Non Local Mirror Neutrinos with $R_h = ct$

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Abstract

The observationally successful FRW constraint of Riofrio provides a viable alternative to ΛCDM. In this context we study neutrinos in quantum gravity, using McCullochs approach to quantum inertia. There is no dark matter and no dark energy, and mirror states are informationally connected to the CMB. Quantitative consequences include (i) a present day temperature of 2.75K arising as a mirror rest mass and (ii) an effective sterile mass of 1.29 eV, in line with oscillation results.

1 Introduction

In the Standard Model, three active neutrinos are massless Weyl fermions. Neutrino oscillations suggest that perhaps neutrinos gain quantum mass outside of the Higgs framework, removing the need to explain mass scale ratios with Majorana masses. Only left handed neutrinos exist. Right handed states, if they exist informationally, belong to a mirror copy of the Standard Model spectrum, but this does not indicate a local mirror Lagrangian for the dark matter sector, because even the modern motivic formulation of the Standard Model is not truly a gauge theory. Rather, we require a cosmology that is free of dark matter and dark energy, and the non local mirror states are associated to the Rindler horizons [1] which define quantised inertia, possibly outside general relativity.

Promising candidates for this restriction to Standard Model states include categorical models for quantum gravity, in which braid or ribbon diagrams determine fundamental degrees of freedom. From the twistor point of view, mass generation was first studied in [2], indicating the need for a categorical approach to higher dimensional cohomology. Penrose has noted that this involves a two dimensional analogue of his famous impossible triangle, since the Dirac mass results from a pairing of two spinors in a second cohomology group H^2.

Whatever the complexities of the Higgs mechanism in quantum gravity, it is possible that simple quantum masses for neutrinos will provide a golden test bed for both cosmology and neutrino phenomenology. Here we go even further, suggesting that the interplay of neutrino mass with the Planck scale underpins the Higgs mechanism in quantum gravity, as indicated by the rough correspondence $M_H \simeq \sqrt{m_\nu M_{Pl}}$.

Since the quantisation of inertia is inherently non local, it has radical consequences for cosmology. We will conclude that the present day CMB temperature is closely connected to neutrino rest masses, something quite impossible in the ΛCDM model.

The CMB photons that we observe were created in a distant part of our universe, having taken 13 billion years to reach us. In ΛCDM one expects these photons to be correlated with distant structure, since primordial perturbations seed structure growth. Similarly, CMB photons that originated near the future Earth are correlated with our local structure, as viewed by distant aliens. And yet what we observe is a correlation between our CMB and our local structure, as if we are the aliens living 13 billion light years away. So maybe we are. After all, we can never observe such aliens in our present epoch, and in quantum gravity, observation is everything.

The only thing we can observe around 13 billion years ago is the CMB itself, but the PTOLEMY experiment in the near future will hunt for low energy relic neutrinos. This is an opportunity to distinguish ΛCDM from $R_h = ct$ with a solid prediction about the behaviour of neutrinos in the early universe. If neutrinos do not decouple and cool at the expected temperature, which is tightly constrained in ΛCDM, this will be observed by PTOLEMY.

The $R_h = ct$ picture, where R_h is the Hubble scale and t the time since the Big Bang, begins with black holes [3]. Riofrio [4] originally used it to derive the baryonic mass fraction by considering the generation of mass through pair production around primordial black holes. This result is valid whatever the ontology of PBHs when mass generation comes from quantum inertia, since it is the existence of relevant horizons that counts.

The alternative cosmology is introduced in the next section, extended by quantised inertia. Section 3 incorporates neutrino masses, and we consider the neutrino anomalies.

2 $R_h = ct$ with Quantised Inertia

Riofrio [4] has long argued that $R_h = ct$ does away with dark energy, since a speed of light that varies in cosmological time can account for the luminosity redshift relation of type Ia supernovae. More recently, a statistical analysis [5] of supernovae data favours $R_h = ct$ over ΛCDM. Other observations listed in [6] also favour the $R_h = ct$ theory.

Melia [7] saw that Rindler horizons define a kind of curvature horizon, naturally associated here with mass generation. He used Birkhoff's corollary: in a spherically symmetric spacetime that is essentially Schwarzschild, the metric inside an empty sphere is that of Minkowski space. Melia et al [8][9] later linked this idea to the $R_h = ct$ theory, as follows. A limiting radius is defined by

$$\frac{dR}{dt} = \frac{da}{dt} r = c, \tag{1}$$

where $R(t)$ is the proper distance for a radial, flat cosmology. Since there is an acceleration between a central observer and a distant point in the cosmos, there is also a gravitational radius. Define the universal mass and associated radius by the rule

$$R_h \equiv \frac{2GM_U}{c^2}. \tag{2}$$

Now the FRW metric is written in terms of R/R_h. Together with the Friedmann equation, (2) gives the Hubble radius

$$R_h = \frac{c}{H(t)} = ct, \tag{3}$$

showing that the Hubble radius is a gravitational radius. Here we assume isotropy and homogeneity.

In defining quantum inertia, McCulloch [10] breaks the equivalence principle mildly in attributing inertia to a Hubble scale Casimir effect, between a local Rindler horizon for an accelerated object and a distant cosmological horizon. Classical inertia is corrected by a term that is only important for low accelerations, such as those attributed to dark matter in galaxies.

So with a non local mechanism for mass generation, $R_h = ct$ gets rid of dark energy and quantised inertia gets rid of dark matter, as shown in the rotation curve analysis of [11]. The breaking of the equivalence principle between inertial and gravitational mass is

$$m_i = m_g(1 - \frac{\beta\pi^2 c^2}{aR_h}), \tag{4}$$

where a is the magnitude of the acceleration and β is the constant from Wien's displacement law

$$m = \beta kT, \tag{5}$$

originally used by Planck to derive the black body spectrum. We will use this to relate neutrino masses to CMB photons. With (4), $R_h = ct$ says the quantum correction to m_i is proportional to c/at, linking the local acceleration to cosmic time.

As explained above, it is possible that neutrino inertial masses detect quantum terms, remaining massless in the Standard Model. The absence of right handed neutrinos is then attributed to the Weyl nature of their classical inertia. There are no oscillations into sterile states in a $3+s$ scenario, but we should now consider effective sterile states that arise from mirror information at the cosmological horizon.

3 Neutrinos and Mirror Neutrinos

In categorical quantum gravity, or even in the categorical formulation of the Standard Model, fundamental degrees of freedom are given by diagrams, such as ribbons in a modular tensor category. The particle spectrum is recovered with the braid group on three stands [12][13], excluding a right handed neutrino except in the mirror copy of the spectrum. We propose that quantum inertia pairs a SM state with its mirror partner, now associated with the cosmological horizon and not with the non existent dark matter.

Table 1: Koide ν masses (eV)

L	0.0507	0.0089	0.0004
R	0.0582	0.00117	0.0006

Quantum perturbations in the early universe, governing the acoustic peaks of the CMB, are closely tied to the characteristic radii of $R_h = ct$. As the universe cools, the wavelength of perturbations grows with the decrease in redshift, linear in the CMB temperature, which is a direct measurement of mirror mass.

In [14] we look at neutrino phenomenology using a mirror pair of mass triplets, both characterised by the same scale of 0.01 eV. One triplet gives the three active neutrino masses, while the second is presumed to represent the mirror states. The resulting exact correspondence [15] between the central mirror mass and the *present day* CMB temperature uses Wien's displacement law (5) to equate the mirror rest mass with temperature. This discovery originated in the Brannen model [16] for quantum gravity, where a neutrino phase of $\pm\pi/12$ perturbs the charged lepton phase in the Brannen-Koide relations for neutrinos [17][18][19], given below. Only mirror masses are redshifted back to the early universe, leaving neutrinos to behave themselves most of the time.

Neutrino oscillations [20][21] prove that neutrinos have inertial mass, and that mass and flavor bases are distinct. Both the charged lepton and neutrino triplets are given by the eigenvalues of a mass matrix M, where

$$\sqrt{M} = \frac{\sqrt{\mu}}{\sqrt{2}} \begin{pmatrix} \sqrt{2} & e^{i\theta} & e^{-i\theta} \\ e^{-i\theta} & \sqrt{2} & e^{i\theta} \\ e^{i\theta} & e^{-i\theta} & \sqrt{2} \end{pmatrix}, \tag{6}$$

for μ the scale parameter. Global fits give a scale of $\mu = 0.01$ eV for active neutrinos. The eigenvalues are

$$m_k = \mu(1 + \sqrt{2}\cos(0.222 + \frac{\pi}{12} + \frac{2\pi k}{3}))^2 \tag{7}$$

for $k = 1, 2, 3$, where the phase $\theta = 0.222$ defines the charged lepton eigenvalues. Fixing μ for neutrinos and their mirror, and selecting $-\pi/12$ as the mirror offset, we obtain the six masses in Table 1. The central 0.00117 eV gives the CMB temperature [15]. A precisely known value of T_{CMB} may be used to further constrain ν masses [14].

Why are mass and flavor states distinct? Astrophysically, it is charged leptons, baryons and photons that localise in four dimensional (quaternionic) spacetime, as required by electromagnetism, but Weyl neutrinos are free to live near $1 + 1$D (complex numbers, while color employs octonions). Then neutrino oscillations occur because our four dimensional spacetime cannot detect a single copy of $1 + 1$D, only three, in the six dimensional twistor space.

Now the apparent sterile neutrino in oscillation experiments is not a local right handed state, as is usually assumed. It belongs in the early universe *as we observe it on Earth*. Applying the CMB redshift of $z =$

1100 to the special central mirror mass, we obtain an apparent sterile mass of precisely 1.29 eV, in agreement with present data. Hopefully, the other two mirror states can further illuminate neutrino anomalies.

4 Summary

A quantised form of the $R_h = ct$ cosmology [4] efficiently eliminates many so called observational problems, notably dark energy and dark matter. It potentially provides a derivation of many cosmological parameters, such as Ω_b, with almost no input parameters. The Brannen-Koide phenomenology is also efficient in its use of parameters, launching an exciting era of quantitative results beyond the SM.

Our detailed knowledge of the solar system and solar neutrinos, including the measurement of the pp flux at Borexino [23], already puts tight constraints on any proposal for dark matter. The proposed PTOLEMY experiment will search for relic neutrinos from the CMB epoch, which in ΛCDM have a present energy just above the endpoint of tritium decay. With $R_h = ct$ on the other hand, one expects quantum gravity to influence the neutrino coupling to baryonic matter.

In quantum gravity, limiting horizons are an observational brick wall, behind which the ontology of matter and spacetime must change. Although ΛCDM is empirically impressive, at some point it must confront the quantum nature of reality even on the large scale.

Acknowledgements

I briefly met Fulvio Melia around 2007 at the University of Canterbury when he was visiting Roy Kerr. His talks on the black hole at the centre of the Milky Way were notable, but I had no idea that he was starting to work on the $R_h = ct$ idea. This came to me years earlier from the blog of Louise Riofrio herself, who participated in many enjoyable online discussions over the following years, along with Carl Brannen and others. In 2009, I heard Roger Penrose comment on the problem of H^2, and briefly met up with Subir Sarkar and colleagues at the University of Oxford. One of them, whose name I do not recall, tried to tell me about statistics problems with type Ia supernovae, but I was already suffering from depression and cyber abuse, no doubt partly due to my support for $R_h = ct$, and many of these ideas were lost to me. Only in October 2017 did I finally discover the cosmology papers of Melia et al, and the work of McCulloch. It was then immediately apparent that this was the correct context for non local mirror neutrinos.

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