Non local mirror neutrinos with $R_h = ct$

G. Dungworth

Hemel Hempstead, Hertfordshire HP11TP, United Kingdom

M. D. Sheppeard

Te Atatu Peninsula, Waitakere, New Zealand

(Dated: November 2017)

Abstract

The observationally successful FRW constraint of Riofrio provides a viable alternative to ΛCDM. In this context we study neutrinos in quantum gravity, using McCulloch's approach to quantum inertia and a new holographic principle. There is no local dark matter and no dark energy, and mirror neutrino states are informationally connected to the CMB. Quantitative consequences include (i) a present day temperature of 2.73K arising as a mirror rest mass and (ii) an effective sterile mass of 1.29eV, in line with oscillation results.

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 of this form. Rather, we require a cosmology that is free of WIMP dark matter and dark energy. Non local mirror states will be associated to the Rindler horizons [1] which define quantised inertia, beyond general relativity.

Promising candidates for this restriction to Standard Model states include categorical constructions in 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 GUT or Planck scale underpins the Higgs mechanism in quantum gravity, as indicated by the rough correspondence $M_H \simeq \sqrt{m_\nu M_P}$.

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

Observed CMB photons were 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 correlated with distant structure, since primordial perturbations seed structure growth. Similarly, CMB photons that originated near past 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. This 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. 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, 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 apparent Big Bang, begins with black holes [4]. Riofrio [5] originally derived 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, if it is the existence of relevant horizons that counts.

This alternative to the failing ΛCDM model is introduced in the next section, extended by quantised inertia. Section 3 incorporates neutrino masses into cosmology, and finally we consider neutrino anomalies.

$R_h = ct$ WITH QUANTISED INERTIA

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 [6] of supernovae favours models like $R_h = ct$ over ΛCDM. Other observations listed in [7] also favour the $R_h = ct$ theory. Here 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 then solved with quantum causality.

In [8], Rindler horizons define a kind of curvature horizon, associated here with mass generation. We begin with Newton's insight: there is no gravity in the centre of a spherical shell. Although apparently inertial, an interior object accelerates relative to distant objects. Melia et al [9][10] introduce 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 a central acceleration, between an observer 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 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.

McCulloch [11] breaks the equivalence principle mildly in attributing quantum inertia to a Hubble scale horizon censorship, using the Casimir effect as inspiration, for both the local Rindler horizon for the 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 local dark matter, as shown in the rotation curve analysis of [12].

The breaking of the equivalence principle between inertial and gravitational mass begins with Unruh radiation for the accelerated object, at a temperature

$$kT = \frac{ha}{4\pi^2 c}, \tag{4}$$

where a is the magnitude of the acceleration. The radiation reduces the gravitational mass. Along with the displacement law

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

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

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

Assume that Unruh wavelengths only fit the size $4R_h$, twice the Hubble diameter. Then the equivalence principle is broken by the relation [12]

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

Using $R_h = ct$, this gives a quantum correction to m_i proportional to the velocity ratio c/at. 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 [13][14].

As explained above, one expects neutrino inertial masses to detect quantum terms while 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 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.

MIRROR NEUTRINOS WITH HOLOGRAPHY

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 for a modular tensor category. The chiral SM particle spectrum is recovered with the braid group on three stands [15][16], 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 local dark matter, which is not observed in the solar system.

Although the Hubble radius is a natural limit in a semiclassical cosmology, in quantum gravity we expect a feedback mechanism to select some special cosmological boundary. We assume that this is the CMB [17].

Quantum perturbations in the early universe, governing the acoustic peaks of 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 is a direct measurement of mirror mass. In the futuristic quantum cosmology we expect a reinterpretation of redshift, allowing for masses and the CMB temperature to remain fixed, removing the Big Bang singularity and the low entropy problem [17]. Here a de Sitter space, roughly representing ΛCDM, is balanced by an AdS space, for which the mirror neutrinos, *at rest*, must gravitate.

In [18] 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 [17] between the central mirror mass and the *present day* CMB temperature uses Wien's displacement law (5) to equate the mirror rest mass E/c^2 with temperature.

Only mirror masses are redshifted back to the early universe, leaving neutrinos to behave themselves most of the time. The use of (5) for neutrino mass is 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 [18]. Whereas quantised inertia gives a mass term proportional to the Unruh wavelength, we now have a mirror mass that is inversely proportional to it, encoding a T duality holographically.

The apparent sterile neutrino in oscillation experiments is now 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 $z = 1090$ to the special central mirror mass, we obtain an apparent sterile mass of precisely 1.29 eV, permitted by current data [19][20][21]. Hopefully, a better understanding of mirror states will further illuminate neutrino anomalies.

This discovery originated in the Brannen model [22] for quantum gravity, where a neutrino phase of $\pm\pi/12$ perturbs the charged lepton phase in the Brannen-Koide relations for neutrinos [23][24][25], given below.

Neutrino oscillations [26][27] 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

$$\sqrt{M} = \frac{\sqrt{\mu}}{\sqrt{2}} \begin{pmatrix} \sqrt{2} & e^{i\theta} & e^{-i\theta} \\ e^{-i\theta} & \sqrt{2} & e^{i\theta} \\ e^{i\theta} & e^{-i\theta} & \sqrt{2} \end{pmatrix}, \tag{8}$$

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

$$m_k = \mu(1 + \sqrt{2}\cos(0.222 + \frac{\pi}{12} + \frac{2\pi k}{3}))^2 \tag{9}$$

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 I. The central 0.00117 eV gives the CMB temperature [17].

A precisely known value of T_{CMB} may be used to further constrain ν masses [18]. The cosmological constant of ΛCDM is associated to the minimal acceleration of (7), or rather here, the minimal rest mass of neutrinos.

Why are mass and flavor states distinct? Astrophysically, it is charged leptons, baryons

TABLE I. Koide ν masses (eV)

L	0.0507	0.0089	0.0004
R	0.0582	0.00117	0.0006

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). Neutrino oscillations occur when our four dimensional spacetime (or six dimensional twistor space) cannot detect a single copy of $1 + 1$D, only three. The holographic role of CFTs is then responsible for the number of generations in general.

CONCLUSIONS

The synthesis of $R_h = ct$, quantised inertia and holography is an observationally successful cosmology, which efficiently eliminates many so called problems, notably dark energy and local dark matter. When combined with the mirror neutrino hypothesis, it potentially provides a derivation of many cosmological parameters, including the CMB temperature, with almost no input parameters. The Brannen-Koide neutrino phenomenology is also efficient in its use of parameters, launching an exciting era of quantitative results beyond the SM.

On supercluster scales, mirror matter may behave a lot like dark matter, as one would expect in the ΛCDM model. This solves the problem 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 [29], 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 $R_h = ct$ on the other hand, since M_U evolves in cosmic time, the early universe relation between neutrino and CMB temperatures presumably changes. In our mirror cosmology, limiting horizons are an observational brick wall, behind which the ontology of matter and spacetime ends. Neutrinos then remain at the CMB temperature even in ΛCDM, due to their interaction with mirror states.

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 charged leptons and quarks. We should aim for a categorical, holographic theory of quantum gravity, based on information theoretic principles. 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.

ACKNOWLEDGMENTS

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.

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

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

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

[7] F. Melia, arXiv:1609.0857

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

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

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

[11] M. McCulloch, arXiv:1302.2775

[12] M. McCulloch, arXiv:1207.7007

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

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

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

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

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

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

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

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

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

[22] C. A. Brannen, viXra:1708.0267

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

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

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

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

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

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

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