

The Dynamical Velocity Superposition Effect in the Quantum-Foam In-Flow Theory of Gravity

Reginald T. Cahill

School of Chemistry, Physics and Earth Sciences

Flinders University

GPO Box 2100, Adelaide 5001, Australia

(Reg.Cahill@flinders.edu.au)

arXiv:physics/0407133 July 26, 2004

To be published in *Relativity, Gravitation, Cosmology*

Abstract

The new ‘quantum-foam in-flow’ theory of gravity has explained numerous so-called gravitational anomalies, particularly the ‘dark matter’ effect which is now seen to be a dynamical effect of space itself, and whose strength is determined by the fine structure constant, and not by Newton’s gravitational constant G . Here we show an experimentally significant approximate dynamical effect, namely a vector superposition effect which arises under certain dynamical conditions when we have absolute motion and gravitational in-flows: the velocities for these processes are shown to be approximately vectorially additive under these conditions. This effect plays a key role in interpreting the data from the numerous experiments that detected the absolute linear motion of the earth. The violations of this superposition effect lead to observable effects, such as the generation of turbulence. The flow theory also leads to vorticity effects that the Gravity Probe B gyroscope experiment will soon begin observing. As previously reported General Relativity predicts a smaller vorticity effect (therein called the Lense-Thirring ‘frame-dragging’ effect) than the new theory of gravity.

Contents

1	Introduction	2
2	The New Theory of Gravity	6
3	Geodesics	10
4	The Velocity Superposition Effect	12
5	Conclusions	18
6	References	19

1 Introduction

A new theory of gravity has recently been proposed [1, 2], with an earlier zero-vorticity version given in [3, 4], that differs significantly in its effects from both the Newtonian theory of gravity and from General Relativity, but which agrees with these theories in those very restricted cases where they have been successfully tested, and as well gives a completely different ontology. In the Newtonian theory gravity is explained as a consequence of the gravitational acceleration field, while in General Relativity the explanation is in terms of the metric of a curved ‘spacetime’ manifold construct. In contrast, in the new theory, gravity is a consequence of a restructuring of a substratum of space; at its deepest level space is non-geometrical and is best described as a processing ‘quantum foam’. Matter effectively dissipates this quantum-foam, and so this substratum essentially ‘flows’ towards matter. In the new theory the inhomogeneities and time-dependencies of this ‘flow’ manifest as the phenomenon we know as gravity. This is a non-metric theory of gravity and, except in the special case of the external Schwarzschild metric in General Relativity (GR), the predictions of GR and the new theory are different. This special case arose in the so-called ‘tests’ of General Relativity, such as the precession of the perihelion of planetary elliptical orbits, the gravitational bending of light by the sun, and the gravitational redshift effect.

In *Process Physics* [1, 5] space is essentially an ‘information-theoretic’ system, and is a totally different category of existence from time, which is modelled as a ‘process’, and not as a geometrical entity. Because of this the new ‘process physics’ predicted that absolute motion should have been observed [5]. Absolute motion is motion relative to space itself. A subsequent review of the experimental data showed that indeed absolute motion had been observed at least seven times, including even the original Michelson-Morley experiment of 1887. It was only in 2002 [6] that it was discovered how the Michelson interferometer actually operated; only in the presence of a gas in the light path can this device detect absolute motion¹, and fortunately several interferometer experiments were done in air while

¹In vacuum the geometrical path difference effect that Michelson had originally considered is cancelled exactly by the Fitzgerald-Lorentz contraction effect upon the arms of the interferometer, which is of course how this effect was proposed. However in the presence of a gas this cancellation is incomplete, and some of the early interferometer experiments were done in air or helium, so permitting the dependence on n to be recently confirmed using this older gas-mode interferometer data [6, 7]. So modern vacuum resonator

two others were done in helium gas. This is explained in detail in [7], but it needs to be emphasised that the operation of the Michelson interferometer requires that the so-called ‘special relativistic’ length contraction effect be taken into account. But even then the fringe shift effect is suppressed by the very small factor $n^2 - 1$, compared to the Newtonian physics theory for the interferometer that Michelson had used in the analysis of the indeed small but not ‘null’ fringe shifts of the 1887 experiment; here n is the refractive index of the gas. The recent 2002 theory for the Michelson interferometer enabled a detailed re-analysis of data from five such experiments, and the extracted velocity of absolute motion was found to be completely consistent, and also consistent with absolute motion experiments done using co-axial cables² [7], giving the velocity of some $417 \pm 40\text{km/s}$ in the direction (Right Ascension = 5.2^{hr} , Declination = -67°)³.

The Miller interferometer experiment [8] of 1925/1926 was so comprehensive in its data that not only was the orbital motion of the earth about the sun detected, and used by Miller to calibrate the interferometer⁴, but now in conjunction with the new theory of gravity, which affects Miller’s calibration protocol and so leading to a re-analysis of his data, it was discovered that experimental evidence of the gravitational ‘in-flow’ past the earth towards the sun was present in the data [7].

The new theory of gravity involves two constants, one being Newton’s gravitational constant G , which now is seen to essentially determine the rate at which matter ‘dissipates’ the quantum foam, and a second new dimensionless ‘gravitational constant’, which determines the self-interaction of the quantum foam; this is a significant dynamical effect absent in both the Newtonian theory and General Relativity. Analysis of the Greenland bore hole g anomaly data [2] revealed the numerical value of this constant to be the fine structure constant, $\alpha \approx 1/137$, to within experimental error. Then the new self-interaction dynamics was shown to explain the so-called ‘dark matter’ effect, which has remained a deep mystery in physics since its discovery in the relative motion of galaxies and in spiral galaxy rotations.

In brief summary we now note some of the successes of this new theory of gravity: (i) a dynamical explanation for the equivalence principle, and experimental evidence in support of the Lorentzian explanation for relativistic effects, namely that length contractions, time dilations, mass increases, etc are real physical effects *caused* by absolute motion of, say, rods and clocks, and that both the Galilean and Lorentz transformations describe reality, but must be applied to different representations of the data, and that after proper analysis of the data we discover that the speed of light c is *only* the speed with respect to the local quantum-foam system. As well Process Physics appears to offer an explanation for the so-called ‘dark energy’ effect [1], (ii) an explanation of the bore hole g anomaly data, (iii) a new theory of black holes in which their properties are determined by the fine structure constant, and not by G ; these black holes are manifestly different from the black holes of General Relativity,

interferometers are incapable of detecting absolute motion. However putting gas into the resonators does enable them to detect absolute motion. One such experiment is about to be performed.

²Optical fibres cannot be used, see [1] for discussion.

³This is different from the Cosmic Microwave Background (CMB) anisotropy determined velocity which is, for the solar system, 369 km/s in the direction ($RA = 11.20^{\text{h}}$, $Dec = -7.22^\circ$). These velocities are different because they relate to different effects; the absolute velocity vector refers to absolute motion wrt local space, and is associated with the rotation of the Milky Way, the Milky Way gravitational inflow, and also with the motion of the Milky Way within the local cluster etc, whereas the CMB velocity is wrt the average ‘universal’ spatial structure, at least that spatial section presently ‘visible’.

⁴And so avoiding the use of the incorrect ‘Newtonian theory’ used by Michelson.

and are not formed by collapsing matter as in General Relativity, (iv) an explanation for the mass of the black holes discovered at the centre of several globular clusters, including a detailed predicted effective mass for these which is in agreement with the observational data, (v) an explanation for the orbital velocity anomaly or ‘dark matter’ effect in spiral galaxies, but absent in elliptical galaxies, (vi) an explanation for the formation of spiral galaxies based on primordial black holes, and so explaining why quasars formed so early in the universe, as these black holes are not formed by in-falling matter, (vii) a confirmation of gravitational waves predicted by the new theory and now apparent in data from various detections of absolute motion. These gravitational waves are essentially turbulence in the quantum-foam ‘flow’, and are very different in characteristics and speed from those predicted by General Relativity, but so far undetected. Indeed one strong prediction of the above analyses is that both the Newtonian theory of gravity and General Relativity are falsified. In particular this implies that the General Relativity gravitational waves do not physically exist, (viii) the prediction of novel effects in Cavendish laboratory experiments designed to measure G . Indeed anomalies in the existing data are already indicating the existence of spatial self-interaction effects, and these experiments are predicted to be able to determine the value of α , so here is a firm prediction that a Cavendish experiment can easily check⁵, (ix) the prediction that the Gravity Probe B satellite experiment [9] will detect precessions of the onboard gyroscopes much larger than predicted by General Relativity, and arising from the effects of the large velocity of absolute motion of the earth upon the so-called ‘frame-dragging’. In the new theory the ‘frame-dragging’ is simply a result of vorticity effects caused by, in the main, this absolute motion, with both rotational and translational motion now playing a role. As well the prediction is made that the GP-B experiment will also be capable of detecting, subject to sufficient precession measurement accuracy, the new gravitational wave phenomenon [10], (x) predictions that the new gravity theory requires a re-analysis of stellar dynamics, which may have a bearing on the solar neutrino problem, (xi) the demonstration that the new theory of gravity gives a comprehensive explanation for the success of the Global Positioning System (GPS) [11] that is totally different, at an ontological level, from that of General Relativity, and that this new explanation may enable, through the observation of subtle effects, the GPS constellation to be used to detect the new gravitational wave phenomena, and also to improve the GPS in being used to establish the global time standard, (xii) an explanation for various other not well-known gravitational anomalies such as the Allais, Saxl and Allen, Zhou, and Shnoll effects and other observed effects, and finally (xiii) the speed of gravity is essentially infinite, that is, that a change in position of matter results in an instantaneous change in g at distant locations, as argued for in [12]. This instantaneous effect results from the ongoing non-local collapse of the quantum foam substratum to a classical state. This non-local effect is not to be confused with gravitational wave effects, which propagate essentially as turbulence in the flow.

All of the above analyses and observed effects imply that gravity is a much more complex phenomena than is contained in either the Newtonian or General Relativity theories. It is also becoming clear why the deep failure of these two theories has escaped detection for so long, over and above the long standing scandalous ban in physics on reporting on-going

⁵Even a review of different past Cavendish experiments, taking into account the new theory of gravity in Sect.2, should reveal the α -dependent dynamics, and at the same time remove the longstanding systematic discrepancies that are evident in the data.

experimental evidence of absolute motion and other anomalies. In the case of the Newtonian theory it turns out that the solar system was too special to have revealed the presence of the ‘dark-matter’ effect, and then when General Relativity was being constructed by Hilbert and Einstein, it was forced to agree with the flawed Newtonian theory in the low speed limit. As well in the case of General Relativity all but one of the so-called tests of this theory used the external Schwarzschild metric, and it went unnoticed that this is completely equivalent to Newton’s inverse square law. So in these cases it was still the Newtonian theory that was being tested, together with novel effects associated with the geodesic equation. It was not until the in-flow formalism was recently developed that it was realised that the so-called ‘new gravity dynamics’ of General Relativity (GR) had in fact never been tested, except for the one indirect case of the decay of the binary pulsar orbits, but this effect is also in the new theory⁶. As George Pugh [13] and Leonard Schiff realised long ago [14] the unique dynamical predictions of General Relativity could only be tested in experiments such as the current Gravity Probe B gyroscope precession experiment, and it is predicted [9] that the observed precessions will be very different from the General Relativity predictions.

It is important to understand that the new theory of gravity is totally unconnected to General Relativity, and does not use at all the notion of a spacetime metric; indeed the very concept of spacetime is totally rejected. In only one special case does it turn out that mathematically the new theory may be mapped onto the mathematical formalism of General Relativity⁷, which explains why the latter supposedly had passed certain checks, but that these circumstances are very restricted, and occur *only* for the external Schwarzschild metric, namely external to a spherically symmetric matter distribution. and then only to the extent that we can ignore the small vorticity effects associated with the absolute motion effect, which is by construction not in General Relativity. Overall the new theory of gravity is totally incompatible with the formalism of General Relativity, and has a totally different ontology. This is evident from the above list of phenomena accounted for by the new theory; all of these effects are manifest failures of General Relativity. Indeed it has been an almost pathological state of affairs through C20 physics that rotational motion was absolute, but linear motion was only relative. This can be traced back to the incorrect conclusion made by Michelson and Morley when interpreting their smaller than expected fringe shifts, i.e. based upon Newtonian physics and also based only upon 36 rotations of the interferometer, and despite this error being corrected by Miller in his extensive experiments of 1925/1926, involving 20,000 rotations throughout a year, and that the time-dependence caused by the orbital motion of the earth about the sun was evident in Miller’s data.

Herein we explain a key dynamical effect that is apparent already in observations of absolute motion [7], namely that an approximate velocity superposition effect is applicable. This means, for example, that in the case of the earth with, in order of decreasing magnitude,

⁶It is a remarkable insight into the profession of physics when only one recent astronomical observation is the sole evidence for a theory, but which has attracted so much attention by theoretical physicists, mathematicians, and philosophers.

⁷GR, by construction, has no ‘dark matter’ effect, but this effect is observationally apparent in all situations, except outside of a spherically symmetric matter distribution, but even then causes a shift in the apparent value of G [1, 2]. Hence the new theory of gravity cannot be mapped onto the GR formalism. However if we make this *ad hoc* re-normalisation of G , then in the case of, for example the GPS, the new theory can be mapped onto GR, which explains why GR, fortuitously, was successful in the design and operation of the GPS [11].

(i) a cosmic velocity of the solar system related, it seems, to galactic and local cluster gravitational quantum-foam flows, (ii) an in-flow of space past the earth towards the sun, (iii) the tangential orbital velocity of the earth about the sun, and (iv) a gravitational in-flow into the earth itself, causing its own gravitational effect, that because of special conditions that prevail in the case of the earth that the velocities (i)-(iii) may be added vectorially, but that velocity (iv) may not be added vectorially and whence leads to various already observed ‘gravitational anomalies’. This is of course totally different to what would happen in classical ‘material’ fluid mechanics. There are exceptions to this superposition approximation which come into play under certain conditions. One class of conditions occurs, for example, where the in-flow velocity becomes large due to the presence of the new gravitational attractors or ‘black holes’ that are predicted to occur, and which have already been detected at the centres of globular clusters [2]. Another class of conditions involve vorticity effects, and the Gravity Probe B gyroscope experiment will soon begin observing spin precessions caused by these vorticity effects. As previously reported General Relativity predicts a much smaller vorticity effect (therein called the ‘frame-dragging’ effect) than the new theory of gravity, because it only includes vorticity caused by rotation of the earth.

The significance of the dynamical vector superposition effect is that it explains why the various observations of absolute motion are consistent with the ‘in-flow’ theory of gravity, and indeed why the data from the absolute motion experiment of Miller is capable of revealing the vector component of the in-flow past the earth towards the sun, because the vector sum changes over the yearly orbit of the earth about the sun.

2 The New Theory of Gravity

Here we ‘derive’ the ‘in-flow’ theory of gravity by re-analysing the implications of Kepler’s laws for planetary motion. The new theory involves a ‘classical’ velocity field [1, 5] and the theory exhibits (i) the ‘dark matter’ effect, with strength set by the fine structure constant, (ii) effects of absolute motion of the matter with respect to the substratum, and (iii) vorticity effects also caused by absolute motion of the matter, whether rotational or translational. This flow theory is a classical description of a quantum foam substructure to space [1], and the ‘flow’ describes the relative motion of this quantum foam with, as we now show, gravity arising from inhomogeneities and time variations in that flow. These gravitational effects can be caused by an in-flow into matter, or even produced purely by the self-interaction of space itself, as happens for instance for the new ‘black holes’, which do not contain in-fallen matter.

The Newtonian theory was formulated in terms of a force field, the gravitational acceleration $\mathbf{g}(\mathbf{r}, t)$, and was based on Kepler’s laws for the observed motion of the planets within the solar system. As we shall see Newton’s theory of gravity is not uniquely determined by Kepler’s laws when rewritten in terms of a velocity vector field, and introducing a unique new dynamical term we immediately obtain the ‘dark matter’ effect, as it has been incorrectly termed.

In the Newtonian theory $\mathbf{g}(\mathbf{r}, t)$ is determined by the matter density $\rho(\mathbf{r}, t)$ according to

$$\nabla \cdot \mathbf{g} = -4\pi G\rho. \tag{1}$$

However there is an alternative formulation [1, 2] in terms of a vector field $\mathbf{v}(\mathbf{r}, t)$ determined by

$$\frac{\partial}{\partial t}(\nabla \cdot \mathbf{v}) + \nabla \cdot ((\mathbf{v} \cdot \nabla) \mathbf{v}) = -4\pi G\rho, \quad (2)$$

with \mathbf{g} now given by the Euler ‘fluid’ acceleration

$$\mathbf{g} = \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla) \mathbf{v} = \frac{d\mathbf{v}}{dt}. \quad (3)$$

Trivially this \mathbf{g} also satisfies (1). Hence (2)-(3) are mathematically equivalent to (1). The scalar eqn.(2) can only be used to determine a zero-vorticity flow, $\nabla \times \mathbf{v} = \mathbf{0}$, for then we may write $\mathbf{v}(\mathbf{r}, t) = \nabla u(\mathbf{r}, t)$, and (2) becomes

$$\frac{\partial u}{\partial t} = -\frac{1}{2}(\nabla u)^2 - \Phi, \quad (4)$$

where Φ is the Newtonian gravitational potential determined by

$$\nabla^2 \Phi(\mathbf{r}, t) = 4\pi G\rho(\mathbf{r}, t). \quad (5)$$

It is a remarkable fact that the Newtonian theory of gravity may be exactly recast in terms of this ‘fluid flow’ formalism, and even more so when in Sect.3 it is shown that the Euler fluid acceleration in (3) arises, in the non-relativistic limit, from the usual relativistic proper-time extremisation, which also yields the generalisation of (3) to include the Helmholtz term associated with vorticity, as shown in (24).

Eqn.(4) always has solutions, simply because if $u(\mathbf{r}, t)$ is given at time t , then by integration $u(\mathbf{r}, t)$ at later times is always uniquely determined. However, in general solutions of (4) are necessarily time-dependent. This is because the equation $(\nabla u)^2 = -2\Phi$, required for $\frac{\partial u}{\partial t} = 0$, does not in general have solutions. So the flow formalism of Newtonian gravity is in general necessarily time-dependent, and then it is the sum of the two terms in (3) which together reproduce the Newtonian prediction for \mathbf{g} . Then if according to an observer $\rho(\mathbf{r})$ is time-independent, then in general $u(\mathbf{r}, t)$ and $\mathbf{v}(\mathbf{r}, t)$ will be time-dependent, but $\mathbf{g}(\mathbf{r})$ will be time-independent. The form for \mathbf{g} for another observer in uniform motion relative to this observer is discussed later. Of course that $\mathbf{v}(\mathbf{r}, t)$ is time-dependent is what would be expected of any flow-like process. Which of these two mathematically equivalent formalisms of gravity is physically meaningful is determined by experiment, and numerous experiments have detected the velocity flow, and indeed also the time-dependence of that flow [4, 6, 7]; this time dependent flow is of course the gravitational waves of the new theory. In the restricted theory, above, these waves do not manifest as waves in \mathbf{g} , but once the generalisations below are included, they do so.

Most significantly we shall see that (2)-(3) permit a generalisation that is not possible for (1), and which is a dynamical explanation of the so called ‘dark matter’ effect. Clearly (2) cannot be the complete equation for the flow as it would only be sufficient for a zero-vorticity flow. As well the flow must take account of relativistic effects.

External to a spherical mass M of radius R a static velocity field solution of (2) is

$$\mathbf{v}(\mathbf{r}) = -\sqrt{\frac{2GM}{r}} \hat{\mathbf{r}}, \quad r > R, \quad (6)$$

which gives from (3) the usual inverse square law \mathbf{g} field

$$\mathbf{g}(\mathbf{r}) = -\frac{GM}{r^2}\hat{\mathbf{r}}. \quad r > R. \quad (7)$$

However the flow equation (2) is not uniquely determined by Kepler's laws since

$$\frac{\partial}{\partial t}(\nabla \cdot \mathbf{v}) + \nabla \cdot ((\mathbf{v} \cdot \nabla)\mathbf{v}) + C(\mathbf{v}) = -4\pi G\rho, \quad (8)$$

where

$$C(\mathbf{v}) = \frac{\alpha}{8}((trD)^2 - tr(D^2)), \quad (9)$$

and

$$D_{ij} = \frac{1}{2}\left(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i}\right), \quad (10)$$

also has the same external solution (6), because $C(\mathbf{v}) = 0$ for the flow in (6). So the presence of the $C(\mathbf{v})$ dynamics would not have manifested in the special case of planets in orbit about the massive central sun. Here α is a dimensionless constant - a new gravitational constant, in addition to the usual Newtonian gravitational constant G . However inside a spherical mass we find [2] that $C(\mathbf{v}) \neq 0$, and using the Greenland ice shelf bore hole g anomaly data we find that $\alpha^{-1} = 139 \pm 5$, which gives the fine structure constant $\alpha = e^2\hbar/c \approx 1/137$ to within experimental error⁸. From (3) and (8) we can write

$$\nabla \cdot \mathbf{g} = -4\pi G\rho - 4\pi G\rho_{DM}, \quad (11)$$

where

$$\rho_{DM}(\mathbf{r}, t) = \frac{\alpha}{32\pi G}((trD)^2 - tr(D^2)), \quad (12)$$

which introduces an effective 'matter density' representing the flow dynamics associated with the $C(\mathbf{v})$ term. However the dynamical effect represented by this new term cannot be included in the gravitational acceleration dynamics formalism of (1) because it cannot be expressed in terms of the gravitational field \mathbf{g} . In [2] this dynamical effect is shown to be the 'dark matter' effect.

The interpretation of the vector flow field \mathbf{v} is that it is a manifestation, at the classical level, of a quantum substratum to space; the flow is a rearrangement of that substratum, and not a flow *through* space. However (8) requires a further generalisation to include vorticity, and also the effects of the absolute motion of matter through this substratum. To do this a precise definition of what is meant by the velocity field $\mathbf{v}(\mathbf{r}, t)$ is needed. To be specific and also to define a possible measurement procedure we can choose to use the Cosmic Microwave Background (CMB) frame of reference for that purpose, as this is itself easy to establish. However that does not imply that the CMB frame is the local 'quantum-foam' rest frame. Relative to the CMB frame and using the local absolute motion detection techniques described in [1, 4, 7], or more modern techniques that are under development,

⁸The occurrence of α does not make these flow equations a quantum theory. In QED α plays the role of a probability measure, and so it presumably arises in the present situation in the same manner. This relates to the deeper information-theoretic *process physics* theory in which an intrinsic stochasticity limits the information content [1].

$\mathbf{v}(\mathbf{r}, t)$ may be measured in the neighbourhood of the observer. Then an ‘object’ at location $\mathbf{r}_0(t)$ in the CMB frame has velocity $\mathbf{v}_0(t) = d\mathbf{r}_0(t)/dt$ with respect to that frame, and then

$$\mathbf{v}_R(\mathbf{r}_0(t), t) = \mathbf{v}_0(t) - \mathbf{v}(\mathbf{r}_0(t), t), \quad (13)$$

where $\mathbf{v}_0(t)$ is the velocity of an object, at $\mathbf{r}_0(t)$, relative to the same frame of reference that defines the flow field, and so \mathbf{v}_R is the velocity of that matter relative to the substratum. To take account of the absolute velocity of matter with respect to the local quantum foam and also of vorticity effects the flow equation (8) is generalised to a 2nd-rank tensor equation [1, 2, 9]

$$\begin{aligned} \frac{dD_{ij}}{dt} + \frac{\delta_{ij}}{3} tr(D^2) + \frac{trD}{2} (D_{ij} - \frac{\delta_{ij}}{3} trD) + \frac{\delta_{ij}}{3} \frac{\alpha}{8} ((trD)^2 - tr(D^2)) \\ + (\Omega D - D\Omega)_{ij} = -4\pi G\rho \left(\frac{\delta_{ij}}{3} + \frac{v_R^i v_R^j}{2c^2} + \dots \right), \quad i, j = 1, 2, 3. \end{aligned} \quad (14)$$

$$\nabla \times (\nabla \times \mathbf{v}) = \frac{8\pi G\rho}{c^2} \mathbf{v}_R, \quad (15)$$

$$\Omega_{ij} = \frac{1}{2} \left(\frac{\partial v_i}{\partial x_j} - \frac{\partial v_j}{\partial x_i} \right) = -\frac{1}{2} \epsilon_{ijk} \omega_k = -\frac{1}{2} \epsilon_{ijk} (\nabla \times \mathbf{v})_k, \quad (16)$$

and the vorticity vector field is $\vec{\omega} = \nabla \times \mathbf{v}$. We obtain from (15) the Biot-Savart form for the vorticity field

$$\vec{\omega}(\mathbf{r}, t) = \frac{2G}{c^2} \int d^3r' \frac{\rho(\mathbf{r}', t)}{|\mathbf{r} - \mathbf{r}'|^3} \mathbf{v}_R(\mathbf{r}', t) \times (\mathbf{r} - \mathbf{r}'). \quad (17)$$

Then (14) becomes an integro-differential equation for the velocity field⁹. The form of these equations was determined by requiring that in the non-relativistic limit they reduce to (8), in which case the vorticity must go to zero. The form of the vorticity dynamics in (15) follows from dimensional considerations¹⁰.

As discussed in [9] (17) explains the so-called Lense-Thirring ‘frame - dragging’ effect in terms of this vorticity in the flow field, but makes predictions very different from General Relativity. These conflicting predictions will soon be tested by the Gravity Probe B [13, 14] satellite experiment. However the smaller component of the frame-dragging effect caused by the earth absolute rotation component of \mathbf{v}_R has been determined from the laser-ranged satellites LAGEOS(NASA) and LAGEOS 2(NASA-ASI) [15], and the data implies the indicated coefficient on the RHS of (15) to $\pm 10\%$. However that experiment cannot detect the larger component of the ‘frame-dragging’ or vorticity induced by the absolute linear motion component of the earth’s \mathbf{v}_R as that effect is not cumulative, while the rotation induced component is cumulative. For that reason we must wait for the GP-B data to fully confirm the RHS of (15). Of course in General Relativity the absolute linear motion induced vorticity is absent.

⁹The superscript notation v_R^i is purely for simplicity of layout.

¹⁰In General Relativity the vorticity is only generated by absolute rotation, and not by absolute linear motion. This peculiarity had its origins in the misunderstanding of the significance of the small fringe shifts seen in the Michelson-Morley experiment. This restriction to rotational motion is claimed to be explainable by the Mach principle. In the new theory, herein, motion is relative to the local quantum-foam system, i.e. the local space, whether rotational or linear.

Eqns.(14)-(15) only make sense if $\mathbf{v}_R(\mathbf{r}, t)$ for the matter at location \mathbf{r} is specified. We now consider the special case where the matter is subject only to the effects of motion with respect to the quantum-foam velocity-field inhomogeneities and variations in time, which causes the acceleration which we know as ‘gravity’.

We note that the first serious attempt to construct a ‘flow’ theory of gravity was by Kirkwood [16, 17]. However the above theory, as expressed in (14)-(15), is very different to Kirkwood’s proposal¹¹. We also note that (14) and (15) need to be further generalised to take account of the cosmological-scale effects, namely that the spatial system is compact and growing, as discussed in [1]. The investigation of possible non-flow substratum effects has been considered in [18] who consider an energy-dependent metric theory.

3 Geodesics

Process Physics [1] leads to the Lorentzian interpretation of so called ‘relativistic effects’. This means that the speed of light is only ‘c’ with respect to the quantum-foam system, and that time dilation effects for clocks and length contraction effects for rods are caused by the motion of clocks and rods relative to the quantum foam. So these effects are real dynamical effects caused by motion through the classicalising quantum foam, and are not to be interpreted as non-dynamical spacetime effects as suggested by Minkowski and Einstein.

To arrive at the dynamical description of the various effects of the quantum foam we shall introduce conjectures that essentially lead to a phenomenological description of these effects. In the future we expect to be able to derive this dynamics directly from the Quantum Homotopic Field Theory (QHFT) that describes the quantum foam system [1]. Here we shall conjecture that the path of an object through an inhomogeneous and time-varying quantum-foam is determined, at a classical level, by a variational principle, namely that the travel time is extremised for the physical path $\mathbf{r}_0(t)$, which presumably would arise from the wave nature of the ‘matter’. The travel time is defined by

$$\tau[\mathbf{r}_0] = \int dt \sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}, \quad (18)$$

with \mathbf{v}_R given by (13). So the trajectory will be independent of the mass of the object, corresponding to the equivalence principle. Under a deformation of the trajectory

$$\mathbf{r}_0(t) \rightarrow \mathbf{r}_0(t) + \delta\mathbf{r}_0(t), \quad \text{we have} \quad \mathbf{v}_0(t) \rightarrow \mathbf{v}_0(t) + \frac{d\delta\mathbf{r}_0(t)}{dt},$$

and also that

$$\mathbf{v}(\mathbf{r}_0(t) + \delta\mathbf{r}_0(t), t) = \mathbf{v}(\mathbf{r}_0(t), t) + (\delta\mathbf{r}_0(t) \cdot \nabla) \mathbf{v}(\mathbf{r}_0(t)) + \dots \quad (19)$$

Then

$$\delta\tau = \tau[\mathbf{r}_0 + \delta\mathbf{r}_0] - \tau[\mathbf{r}_0]$$

¹¹Kirkwood constructed, supposedly from ‘first principles’, what turned out to be an exact velocity field representation of Newtonian gravity, and so *ipso facto* missed the ‘dark matter’ generalisation, the absolute motion effect, the relativistic terms on the RHS of (14)-(15), and also the vorticity dynamics.

$$\begin{aligned}
&= - \int dt \frac{1}{c^2} \mathbf{v}_R \cdot \delta \mathbf{v}_R \left(1 - \frac{\mathbf{v}_R^2}{c^2}\right)^{-1/2} + \dots \\
&= \int dt \frac{1}{c^2} \left(\mathbf{v}_R \cdot (\delta \mathbf{r}_0 \cdot \nabla) \mathbf{v} - \mathbf{v}_R \cdot \frac{d(\delta \mathbf{r}_0)}{dt} \right) \left(1 - \frac{\mathbf{v}_R^2}{c^2}\right)^{-1/2} + \dots \\
&= \int dt \frac{1}{c^2} \left(\frac{\mathbf{v}_R \cdot (\delta \mathbf{r}_0 \cdot \nabla) \mathbf{v}}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} + \delta \mathbf{r}_0 \cdot \frac{d}{dt} \frac{\mathbf{v}_R}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} \right) + \dots \\
&= \int dt \frac{1}{c^2} \delta \mathbf{r}_0 \cdot \left(\frac{(\mathbf{v}_R \cdot \nabla) \mathbf{v} + \mathbf{v}_R \times (\nabla \times \mathbf{v})}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} + \frac{d}{dt} \frac{\mathbf{v}_R}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} \right) + \dots \quad (20)
\end{aligned}$$

Hence a trajectory $\mathbf{r}_0(t)$ determined by $\delta \tau = 0$ to $O(\delta \mathbf{r}_0(t)^2)$ satisfies

$$\frac{d}{dt} \frac{\mathbf{v}_R}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} = - \frac{(\mathbf{v}_R \cdot \nabla) \mathbf{v} + \mathbf{v}_R \times (\nabla \times \mathbf{v})}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}}. \quad (21)$$

Let us now write this in a more explicit form. This will also allow the low speed limit to be identified. Substituting $\mathbf{v}_R(t) = \mathbf{v}_0(t) - \mathbf{v}(\mathbf{r}_0(t), t)$ and using

$$\frac{d\mathbf{v}(\mathbf{r}_0(t), t)}{dt} = \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}_0 \cdot \nabla) \mathbf{v}, \quad (22)$$

we obtain

$$\frac{d}{dt} \frac{\mathbf{v}_0}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} = \mathbf{v} \frac{d}{dt} \frac{1}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} + \frac{\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla) \mathbf{v} + (\nabla \times \mathbf{v}) \times \mathbf{v}_R}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}}, \quad (23)$$

and finally

$$\frac{d\mathbf{v}_0}{dt} = - \frac{\mathbf{v}_R}{1 - \frac{\mathbf{v}_R^2}{c^2}} \frac{1}{2} \frac{d}{dt} \left(\frac{\mathbf{v}_R^2}{c^2} \right) + \left(\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v} \cdot \nabla) \mathbf{v} \right) + (\nabla \times \mathbf{v}) \times \mathbf{v}_R. \quad (24)$$

This is a generalisation of the acceleration in (3) to include the vorticity effect, as the last term - also known as the Helmholtz acceleration in fluid flows, and the first term which is the resistance to acceleration caused by the relativistic ‘mass’ increase effect. This term leads to the so-called geodetic effects. The vorticity term causes the GP-B gyroscopes to develop the vorticity induced precession [9], which is simply the rotation of space carrying the gyroscope along with it, compared to more distant space which is not involved in that rotation. The middle term, namely the acceleration in (3), is simply the usual Newtonian gravitational acceleration, but now seen to arise from the inhomogeneity and time-variation of the flow velocity field. As already noted it was this geodesic equation that has been checked in various experiments, but always, except in the case of the binary pulsar slow-down, with the velocity field given by the Newtonian ‘inverse square law’ equivalent form in

(6). As discussed elsewhere [1, 2] this flow is exactly equivalent to the external Schwarzschild metric.

Note that the occurrence of $1/(1 - \mathbf{v}_R^2/c^2)$ in (24) will lead to horizon effects wherever $|\mathbf{v}| = c$: the region where $|\mathbf{v}| < c$ is inaccessible from the region where $|\mathbf{v}| > c$. Also (18) is easily used to determine the clock rate offsets in the GPS satellites, when the in-flow is given by (6).

So the fluid flow dynamics in (14) and (15) and the gravitational dynamics for the matter in (21) now form a closed system. This system of equations is a considerable generalisation from that of Newtonian gravity, and is very different from the curved spacetime metric formalism of General Relativity.

The above may be modified when the ‘object’ is a massless photon, and the corresponding result leads to the gravitational lensing effect. But not only will ordinary matter produce such lensing, but the effective ‘dark matter’ density will also do so, and that is relevant to the recent observation by the weak lensing technique of the so-called ‘dark matter’ networks.

4 The Velocity Superposition Effect

Despite being non-linear (14)-(15) possess an approximate superposition effect, which explains why the existence of absolute motion and as well the presence of the $C(\mathbf{v})$ term appear to have almost escaped attention in the case of gravitational experiments near the earth.

First note that in analysing (14)-(15) we need to recognise two distinct effects: (i) the effect of a change of description of the flow when changing between observers, and (ii) the effects of absolute motion of the matter with respect to the quantum foam substratum. Whether the matter is at rest or in absolute motion with respect to this substratum does have a dynamical effect, and this paper is primarily about understanding this effect. While the Newtonian theory and GR both offer an account of the first effect, and different accounts at that, neither have the second dynamical effect, as this is a unique feature of the new theory of gravity. Let us consider the first effect, as this is somewhat standard. It basically comes down to noting that under a change of observer (14)-(15) transform covariantly under a Galilean transformation. Suppose that according to one observer O the matter density is specified by a form $\rho_O(\mathbf{r}, t)$, and that (14)-(15) has a solution $\mathbf{v}_O(\mathbf{r}, t)$, and then with acceleration $\mathbf{g}_O(\mathbf{r}, t)$ given by (23)¹². Then for another observer O' (and for simplicity we assume that the observers use coordinate axes that have the same orientation, and that at time $t = 0$ they coincide), moving with uniform velocity \mathbf{V} relative to observer O , observer O' describes the matter density with the form $\rho_{O'}(\mathbf{r}, t) = \rho_O(\mathbf{r} + \mathbf{V}t, t)$. Then, as we now show, the corresponding solution to (14)-(15) for O' is *exactly*

$$\mathbf{v}_{O'}(\mathbf{r}, t) = \mathbf{v}_O(\mathbf{r} + \mathbf{V}t, t) - \mathbf{V}. \quad (25)$$

This is easily established by substitution of (25) into (14)-(15), and noting that the LHS leads to a RHS where the density has the different form noted above, but that \mathbf{v}_R is *invariant* under this change of observer, for each observer agrees on the absolute velocity of each piece

¹²Note that here and in the following, except where indicated, the subscripts are O and not 0.

of matter with respect to the local quantum foam. Under the change of observers, from O to O' , (25) gives

$$D_{ij}(\mathbf{r}, t) \rightarrow D_{ij}(\mathbf{r} + \mathbf{V}t, t) \quad \text{and} \quad \Omega_{ij}(\mathbf{r}, t) \rightarrow \Omega_{ij}(\mathbf{r} + \mathbf{V}t, t). \quad (26)$$

Then for the total or Euler fluid derivative in (14) we have for observer O'

$$\begin{aligned} \frac{dD_{ij}(\mathbf{r} + \mathbf{V}t, t)}{dt} &\equiv \frac{\partial D_{ij}(\mathbf{r} + \mathbf{V}t, t)}{\partial t} + (\mathbf{v}_O(\mathbf{r} + \mathbf{V}t, t) - \mathbf{V}) \cdot \nabla D_{ij}(\mathbf{r} + \mathbf{V}t, t), \\ &= \left. \frac{\partial D_{ij}(\mathbf{r} + \mathbf{V}t', t)}{\partial t'} \right|_{t' \rightarrow t} + \left. \frac{\partial D_{ij}(\mathbf{r} + \mathbf{V}t, t'')}{\partial t''} \right|_{t'' \rightarrow t} + \\ &\quad (\mathbf{v}_O(\mathbf{r} + \mathbf{V}t, t) - \mathbf{V}) \cdot \nabla D_{ij}(\mathbf{r} + \mathbf{V}t, t), \\ &= (\mathbf{V} \cdot \nabla) D_{ij}(\mathbf{r} + \mathbf{V}t, t) + \left. \frac{\partial D_{ij}(\mathbf{r} + \mathbf{V}t, t'')}{\partial t''} \right|_{t'' \rightarrow t} + \\ &\quad (\mathbf{v}_O(\mathbf{r} + \mathbf{V}t, t) - \mathbf{V}) \cdot \nabla D_{ij}(\mathbf{r} + \mathbf{V}t, t), \\ &= \left. \frac{\partial D_{ij}(\mathbf{r} + \mathbf{V}t, t'')}{\partial t''} \right|_{t'' \rightarrow t} + \mathbf{v}_O(\mathbf{r} + \mathbf{V}t, t) \cdot \nabla D_{ij}(\mathbf{r} + \mathbf{V}t, t), \\ &= \left. \frac{dD_{ij}(\mathbf{r}, t)}{dt} \right|_{\mathbf{r} \rightarrow \mathbf{r} + \mathbf{V}t} \end{aligned} \quad (27)$$

as there is a key cancellation of two terms in (27). Clearly then all the terms on the LHS of (14)-(15) have the same transformation property. Then, finally, from the form of the LHS, both equations give the density dependent RHS, but which now involves the form $\rho_O(\mathbf{r}, t)|_{\mathbf{r} \rightarrow \mathbf{r} + \mathbf{V}t}$, and this is simply $\rho_{O'}(\mathbf{r}, t)$ given above. If the observers coordinate axes do not have the same orientation then a time-independent orthogonal similarity transformation $D \rightarrow SDS^T$, $\Omega \rightarrow S\Omega S^T$, and $v_R^i \rightarrow \sum_j S_{ij} v_R^j$ arises as well. Hence the description of the flow dynamics for observers in uniform relative motion is Galilean covariant. While this transformation rule for the Euler derivative is not a new result, there are some subtleties in the analysis, as seen above. The subtlety arises because the change of coordinate variables necessarily introduces a time dependence in the observer descriptions, even if the flow is inherently stationary.

Finally, using an analogous argument to that in (27), we see explicitly that the acceleration in (24) is also Galilean covariant under the above change of observer with transformation (25), and indeed each of the three terms is separately covariant, with again the time derivative part of the middle term playing a key role, and then $\mathbf{g}(\mathbf{r}, t) \rightarrow \mathbf{g}(\mathbf{r} + \mathbf{V}t, t)$ (in the case of observer axes with the same orientation). This simply asserts that all observers actually agree on the gravitational acceleration, up to the indicated trivial translation effect caused by the motion of the observer.

We now come to item (ii) above, namely the more subtle but experimentally significant *approximate* velocity superposition effect. This approximate effect relates to the change in the form of the solutions of (14)-(15) when the matter density is in motion, as a whole, with respect to the quantum-foam substratum, as compared to the solutions when the matter is, as a whole, at rest. Already even these descriptions involve a subtlety. Consider the case when a star, say, is 'at rest' with respect to the substratum. Then the flow dynamics in (14)-(15) will lead to a position and time dependent flow solution $\mathbf{v}(\mathbf{r}, t)$. But that flow

leads to a position and time dependent $\mathbf{v}_R(\mathbf{r}, t) = \mathbf{v}_0(\mathbf{r}, t) - \mathbf{v}(\mathbf{r}, t)$ on the RHS of (14)-(15), where $\mathbf{v}_0(\mathbf{r}, t)$ is the velocity of the matter at position \mathbf{r} and time t according to some specific observer's frame of reference¹³. Hence the description of the matter being 'at rest' or 'in motion' relative to the substratum is far from simple. In general, with time-dependent flows, none of the matter will ever be 'at rest' with respect to the substratum, and this description is covariant under a change of observer. In the case of a well isolated star existing in a non-turbulent substratum we could give the terms 'at rest as a whole' or 'moving as whole' a well defined meaning by deciding how the star as a whole, considered as a rigid body, was moving relative to the more distant unperturbed substratum. Despite these complexities the solutions of (14)-(15) have, under certain special conditions, an approximate dynamical velocity superposition effect, and these conditions actually occur for the earth, and have played a key role in observations of absolute motion. To see this effect we need to make some approximations in considering the form of the solutions of (14)-(15). First we note that the vorticity from (15) is small, $\nabla \times \mathbf{v} \approx \mathbf{0}$, as it is a 'relativistic effect'. So for simplicity we shall assume zero vorticity, and also neglect on the RHS the $(\mathbf{v}_R/c)^2$ terms. We may then write $\mathbf{v} = \nabla u$, and then (14) reduces to

$$\frac{\partial u}{\partial t} = -\frac{1}{2}(\nabla u)^2 - \Phi - \Phi_{DM}, \quad (28)$$

where Φ is the Newtonian gravitational potential, as in (5), and Φ_{DM} is an effective 'gravitational potential' that describes the dynamical 'dark matter' effect,

$$\nabla^2 \Phi_{DM}(\mathbf{r}, t) = 4\pi G \rho_{DM}(\mathbf{r}, t), \quad (29)$$

with ρ_{DM} defined in (12), and so $\Phi_{DM}[\mathbf{v}]$ depends functionally on $\nabla u(\mathbf{r}, t)$. Of course Φ , like Φ_{DM} , has the form

$$\Phi(\mathbf{r}, t) = -G \int d^3r' \frac{\rho(\mathbf{r}', t)}{|\mathbf{r} - \mathbf{r}'|}. \quad (30)$$

Eqn.(28) is then an integro-differential equation determining the time evolution of $u(\mathbf{r}, t)$ from any given initial flow state $u(\mathbf{r}, t_0)$. The Φ_{DM} term is an important non-Newtonian dynamical feature of gravity, and leads to, for example, the bore hole g anomaly, the phenomenon of black holes, and the non-Keplerian rotation of spiral galaxies.

Eqn.(28) gives for the time-evolution of the velocity field

$$\mathbf{v}(\mathbf{r}, t) = \mathbf{v}(\mathbf{r}) - \nabla \int_0^t dt' \left(\frac{1}{2} |\mathbf{v}(\mathbf{r}, t')|^2 + \Phi + \Phi_{DM}[\mathbf{v}] \right), \quad (31)$$

where clearly $\mathbf{v}(\mathbf{r})$ is that flow at $t = 0$.

The flow fields have wavelike substructure. To see this suppose that (28) has a time evolution $u_0(\mathbf{r}, t)$ with corresponding velocity field $\mathbf{v}_0(\mathbf{r}, t)$. Then we look for time-dependent perturbative solutions of (28) with $u = u_0 + \bar{u}$. To first order in \bar{u} we then have

$$\frac{\partial \bar{u}(\mathbf{r}, t)}{\partial t} = -\nabla \bar{u}(\mathbf{r}, t) \cdot \nabla u_0(\mathbf{r}, t). \quad (32)$$

¹³Here the subscript is 0 and not an O . $\mathbf{v}_R(\mathbf{r}, t)$ was defined in (13). For matter described by a density distribution it is appropriate to introduce the field $\mathbf{v}_0(\mathbf{r}, t)$.

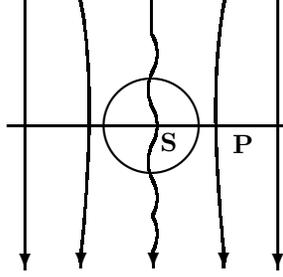


Figure 1: Velocity field \mathbf{v} , with asymptotic flow \mathbf{V} , expected from (31) showing greatest turbulence effects along the direction parallel to \mathbf{V} and through the bulk of the sun S . Flow described by network of observers co-moving with the sun. On and near the plane P , with normal \mathbf{V} , we have $\mathbf{v}_{in} \cdot \mathbf{V} \approx \mathbf{0}$. The direction of absolute motion \mathbf{V} of the solar system is such that P is very accurately the plane of the ecliptic.

This equation has wave solutions of the form $\bar{u}(\mathbf{r}, t) = A \cos(\mathbf{k} \cdot \mathbf{r} - \omega t + \phi)$ where $\omega(\mathbf{k}, \mathbf{r}, t) = \mathbf{v}_0(\mathbf{r}, t) \cdot \mathbf{k}$, for wavelengths and time-scales short compared to the scale of changes in $\mathbf{v}_0(\mathbf{r}, t)$. The local phase velocity of these waves is then $\mathbf{v}_\phi = \mathbf{v}_0$, and the local group velocity is $\mathbf{v}_g = \nabla_k \omega = \mathbf{v}_0$. Then the velocity field is

$$\mathbf{v}(\mathbf{r}, t) = \mathbf{v}_0(\mathbf{r}) - A \mathbf{k} \sin(\mathbf{k} \cdot \mathbf{r} - w(\mathbf{k}, \mathbf{r}, t)t + \phi). \quad (33)$$

In general we have, perturbatively, the superposition of such waves, giving

$$\mathbf{v}(\mathbf{r}, t) = \mathbf{v}_0(\mathbf{r}, t) - \int d^3k A(\mathbf{k}) \mathbf{k} \sin(\mathbf{k} \cdot \mathbf{r} - w(\mathbf{k}, \mathbf{r}, t)t + \phi(\mathbf{k})). \quad (34)$$

This perturbative analysis then suggests waves within waves, and with these waves interacting according to the non-linear terms neglected in (32), that is a turbulent fractal structure, where the equipotential surfaces for u have dimples upon dimples etc. Such wave effects have been detected [2, 4].

Let us first consider the time evolution from (31) for the case of the sun undergoing an absolute linear motion with absolute velocity $-\mathbf{V}$ (with respect to the substratum). This motion would be a consequence of galactic in-flows and the galactic orbital velocity of the solar system. We shall neglect here any time-dependence or inhomogeneity in \mathbf{V} , as we are interested here in the local effects caused by the absolute motion of the sun through space. Let us start (31) with

$$\mathbf{v}(\mathbf{r}) = \mathbf{v}_{in}(\mathbf{r}) + \mathbf{V}, \quad (35)$$

where $\mathbf{v}_{in}(\mathbf{r})$ is a radial in-flow which is an exact time-independent solution of (31) when $\mathbf{V} = \mathbf{0}$, which exists if the matter density of the sun is taken to be spherically symmetric [2]. This $\mathbf{v}(\mathbf{r})$ has the asymptotic limit of $+\mathbf{V}$, appropriate to the above absolute motion of the sun, and where in (35) we are using a network of observers co-moving with the sun. We can easily see how this absolute motion of the sun affects the flow. For a small time interval the change in $\mathbf{v}(\mathbf{r}, t)$ from (31) is

$$\Delta \mathbf{v}(\mathbf{r}, t) = -\nabla(\mathbf{v}_{in}(\mathbf{r}) \cdot \mathbf{V}) \Delta t + \dots \quad (36)$$

This gives a growing change in $\mathbf{v}(\mathbf{r}, t)$, which to a first approximation is a non-uniform displacement of the in-flow. This is smallest in those regions where $\mathbf{v}_{in} \cdot \mathbf{V} \approx \mathbf{0}$, which is near the plane P in Fig.1. The flow is thus expected to be most affected along the direction parallel to \mathbf{V} and through the bulk of the sun S . The change in (36) cannot continue indefinitely, and a better *ansatz* is to begin with a displaced in-flow as in

$$\mathbf{v}(\mathbf{r}) = \mathbf{v}_{in}(\mathbf{r} - \mathbf{a}) + \mathbf{V}, \quad (37)$$

where \mathbf{a} parametrises a uniform displacement to be estimated from the dynamics. This corresponds to the notion that the in-flow is somewhat ‘dragged’ or displaced by the absolute motion¹⁴. Using (37) in (31) gives, exactly,

$$\frac{\partial \mathbf{v}}{\partial t} = \nabla (-\mathbf{v}_{in}(\mathbf{r} - \mathbf{a}) \cdot \mathbf{V} + \Phi(\mathbf{r} - \mathbf{a}) - \Phi(\mathbf{r}) + \Phi_{DM}(\mathbf{r} - \mathbf{a}) - \Phi_{DM}(\mathbf{r})), \quad (38)$$

where we have used the equation satisfied by the displaced in-flow $\mathbf{v}_{in}(\mathbf{r} - \mathbf{a})$. Then the displacement \mathbf{a} is to be determined by demanding that the time and spatial average $\langle \frac{\partial \mathbf{v}}{\partial t} \rangle_{t, \mathbf{r}}$ is minimised. Then the time-dependence is reduced to that only of the necessary turbulence induced by the absolute motion of the matter through space. Starting the time-evolution with the flow in (35) will result in a relaxation to something like the flow in (37) accompanied by excessive turbulence initially. To do better than (37) will require numerical modelling. The approximate flow in (37) has an important property, namely that the so-called ‘dark-matter’ density is unchanged by a non-zero \mathbf{V} , except for the displacement $\rho_{DM}(\mathbf{r}) \rightarrow \rho_{DM}(\mathbf{r} - \mathbf{a})$. As well in the limit $\Phi_{DM} \rightarrow 0$ this flow gives exactly the same \mathbf{g} , up to the translation effect, because of the time-derivative term in (3), as when the sun is not in absolute motion, for the reasons discussed above.

Hence the time-averaged flow is approximately $\mathbf{v}(\mathbf{r}) = \mathbf{v}_{in}(\mathbf{r}) + \mathbf{V}$, where well away from the sun we can ignore any displacement effect, with measure \mathbf{a} . This is even more accurate in the plane P . This is the dynamical superposition effect. Now for the solar system, and thus the sun, the observed direction of \mathbf{V} is such that P is the plane of the ecliptic¹⁵.

For the earth we may in the first instance ignore the mass of the earth, and treat it as a test particle in motion through the above superposed flow determined by the flow into the sun and the absolute linear motion of the sun. Then for observers co-moving with the earth the observed velocity is the vector sum of the cosmic velocity of the solar system, the in-flow of space past the earth into the sun, and the orbital velocity of the earth about the sun (which enters with a minus sign for a co-moving observer). Then, as in Fig.2,

$$\mathbf{v} \approx \mathbf{V} + \mathbf{v}_{in} - \mathbf{v}_{tangent}. \quad (39)$$

This neglects the flow component \mathbf{v}_E caused by the matter of the earth. In the absence of absolute motion of the earth this has a value of 11km/s near the surface, and so is much smaller than the observed speed of absolute motion of the earth. To include at first

¹⁴This is completely different to the old idea by Stokes of ‘entrainment’, wherein the flow is supposed to have no \mathbf{V} component in and near the earth. This outdated idea arose from the erroneous conclusion that the Michelson-Morley 1887 experiment had failed to detect absolute motion.

¹⁵That the direction of absolute motion of the solar system is almost exactly normal to the plane of the ecliptic was discovered by Miller [8]. This is probably not a coincidence as only then is the relativistic acceleration term in (24) a minimum.

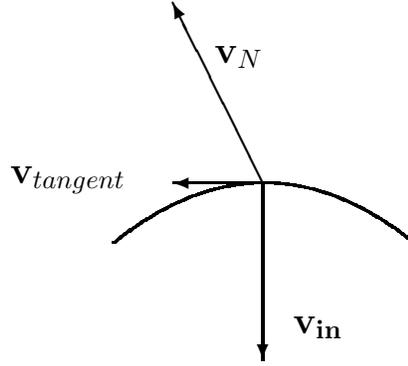


Figure 2: Orbit of earth about the sun with tangential orbital velocity $\mathbf{v}_{tangent}$ and quantum-foam in-flow velocity \mathbf{v}_{in} . Then $\mathbf{v}_N = \mathbf{v}_{tangent} - \mathbf{v}_{in}$ is the velocity of the earth relative to the quantum foam, after subtracting the solar system cosmic velocity \mathbf{V} .

approximation \mathbf{v}_E we can again use the displacement *ansatz*, namely $\mathbf{v}_E(\mathbf{r}) \rightarrow \mathbf{v}_E(\mathbf{r} - \mathbf{b})$, where here \mathbf{b} is the displacement vector for the earth in-flow. Then (39) becomes

$$\mathbf{v}(\mathbf{r}) \approx \mathbf{V} + \mathbf{v}_{in} - \mathbf{v}_{tangent} - \mathbf{v}_E(\mathbf{r} - \mathbf{b}). \quad (40)$$

For the earth this means also that to this degree of approximation the earth's absolute motion does not affect the magnitude of the 'dark-matter' effect within the earth, causing only a displacement. This is important as in [2] the effects of absolute motion of the earth were neglected in analysing the bore-hole g anomaly data, from which the parameter α was found to be equal to the value of the fine structure constant, to within errors. That analysis thus effectively assumed that the displacement effect was sufficiently small.

The velocity superposition effect in (39) was assumed in [7], but it was also assumed implicitly by Miller [8] in the analysis of his data, but there Miller did not include the \mathbf{v}_{in} component as Miller was of course unaware of the flow theory of gravity. For that reason a re-analysis of the Miller scaling argument was required in [7], and only then did the corrected Miller's scaling argument results for the cosmic velocity of the solar system come into agreement with the new velocity from analysis of the Miller data using the refractive index effect.

For circular orbits of the earth about the sun $v_{tangent}$ and v_{in} are given by

$$v_{tangent} = \sqrt{\frac{GM}{R}}, \quad (41)$$

$$v_{in} = \sqrt{\frac{2GM}{R}}, \quad (42)$$

while the net speed v_N of the earth from the vector sum $\mathbf{v}_N = \mathbf{v}_{tangent} - \mathbf{v}_{in}$ is

$$v_N = \sqrt{\frac{3GM}{R}}, \quad (43)$$

where M is the mass of the sun, R is the distance of the earth from the sun, and G is Newton's gravitational constant. The gravitational acceleration of the earth towards the sun arises

from inhomogeneities in the v_{in} flow component. These expressions give $v_{tangent} = 30\text{km/s}$, $v_{in} = 42.4\text{km/s}$ (at the earth distance) and $v_N = 52\text{km/s}$. As discussed in [7] \mathbf{v}_{in} is extractable from Miller's 1925/26 air-mode Michelson interferometer experiment because Miller took data during four separate months of the year, and over a year the vector sum of the three velocities varies. The extraction of v_{in} from the Miller data provided, some 80 years after that most significant experiment, the first experimental confirmation of the new 'in-flow' theory of gravity.

5 Conclusions

The Newtonian theory of gravity and General Relativity have, perhaps somewhat surprisingly, only been tested within very special circumstances; and when they failed in numerous other circumstances the experimental data was either banned from the physics journals or spurious explanations were invoked, the most infamous being of course the 'dark matter' explanation for the large non-Keplerian orbital velocities of the stars and gas clouds in the outer regions of spiral galaxies. The new theory of gravity has, however, not only agreed with the older two theories in those special 'successful' tests, but at the same time given explicit and checkable explanations and quantified predictions for all the other 'anomalies'. In particular we have seen previously that the bore hole g 'anomaly' data is directly linked to the spiral galaxy rotation 'anomaly', and that this spatial self-interaction effect, as it is now understood, may be studied in Cavendish laboratory experiments. However the main result of this paper has been to explain the dynamical effects behind the success of the velocity superposition effect, an effect already assumed in the initial studies of the various absolute motion experiments [6, 7]. A feature of the new theory of gravity is that it also explains the Lense-Thirring 'frame-dragging' effect as a flow vorticity effect. In General Relativity the absolute rotation induced frame-dragging effect has always been understood via the Mach Principle: that motion of a particle is only meaningful when referred to the rest of the matter in the universe. In the new theory of space and gravity we see that this is not so, namely that motion is observable with respect to a substratum structure constituting the local space. The Gravity Probe B satellite gyroscope experiment will thus explore the vorticity effects, together with the geodetic effect, which is unrelated to vorticity. For the vorticity effect the new theory of gravity makes an additional prediction for the precession of the GP-B gyroscopes that is much larger than that produced by the earth rotation-induced only vorticity predicted by General Relativity, which implies the prediction that in its first experimental dynamical test GR will fail badly. This is because in GR the effects of the very large, and already observed, absolute velocity of the earth through the substratum of space is explicitly excluded: *absolute linear motion* is a concept absent from GR by definition, and totally banned from physics. Nevertheless the rotation induced precessions are cumulative, while the linear motion induced precessions are not and have the periodicity of the orbit. This may make the detection of the latter precessions difficult against a background of other effects having the same periodicity. As well one must always emphasize that absolute linear motion is completely consistent with the so-called 'relativistic effects'; these are indeed caused by the dynamical effects of absolute motion.

We are entering an era where the full complexity of the phenomenon of gravitation will be, for the first time, subjected to extensive experimental and observational study, both by

means of astronomical observations, for example the spiral galaxy rotation data and also the globular cluster black hole mass observations, but also laboratory experiments, such as those of the Cavendish kind where the effects associated with different matter shapes gives a handle on the α dependent spatial self-interaction effect, which has actually plagued the accurate determination of G for many decades, and resulted in G being the most poorly measured fundamental constant. And also most significantly we will see the beginning of systematic observations of the new gravitational wave phenomenon predicted by the new theory of gravity, and now apparent in existing experimental data.

As argued elsewhere the occurrence of α as a second fundamental gravitational constant is a major development in our understanding of gravity, and is surely indicating that we are now entering the phenomena of quantum gravity, and that such effects are much larger than previously predicted, that is, they do not manifest at the Planck scales. The argument that the Planck scales set the regime of quantum gravity effects only followed when there was one dimensional gravitational constant, namely G . But of course now we have α being the second but dimensionless gravitational constant.

6 References

References

- [1] R.T. Cahill, *Process Physics: From Information Theory to Quantum Space and Matter*, (Nova Science Pub., NY 2005), in book series *Contemporary Fundamental Physics*, edited by V.V. Dvoeglazov.
- [2] R.T. Cahill, ‘Dark Matter’ as a Quantum Foam In-Flow Effect, in *Progress In Dark Matter Research*, (Nova Science Pub., NY to be pub. 2004), physics/0405147; R.T. Cahill, *Gravitation, the ‘Dark Matter’ Effect and the Fine Structure Constant*, physics/0401047.
- [3] R.T. Cahill, *Gravity as Quantum Foam In-Flow*, *Apeiron* **11**, No.1 (2004)1-52.
- [4] R.T. Cahill, *Quantum Foam, Gravity and Gravitational Waves*, in *Relativity, Gravitation, Cosmology*, pp. 168-226, eds. V. V. Dvoeglazov and A. A. Espinoza Garrido (Nova Science Pub., NY 2004).
- [5] R.T. Cahill, *Process Physics: Inertia, Gravity and the Quantum*, *Gen. Rel. and Grav.* **34**(2002)1637-1656.
- [6] R.T. Cahill and K. Kitto, *Michelson-Morley Experiments Revisited and the Cosmic Background Radiation Preferred Frame*, *Apeiron* **10**, No.2 (2003)104-117.
- [7] R.T. Cahill, *Absolute Motion and Gravitational Effects*, *Apeiron* **11**, No.1 (2004)53-111.
- [8] D.C. Miller, *Rev. Mod. Phys.* **5**(1933)203-242.
- [9] R.T. Cahill, *Novel Gravity Probe B Frame-Dragging Effect*, physics/0406121.

- [10] R.T. Cahill, *Novel Gravity Probe B Gravitational Wave Detection*, physics/0408097.
- [11] R.T. Cahill, *Quantum-Foam In-Flow Theory of Gravity and the Global Positioning System (GPS)*, physics/0309016.
- [12] T. van Flandern, *Phys. Lett.* **A250**(1998)1-11.
- [13] G. Pugh, in *Nonlinear Gravitodynamics: The Lense - Thirring Effect*, eds. R. Ruffini and C. Sigismondi, *World Scientific Publishing Company, 2003*, pp 414-426, (Based on a 1959 report).
- [14] L.I. Schiff, *Phys. Rev. Lett.* **4**(1960)215.
- [15] I. Ciufolini and E. Pavlis, *A Confirmation of the General Relativistic Prediction of the Lense-Thirring Effect*, *Nature*, **431**(2004)958-960.
- [16] R.L. Kirkwood, *The Physical Basis of Gravitation*, *Phys. Rev.* **92**(6)(1953)1557.
- [17] R.L. Kirkwood, *Gravitational Field Equations*, *Phys. Rev.* **95**(4)(1954)1051.
- [18] F. Cardone and R. Mignani, *Intl. J. Mod. Phys.*, **14**, 24 (1999)3799-3811.