Guide to Dynamical Space and Emergent Quantum Gravity: Experiments and Theory

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This report provides a brief outline and literature listing dealing with the discovery of the existence of Dynamical Space, and the subsequent generalisation to Maxwell Electromagnetic Theory, Schrödinger and Dirac Quantum Theory, and the emergence of Gravity as a quantum effect. This amounts to the unified theory of gravity and quantum phenomena. All theory developments have been experimentally and observationally checked.

1 Introduction

The essence of a science is the ongoing interaction between theory and experiment, as a theory is needed to design and analyse data from experiments or observations, and that data is essential to the testing of any putative theory. In physics this interaction ceased more than 100 years ago when one theory was adopted as being absolutely valid and unchallengeable. This happened because of an unrecognised design flaw in a key experiment, namely the Michelson interferometer [1], resulting in the vacuum mode experiments being unable to detect a particular phenomenon, and then the invalid conclusion being reached that the phenomena did not exist. The phenomenon was the anisotropy of the speed of light. However a number of experiments did detect this phenomenon, but the experimental data was totally rejected, as noted below. This situation went uncorrected until 2002 when the above design flaw was first recognised [18, 34]. The implications are indeed very profound, namely that space is a detectable complex dynamical system [28, 61, 102, 108–110] in motion wrt the earth. This dynamical space is missing from all of the theories in physics. When these theories are generalised to include the dynamical effects of this space numerous phenomena are explained, including the emergence of gravity as a quantum effect from the Schrödinger and Dirac Quantum Theories [76]. This emergent gravity theory differs from that of Newton and General Relativity (GR), and which no longer require "dark matter" nor "dark energy" [59], explaining bore hole gravity anomalies, spiral galaxy flat rotation curves, non-singular back holes, light bending and lensing by stars and galaxies, and the magnitude-redshift data of the expanding universe. As well the data from all experiments that detected this dynamical space revealed gravitational waves, namely fractal turbulence in the space flow. It is important to note that vacuum mode Michelson interferometers, such as LIGO and related detectors, cannot, because of the above noted design flaw, detect this wave phenomenon [112]. The latest quantum technique to detect this dynamical space flow and its turbulence measures current fluctuations in reverse biased diodes, and at a trivial cost [105]. It is important to note that this dynamical space is not a geometrical space construct, but a complex structured dynamical system that at a suitable level supports a geometrical coordinate system, that is used to locate various phenomena wrt observers, but this geometrical construct is not valid at all length scales [102]. Another aspect of the dynamical space is that motion of systems through that space result is the so-called relativistic effects, such as length contractions and clock slowing. These effects are different from those of Special Relativity (SR), where these effects are supposedly caused by the motion of rods and clocks wrt the observer. These differences have been exposed experimentally, and a new neo-Lorentz Relativity (nLR) emerges to replace SR [57, 86].

2 Measuring Light Speed Anisotropy

Electromagnetic radiation has played various key roles in attempts to understand reality. Indeed the most significant experiment in the history of physics was performed by Michelson and Morley [1] in 1887 in Cleveland Ohio, designed to detect and quantify light speed anisotropy, assumed to be caused by the orbital speed of the Earth of 30km/s through an "aether". The prevailing ontology was that reality consisted of an aether material embedded in an unstructured static three-dimensional geometrical space, with time a one-dimensional geometrical entity. The experiment used the light interferometer designed by Michelson, see Fig.1 and 2. They reported, based upon only 36 rotations, the observation of fringe shifts and inferred a light speed anisotropy of 8-10km/s. The extraction of that speed depends upon the calibration theory for the interferometer, namely how to calculate that speed from the magnitude of the observed fringe shifts, which are tabulated in the Michelson-Morley paper [1]. The calibration theory that was used was based upon Newtonian physics, and because the deduced speed was less than the expected speed of 30km/s they concluded that the speed of light was isotropic, namely the same in all directions. As is well known this led to Einstein in 1905 abandoning Galilean Relativity, and constructing a new relativity theory, namely Special Relativity (SR), in which the invariance of the speed of light is the basic assumption. This theory has been the foundation of physics ever since. However in 1925/26 Miller, a junior colleague of Michelson, repeated the interferometer experiment with a much larger and refined instrument, see Fig.1, atop Mt Wilson in California. Miller knew that Michelson and Morley had indeed detected the expected fringe shifts, and suspected that the problem lay with the Newtonian physics based calibration theory they had used. To that end Miller used a different technique, namely to assume that the observed fringe shifts from his extensive data set, collected over a year, were analysed assuming that the earth orbital speed provided an aberration effect that merely modulated the fringe shifts. An extensive analysis of the data, from 1000 rotations, then led Miller [3], reporting in 1933, and still assuming the existence of an aether, to an average light speed anisotropy of 208km/s, with the speed smaller in the direction Right Ascension (RA) $=4^h 54^m$, Declination (DEC)=$70°33'$S, see Fig.3. However by then SR had become firmly established and beyond experimental challenge. SR involves the notion that space and time do not exist, and that it is a 4-dimensional spacetime only that exists, and which cannot be separated into a space and time component valid for all observers. There have been later experiments to detect light speed anisotropy: the astronomer Courvoiser [78] in the 1930's did many and varied experiments, and reported an anisotropy speed of 500-810km/s, and various directions. DeWitte [43, 77] performed a key experiment in 1991 measuring the varying speed of RF EM waves in coaxial cables as the Earth rotated, and reported an anisotropy speed of 500km/s with a RA $= 5^h$, as discussed later, but with an undetermined Declination (DEC). These experimental results were also ignored by academic physics. However a major development occurred in 2002 when a new calibration theory for the Michelson interferometer was finally formulated [18, 34], resulting in close agreement between the new results from the analysis of the Michelson-Morley and Miller data. As discussed later this involved a new relativity theory, namely neo-Lorentz Relativity* (nLR) [57, 86], which differed completely from SR. Subsequent to that various new experimental techniques were developed by the author, all giving the same speed, RA and DEC for the light speed anisotropy. The interpretation was that the light speed anisotropy was caused, in the main, by the motion of the Solar system, with the speed of light being fixed at 300,000km/s, in vacuum, wrt a dynamical space with fluctuating speed of some 500km/s, from a direction RA=5^h, DEC=80°S, and with no aether. In physics, as a science, theories must be repeatedly tested against various and different experimental techniques, as the theory not only determines the nature of various phenomena, but also plays a key role in the design of experimental apparatus, as well as the extraction of measured quantities from the raw data. Herein we briefly review some of these new key observational techniques. A major development occurred in 2013, with the discovery of a quantum effect that permitted the measurement of the speed and direction of the Earth through the dynamical space using a quantum diode direct detection of that space flow [89, 96, 105], and so independent of earlier light and RF anisotropy speed techniques. One particular EM anisotropy speed determination used NASA Doppler shift data form spacecraft Earth-Flybys [64].

3 Gas-Mode Michelson Interferometer

The Michelson interferometer Fig.2 is a brilliant instrument for measuring the light speed anisotropy and hence velocity of space $\mathbf{v}(\mathbf{r}, t)$, but only when operated in dielectric mode. This is because two different and independent effects exactly cancel in vacuum mode, a discovery only made in 2002 [18, 34]. The same design flaw is encountered when using RF resonant vacuum cavity devices, essentially RF Michelson interferometers † Taking account of the geometrical path differences, the Fitzgerald-Lorentz arm-length contraction and the Fresnel drag effect, leads to the travel time difference between the two arms, and which is detected by interference effects upon rotation of the interferometer. The key effect is the Fitzgerald-Lorentz arm length contraction effect: $L = L_0 \sqrt{1 - v_P^2/c^2}$. In SR v_P is the projected speed in the arm direction relative to the observer, which is zero in the case of the usual operation condition. In nLR v_P is the projected speed of the arm relative to the local dynamical space. Taking account of the arm contraction effect in nLR and the presence of the dielectric in the

*In nLR the Lorentz transformation is not relevant as it does not give the mapping between different observer's space and time coordinates for an event, rather this mapping is given by the Galilean Relativity transformation [86].

†For example: Muller, H., C. Braxmaier, S. Herrmann and A. Peters, 2003b. Electromagnetic cavities and Lorentz invariance violation. Phys. Rev. D. 10.1103/PhysRevD.67.056006.

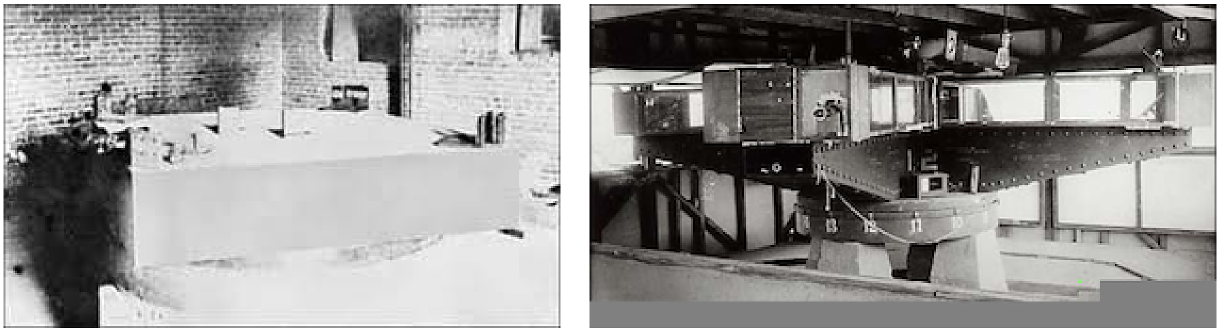

Figure 1: Left: Michelson-Morley interferometer experiment of 1887. Right: Miller 1925/26 interferometer experiment. Examples of detected fringe shifts on rotation shown in Fig.4, after extracting the temperature and non-orthogonal mirror effects.

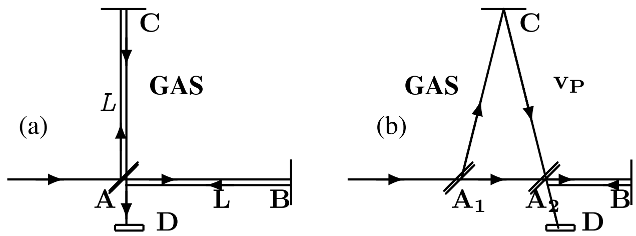

Figure 2: Schematic diagrams of the gas-mode Michelson Interferometer, with beam splitter/mirror at A and mirrors at B and C mounted on arms from A, with the arms of equal length L_0 when at rest. D is the detector screen. In (a) the interferometer is at rest in space. In (b) the instrument and gas are moving through 3-space with speed v_P parallel to the AB arm. Interference fringes are observed at D when mirrors B and C are not exactly perpendicular - the Hick's effect. As the interferometer is rotated shifts of these fringes are seen in the case of absolute motion, but only if the apparatus operates in a gas, or other dielectric. By measuring fringe shifts the speed v_R may be determined.

light paths, with refractive index n, we obtain for the difference in travel time Δt for the light in the two arms

$$\Delta t = k^2 \frac{L v_P^2}{c^3} \cos\big(2(\theta - \psi)\big), \tag{1}$$

where ψ specifies the direction of $\mathbf{v}(\mathbf{r}, t)$ projected onto the plane of the interferometer, giving projected value v_P, and where θ is the orientation of the arm relative to the local meridian. Here the key calibration constant is $k^2 = (2 - n^2)(n^2 - 1)/n$. Neglect of the absolute motion Fitzgerald-Lorentz contraction effect gives $k^2 \approx n^3 \approx 1$ for gases, which is essentially the calibration theory that Michelson used in 1887. With air present $n = 1.00029$ gives $k^2 = 0.00058$. So with air present the Michelson interferometer is very much less sensitive than assumed by Michelson.

However the above analysis does not correspond to how the interferometer is actually operated. That analysis does not actually predict fringe shifts, for the field of view would be uniformly illuminated, and the observed effect would be a changing level of luminosity rather than fringe shifts. As Michelson and Miller knew, the mirrors must be made slightly non-orthogonal with the degree of non-orthogonality determining how many fringe shifts were visible in the field of view. Experimenting with this effect permits the determination of a comfortable number of fringes: not too few and not too many. The non-orthogonality reduces the symmetry of the device, and instead of having period of 180° the symmetry now has a period of 360°, so that to (1) we must add the extra term $a\cos(\theta - \beta)$ in

$$\Delta t = k^2 \frac{L(1 + e\theta) v_P^2}{c^3} \cos\big(2(\theta - \psi)\big) + a(1 + e\theta)\cos(\theta - \beta) + f \tag{2}$$

The factor $1 + e\theta$ models the temperature effects, namely that as the arms are uniformly rotated, one rotation taking several minutes, there will be a temperature induced change in the length of the arms. If the temperature effects are linear in time, as they would be for short time intervals, then they are linear in θ. In the non-orthogonality term the parameter a is proportional to the length of the arms, and so also has the temperature factor. The term f simply models any offset effect. Michelson and Morley and Miller took these two effects into account when analysing his data.

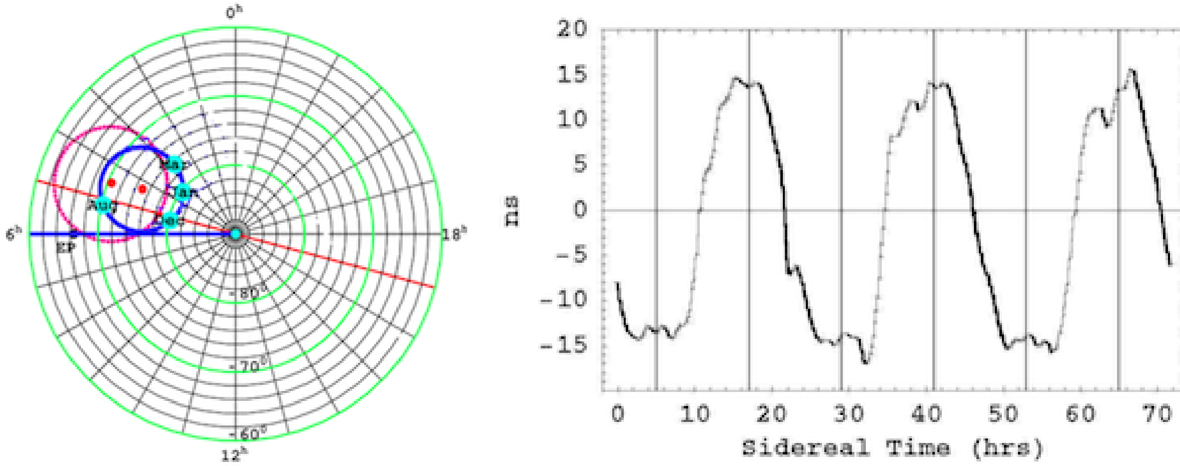

Figure 3: Left: South celestial pole region. The dot at RA=4.3^h, Dec=75°S, and with speed 486km/s, is the year-averaged direction of motion of the solar system through space determined from NASA spacecraft Earth-flyby Doppler shifts [64], as revealed by the EM radiation speed anisotropy. The thick circle centred on this direction is the observed velocity direction for different months of the year, caused by Earth orbital motion and Sun 3-space inflow. The corresponding results from the 1925/26 Miller gas-mode interferometer are shown by 2nd dot and its aberration circle. For December 8, 1992, the speed is 491km/s from direction RA=5.2^h, Dec=80°S, see Table 2 of Cahill [64]. EP is the pole direction of the plane of the ecliptic, and so the space flow is close to being perpendicular to the plane of the ecliptic. Right: Variations in travel time from DeWitte's RF coaxial cable experiment of 1991, resulting in a speed of 500km/s with RA=5hrs.

The interferometers are operated with the arms horizontal. Then in (2) θ is the azimuth of one arm relative to the local meridian, while ψ is the azimuth of the absolute motion velocity projected onto the plane of the interferometer, with projected component v_P. The instrument is operated by rotating at a rate of one rotation over several minutes, and observing the shift in the fringe pattern through a telescope during the rotation. Then fringe shifts from 6 (Michelson and Morley) or 20 (Miller) successive rotations are averaged to improve the signal to noise ratio, and the average sidereal time noted. Some examples are shown in Fig.4, and illustrate the incredibly clear fringe shift signal after removing the temperature and non-orthogonality effects from the data. The ongoing claim that the Michelson-Morley experiment was a null experiment is disproved. And as well, as discussed in Cahill [58,94], Michelson and Morley detected gravitational waves, *viz* 3-space flow turbulence in 1887. The agreement of these gas-mode interferometer determined velocities with velocities from the EM anisotropy measurements using the NASA Doppler shift Earth-fly spacecraft data [64], which does not involve any physical arm length contraction effects, see Fig.3, demonstrates that the validity of the above theory and consequent calibration for these interferometers. The observed null results from the various RF vacuum-mode interferometers, and in particular the vacuum mode LIGO optical Michelson interferometers, follow simply from having $n = 1$ (for vacuum) giving $k^2 = 0$ in (1). A better interferometer technique is to use optical fibers, as then $n \approx 1.4$, and so k^2 is very much larger, see Cahill [94].

4 Determination of Dynamical Space Flow Velocity from RF Coaxial Cable Experiments

The enormously significant 1991 DeWitte [43] double one-way 1st order in v/c experiment successfully measured the anisotropy of the speed of RF EM waves using atomic clocks at each end of 1.5km of buried RF coaxial cables in Brussels. The technique uses rotation of the coaxial cables by means of the earth rotation, to permit extraction of the EM speed anisotropy, despite the atomic clocks not being synchronised [82]. Data from this 1st order in v/c experiment agrees with the speed and direction of the anisotropy results from all the other viable experiments, see Fig.3.

A much improved RF coaxial a cable experiment uses the Dual RF Coaxial Cable Detector design in Fig.5, Cahill [81], as shown in Fig.6, with the data shown in Fig.7.

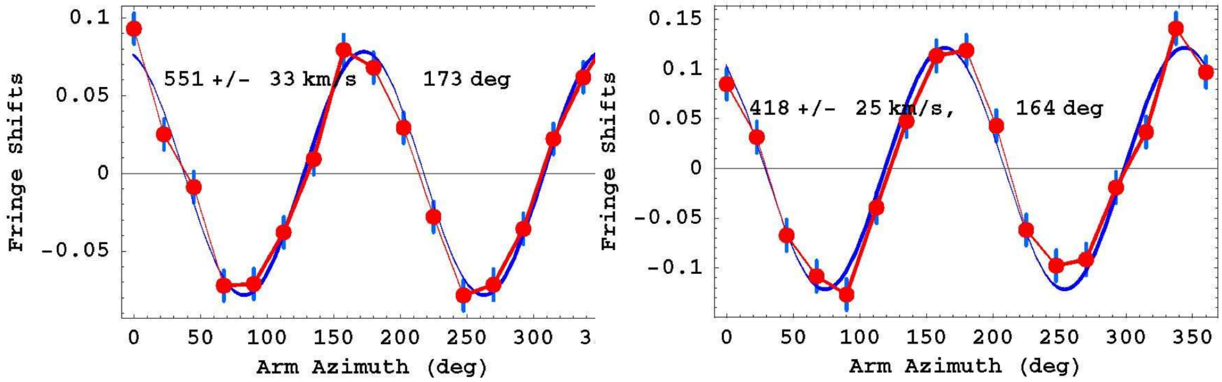

Figure 4: Examples of detected fringe shifts from rotation after removing the temperature and non-orthogonal mirror effects from the data. Left: Michelson-Morley fringe shifts, from 1887. Right: Miller interferometer fringe shifts 1925/26. Plots show both data and expected $\cos\big(2(\theta-\psi)\big)$ form in (2). Error bars show rms deviation between these.

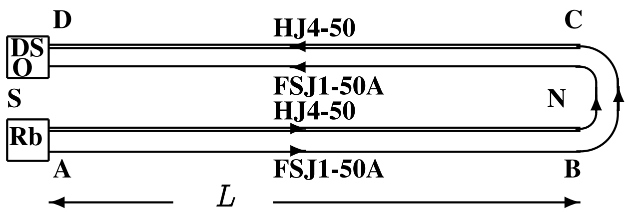

Figure 5: Because Fresnel drag is absent in RF coaxial cables this dual cable setup, using one clock, is capable of detecting the absolute motion of the detector wrt to space, revealing the sidereal rotation effect as well as wave/turbulence effects. The cables in each circuit are configured into 8 loops, as in Fig.6, giving $L = 8 \times 1.85$m $= 14.8$m.

5 Dynamical 3-Space

The detection of the dynamical space is a phenomenon that physics missed from its beginning, with space modelled as a geometric entity without structure or time dependence. That has changed recently with the determination of the speed and direction of the solar system through the dynamical space, and the characterisation of the flow turbulence: gravitational waves. As noted above detections using various techniques have all produced the same speed and direction Cahill [64, 89, 90, 94, 96, 105]. The detection of the dynamical space has led to a new and extensively tested theory of reality, and goes under the general name of Process Physics [28],PPClaremont, [102, 108–110].

To develop the theory for the dynamical space and develop further experimental detection techniques we must first correct the long-standing Schrödinger equation to include the dynamical space. Light speed anisotropy requires that Maxwell's EM equations be modified by the replacement of the usual time derivative by the Euler time derivative:

$$\partial/\partial t \to \partial/\partial t + \mathbf{v}(\mathbf{r},t)\cdot\nabla \tag{3}$$

where $\mathbf{v}(\mathbf{r},t)$ is the classical field description of the dynamical space velocity, at location and time used by the observer. This modification was first suggested by Hertz [2] in 1890, and also discussed by Edgar in 1994 [4]. When using the appropriate and detected space inflow velocity component for the Sun this results in the observed bending of star light by the Sun. The corrected Schrödinger equation is

$$i\hbar\frac{\partial\psi(\mathbf{r},t)}{\partial t} = -\frac{\hbar^2}{2m}\nabla^2\psi(\mathbf{r},t) + V(\mathbf{r},t)\psi(\mathbf{r},t) + -i\hbar\left(\mathbf{v}(\mathbf{r},t)\cdot\nabla + \frac{\mathbf{1}}{\mathbf{2}}\nabla\cdot\mathbf{v}(\mathbf{r},\mathbf{t})\right)\psi(\mathbf{r},t) \tag{4}$$

Here $\mathbf{v}(\mathbf{r},t)$ is the velocity field describing the dynamical space at a classical field level, and the coordinates $\mathbf{r}$ give the relative location of $\psi(\mathbf{r},t)$, the quantum matter wave function, relative to a Euclidean embedding space used by an observer to locate structures. This is not an aether embedded in a non-dynamical space, but a dynamical space which induces an

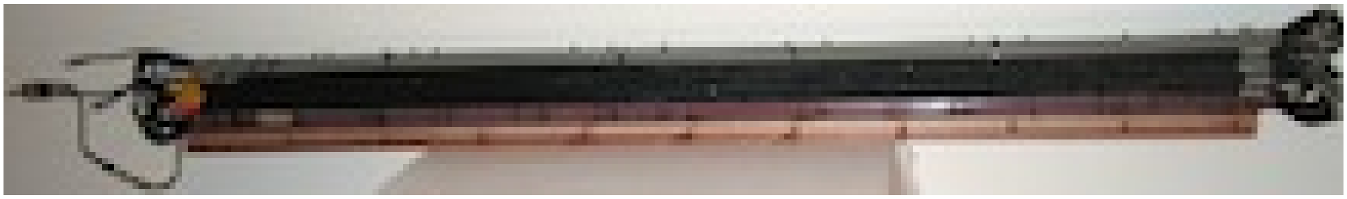

Figure 6: Photograph of the RF coaxial cables arrangement, based upon 16 $\times$1.85m lengths of phase stabilised Andrew HJ4-50 coaxial cable and 16 lengths of phase stabilised Andrew FSJ1-50A cable, in the manner shown schematically in Fig.5. The 16 HJ4-50 coaxial cables have been tightly bound into a 4$\times$4 array, so that the cables, locally, have the same temperature, with cables in one of the circuits embedded between cables in the 2nd circuit. This arrangement of the cables permits the cancellation of temperature differential effects in the cables. A similar array of the smaller diameter FSJ1-50A cables is located inside the conduit boxes.

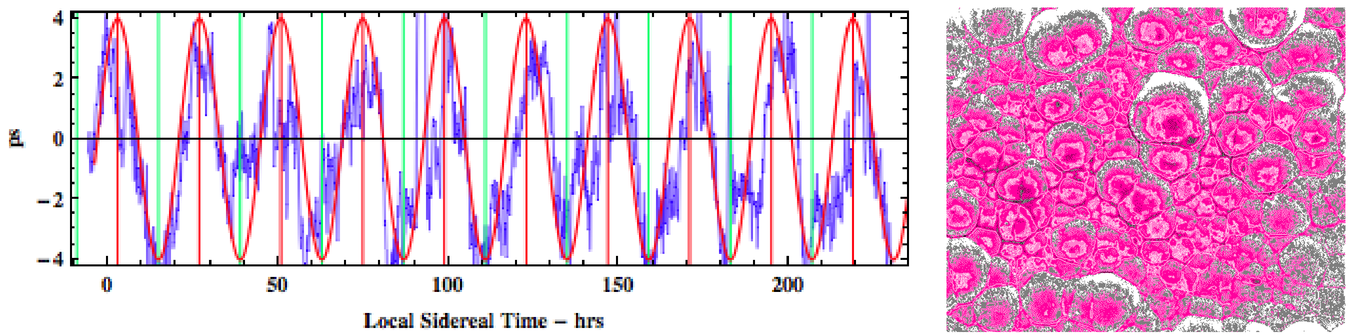

Figure 7: Left: Travel time differences (ps) between the two coaxial cable circuits in Fig.5, orientated NS and horizontal, over 9 days (March 4-12, 2012, Adelaide) plotted against local sidereal time. Sinewave, with dynamic range 8.03ps, is prediction for sidereal effect from flyby Doppler shift data with RA=2.75^h from Fig.3, shown by smooth curve with fiducial lines, Dec=76.6°S, and with speed 500km/s. Data shows sidereal effect and significant wave/turbulence effects. Right: Representation of the fractal dynamical space, showing cells moving at speed ∼500km/s relative to the detector.

embedding space or coordinate system. At sufficiently small distance scales that embedding and the velocity description is conjectured to be not possible, as then the dynamical space requires an indeterminate dimension embedding space, being possibly a quantum foam [28]. This minimal generalisation of the original Schrödingier equation arises from the replacement $\partial/\partial t \to \partial/\partial t + \mathbf{v}.\nabla$, the Euler derivative, which ensures that the quantum system properties are determined by the dynamical space, and not by the embedding coordinate system. The same replacement is also to be implemented in the original Maxwell EM equations, yielding that the speed of light is constant only wrt the local dynamical space, as observed, and which results in lensing from stars and black holes. The extra $\nabla\cdot\mathbf{v}$ term in (4) is required to make the hamiltonian in (4) hermitian. Essentially the existence of the dynamical space in all theories has been missing. The dynamical theory of space itself is now briefly. The dynamical space velocity has been detected with numerous techniques [90], dating back to the 1st detection by the Michelson-Morley experiment of 1887, for which the appropriate neo-Lorentz Relativity [86] calibration was not then available, and which lead to physics developing flawed theories of the various phenomena; SR and GR. All successful detection techniques have observed significant fluctuations in speed and direction: these are the actual “gravitational waves”, because they are associated with gravitational effects as noted below.

6 Emergent Quantum Gravity

A significant effect follows from (4), namely the emergence of gravity as a quantum effect: an Ehrenfest wave-packet analysis reveals the classical limit and shows that the acceleration of a localised wave packet, due to the space terms alone (when $V(\mathbf{r},t)=0$), determined by
$\mathbf{g} = d^2\langle\mathbf{r}\rangle/dt^2$, gives [40]

$$g(\mathbf{r},t) = \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}\cdot\nabla)\mathbf{v} \tag{5}$$

This derivation shows that the quantum matter acceleration is independent of the mass m: whence we have the 1st derivation of the Weak Equivalence Principle, discovered experimentally by Galileo. As noted below the dynamical theory for $\mathbf{v}(\mathbf{r},t)$ has explained numerous gravitational phenomena. The derivation of (5) is now given.

The key insight is that conventional physics has neglected the interaction of various systems with the dynamical 3-space. Here we generalise the Schrödinger equation to take account of this new physics. Now gravity is a dynamical effect arising from the time-dependence and spatial inhomogeneities of the 3-space velocity field $\mathbf{v}(\mathbf{r},t)$, and for a 'free-falling' quantum system with mass m the Schrödinger equation now has the generalised form

$$i\hbar\left(\frac{\partial}{\partial t}+\mathbf{v}.\nabla+\frac{1}{2}\nabla.\mathbf{v}\right)\psi(\mathbf{r},t)=-\frac{\hbar^2}{2m}\nabla^2\psi(\mathbf{r},t), \tag{6}$$

which we write as

$$i\hbar\frac{\partial\psi(\mathbf{r},t)}{\partial t}=H(t)\psi(\mathbf{r},t), \tag{7}$$

where now

$$H(t)=-i\hbar\left(\mathbf{v}.\nabla+\frac{1}{2}\nabla.\mathbf{v}\right)-\frac{\hbar^2}{2m}\nabla^2 \tag{8}$$

This form for $H(t)$ specifies how the quantum system must couple to the velocity field, and it uniquely follows from two considerations: (i) the generalised Schrödinger equation must remain form invariant under a change of observer, i.e. with $t\rightarrow t$, and $\mathbf{r}\rightarrow\mathbf{r}+\mathbf{V}t$, where $\mathbf{V}$ is the relative velocity of the two observers. Then we compute that $\dfrac{\partial}{\partial t}+\mathbf{v}.\nabla+\dfrac{1}{2}\nabla.\mathbf{v}\rightarrow\dfrac{\partial}{\partial t}+\mathbf{v}.\nabla+\dfrac{1}{2}\nabla.\mathbf{v}$, i.e. that it is an invariant operator, and (ii) requiring that $H(t)$ be hermitian, so that the wavefunction norm is an invariant with time evolution. This implies that the $\frac{1}{2}\nabla.\mathbf{v}$ term must be included, as $\mathbf{v}.\nabla$ by itself is not hermitian for an inhomogeneous $\mathbf{v}(\mathbf{r},t)$. Then the consequences for the motion of wavepackets are uniquely determined; they are fixed by these two quantum-theoretic requirements*.

Then the classical-limit trajectory is obtained via the position 'expectation value', first with

$$\begin{aligned}\mathbf{v}_O\equiv\frac{d{<}\mathbf{r}{>}}{dt} &= \frac{d}{dt}(\psi,\mathbf{r}\psi)=\frac{i}{\hbar}(\psi,[H,\mathbf{r}]\psi),\\ &= (\psi,(\mathbf{v}(\mathbf{r},t)-\frac{i\hbar}{m}\nabla)\psi)\\ &= {<}\mathbf{v}(\mathbf{r},t){>}-\frac{i\hbar}{m}{<}\nabla{>},\end{aligned} \tag{9}$$

on evaluating the commutator using $H(t)$ in (8), and which is again valid for a normalised state.

*For two or more 'particles' we have by the same arguments $H(t)=\sum_j -i\hbar\left(\mathbf{v}.\nabla_j+\frac{1}{2}\nabla_j.\mathbf{v}\right)-\frac{\hbar^2}{2m_j}\nabla_j^2$

Then for the 'acceleration' we obtain from (9) that*

$$
\begin{aligned}
\frac{d^2\!<\!\mathbf{r}\!>}{dt^2} &= \frac{d}{dt}(\psi, (\mathbf{v} - \frac{i\hbar}{m}\nabla)\psi) \\
&= (\psi, \left(\frac{\partial \mathbf{v}(\mathbf{r},t)}{\partial t} + \frac{i}{\hbar}[H, (\mathbf{v} - \frac{i\hbar}{m}\nabla)]\right)\psi), \\
&= (\psi, \frac{\partial \mathbf{v}(\mathbf{r},t)}{\partial t}\psi) + (\psi, \left(\mathbf{v}.\nabla + \frac{1}{2}\nabla.\mathbf{v} - \frac{i\hbar}{2m}\nabla^2\right)\left(\mathbf{v} - \frac{i\hbar}{m}\nabla\right)\psi) - \\
&\quad (\psi, \left(\mathbf{v} - \frac{i\hbar}{m}\nabla\right)\left(\mathbf{v}.\nabla + \frac{1}{2}\nabla.\mathbf{v} - \frac{i\hbar}{2m}\nabla^2\right)\psi), \\
&= (\psi, \left(\frac{\partial \mathbf{v}(\mathbf{r},t)}{\partial t} + ((\mathbf{v}.\nabla)\mathbf{v}) - \frac{i\hbar}{m}(\nabla\times\mathbf{v})\times\nabla\right)\psi) + (\psi, \frac{i\hbar}{2m}(\nabla\times(\nabla\times\mathbf{v}))\psi), \\
&\approx \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}.\nabla)\mathbf{v} + (\nabla\times\mathbf{v})\times\left(\frac{d\!<\!\mathbf{r}\!>}{dt} - \mathbf{v}\right) + \frac{i\hbar}{2m}(\nabla\times(\nabla\times\mathbf{v})), \\
&= \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}.\nabla)\mathbf{v} + (\nabla\times\mathbf{v})\times\left(\frac{d\!<\!\mathbf{r}\!>}{dt} - \mathbf{v}\right) \\
&= \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}.\nabla)\mathbf{v} + (\nabla\times\mathbf{v})\times\mathbf{v}_R
\end{aligned}
\tag{10}
$$

where in arriving at the 3rd last line we have invoked the small-wavepacket approximation, and also used (9) to identify

$$\mathbf{v}_R \equiv -\frac{i\hbar}{m} <\!\nabla\!>= \mathbf{v}_O - \mathbf{v}, \tag{11}$$

where $\mathbf{v}_O$ is the velocity of the wavepacket or object 'O' relative to the observer, so then $\mathbf{v}_R$ is the velocity of the wavepacket relative to the local 3-space. Then all velocity field terms are now evaluated at the location of the wavepacket. Note that the operator

$$-\frac{i\hbar}{m}(\nabla\times\mathbf{v})\times\nabla + \frac{i\hbar}{2m}(\nabla\times(\nabla\times\mathbf{v})) \tag{12}$$

is hermitian, but that separately neither of these two operators is hermitian. Then in general the scalar product in (10) is real. But then in arriving at the last line in (10) by means of the small-wavepacket approximation, we must then self-consistently use that $\nabla\times(\nabla\times\mathbf{v}) = \mathbf{0}$, otherwise the acceleration acquires a spurious imaginary part.

We see that the test 'particle' acquires the acceleration of the velocity field, as in (5), and as well an additional vorticity induced acceleration which is the analogue of the Helmholtz acceleration in fluid mechanics. Then $\vec{\omega}/2$ is the instantaneous angular velocity of the local 3-space, relative to a distant observer. Hence we find that the equivalence principle arises from the unique generalised Schrödinger equation and with the additional vorticity effect. This vorticity effect depends on the absolute velocity $\mathbf{v}_R$ of the object relative to the local space, and so requires a change in the Galilean or Newtonian form of the equivalence principle.

The experimental data reveals the existence of dynamical space, characterised by $\mathbf{v}(\mathbf{r}, t)$. It is a simple matter to arrive at the dynamical theory of space, and the emergence of gravity as a quantum matter effect, as noted above. The key insight is to note that the emergent quantum-theoretic matter acceleration in (5), $\partial\mathbf{v}/\partial t + (\mathbf{v}\cdot\nabla)\mathbf{v}$, is also, and independently, the constituent Euler acceleration $\mathbf{a}(\mathbf{r}, t)$ of the space flow velocity field,

$$
\begin{aligned}
\mathbf{a}(\mathbf{r},t) &= \lim_{\Delta t\to 0}\frac{\mathbf{v}(\mathbf{r}+\mathbf{v}(\mathbf{r},t)\Delta t, t+\Delta t) - \mathbf{v}(\mathbf{r},t)}{\Delta t} \\
&= \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}\cdot\nabla)\mathbf{v}
\end{aligned}
\tag{13}
$$

which describes the acceleration of a constituent element of space by tracking its change in velocity. This means that space has a structure that permits its velocity to be defined and detected, which experimentally has been done. This then suggests, from (5) and (13), that the simplest dynamical equation for $\mathbf{v}(\mathbf{r}, t)$ is

$$\nabla\cdot\left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}\cdot\nabla)\mathbf{v}\right) = -4\pi G\rho(\mathbf{r},t); \quad \nabla\times\mathbf{v} = \mathbf{0} \tag{14}$$

*Care is needed to indicate the range of the various ∇'s. Extra parentheses (...) are used to limit the range when required.

because it then gives $\nabla.\mathbf{g} = -4\pi G\rho(\mathbf{r}, t),\ \nabla \times \mathbf{g} = \mathbf{0}$, which is Newton's inverse square law of gravity in differential form. Hence the fundamental insight is that Newton's gravitational acceleration field $\mathbf{g}(\mathbf{r}, t)$ for matter is really the acceleration field $\mathbf{a}(\mathbf{r}, t)$ of the structured dynamical space*, and that quantum matter acquires that acceleration because it is fundamentally a wave effect, and the wave is refracted by the accelerations of space.

While the above leads to the simplest 3-space dynamical equation this derivation is not complete yet. One can add additional terms with the same order in speed spatial derivatives, and which cannot be *a priori* neglected. There are two such terms, as in

$$\nabla\cdot\left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}\cdot\nabla)\mathbf{v}\right) + \frac{5\alpha}{4}\left((trD)^2 - tr(D^2)\right) + ... = -4\pi G\rho$$

where $D_{ij} = \partial v_i/\partial x_j$. However to preserve the inverse square law external to a sphere of matter the two terms must have coefficients α and $-\alpha$, as shown. Here α is a dimensionless space self-interaction coupling constant, which experimental data reveals to be, approximately, the fine structure constant, $\alpha = e^2/\hbar c$ [42]. The ellipsis denotes higher order derivative terms with dimensioned coupling constants, which come into play when the flow speed changes rapidly wrt distance. The observed dynamics of stars and gas clouds near the centre of the Milky Way galaxy has revealed the need for such a term [75], and we find that the space dynamics then requires an extra term:

$$\nabla\cdot\left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}\cdot\nabla)\mathbf{v}\right) + \frac{5\alpha}{4}\left((trD)^2 - tr(D^2)\right) + \delta^2\nabla^2\left((trD)^2 - tr(D^2)\right) + ... = -4\pi G\rho \qquad (15)$$

where δ has the dimensions of length, and appears to be a very small Planck-like length [58]. This then gives us the dynamical theory of 3-space. It can be thought of as arising via a derivative expansion from a deeper theory, such as a quantum foam theory [28]. Note that the equation does not involve c, is non-linear and time-dependent, and involves non-local direct interactions. Its success implies that the universe is more connected than previously thought. Even in the absence of matter there can be time-dependent flows of space.

Note that the dynamical space equation, apart from the short distance effect - the δ term, there is no scale factor, and hence a scale free structure to space is to be expected, namely a fractal space. That dynamical equation has back hole and cosmic filament solutions [74], which are non-singular because of the effect of the δ term. At large distance scales it appears that a homogeneous space is dynamically unstable and undergoes dynamical breakdown of symmetry to form the observed spatial network of black holes and filaments, [87] to which matter is attracted and coalesces into gas clouds, stars and galaxies.

The dynamical space equation (15) explains phenomena such as Earth bore-hole gravity anomalies, from which the value of α was extracted, flat rotation curves for spiral galaxies, galactic black holes and cosmic filaments, the universe growing/expanding at almost a constant rate, and the weak and strong gravitational lensing of light [87, 90]. A significant aspect of the space dynamics is that space is not conserved: it is continually growing, giving the observed universe expansion, and is dissipated by matter.

7 Quantum Detectors of Dynamical Space

Above we have briefly reviewed some of the classical physics detections of the dynamical space velocity field, involving anisotropy of light velocity, and anisotropy of EM RF velocity in both coaxial cables and free propagation as in the Earth-flyby Doppler shift data. We now review the recently discovered theory and data from quantum detectors, which directly detect $\mathbf{v}(\mathbf{r}, t)$. This utilises the effect of the $-i\hbar\mathbf{v}\cdot\nabla\psi$ dynamical space interaction on the quantum tunnelling of electrons through a reverse-biased pn junction. The operating voltage and energy levels for the electrons at the pn function are shown schematically in Fig.9. For simplicity consider plane wave solution to (4) applicable to the situation in Fig.8, $\psi(\mathbf{r}, t) = Exp(i\mathbf{k}\cdot\mathbf{r} - i\omega t)$. Then the space term contributes the extra energy $\hbar\mathbf{v}\cdot\mathbf{k}$, assuming we can approximate $\mathbf{v}(\mathbf{r}, t)$ by a constant over a short distance and interval of time. This then changes the barrier quantum tunnelling amplitude, $T(E) \to T(E+\hbar\mathbf{v}\cdot\mathbf{k})$, where E is the electron energy when $v = 0$, and this amplitude will then be very sensitive to fluctuations in $\mathbf{k}\cdot\mathbf{v}$. In Fig.11 Left, shows current fluctuations from two collocated parallel detectors, as shown in Fig.9, showing that they produce essentially identical fluctuations. However on the Right are the anti-correlated current fluctuations from the two collocated but antiparallel detectors, also shown in Fig.9. This data confirms the dynamical consequences of the $\hbar\mathbf{v}\cdot\mathbf{k}$ term as the angle dependence is now apparent.

Quantum theory accurately predicts the transition amplitude $T(E)$, with $|T|^2 I$ giving the average electron current, where I is the incident current at the pn junction. However quantum theory contains no randomness or probabilities, the original

*With vorticity $\nabla \times \mathbf{v} \neq \mathbf{0}$ and relativistic effects, the acceleration of matter becomes different from the acceleration of space [28].

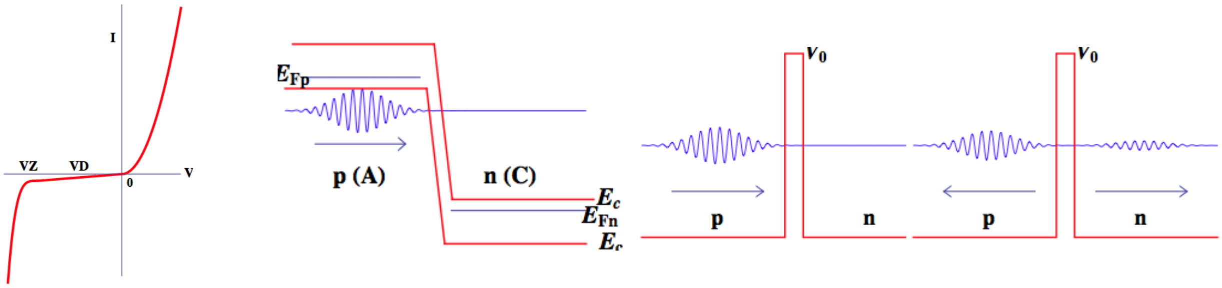

Figure 8: Left: Current-Voltage (IV) characteristics for a Zener Diode. $VZ = -3.3V$ is the Zener voltage, and $VD \approx -1.5V$ is the operating voltage for the diode in Fig.9. $V > 0$ is the forward bias region, and $V < 0$ is the reverse-bias region. The current near VD is very small and occurs only because of wave function quantum tunnelling through the potential barrier, as shown to the Right: Electron before tunnelling, in reverse-biased Zener diode, from valence band in doped p semiconductor, with hole states available, to conduction band of doped n semiconductor. A and C refer to anode and cathode labelling in Fig.9. E_c is bottom of conduction bands, and E_v is top of valence bands. E_{Fp} and E_{Fn} are Fermi levels. There are no states available in the depletion region. Next: Schematic for electron wave packet incident on idealised effective interband barrier in a pn junction, with electrons tunnelling A to C, appropriate to reverse-bias operation. Next: Reflected and transmitted wave packets after interaction with barrier. Energy of wave packet is less than potential barrier height V_0. The wave function transmission fluctuations and collapse to one side or the other after barrier tunnelling is now experimentally demonstrated to be caused by passing space fluctuations.

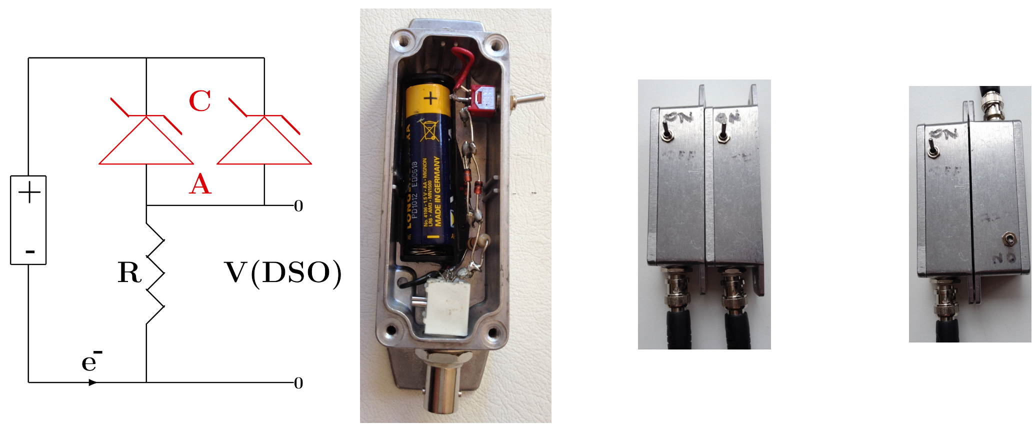

Figure 9: Circuit of Zener Diode Gravitational Wave Detector, showing 1.5V AA battery, two 1N4728A Zener diodes operating in reverse-bias mode, and having a Zener voltage of 3.3V, and resistor R= 10KΩ. Voltage V across resistor is measured by a Digital Storage Oscilloscope (DSO) and used to determine the space driven fluctuating tunnelling current through the Zener diodes. Right: Photo of detector with 6 Zener diodes in parallel. Next Right: Photos show two collocated detectors in parallel and antiparallel configurations. Data are shown in Fig.11 .

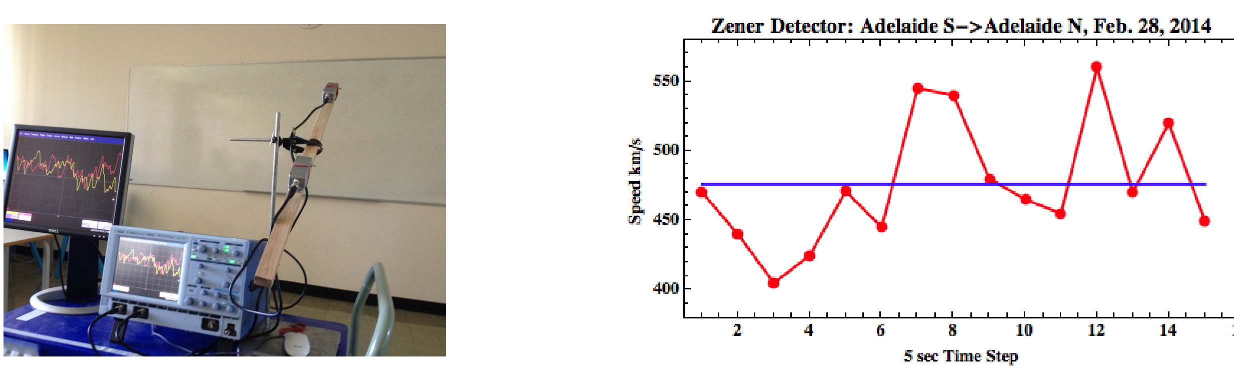

Figure 10: Left: Photo of two detectors oriented for maximum correlated time delay, giving speed and direction of dynamical space flow. Right: Measured speeds over 15s showing fluctuating speeds, indicative of the fractal structure of space, as seen in all experiments.

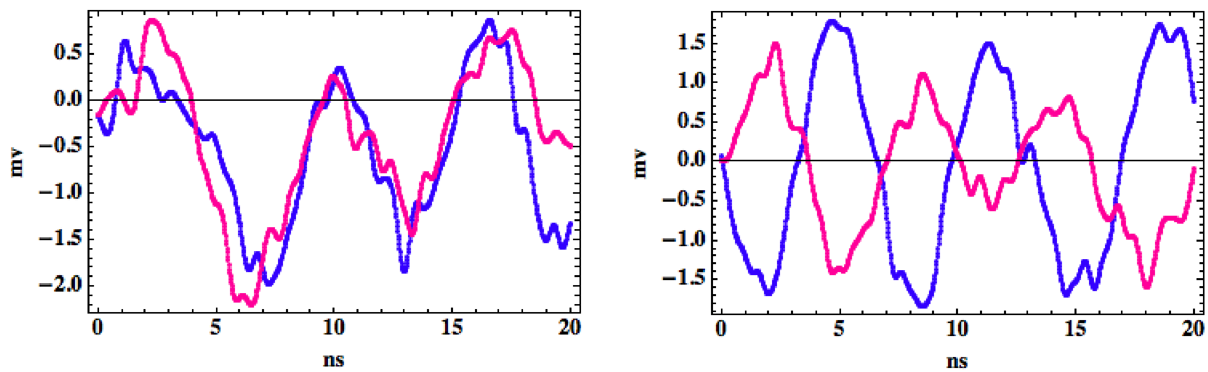

Figure 11: Correlated current fluctuations, as indicated by voltage across resistor R, and with DSO operated with 1MΩ AC input, and no filters. Left: From two collocated parallel detectors, as shown in Fig.9. Right: From anti-correlated current fluctuations from the two collocated but antiparallel detectors, also shown in Fig.9. This data confirms the dynamical consequences of the $-i\hbar\mathbf{v}\cdot\nabla\psi$ term in the new Schrödinger equation. This term is the origin of the quantum theory of matter gravitational accelerations. [105]

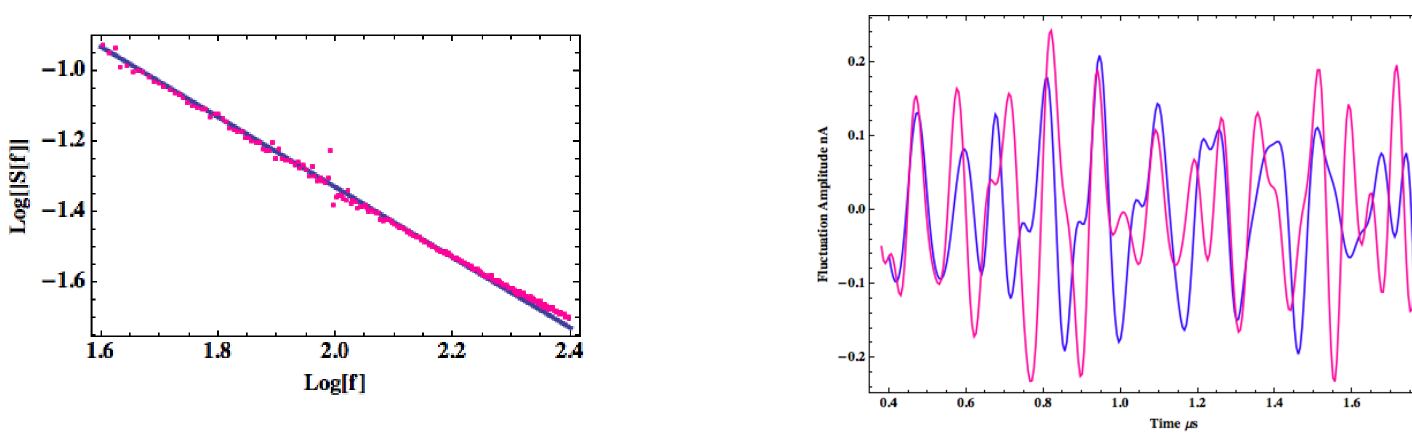

Figure 12: Left: Typical frequency spectrum from the current fluctuation data showing $1/f$ spectrum, typical of Johnson 1/f electronic systems “noise”, and so explaining the origin of Johnson noise, and also demonstrating again the fractal structure of the dynamical space. Right: Data from experimental set-up as in Fig.10 but with detectors separated by 25cm, with southerly detector signal delayed in DSO by 0.48 μs, and then showing strong correlations with northerly detector signal. This time delay effect reveals space traveling from S to N, with RA and Dec the same as NASA Doppler shift analysis, and other experiments, at a speed of approximately 476km/s. Data has been smoothed by FFT filtering to remove high frequency components. Fig.10 shows more results over a 15s time interval.

Schrödinger equation is purely deterministic: probabilities arise solely from *ad hoc* interpretations, and these assert that the actual current fluctuations are purely random, and intrinsic to each quantum system, here each diode. However the experimental data shows that these current fluctuations are completely determined by the fluctuations in the passing space, as demonstrated by the time delay effect, herein at the μs time scale and in Fig.10 Right over a 15s time scale.

As another experimental consequence of the $-i\hbar\mathbf{v}\cdot\nabla\psi$ term dynamics was discovered by Shnoll [84] namely that the α decay rate of ^{239}Pu is also direction dependent. This α decay process is another example of quantum tunnelling: here the tunnelling of the α wave packet through the potential energy barrier arising from the Coulomb repulsion between the α "particle" and the residual nucleus. The analysis above for the Zener diode also applies to this decay process: the major effect is the changing energy $E- \to E+\hbar\mathbf{v}\cdot\mathbf{k}$ produced by space velocity fluctuations. Shnoll also reported correlations between decay rate fluctuations measured at different locations. However the time resolution was $>$60sec, and so no speed and direction for the underlying space velocity was determined. It is predicted that α decay fluctuation rates with a time resolution of $\sim$1 sec would show the time delay effect for experiments well separated geographically.

A further confirmation of the $-i\hbar\mathbf{v}\cdot\nabla\psi$ space dynamics was the discovery of the anisotropic Brownian motion of dye drops placed in water [99,100], as this dynamics generates an anisotropic energy distribution of the water molecules impacting on the dye molecules.

8 Reinterpretation of Quantum Theory

The experimental data herein clearly implies a need for a reinterpretation of quantum theory, as it has always lacked the dynamical effects of the fractal space: it only ever referred to the Euclidean static embedding space, which merely provides a position labelling. However the interpretation of the quantum theory has always been problematic and varied. The main problem is that the original Schrödinger equation does not describe the localisation of quantum matter when measured, e.g. the formation of spots on photographic films. From the beginning of quantum theory a metaphysical addendum was created, as in the Born interpretation, namely that there exists an almost point-like "particle", and that $|\psi(\mathbf{r},t)|^2$ gives the probability density for the location of that particle, whether or not a measurement of position has taken place. This is a dualistic interpretation of the quantum theory: there exists a "wave function" as well as a "particle", and that the probability of a detection event is completely internal to a particular quantum system. So there should be no correlations between detection events for different systems, contrary to the experiments reported here. To see the failure of the Born and other interpretations consider the situation shown in Fig.8. In the top figure the electron state is a wave packet $\psi_1(\mathbf{r},t)$, partially localised to the left of a potential barrier. After the barrier tunnelling the wave function has evolved to the superposition $\psi_2(\mathbf{r},t)+\psi_3(\mathbf{r},t)$: a reflected and transmitted component. The probability of the electron being detected to the LHS is $||\psi_2(\mathbf{r},t)||^2$, and to the RHS is $||\psi_3(\mathbf{r},t)||^2$. These values do indeed predict the observed average reflected and transmitted electron currents, but makes no prediction about the fluctuations that lead to these observed averages. As well, in the Born interpretation, there is no mention of a collapse of the wave function, to one of the states in the linear combination, as the single location is in the metaphysics of the interpretation, and not in any physical process.

There is another process whose explanation has also never been satisfactorily explained, namely that when a quantum system, such as an electron or photon in a de-localised state, interacts with a detector, i.e. a system in a metastable state, the electron would put the combined system into a de-localised state, which is then observed to localise: the detector responds with an event at one location, but for which the quantum theory can only provide the expected average distribution, $|\psi(\mathbf{r},t)|^2$, and is unable to predict fluctuation details. In [28] it was conjectured that the delocalised electron-detector state is localised by the interaction with the dynamical space, and that the fluctuation details are produced by the space fluctuations, as we see in Zener diode electron tunnelling and α decay tunnelling. Percival* has produced detailed models of this wave function collapse process, which involved an intrinsic randomness, and which involves yet another dynamical term being added to the original Schrödinger equation. It thus appears that this randomness is a consequence of space fluctuations.

The space driven localisation of quantum states could give rise to our experienced classical world, in which macroscopic "matter" is not seen in de-localised states. It was the inability to explain this localisation process that gave rise to the Copenhagen and numerous other interpretations of the original quantum theory, and in particular the dualistic model of wave functions and almost point-like localised "particles".

*Percival I., *Quantum State Diffusion*, Cambridge University Press(1998).

9 Maxwell EM Theory Updated to Include Dynamical 3-Space

As noted above we must also generalise the Maxwell equations so that the electric and magnetic fields are excitations within the dynamical 3-space, and not of the embedding space. The minimal form again uses the Euler derivative, and in the absence of charges and currents we obtain

$$\nabla\times\mathbf{E}=-\mu_0\left(\frac{\partial\mathbf{H}}{\partial t}+\mathbf{v}.\nabla\mathbf{H}\right),\quad \nabla.\mathbf{E}=\mathbf{0},\quad \nabla\times\mathbf{H}=\epsilon_0\left(\frac{\partial\mathbf{E}}{\partial t}+\mathbf{v}.\nabla\mathbf{E}\right),\quad \nabla.\mathbf{H}=\mathbf{0} \tag{16}$$

which was first suggested by Hertz [2] in 1890, but with v then being only a constant vector field, and not interpreted as a moving space effect. As easily determined the speed of EM radiation is now $c = 1/\sqrt{\mu_0\epsilon_0}$ wrt the 3-space, and not wrt an observer in motion through the 3-space. The Michelson-Morley 1887 experiment 1st detected this anisotropy effect, as have numerous subsequent experiments. A time-dependent and/or inhomogeneous velocity field causes the refraction of EM radiation. This can be computed by using the Fermat least-time approximation - the opposite of that for quantum matter. This ensures that EM waves along neighbouring paths are in phase. Then an EM ray path $\mathbf{r}(t)$ is determined by minimising the elapsed travel time:

$$T=\int_{s_i}^{s_f}\frac{ds|\frac{d\mathbf{r}}{ds}|}{|c\hat{\mathbf{v}}_R(s)+\mathbf{v}(\mathbf{r}(\mathbf{s}),\mathbf{t}(\mathbf{s}))|},$$

with $\mathbf{v}_R=\frac{d\mathbf{r}}{dt}-\mathbf{v}(\mathbf{r}(\mathbf{t}),\mathbf{t})$, by varying both $\mathbf{r}(s)$ and $t(s)$, finally giving $\mathbf{r}(t)$. Here s is an arbitrary path parameter, and $c\hat{\mathbf{v}}_R$ is the velocity of the EM radiation wrt the local 3-space, namely c. The denominator is the speed of the EM radiation wrt the observer's Euclidean spatial coordinates. This equation may also be used to calculate the gravitational lensing by black holes, filaments, Cahill [74], and by ordinary matter, using the appropriate 3-space velocity field. It produces the measured light bending by the sun.

10 Dynamical Space and Cosmology

Dynamical Space gives a new dynamical model of the universe. The dynamical space theory

$$\begin{aligned}\nabla\cdot\left(\frac{\partial\mathbf{v}}{\partial t}+(\mathbf{v}\cdot\nabla)\mathbf{v}\right)+\frac{\alpha}{8}\left((trD)^2-tr(D^2)\right)+\\ +\frac{\delta^2}{8}\nabla^2\left((trD)^2-tr(D^2)\right)+...=-4\pi G\rho\\ \nabla\times\mathbf{v}=\mathbf{0},\quad D_{ij}=\frac{\partial v_i}{\partial x_j}\end{aligned} \tag{17}$$

Quantum theory determines the "gravitational" acceleration of quantum matter to be, as a quantum wave refraction effect,

$$\mathbf{g}=\frac{\partial\mathbf{v}}{\partial t}+(\mathbf{v}\cdot\nabla)\mathbf{v}. \tag{18}$$

where $\mathbf{v}_R=\mathbf{v}_0-\mathbf{v}$ is the velocity of matter relative to the local space. Substituting the Hubble form $\mathbf{v}(\mathbf{r},t)=H(t)\mathbf{r}$, and then $H(t)=\dot{a}(t)/a(t)$, where $a(t)$ is the scale factor of the universe,we obtain

$$4a\ddot{a}+\alpha\dot{a}^2=-\frac{16}{3}\pi G a^2\rho \tag{19}$$

This has a number of key features: (i) even when $\rho=0$, i.e. no matter, $a(t)\neq 0$ and monotonically increasing. This is because the space itself is a dynamical system, and the (small) amount of actual baryonic matter merely slightly slows that expansion, as the matter dissipates space. As well there no longer a "critical density", (ii) the redshift z is no longer a Doppler shift; now it is caused by the expansion of the space removing energy from photons. Because of the small value of $\alpha=1/137$, the α term only plays a significant role in extremely early epochs, but only if the space is completely homogeneous*. In the limit $\rho\to 0$ and neglecting the α term, we obtain the solution $a(t)=t/t_0$. This uniformly expanding universe solution is exactly the form directly determined from the supernovae data. It requires neither "dark energy" nor "dark matter" - these effects have evaporated, and are clearly revealed as nothing more than artifacts of the GR model [80, 87]. The spurious "accelerating expansion of the universe" has disappeared.

*Keeping the α term we obtain $a(t)=(t/t_0)^{1/(1+\alpha/4)}$

11 Conclusions

As initially revealed by photon experiments, but contrary to accepted wisdom, space is a complex dynamical system that has a time-dependent fractal structure that has a determining effect upon photon propagation, as in light and RF regimes, and also affects quantum tunnelling rates, and indeed the formation of the classical world via space-driven wave function collapse. This dynamical space has now been detected and characterised by numerous experiments dating back to 1887. The simplest and most robust and cheap detection methods uses current fluctuations in reverse-biased Zener diodes. The same quantum process results in a new quantum theory of gravity, namely that matter gravitational accelerations are an emergent quantum process, namely the refraction of quantum waves by the time-dependent and inhomogeneous flow of space. This theory is in contrast to the spurious notion that quantum gravity should arise from the "quantisation" of a classical theory or gravity. This new emergent theory of gravity thus represents the unification of the quantum and gravity phenomena. This gravity theory has also been extensively tested against bore hole g anomalies, rotation curves for spiral galaxies, non-singular black holes, light bending by stars, galaxies and black holes [75], and space filaments [74], and the expansion of the universe without the need for the undetected "dark matter" nor "dark energy" [80, 87], and the detection of gravitational waves generated by Earth vibrations [91]. The "black holes" are an entirely space dynamical phenomenon, namely where the inflow of space is a self-dissipation process, which at some distance from the centre results in the inflow speed exceeding the photon escape speed. As well the gravitational acceleration of matter by such a black hole is $1/r$, and is no longer of a $1/r^2$ form, which explains away the "dark matter" speculation. Also Solar flares are predictable by detecting dynamical space fractal flow turbulence. [95]. This turbulence and the generation of heat energy within matter explains the long-known correlations between Solar flare counts and the Earth climate [95]. Physics has repeatedly missed the experimental evidence for the existence of the dynamical space for over a century.

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