The mirror neutrino dark matter hypothesis

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ABSTRACT

In a quantum information approach to quantum gravity, one naturally extends the Bilson-Thompson braid particle spectrum by a right handed neutrino sector. This suggests a parity restoring non local form of mirror matter, considered as a novel contributor to the dark matter sector. In the non standard Riofrio cosmology, where the entire dark matter sector is approximated by black hole states, the mirror matter should occupy a space on the other side of our conformal horizons, which are present everywhere in our universe. In particular we note that the Koide matrix antineutrino rest mass prediction of 0.00117 eV corresponds precisely to a black body peak temperature of 2.73 K, the CMB temperature, as a result of its annihilation with mirror antineutrinos. Initial consequences of these ideas for dark matter profiles are discussed.

Subject headings: Burkert, holography, mirror, neutrino, quantum information

1. Introduction

Most approaches to the dark matter problem assume a localizable particle form for dark matter, in the context of a traditional Lagrangian effective field theory. However, modern twistor techniques in field theory prove that such a local description of the particle spectrum cannot fully capture the physics even of the known particle zoo. Recent direct searches for local WIMP dark matter via nuclear recoil have produced mixed results, but appear to rule out the massive WIMPs favoured by supersymmetric theories (19). Moreover, the universal galactic rotation curve profile is better fitted by modified forms of Newtonian gravity (7). On the other hand, lensing observations on intergalactic scales strongly suggest matter like properties for dark matter.

Although modified forms of Newtonian gravity provide a better fit to galactic dark matter profiles than the CDM picture, they are merely empirical rules. Any form of matter arising from non local physics, which only interacts gravitationally with ordinary matter, could generate effective modified gravity rules. Not much has been said about non localizable, or rather semi localisable, dark matter, despite the fact that non local aspects of quantum information are expected to play an important role in a theory of quantum gravity. We will demonstrate a possible tight association between mirror dark matter, ordinary matter and quantum information.

This leads to the following position on current observations. Firstly, there are no Higgs bosons or astrophysical gravitational waves, because gravity is mediated by non local interactions closely linked to the electroweak sector. The semi classical Riofrio cosmology (11) can account for the full dark matter sector in terms of localisable black holes, with no dark energy. The mirror matter proposed here may then be viewed as the low energy non local manifestation of interior black hole states, whereby the splitting of ordinary and mirror matter is related to neutrino mediated mass generation, which must take place at abstract horizons.

This picture has some similarities to the well studied quasi steady state cosmology, including the possibility of antigravity (1). It is also conceptually related to the classical thermodynamic cosmology of (9), except that the classical cyclicity of the universe is replaced by a more quantum view of space generation, for which the other side of a past cosmological horizon inhabits a reality no more or no less present than our own.

As Heisenberg and Schwinger understood, measurement is paramount and there is no such thing as empty space. The ugly wave function imposes an underlying absolute that does not exist. It was for roughly this reason that Newton was opposed to a wave theory for light. Einstein too despaired, at the necessary reintroduction of curved backgrounds in the Riemannian geometry of General Relativity. Abstract aspects of localization in neutral particle gravity will be discussed elsewhere (14). This paper briefly outlines the low energy particle spectrum, in the next section, and then lists a number of quantitative astrophysical predictions for this framework.

2. The Braid Particle Spectrum and Gravity

The low energy massless spectrum of leptons and quarks is neatly catalogued by a set of three strand braid diagrams, as shown in (2). The exclusion of right handed neutrinos is unnatural in this context, because their inclusion results in the full set of chiral three stranded diagrams. Given that both left and right charged leptons and quarks appear in the Standard Model, the only extra states are the right handed neutrinos and their antiparticles. An extended beta decay

$$n \rightarrow p^{+} + e^{-} + \overline{\nu}_{R} + \overline{\nu}_{L}$$

with an unseen mirror antineutrino restores parity to the electroweak interaction. We also imagine a mirror beta decay process involving the same two antineutrinos. This introduces a left right pairing for each component of the interaction, and is therefore associated with mass generation.

This form of mirror matter may be distinct from that considered in local gauge theories, because it is specified in terms of non local operators from which the local Lagrangians and classical spacetimes are supposed to emerge. We will see that such an antineutrino pair has equal rest masses, and so neutrinos and antineutrinos annihilate with the mirror matter sector, unlike the charged particles that annihilate with ordinary antimatter.

The non equivalence of neutrino mass and weak states is responsible for their observed oscillations, which we now view as interference involving both the ordinary and mirror matter sectors. This neutral interface is responsible for gravity, via the apparent mass charge attraction of ordinary and mirror objects. In such a framework for emergent geometry there is no need for a Higgs boson or gravitational waves, which now occupy a non existent a priori space.

As discussed by Brannen (4; 3) and others (15), the 3×3 Koide matrix defines rest masses in terms of eigenvalue triplets

$$\sqrt{m_k} = \sqrt{\mu}(1 + r\cos(\delta + 2\pi k/3)) \tag{1}$$

where μ is a scale parameter and $k = 1, 2, 3$ labels the generation quantum number. All charged lepton and neutral lepton masses are fitted with parameters $r = \sqrt{2}$ and $\delta = 2/9 + x$. For charged leptons $x = 0$, and the charged lepton scale of 313.8 MeV is very close to the dynamical quark mass. For a suitable choice of μ, the neutrino masses were fitted to known bounds (4) using $x = +\pi/12$. Recently it was observed (16) that a *different* set of antineutrino masses results from the conjugate choice $x = -\pi/12$. These phase choices agree quantitatively (15) with preliminary results from MINOS (18) that indicate such mass differences. The predicted rest masses, in eV, are:

$$\nu : \quad 0.00038, 0.00895, 0.05071$$

$$\overline{\nu} : \quad 0.00117, 0.05823, 0.00060.$$

The mass differences clearly suggest that neutrino annihilation occurs with mirror particles of opposite chirality. In the next section we observe that such low masses have immediate consequences for cosmology and astrophysics, irrespective of one's views on the underlying motivations from quantum gravity.

Since phase conjugation leaves the rest mass eigenvalues invariant, there is some choice in assigning two component phases to particles. Let us allow a small offset from 2/9 for the charged leptons, in the form $\pm\pi/N$ for large N. Then all particles have two phase components, and we assign the signs as follows. The $+2/9$ component is given to left handed particles, and $-2/9$ to right handed particles. The electron, standard antineutrino and neutrino are all assigned a $+\pi/n$ phase, interpreted as a quantum information dimension n. Their *annihilators*, including the positron, take the phase $-\pi/n$.

So the sign of the π/n component can vary within either the ordinary or mirror matter sectors. This choice is natural, because photons now always have a net phase of zero. The standard antineutrino has a Koide phase of $-2/9 + \pi/12$, resulting in the same mass as its left handed mirror, with phase $+2/9 - \pi/12$. Electrons and positrons, like other charged pairs, have equal masses.

The whole charged mirror sector might have mass states matching those of ordinary matter, but alternatives are also considered. In fact, the demand of universal parity symmetry suggests dark matter in terms of a distinct set of mass quantum numbers. But it is possible that mass differences reside only in the neutral particle spectrum.

The easiest way to envisage an emergent space, namely that defined by the constraints of the observer's measurements, is to use networks of particle diagrams, such as the two dimensional thickened braid diagrams of ribbon categories. These massless surfaces may be viewed as holographic screens in an entropic form of gravity, where mass generation occurs near black hole horizons whose area measures the black hole entropy. All we need to know here is that these horizons are everywhere, and they define a cosmological version of Kepler's law. Due to Riofrio (11), this law states that

$$GM = tc^3 \tag{2}$$

where M is the observed total universal mass, t is a cosmic measure of time, G Newton's constant and c the speed of light. Here G and c will be assumed constant, since we consider only the domain of local particle production. In other words, the observed mass M increases with cosmic epoch, which is measured locally by CMB temperature. Different interacting observers are capable of measuring distinct cosmological times.

The light neutrino sector is thus closest to its zero entropy horizon. It is expected to play a significant role in structure formation in our universe, which is manifestly quantum on all scales.

3. Cosmology and a Dark Matter Profile

The new neutrino and antineutrino masses alone have much to say for astrophysics. We propose that basic neutrino physics is a fertile ground for considering dark matter components in different astrophysical environments.

To begin with, the apparent dimming of type IA supernovae (8) with increasing redshift is potentially explained by a changing cosmic history of neutrino production within stellar cores. Although this idea merits further analysis, it is merely one of a number of ways to eliminate dark energy. In the Riofrio cosmology (11), one may interpret the cosmological

Kepler law $GM = tc^3$ as a variation in the speed of light with cosmological epoch t. This accounts for the apparent dimming of supernovae without the need for dark energy. Riofrio's law then equates the total mass of the observable universe with cosmological epoch, reducing the mass to zero at conformal boundaries in the Big Bang era.

In this cosmology (11) the exact baryonic mass fraction is $\Omega_b = 1 - 3/\pi$. Such a semi classical picture should eventually emerge from the quantum gravitational zoo. It suggests that ordinary matter can be created both initially and also as the universe cools on expansion, beginning with a large array of black hole states. However, at late cosmological times the total matter formation rate drops as the critical density is reached.

The different neutrino species are preferentially created in different epochs, since their masses differ, and they are generated according to the CMB temperature. Observe (6) that the first antineutrino mass of 0.00117 eV corresponds precisely under Wien's law for black body radiation to a peak temperature of 2.73 K. We split the 0.00117 eV equally between the right handed antineutrino $\overline{\nu}_R$ and its mirror counterpart $\overline{\nu}_L$, which both partake in oscillations and the weak interaction. These antineutrinos annihilate to create CMB photons, which in turn allow antineutrino pair creation. Thus the CMB must be considered as a thermal bath of both photons and neutrinos.

The CMB temperatures associated to the other neutrino and antineutrino masses correspond to specific redshift epochs, via the usual rule $T/T_0 = 1 + z$. In particular, the appearance threshold temperature for the next lightest neutrino, at 20.8 K, corresponds to a redshift of $z = 6.65$.

The evolution between neutrino and antineutrino species in cosmic history is interpreted as an alternation of matter types for all particle species. The current preponderance of matter over antimatter is usually extrapolated back to the Big Bang, creating the mystery of matter domination. With varying phases in cosmic history, and an observer dependent cosmology, matter need be no more dominant than antimatter, and the two are treated equally in the braid particle spectrum.

Given a set of distinct particle species, indexed by i, the classical abundance fraction N_i for a species at temperature T is given by the Boltzmann distribution

$$N_i = \frac{e^{E_i/kT}}{\sum_i e^{E_i/kT}}. \tag{3}$$

This suggests a predominance of the lightest 0.0006 eV tau antineutrino over the electron antineutrino, by a factor of 10^8 at the current CMB temperature of 2.73 K. Actual antineutrino densities could thus be far greater than in the standard cosmology.

At the minimal neutrino rest mass temperature of 0.89 K there are $(8\pi/3)(kT)^3 = 2.0 \times 10^6$ photons per m^3, giving a photon energy density of around 150 eVm^{-3}. Taking two electron antineutrinos per photon at 0.89 K, we estimate a total photon neutrino density of 900 eVm^{-3}. From a measured Hubble constant of 2.3×10^{-18} s^{-1} the cosmological critical density is about 5.3×10^9 eVm^{-3}, which is 6×10^6 greater than the photon antineutrino bath. Thus these states are a small but not insignificant contributor to the total energy budget, noting that other particle species remain to be analysed.

At a higher temperature T, the number of photons per m^3 is given by 2.84×10^6 T^3. Compared to a high cosmic total energy density of $8\pi^5/15$ $(kT)^4$ this gives an average energy per photon per Kelvin of $\pi^4 k/5 = 0.0017$ eV/K. Including kinetic energies for neutrinos and antineutrinos, the Boltzmann distribution for the 0.00117 eV and 0.00038 eV species then predicts relative abundances of 0.22 and 0.78 respectively, at 2.73 K.

If the neutrino masses are used to scale the masses of unseen heavier particles, then this means a roughly equal mass distribution at low temperature. For higher temperatures, however, the 0.00038 eV neutrino dominates. If, on the other hand, the dark sector masses roughly match those of ordinary particles, then the 0.22 fraction would be characteristic of observed baryonic abundances at low energy. More sophisticated models could easily be made to fit any abundance profile, making neutrino physics a useful empirical tool.

Although today's dominant species is the electron antineutrino, in our last cosmic epoch it was the 0.00895 eV neutrino, and this species should also be considered as an important guide to astrophysical observation. In other words, missing antimatter from the early universe is confined within the mass that we observe around us.

Unequal abundances would mean that parity symmetry remains broken. As a model, we could use a chiral quantum vacuum to restore the parity symmetry. Maintaining an equation of state $w = -1$ requires a negative pressure real vacuum with density of order the total matter density. This can be achieved by adjusting the amount of space associated with the unknown vacuum species, so that the critical density $\Omega = 1$ is always maintained. As a cold initial condition, the 2.73 K photon neutrino bath can exist without the heavier charged leptons or baryons.

Mirror matter annihilates to ordinary photons and since the mirror Rydberg constant may be identical to that for ordinary matter, mirror neutral hydrogen in particular will produce photons just like its counterpart. Thus a certain fraction of presumed baryonic matter in galaxies could be dark matter. This may be a substantial fraction. For the currently observed galactic dark matter fraction of around 0.7, the apparent universal baryonic fraction would be double the accepted Riofrio figure of $\Omega_b = 0.045$ (11). This suggests an equal division between the baryonic matter and the atomic mirror matter, with the remainder of the energy budget in black hole states.

The temperature dependence of Ω_d / Ω_b is presumably the main issue in the luminosity dependence of dark matter profiles. Luminosity is the only remaining parameter in the determination of universal galactic rotation curves (12; 10; 13), and this parameter is given also in terms of disk mass or other alternatives (13). It is therefore possible that the overestimation of the baryonic component in luminous galaxies contributes to this remaining free parameter for rotation curves.

Given the supposed fundamental nature of the braid diagrams, we expect a tight coupling between the mirror and baryonic components, even if the mirror sector is not fully localizable. The creation of mirror neutrinos with every electroweak interaction is presumed to be responsible for gravity. The increased neutrino abundance is sufficient to *quantitatively* account for Newtonian gravity through the usual absorption of one species along with a rest mass charge attraction between obligatory neutrino pairs. However, this is a highly non local procedure and should not be envisaged in terms of traditional scattering.

The low energy *attractiveness* of gravity may be attributed to the Koide ordering of increasing masses within each triplet. But the tau antineutrino is the lightest particle of its type, suggesting a sign change for the gravitational force between more massive neutrino pairs (4), allowing for an antigravity effect at high energies.

Thus antigravity may also be an important aspect of the dark matter problem. As noted above, although galactic dark matter profiles do exhibit universal behaviour, more luminous galaxies have a smaller central dark matter density. A more energetic baryonic region may generate a stronger antigravity effect to partly account for this lower density.

The redshift dependence of galactic dark matter profiles may be attributed to changes in black hole distributions with cosmic epoch. For the highest redshifts, the observed increase in matter concentration with increasing virial mass signifies a tighter coupling between all matter states and the primordial black hole spectrum, in an epoch before the current equilibrium between black holes and new matter creation. Note that in a universe where no true zero or infinity of temperature exists, black holes are unlikely to evaporate beneath a minimal size.

The minimal rest mass neutrino sector is supposed to sit, in a very abstract sense, closest to a space generating horizon. We would like to characterize the scale of this entire sector, before the mass splitting, by its thermal analogue. The Koide scale parameter for all neutrinos and antineutrinos gives an average rest mass $\mu = 0.01$ eV, which corresponds to a thermal bath of 23.3 K. This is precisely one of the temperature fits for warm interstellar dust observed at the lower galactic latitudes by COBE (17), with a non granular emissivity index. This emission is highly correlated with the low temperature emissions, as would be expected if neutrinos play a role in defining this thermal regime.

Sky brightness has three major components: the CMB, galactic dust and zodiacal dust. Interplanetary zodiacal dust is generally measured at much higher temperatures and is thus not easily correlated to the neutrino photon CMB bath. The upcoming Planck results should clarify the structure of dust spectra.

In summary, we stress the potential of neutrino physics to clarify the observation of a variation in luminous to dark matter mass fractions between galaxies. The dark matter profile is known to be tightly correlated with the luminous matter one and it exhibits a universal behaviour across all galaxy types (12; 10; 13; 7). The universal Burkert density profile (5) for dark matter within a galaxy is given by

$$\rho(r) = \frac{\rho_0 r_0^3}{(r + r_0)(r^2 + r_0^2)} \tag{4}$$

for ρ_0 and r_0 a characteristic core surface density and radius. Moreover, for all galaxies the product $\rho_0 r_0$ is a constant (7). Choosing galactic units such that $\rho_0 = r_0 = 1$, we have the simple empirical rule

$$\rho(r) = \frac{1}{1 + r + r^2 + r^3}. \tag{5}$$

The 1 represents the constant surface density term, which does not appear in the standard NFW ΛCDM profile. It suggests a significant contribution from a pervasive medium, such as the dense neutrino bath, although a fuller analysis should incorporate black hole states.

4. Conclusions

The explicit correspondence between the 0.00117 eV electron antineutrino and the peak CMB temperature is strongly suggestive of non local foundations for beyond the standard model physics. These ideas generate more questions than they answer, but the importance of their quantitative consequences certainly warrants investigation. MINOS have yet to confirm the preliminary results (18) upon which the antineutrino masses are based, but we consider this prediction (14) to be robust.

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