Non local neutrinos with $R_h = ct$

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Abstract

Beginning with the observationally successful FLRW constraint of Riofrio, a classical alternative to ΛCDM, we introduce a mass gap correction to cosmology, incorporating a few aspects of the ΛCDM model, wherein both neutrinos and non local mirror neutrinos play a key role. Non local neutrinos are antineutrinos. The equivalence principle is mildly broken using McCulloch's approach to quantum inertia and a new holographic principle. There is no dark matter and no dark energy, and mirror neutrino states are informationally connected to the CMB. Consequences include (i) a present day temperature of 2.73K arising as a mirror rest mass, (ii) an estimate of the observable mass of the universe and (iii) an effective sterile mass of 1.29eV, permitted by current oscillation results.

INTRODUCTION

In the Standard Model, three active neutrinos are massless Weyl fermions. Neutrino oscillations suggest that perhaps neutrinos gain mass outside of the Higgs framework, removing the need to explain mass scale ratios with Majorana masses. Only left handed neutrinos exist locally. Right handed states, if they exist informationally, belong to a mirror copy of the Standard Model spectrum, but this does not necessarily indicate a local mirror Lagrangian for the dark matter sector, because even the modern motivic formulation of the Standard Model is not of this form. We want a cosmology free of dark matter and dark energy.

Promising candidates for this restriction to Standard Model states employ categorical constructions in quantum gravity, in which braid or ribbon diagrams determine fundamental degrees of freedom. From the twistor point of view [1], 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, and the Dirac mass is a pairing of two spinors in a second cohomology group H^2. This mechanism somehow combines left and right handed states topologically.

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 GUT or Planck scale L underpins the Higgs mechanism in quantum gravity, as indicated by the rough correspondence $M_H \simeq \sqrt{m_\nu M_P}$. Neutrinos at rest give the minimum particle mass in quantum gravity, while M_P is an upper limit for particle masses.

With quantum inertia, which mildly breaks the equivalence principle, mass generation is maximally non local, employing wavelengths on cosmological scales. It accounts for galactic rotation curves with a MOND rule, but we will also introduce non local mirror states which can mimic dark matter on large scales. We will show that the present day CMB temperature is closely connected to mirror neutrino rest masses, something quite impossible in the ΛCDM model.

Starting with the classical $R_h = ct$ picture, for which the equivalence principle holds, we see observed CMB photons being created in a distant part of our universe, having taken around 13 billion years to reach us. In ΛCDM one expects these photons to be entangled with distant structure, since primordial perturbations seed structure growth. Similarly, CMB photons that originated near past Earth are entangled with our local structure, when 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, beyond our horizon, in a mirror image of creation. So maybe we are. After all, we can never otherwise observe such aliens in our present epoch. Such a non local correlation is a holographic principle [3].

The only thing we 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 [4]. This is an opportunity to distinguish ΛCDM from $R_h = ct$ models with a solid prediction about the behaviour of neutrinos in the early universe. If neutrinos do not decouple and cool at the expected temperature, tightly constrained in ΛCDM, this will be observed by PTOLEMY.

Riofrio [5] originally derived the baryonic mass fraction in ΛCDM by considering the generation of mass through pair production near black hole horizons [6]. This result may be valid whatever the ontology of PBHs when mass generation is non local, if it is the existence of appropriate horizons that counts. Here quantum causality will replace the confinement of fermions in the cyclic cosmology [7] with a link between past and local fermion states, presumably holographic in some sense.

The next two sections introduce (i) the $R_h = ct$ alternative to the ΛCDM model, then breaking the equivalence principle with quantum inertia, and (ii) a truly quantum view, in which the true cosmological boundary is represented by the CMB. Neutrinos play a pivotal role in creating a mass gap over the semiclassical view. Finally, we briefly consider neutrino anomalies.

$R_h = ct$ WITH QUANTISED INERTIA

Let R_h be the Hubble radius and t the time since the apparent Big Bang. Riofrio [5] 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 [8] of supernovae appears to favour models like $R_h = ct$ over ΛCDM. Observations listed in [9] also favour the $R_h = ct$ theory. Initially, the horizon problem is explained with a large value for c in the early universe, but in the next section we will use quantum gravity to truncate the early universe at the CMB, and the horizon problem is morally solved by quantum causality.

Although apparently inertial, an object in the interior of the universe accelerates relative to distant objects. Locally there is a Rindler horizon, associated now with the generation of inertial mass. Far away there will be cosmological horizons. Melia et al [10][11][12] introduce a limiting radius, 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 a central acceleration, between the object and the distant cosmos, there is also a gravitational radius. Define the universal mass and associated radius by Riofrio's rule

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

Now the FRW metric may be 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 naturally a gravitational radius.

McCulloch [13] breaks the equivalence principle mildly in attributing local inertia to a Hubble scale horizon censorship principle, using the Casimir effect as inspiration, between both the local Rindler horizon for the accelerated object and a distant cosmological horizon. Classical inertia is corrected by a quantum term that is only important for low accelerations, such as those attributed to dark matter in galaxies. With such a non local mechanism for mass generation, $R_h = ct$ gets rid of dark energy and then quantised inertia gets rid of local dark matter, as shown in a rotation curve analysis [14].

The breaking of the equivalence principle begins with the Unruh radiation associated to the accelerated object, at a temperature

$$kT_U = \frac{ha_U}{4\pi^2 c}, \tag{4}$$

where a_U is the magnitude of the acceleration. This radiation reduces the gravitational mass. Along with the displacement law

$$E \equiv \frac{hc}{\lambda} = \beta kT_U \tag{5}$$

for Wien's constant β (originally used by Planck to derive the black body spectrum) we obtain the Unruh wavelength

$$\lambda = \frac{4\pi^2 c^2}{\beta a_U}. \tag{6}$$

Assume that Unruh wavelengths only fit the size limit $4R_h$, twice the Hubble diameter. Then the equivalence principle breaks to the relation [14]

$$m_i = m_g(1 - \frac{\lambda}{4R_h}) = m_g(1 - \frac{\pi^2 c^2}{\beta a_U R_h}). \tag{7}$$

For $\lambda = 4R_h$, when the inertial mass vanishes, the minimal acceleration is

$$a_U = \frac{\pi^2 c}{\beta t}, \tag{8}$$

so that $a_U t$ is close to the boundary speed of $2c$.

Below we will use (5) to relate one neutrino mass supersymmetrically to CMB photons. The connection between quantised inertia and the holographic principle has been studied in [15][16]. Quantum perturbations in the early universe, governing the acoustic peak in the CMB, are closely tied to the characteristic radii of $R_h = ct$, starting with the Planck scale. As the universe cools, the wavelength of perturbations grows with the decrease in redshift, linear in the CMB temperature, which therefore directly measures a characteristic energy. We will now quantise this semiclassical cosmology, considering also the ΛCDM empiricism, by introducing the rest mass gap of neutrinos.

MIRROR NEUTRINOS WITH HOLOGRAPHY

Although the Hubble radius is a natural limit in the semiclassical cosmology, in quantum gravity we expect a backreaction mechanism to select a confluence of special cosmological boundaries. This need not be the spheres of classical intuition, but rather an inhomogeneous chaotic boundary, not necessarily connected. We assume this boundary is defined by the observational limit of photons, neutrinos and gravitons, in particular the CMB [19]. The CMB temperature T_C will be interpreted as a direct measurement of a mirror neutrino mass.

In this quantum cosmology, we envisage a reinterpretation of CMB redshift, allowing for the neutrino masses and T_C to remain fixed according to the most fundamental timeless clock, replacing the Big Bang singularity with a more conformal Brahma. As in the ΛCDM model, where the CMB defines an absolute frame of reference, the CMB dipole defines a centre of mass for M_U. Lorentz invariance is never broken locally, and the entropy at a cold boundary is always low [19]. As a model, a de Sitter space roughly represents ΛCDM, and is balanced by an AdS space in which the mirror neutrinos, naturally *at rest* with the CMB, gravitate [**?**].

Mirror neutrinos are antineutrinos. In 2010 [20], the authors noted that the $\overline{\nu}$ mass square differences at MINOS [21] agreed precisely with the mirror neutrino phase, given below. At the time it was difficult to see how Lorentz invariance could be preserved, but it is simple: we do not require the ν_L and $\overline{\nu}_R$ to form Dirac spinors, or to annihilate each other. Right handed neutrinos are free to exist non locally, along with the mirror partners of all other leptons and quarks, but local right handed ν states simply do not exist.

In principle, cosmological boundaries occur everywhere in spacetime, and all *local* antimatter inherits the reversed clock from behind the cosmological horizon.

In mathematical quantum gravity, or even in the categorical formulation of the Standard Model, fundamental degrees of freedom are given by CFT type diagrams, such as ribbons for a modular tensor category. The chiral SM particle spectrum is recovered with the braid group on three stands [17][18], excluding a right handed neutrino except in the mirror copy of the spectrum. We propose that quantum mass cohomologically pairs a SM state with its mirror partner, now associated with the cosmological horizon.

Neutrino phenomenology is modelled [22] 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 at first to represent non local mirror states. We will now justify the resulting exact correspondence [19] between the central mirror mass and the *present day* value of T_C, using Wien's universal displacement law (5) in the form

$$mc^2 = \beta k T_C. \tag{9}$$

Here T_C defines a global bath. The inversion in wavelength dependence, compared to the local formula, is justified by the de Broglie principle, by dualities, and perhaps also by the inversion of mass in the Hawking temperature

$$kT_H = \frac{hc^3}{16\pi^2 GM}. \tag{10}$$

At the present day CMB temperature, the Hawking mass M is near 10^{44}kg, close to the maximum size for gravitationally bound objects in our universe. Elsewhere we estimated $M_U \sim 10^{52}$kg, before this quantity was correctly observed. Surely these coincidences suggest that CMB photons are a kind of Hawking radiation for the universe itself.

Here T_H replaces T_U at the local horizon. Now if the Wien mass m is a particle, take the Unruh wavelength for T_C to get

$$m = \frac{L^2 \beta a_C}{G}, \tag{11}$$

where L is the Planck length. To obtain a minimal temperature, at the minimal acceleration, we use (11) to compute a mass of 10^{-54}kg, giving a minimum energy of around 10^{-37}J. This rule agrees with the holographic Planck mass formula of [15] for the maximal acceleration

$$a_C = a_P \equiv \frac{\sqrt{\pi} c^2}{\beta L}. \tag{12}$$

It is the rest mass of mirror neutrinos that is converted into CMB photons. Only mirror masses are redshifted back to the early universe in the $R_h = ct$ picture, leaving neutrinos to behave themselves most of the time. The use of (5) for neutrino mass is further justified by a supersymmetric relation between SM states, in which the 3×3 quantum Fourier transform $F \nu F^{\dagger}$ sends a neutrino braid to the photon [22].

There appear to be no oscillations into local sterile states in a $3 + s$ scenario, but we should now consider effective sterile states that arise from mirror information associated to a cosmological horizon. Our non local sterile neutrino belongs in the so called early universe even as we *observe it on Earth.* Applying the CMB redshift of $z = 1090$ to the central mirror mass, we obtain an apparent sterile mass of precisely 1.29 eV, still permitted by current data [23][24][25].

Mirror masses are antineutrino masses. Reactor $\overline{\nu}$ states are therefore mirror states, some of which may tunnel into the redshifted regime, although their oscillations are standard. Similarly, the MiniBooNe asymmetry is attributed to the mirrored nature of antimatter, although the mixing parameters may be the same. There is no need for dark matter at all, as predicted by quantum inertia.

This discovery [20] originated in the Brannen model [26] for quantum gravity, where a neutrino phase of $\pm\pi/12$ perturbs the basic lepton phase in the Brannen-Koide relations for neutrinos [27][28][29], which we now summarise. Neutrino oscillations [30][31] prove that neutrinos have mass, and that mass and flavor bases are distinct. Both the charged lepton and neutrino mass triplets are given by the eigenvalues of a mass matrix M, where

$$\sqrt{M} = \frac{\sqrt{\mu}}{\sqrt{2}} \begin{pmatrix} \sqrt{2} & e^{i\theta} & e^{-i\theta} \\ e^{-i\theta} & \sqrt{2} & e^{i\theta} \\ e^{i\theta} & e^{-i\theta} & \sqrt{2} \end{pmatrix}, \tag{13}$$

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

$$m_k = \mu(1 + \sqrt{2}\cos(\frac{2}{9} + \frac{\pi}{12} + \frac{2\pi k}{3}))^2 \tag{14}$$

TABLE I. neutrino masses (eV)

L	0.0507	0.0089	0.0004
R	0.0582	0.00117	0.0006

for $k = 1, 2, 3$, where the 2/9 phase differs from the charged lepton phase by a very small quantity. Fixing μ for both neutrinos and their mirrors, and selecting $-\pi/12$ as the mirror offset, we obtain the six masses in Table I. The central 0.00117 eV gives the CMB temperature T_C [19].

The precisely known value of T_C was used to further constrain ν masses [22].

CONCLUSIONS

The synthesis of $R_h = ct$, quantised inertia and holography is a viable cosmology, which efficiently eliminates many so called problems, notably dark energy and dark matter. When combined with the mirror neutrino hypothesis, it potentially provides a derivation of many other cosmological and Standard Model parameters, including the CMB temperature, with very little input. The Brannen-Koide neutrino phenomenology is already efficient in its use of parameters, launching an exciting era of quantitative results beyond the SM.

On supercluster scales, mirror states may behave a lot like the non existent dark matter, as one would expect in the ΛCDM model. This solves the problem [33] of reconciling MOND on small scales, which follows from quantised inertia, with galaxy cluster dynamics.

Our detailed knowledge of the solar system and solar neutrinos, including the measurement of the pp flux at Borexino [34], already puts tight constraints on any proposal for local 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. In $R_h = ct$ with mirror neutrinos, since M_U evolves in cosmic time, the early universe relation between neutrino and CMB temperatures presumably changes. But it would be preferable to have a clean theory for the relation between active and mirror states before PTOLEMY. Note that mirror neutrinos at the CMB epoch in ΛCDM must be non relativistic to meet known constraints.

In the $1 + 1$D ribbon scheme, every chiral fermion has a mirror partner state. We have associated SM states (including right handed singlets for charged leptons and quarks) to *mass* interior to spacetime and mirror states to *information* on the boundary, implementing a holographic principle. An important open question is the role of mirror states for the charged leptons and quarks.

In summary, although the ΛCDM model is a great empirical success, at some point it must confront the quantum nature of reality even on large scales.

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MDS 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 she had no idea that he was starting to work on the $R_h = ct$ idea. MDS learned of this 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, she 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 is unknown, tried to talk about statistics problems with type Ia supernovae, but MDS was already suffering from depression and abuse, no doubt partly due to her support for $R_h = ct$, and many of these ideas were lost to her. Only in October 2017 did she 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, recalling that quantised inertia appears in the 2012 work of MDS.

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[1] R. Penrose and W. Rindler, *Spinors and spacetime*, vols I/II, Cambridge U. P., 1986

[2] L. P. Hughston and T. R. Hurd, Proc. Roy. Soc. Lond. A378, 141-154, 1981

[3] G. 't Hooft, Nucl. Phys. B 256, 727, 1985

[4] G. Y. Huang and S. Zhou, arxiv:1610.01347, 2016

[5] L. Riofrio, riofriospacetime.blogspot.com, 2004

[6] F. Melia, *The galactic supermassive black hole*, Princeton U. P., 2007

[7] R. Penrose, Proc. EPAC Scotland, 2759-2767, 2006

[8] J. T. Nielsen, A. Guffanti and S. Sarkar, Sci. Rep. 6, 35596, 2016

[9] F. Melia, arXiv:1609.0857, 2016

[10] F. Melia, Mon. Not. R. Astron. Soc. 382, 1917-1921, 2007

[11] F. Melia and M. Abdelqader, Int. J. Mod. Phys. D18, 1889, 2009

[12] F. Melia and A. S. H. Shevchuk, Mon. Not. R. Astron. Soc. 419, 2579-2586, 2012

[13] M. McCulloch, arXiv:1302.2775, 2013

[14] M. McCulloch, arXiv:1207.7007, 2012

[15] J. Gine, Mod. Phys. A27, 34, 1250208, 2012

[16] M. E. McCulloch and J. Gine, Mod. Phys. A32, 28, 1750148, 2017

[17] S. O. Bilson-Thompson, arXiv:hep-ph/0503213, 2005

[18] M. D. Sheppeard, PhD Thesis, University of Canterbury, 2007

[19] G. Dungworth and M. D. Sheppeard, viXra:1102.0010, 2011

[20] G. Dungworth and M. D. Sheppeard, June posts at both the *GalaxyZoo* forum and the blog *Arcadian Pseudofunctor*, 2010

[21] MINOS Collaboration, https://www-numi.fnal.gov, 2010

[22] M. D. Sheppeard, viXra:1709.0035; viXra:1304.0003, 2017

[23] P. Adamson et al. (Daya Bay Collaboration, MINOS Collaboration) Phys. Rev. Lett. 117, 151801, 2016; Phys. Rev. Lett. 117, 209901, 2016

[24] G.H. Collin, C.A. Argüelles, J.M. Conrad and M.H. Shaevitz, Nucl. Phys. B908, 354-365, 2016; arXiv:1602.00671

[25] S. Gariazzo, C. Giunti, M. Laveder and Y.F. Li, J. High Energ. Phys. 2017, 135, 2017; arXiv:1703.00860

[26] C. A. Brannen, viXra:1708.0267, 2017

[27] C. A. Brannen, http://www.brannenworks.com/, 2006

[28] Y. Koide, Phys. Rev. D28, 1, 252-254, 1983

[29] Y. Koide, Phys. Lett. B120, 161-165, 1983

[30] B. Pontecorvo, Sov. Phys. JETP, 7, 172, 1958

[31] Z. Maki, M. Nakagawa and S. Sakata, Prog. Theor. Phys. 28, 870, 1962

[32] P. F. de Salas, D. V. Forero, C. A. Ternes, M. Tortola and J. W. F. Valle, arXiv:1708.01186, 2017

[33] L. Berezhiani and J. Khoury, Phys. Rev. D92, 103510, 2015; arXiv:1507.01019

[34] G. Bellini et al. (Borexino Collaboration), Phys. Rev. Lett. 108, 051302, 2012