Bonner, 1991). This astrophysical scenario 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. Indeed, it is of considerable interest that CDM astrophysics may relate to the origin of the biopolymers in living cells.

CDM astrophysics is relevant because of homochirality, a unifying structural characteristic of the biopolymers and a likely prerequisite (Bonner, 1991; Joyce, 1984) for their origin. 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

Origins of Life and Evolution of the Biosphere **32:** 299–302, 2002.

exclusively. Of the three established fundamental interactions, the strong, the electroweak and the gravitational, only the electroweak can impart homochirality. Circularly polarized electromagnetic radiation (Bailey *et al.*, 1998; Bonner and Bean, 1999; Mason, 2000) can produce an enantiomeric excess in special racemic substances. More potently, electrons with definite spin-momentum helicities $\vec{\sigma} \cdot \vec{p} / | \vec{p} | = \mp 1$, 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). 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) or Gottfried and Weisskopf (1984)]. 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 on Earth (Mason, 1988; Kondepudi and Nelson, 1985). Although precluded for the Earth, a chirality-imbued quantum chemistry may derive from a CDM field of large magnitude in the outer halo regions of galaxies. A field-theoretic mechanism for this is described as follows.

2. Homochirality-Inducing Field-Theoretic Mechanism Based on a CDM Scalar Field

Consider a Hu-Barkana-Gruzinov (2000) CDM real scalar field ϕ that carries an ultralight mass $m \sim 10^{-22}$ eV with an associated astrophysical Compton distance $m^{-1} \sim 0.07$ pc. The ϕ field Lagrangian density terms are

$$\mathcal{L}_\phi = \frac{1}{2}(g^{\mu\nu}(\partial_\mu\phi)(\partial_\nu\phi) \ + \ m^2\phi^2)\sqrt{-g}\,, \tag{1}$$

in physical units such that h = c = 1. From (1) there follows the general relativistic Klein-Gordon field equation

$$\partial_\mu(\sqrt{-g}g^{\mu\nu}\partial_\nu\phi) \ = \ m^2\sqrt{-g}\phi\,, \tag{2}$$

with ϕ coupled to the gravitational metric tensor $g^{\mu\nu}$. Equation (2) admits galactic halo quasistatic solutions, in which ϕ is near zero through the center and disc of a galaxy and of large magnitude through the outer galactic halo regions (Hu, Barkana and Gruzinov, 2000). As a consequence of the fact that Equation (2) is linear and homogeneous, ϕ is determined by Equation (2) to within a normalization constant. To yield a total ϕ-field energy [obtainable from (1) by the canonical Lagrangian-density-to-energy-integral formula] that gives the required missing mass for the rotation of our Galaxy, the maximum value of ϕ attained in the Galaxy's halo must be of the order 10^{10} GeV.

The CDM scalar field ϕ may also couple to matter. In particular, consider the weak isospin invariant interaction described by the Lagrangian density term

$$\mathcal{L}_{\text{int}} = g(\partial_\mu \phi)\bar{\Psi}_R \gamma^\mu \Psi_R \,. \tag{3}$$

In (3) g is a coupling constant with the physical dimensions of length, and the right-handed weak isospin singlet Ψ_R enters with exclusion of the weak isospin doublet component Ψ_L, thereby making the right side of (3) manifestly invariant with regard to weak isospin unitary transformations. Concomitant with ϕ, the derivative four-vector $(\partial_\mu \phi)$ has large spatial components (*i.e.*, for $\mu = 1, 2, 3$) through galactic halo regions, while $(\partial_\mu \phi)$ is near zero through the center and disc of a galaxy. Assuming that g in (3) is comparable to or orders of magnitude greater than $m^{-1} \sim 0.07$ pc, the right-handed electron flow vector $\bar{\Psi}_R \vec{\gamma} \Psi_R$ will tend to align parallel to $(\vec{\nabla}\phi)$ in order to minimize the interaction Hamiltonian density

$$\mathcal{H}_{\text{int}} = \left((\partial_0 \phi) \frac{\partial}{\partial(\partial_0 \phi) - 1} \right) \mathcal{L}_{\text{int}} = -g(\vec{\nabla}\phi) \cdot \bar{\Psi}_R \vec{\gamma} \Psi_R \,, \tag{4}$$

for the groundstate field energy per unit spatial volume. In effect then, the interaction (3) acts dynamically on the electron field $\Psi = \Psi_L + \Psi_R$ and imposes a preferential directional alignment on the Ψ_R flux with field quanta e_R.

Such a preferential directional flow for all e_R is clearly conducive to a chirality-imbued quantum chemistry. The phenomenological Hamiltonian for a precursor biopolymer would take the form $\mathbf{H} = \mathbf{H}_0 + (\vec{\nabla}\phi) \cdot \vec{\Lambda}$ in which $\mathbf{H}_0$ contains the kinetic and potential energy operators of terrestrial molecular physics and $\vec{\Lambda}$ is an axial vector operator (invariant under spatial reflection) in the coordinates of the molecular components. Owing to the $(\vec{\nabla}\phi)$ directional term, the groundstate energy for a precursor biopolymer molecule would thus be substantially lower than its terrestrial value. Precursor biopolymers with homochirality may thus form abundantly on interstellar dust grains, comets and meteors in the outer regions of galaxies and subsequently be delivered to planets in the inner regions, where ϕ and $(\vec{\nabla}\phi)$ are concomitantly near zero and left- right symmetric terrestrial quantum chemistry prevails. Hence, the missing mass of astrophysics may also serve as a missing instigator of biophysics.

References

Bailey, J. *et al.*: 1998, Circular Polarization in Star-formation Regions: Implications for Biomolecular Homochirality, *Science* **281**, 672–4.

Bonner, W. A.: 1991, Chirality Amplification – The Accumulation Principle Revisited, *Orig. Life* **21**, 59–63.

Bonner, W. A. and Bean, B. D.: 2000, Asymmetric Photolysis with Elliptically Polarized Light, *Orig. Life* **30**, 513–517.

Dick, S. J.: 1996, *The Biological Universe*, Cambridge University Press, pp. 325–329, 361.

Gottfried, K. and Weisskopf, V. F.: 1984, *Concepts of Particle Physics*, *Vol. I*, Oxford University Press, pp. 137–161.

Hegstrom, R. A.: 1982, Molecular Homochirality Induced by Chiral Electrons, *Nature* **297**, 643–649.

Hu, W., Barkana, H. and Gruzinov, A.: 2000, Fuzzy Cold Dark Matter: The Wave Properties of Ultralight Particles, *Phys. Rev. Lett.* **85**, 1158–1161.

Joyce, G. R.: 1984, Chiral Selection in Poly(C)-directed Synthesis of Oligio(G), *Nature* **310**, 602–604.

Kamionkowski, M. and Liddle, A. R.: 2000, The Dearth of Halo Dwarf Galaxies: Is There Power on Short Scales?, *Phys. Rev. Lett.* **84**, 4525–4528.

Kondepudi, D. K. and Nelson, G. W.: 1985, Weak Neutral Currents and the Origin of Biomolecular Chirality, *Nature* **314**, 438–441.

Mason, S. F.: 1988, Biomolecular Homochirality, *Chem. Soc. Rev.* **17**, 347–359.

Mason, S. F.: 2000, Extraterrestrial Handedness Revisited, *Orig. Life* **30**, 435–437.

Matos, T., Guzmán, F. S. and Nuñez, D.: 2000, Spherical Scalar Field Halo in Galaxies, *Phys. Rev. D* **62**, 061301–061304.

Mattioli, G. S. and Wood, B. J.: 1986, Upper Mantle Oxygen Fugacity Recorded by Spinel Herzolites, *Nature* **322**, 626–628.

Raffelt, G. G.: 1996, *Stars as Laboratories for Fundamental Physics*, Univ. Chicago Press, pp. 528–530, 545–546. 583–584.

Raulin-Cerceau, F., Maurel, M. and Schneider, J.: 1998, From Panspermia to Bioastronomy, the Evolution of the Hypothesis of Universal Life, *Orig. Life* **28**, 597–612.

Schrödinger, E.: 1944, *What is Life?* Cambridge University Press, in particular, p. 68.

Shapiro, R.: 1986, *A Sceptic's Guide to the Creation of Life on Earth*, Summit.

Spergel, D. N. and Steinhardt, P. J.: 2000, Observational Evidence for Self-Interacting Cold Dark Matter, *Phys. Rev. Lett.* **84**, 3760–3763.