'DARK MATTER' AS A QUANTUM FOAM IN-FLOW EFFECT

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Abstract

The galactic 'dark matter' effect is regarded as one of the major problems in fundamental physics. Here it is explained as a self-interaction dynamical effect of space itself, and so is not caused by an unknown form of matter. Because it was based on Kepler's Laws for the motion of the planets in the solar system the Newtonian theory of gravity was too restricted. A reformulation and generalisation of the Newtonian theory of gravity in terms of a velocity in-flow field, representing at a classical level the relative motion of a quantum-foam substructure to space, reveals a key dynamical feature of the phenomenon of gravity, namely the so called 'dark matter' effect, which manifests not only in spiral galaxy rotation curves, but also in the borehole g anomaly, globular and galactic black holes, and in ongoing problems in improving the accuracy with which Newton's gravitational constant G is measured. The new theory of gravity involves an additional new dimensionless gravitational constant, and experimental data reveals this to be the fine structure constant. The new theory correctly predicts the globular cluster black hole masses, and that the 'frame-dragging' effect is caused by vorticity in the in-flow. The relationship of the new theory of gravity to General Relativity which, like Newtonian gravity, does not have the 'dark matter' dynamics, is explained.

Contents

1 Introduction

The 'dark matter' effect first came to notice some 60 years ago from observations of a mass paradox in galaxies and galactic clusters by Oort (1932) [1]; the dynamical estimates of the local matter density differed from that determined from the luminosity. Zwicky (1933) [2] measured the radial velocities of galaxies in the Coma cluster and also found that there was a mass discrepancy, with the required mass, based on the Newtonian theory of gravity, being ten-fold greater than that deduced from the luminosities. This supposedly extra 'mass' was called 'dark matter' because it produced no luminosity. In 1959 Kahn and Woltjer [3] noticed that the relative motion of the Andromeda galaxy and the Milky Way galaxy suggested again a ten-fold mass discrepancy. Then Einasto [4], Sizikov [5] and Freeman [6] realised that the rotation velocities in the outer regions of spiral galaxies were again much greater than expected from the luminosity. So it began to be realised that this 'dark matter' effect was a general property of galaxies and clusters of galaxies. Possible 'matter' interpretations for this effect have been numerous. Here we argue that it is simply a failure of Newtonian gravity, a failure 'inherited' by General Relativity.

Newtonian gravity was based on Kepler's Laws of motion for planets in the solar system, which were abstracted from observational data; the most famous being that for circular orbits the orbital speed of a planet is inversely proportional to the inverse of the square root of the orbit radius; $v_O \propto 1/\sqrt{r}$. This led Newton to introduce the 'universal' inverse square law of gravity, namely that the gravitational force between two masses is inversely proportional to the square of the separation,

$$F = \frac{Gm_1 m_2}{r^2}, \tag{1}$$

which together with the acceleration equation $F = ma$, where here $a = v_O^2/r$ is the centripetal acceleration, explained Kepler's Laws. This led to the introduction of the gravitational acceleration vector field $\mathbf{g}(\mathbf{r})$ as the fundamental dynamical variable for the phenomenon of gravity, and which is determined by (2), which relates $\mathbf{g}(\mathbf{r})$ to the matter density $\rho(\mathbf{r})$. Here G is Newton's gravitational constant, the only constant, until recent discoveries in [7] and herein, that is involved in the phenomenon of gravity. Much later Hilbert and Einstein introduced a more general theory of gravity, but which was constrained to agree with this Newtonian theory in the appropriate limits. However while (2) for $\mathbf{g}$ is uniquely determined by Kepler's Laws, if we rewrite (2) in terms of a velocity field $\mathbf{v}(\mathbf{r}, t)$ then the equation for this vector field is not uniquely determined by Kepler's laws: a new unique 'space' self-interaction dynamical term may be incorporated that does not manifest itself in the planetary motions of the solar system. Numerous major developments then unfold from using this in-flow vector field as the fundamental degree of freedom for the phenomenon of gravity, foremost being that the new term has a strength determined by a dimensionless constant, a second gravitational constant. Experimental data reveals [7] that this constant is, to within experimental error, none other than the fine structure constant $\alpha = e^2\hbar/c \approx 1/137$. Then the most immediate result is the explanation of the so called 'dark matter' effect in spiral galaxies, though various other gravitational anomalies, as they are known, are also now explainable. So it turns out that the 'dark matter' effect is not caused by a new so-far unidentified form of matter, but is an effect associated with a new feature of the phenomenon of gravity; basically gravity is a much richer and more complex phenomenon than currently appreciated. As discussed in more detail elsewhere [8, 9] the velocity $\mathbf{v}(\mathbf{r}, t)$ field is associated with a restructuring and effective relative 'flow' of a quantum foam which *is* space; this is *not* a flow of something through space but is a manifestation of a non-geometrical structure to space, with matter effectively acting as a 'sink' for this quantum foam. These deeper insights, which are based upon an information-theoretic modeling of reality, are discussed at length in [8, 9]; here we mainly concentrate on various experimentally observable and observed gravitational phenomena emerging from this new theory of gravity. As well we show that this theory is in agreement with various phenomena of gravity, such as precessing orbits, gravitational lensing etc, which were believed to have suggested that General Relativity was a viable theory of gravity. We show here, of course, that the new dynamics involving the fine structure constant is not contained in General Relativity. It is asserted here that the failure of both the Newtonian theory and General Relativity to account for the 'dark matter' effect, and other gravitational phenomena discussed herein, represents a fatal flaw for both these theories; and that Newton's 'universal' inverse square law (1) is not at all 'universal'; it is in fact very restricted in its applicability.

Herein the connection of the new theory of gravity to both the Newtonian theory and to General Relativity is analysed, but the most significant results relate to an analysis of the various phenomena that only this new theory now explains, including the borehole g anomaly effect, the difficulties over the last 60 years in ongoing attempts to increase the accuracy with which G could be measured in Cavendish-type experiments, which are all manifestations of the 'dark matter' effect, but which is, as explained here, most evident in the rotation velocity curves of spiral galaxies [7]. This new theory introduces a new form of quantum-foam black hole, the properties of which are determined by the fine structure constant, and which have either 'minimal' of 'non-minimal' forms. The 'minimal' black holes are mandated by the in-flow into matter, and occur in all forms of matter. In the case of the globular clusters the effective mass of the 'minimal' central black holes are computable and found to be in agreement with recent observations. The 'non-minimal' black holes are not caused by matter and appear to be primordial, namely residual effects of the big bang. They have a non-inverse square law acceleration field, and are the cause of both the rapid formation of galaxies and of the non-Keplerian rotation dynamics of spiral galaxies. They have an effective 'dark matter' density that falls off as almost the inverse of the square of the distance form the black hole, as is indeed observed. The presence of the minimal black holes in stars affects their internal central dynamics, but the effect of this upon the solar neutrino flux problem has yet to be studied.

As already discussed elsewhere [10, 11, 12] the quantum-foam 'in-flow' past the earth towards the sun has already been shown to be present in the data from the Miller interferometer experiment of 1925/1926. That experiment and others have also revealed the existence of gravitational waves, essentially a flow turbulence, predicted by the new theory of gravity, but which are very unlike those predicted, but so far unobserved, by General Relativity.

The new theory also has a 'frame-dragging' effect which is being tested by the Gravity Probe B. This effect is caused by vorticity in the in-flow. As well the new theory has quantum-foam vortex filaments linking, in particular, galactic black holes, and these manifest, via weak gravitational lensing, as the recently observed 'dark matter' networks.

To avoid possible confusion it is important to understand that the special relativity effects, such as length contractions, time dilations and mass increases, are very much a part of the new gravity theory, but that it is the Lorentz interpretation of these effects, namely that these effects are real dynamical effects, that is being indicated by experiment and observation to be the correct interpretation, and not the usual non-dynamical spacetime interpretation of these effects. In the same vein it is the failure of the Newtonian theory of gravity that is fatal for General Relativity, and not its connection to these so-called special relativity effects. Finally, while the 'flow equations' are classical equations, the occurrence of α strongly suggests, and as predicted in [8, 9], that this is a manifestation of a quantum-foam substructure to space, and that we have the first experimental evidence of a quantum theory of gravity. As discussed here this leads to relatively easy Cavendish-type laboratory experiments that can explore the α-dependent aspects of gravity - essentially laboratory quantum-gravity experiments. This quantum-foam substructure to space also indicates an explanation of a different effect to that of 'dark matter', namely the so-called 'dark energy' effect, as discussed in [8].

2 Gravity as Inhomogeneous Quantum Foam In-Flow

Here we show that the Newtonian theory of gravity may be exactly re-written as a 'fluid flow' system, as can General Relativity for a class of metrics. This 'fluid' system is interpreted [8, 9] as a classical description of a quantum foam substructure to space, and the 'flow' describes the relative motion of this quantum foam with, as we now show, gravity arising from inhomogeneities in that flow. These inhomogeneities can be caused by an in-flow into matter, or even as inhomogeneities produced purely by the self-interaction of space itself, as happens for instance for the black holes. The Newtonian theory was originally formulated in terms of a force field, the gravitational acceleration $\mathbf{g}(\mathbf{r}, t)$, which is determined by the matter density $\rho(\mathbf{r}, t)$ according to

$$\nabla.\mathbf{g} = -4\pi G\rho. \tag{2}$$

For $\nabla \times \mathbf{g} = 0$ this gravitational acceleration $\mathbf{g}$ may be written as the gradient of the gravitational potential Φ

$$\mathbf{g} = -\nabla\Phi, \tag{3}$$

where the gravitational potential is now determined by

$$\nabla^2\Phi = 4\pi G\rho. \tag{4}$$

Here, as usual, G is the Newtonian gravitational constant. Now as $\rho \geq 0$ we can choose to have $\Phi \leq 0$ everywhere if $\Phi \to 0$ at infinity. So we can introduce $\mathbf{v}^2 = -2\Phi \geq 0$ where $\mathbf{v}$ is some velocity vector field. Here the value of $\mathbf{v}^2$ is specified, but not the direction of $\mathbf{v}$. Then

$$\mathbf{g} = \frac{1}{2}\nabla(\mathbf{v}^2) = (\mathbf{v}.\nabla)\mathbf{v} + \mathbf{v} \times (\nabla \times \mathbf{v}). \tag{5}$$

For zero-vorticity (irrotational) flow $\omega = \nabla \times \mathbf{v} = \mathbf{0}$. Then $\mathbf{g}$ is the usual Euler expression for the acceleration of a fluid element in a time-independent or stationary fluid flow. If the flow is time dependent that expression is expected to become

$$\mathbf{g} = \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}.\nabla)\mathbf{v} = \frac{d\mathbf{v}}{dt}, \tag{6}$$

which has given rise to the total derivative of $\mathbf{v}$ familiar from fluid mechanics. This equation is then to be accompanied by the 'Newtonian equation' for the flow field

$$\frac{1}{2}\nabla^2(\mathbf{v}^2) = -4\pi G\rho, \tag{7}$$

but to be consistent with (6) in the case of a time-dependent matter density this equation should be generalised to

$$\frac{\partial}{\partial t}(\nabla.\mathbf{v}) + \nabla.((\mathbf{v}.\nabla)\mathbf{v}) = -4\pi G\rho. \tag{8}$$

This exhibits the fluid flow form of Newtonian gravity in the case of zero vorticity $\nabla \times \mathbf{v} = 0$. For zero vorticity (8) determines both the magnitude and direction of the velocity field, for in this case we can write $\mathbf{v} = \nabla u$, where $u(\mathbf{r}, t)$ is a scalar velocity potential, and in terms of $u(\mathbf{r}, t)$ (8) specifies uniquely the time evolution of $u(\mathbf{r}, t)$. Note that (6) and (8) are exactly equivalent to (2) for the acceleration field $\mathbf{g}$, and so within the fluid flow formalism (6) and (8) are together equivalent to the Universal Inverse Square Law for $\mathbf{g}$, and so both are equally valid as regards the numerous experimental and observational checks of the acceleration field $\mathbf{g}$ formalism, particularly the Keplerian rotation velocity law. So we appear to have two equivalent formalisms for the same phenomenon. Indeed for a stationary spherically symmetric distribution of matter of total mass M the velocity field outside of the matter

$$\mathbf{v}(\mathbf{r}) = -\sqrt{\frac{2GM}{r}}\hat{\mathbf{r}}, \tag{9}$$

satisfies (8) and reproduces the inverse square law form for $\mathbf{g}$ using (6):

$$\mathbf{g} = -\frac{GM}{r^2}\hat{\mathbf{r}}. \tag{10}$$

So the immediate questions that arise are (i) can the two formalisms be distinguished experimentally, and (ii) can the velocity field formalism be generalised, leading to new gravitational phenomena? To answer these questions we note that

1. The velocity flow field of some 430km/s in the direction (Right Ascension $= 5.2^{hr}$, Declination$= -67^0$) has been detected in several experiments, as described in considerable detail in [8, 11, 12]. The major component of that flow is related to a galactic flow, presumably within the Milky Way and the local galactic cluster, but a smaller component of some 50km/s being the flow past the earth towards the sun has also recently been revealed in the data.

2. In terms of the velocity field formalism (8) a unique term may be added that does not affect observations within the solar system, such as encoded in Kepler's laws, but outside of that special case the new term causes effects which vary from small to extremely large. This term will be shown herein to cause those effects that have been mistakenly called the 'dark matter' effect.

3. Eqn.(8) and its generalisations have time-dependent solutions even when the matter density is not time-dependent. These are a form of flow turbulence, a gravitational wave effect, and they have also been detected, as discussed in [8, 11, 12].

4. The need for a further generalisation of the flow equations will be argued for, and this in particular includes flow vorticity that leads to a non-spacetime explanation of the 'frame-dragging' effect, and of the 'dark matter' network observed using the weak gravitational lensing technique.

First let us consider the arguments that lead to a generalisation of (8). The simplest generalisation is

$$\frac{\partial}{\partial t}(\nabla.\mathbf{v}) + \nabla.((\mathbf{v}.\nabla)\mathbf{v}) + C(\mathbf{v}) = -4\pi G\rho, \tag{11}$$

where

$$C(\mathbf{v}) = \frac{\alpha}{8}((trD)^2 - tr(D^2)), \tag{12}$$

and

$$D_{ij} = \frac{1}{2}(\frac{\partial v_i}{\partial x_j} + \frac{\partial v_j}{\partial x_i}) \tag{13}$$

is the symmetric part of the rate of strain tensor $\partial v_i/\partial x_j$, and α is a dimensionless constant - a new gravitational constant in addition to G. It is possible to check that for the in-flow in (9) $C(\mathbf{v}) = 0$. This is a feature that uniquely determines the form of $C(\mathbf{v})$. This means that effects caused by this new term are not manifest in the planetary motions that formed the basis of Kepler's phenomenological laws and that then lead to Newton's theory of gravity. As we shall see the value of α determined from experimental data is found to be the fine structure constant, to within experimental error. As well, as discussed in Sect.5 and extensively after that, (11) predicts precisely the so-called 'dark matter' effect, with the effective 'dark matter' density defined by

$$\rho_{DM}(\mathbf{r}) = \frac{\alpha}{32\pi G}((trD)^2 - tr(D^2)). \tag{14}$$

So the explanation of the 'dark matter' effect becomes apparent once we use the velocity field formulation of gravity. However (11) must be further generalised to include (i) the velocity of absolute motion of the matter components with respect to the local quantum foam system, and (ii) vorticity effects.

For these further generalisations we need to be precise by what is meant by the velocity field $\mathbf{v}(\mathbf{r}, t)$. 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 [8, 11, 12], or more modern techniques that are under development, $\mathbf{v}(\mathbf{r}, t)$ 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. We then define

$$\mathbf{v}_R(\mathbf{r}_0(t), t) = \mathbf{v}_0(t) - \mathbf{v}(\mathbf{r}_0(t), t), \tag{15}$$

as the velocity of the object relative to the quantum foam at the location of the object. However this absolute velocity of matter $\mathbf{v}_R(t)$ does not appear in (11), and so not only is that equation lacking vorticity effects, it presumably is only an approximation for when the matter has a negligible speed of absolute motion with respect to the local quantum foam. To introduce the vector $\mathbf{v}_R(t)$ we need to construct a 2nd-rank tensor generalisation of (11), and the simplest form is

$$\frac{dD_{ij}}{dt} + \frac{\delta_{ij}}{3}tr(D^2) + \frac{trD}{2}(D_{ij} - \frac{\delta_{ij}}{3}trD)$$
$$+\frac{\delta_{ij}}{3}\frac{\alpha}{8}((trD)^2 - tr(D^2)) = -4\pi G\rho(\frac{\delta_{ij}}{3} + \frac{v^i_R v^j_R}{2c^2} + ..),\ i, j = 1, 2, 3. \tag{16}$$

which uses the total derivative of the D_{ij} tensor in (13). Because of its tensor structure we can now include the direction of absolute motion of the matter density with respect to the quantum foam, with the scale of that given by c, which is the speed of light relative to the quantum foam. The superscript notation for the components of $\mathbf{v}_R(t)$ is for convenience only, and has no other significance. The trace of (16), using the identity

$$(\mathbf{v}.\nabla)(trD) = \frac{1}{2}\nabla^2(\mathbf{v}^2) - tr(D^2) - \frac{1}{2}(\nabla\times\mathbf{v})^2 + \mathbf{v}.\nabla\times(\nabla\times\mathbf{v}), \tag{17}$$

gives, for zero vorticity,

$$\frac{\partial}{\partial t}(\nabla.\mathbf{v}) + \nabla.((\mathbf{v}.\nabla)\mathbf{v}) + C(\mathbf{v}) = -4\pi G\rho(1 + \frac{v_R^2}{2c^2} + ..), \tag{18}$$

which is (11) in the limit $v_R \to 0$. As well the off-diagonal terms, $i \neq j$, are satisfied, to $O(v_R^i v_R^j/c^2)$, for the in-flow velocity field in (9). The conjectured form of the RHS of (18) is, to $O(v_R^2/c^2)$, based on the Lorentz contraction effect for the matter density, with ρ defined as the matter density if the matter were at rest with respect to the quantum foam. Hence, because of (18), (16) is in agreement with Keplerian orbits for the solar system with the velocity field given by (9).

We now consider a further generalisation of (16) to include vorticity effects, namely

$$\begin{aligned}&\frac{dD_{ij}}{dt} + \frac{\delta_{ij}}{3}tr(D^2) + \frac{trD}{2}(D_{ij} - \frac{\delta_{ij}}{3}trD)\\ &+\frac{\delta_{ij}}{3}\frac{\alpha}{8}((trD)^2 - tr(D^2)) - (D\Omega - \Omega D)_{ij}\\ &\qquad = -4\pi G\rho(\frac{\delta_{ij}}{3} + \frac{v_R^i v_R^j}{2c^2} + ..), \quad i,j = 1,2,3,\end{aligned} \tag{19}$$

$$\nabla\times(\nabla\times\mathbf{v}) = \frac{8\pi G\rho}{c^2}\mathbf{v}_R, \tag{20}$$

where

$$\Omega_{ij} = \frac{1}{2}(\frac{\partial v_i}{\partial x_j} - \frac{\partial v_j}{\partial x_i}) = -\frac{1}{2}\epsilon_{ijk}\omega_k = -\frac{1}{2}\epsilon_{ijk}(\nabla\times\mathbf{v})_k \tag{21}$$

is the antisymmetric part of the rate of strain tensor $\partial v_i/\partial x_j$, which is the vorticity vector field ω in tensor form. The term $(D\Omega - \Omega D)_{ij}$ allows the vorticity vector field to be coupled to the symmetric tensor D_{ij} dynamics. Again the vorticity is generated by absolute motion of the matter density with respect to the local quantum foam. Eqns (19) and (20) now permit the time evolution of the velocity field to be determined. Note that the vorticity equation in (20) may be explicitly solved, for it may be written as

$$\nabla(\nabla.\mathbf{v}) - \nabla^2\mathbf{v} = \frac{8\pi G\rho}{c^2}\mathbf{v}_R, \tag{22}$$

which gives, using

$$\nabla^2 \left(\frac{1}{|\mathbf{r}-\mathbf{r}'|} \right) = -4\pi\delta(\mathbf{r}-\mathbf{r}'), \tag{23}$$

$$\mathbf{v}(\mathbf{r},t) = \frac{2G}{c^2} \int d^3r' \frac{\rho(\mathbf{r}',t)}{|\mathbf{r}-\mathbf{r}'|} \mathbf{v}_R(\mathbf{r}',t) - \frac{1}{4\pi} \int d^3r' \frac{1}{|\mathbf{r}-\mathbf{r}'|} \nabla(\nabla.\mathbf{v}(\mathbf{r}',t)). \tag{24}$$

This suggests that $\mathbf{v}(\mathbf{r},t)$ is now determined solely by the vorticity equation. However (24) is misleading, as (20) only specifies the vorticity, and taking the $\nabla\times$ of (24) we obtain

$$\omega(\mathbf{r},t) = \nabla \times \mathbf{v}(\mathbf{r},t) = \frac{2G}{c^2} \int d^3r' \frac{\rho(\mathbf{r}',t)}{|\mathbf{r}-\mathbf{r}'|^3} \mathbf{v}_R(\mathbf{r}',t) \times (\mathbf{r}-\mathbf{r}') + \nabla\psi, \tag{25}$$

which is the Biot-Savart form for the vorticity, with the additional term being the homogeneous solution. Then (19) becomes an integro-differential equation for the velocity field, with ψ determined by self-consistency. As we shall see in Sect.7 (25) explains the so-called 'frame-dragging' effect in terms of this vorticity in the in-flow. Of course (19) and (25) 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 a 'gravitational' acceleration.

We also not that (19) and (20) 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 [8].

3 Geodesics

Process Physics [8] 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 quantum foam, and are not to be interpreted as non-dynamical spacetime effects as suggested by 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 [8]. 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 $\mathbf{r}_0(t)$. The travel time is defined by

$$\tau[\mathbf{r}_0] = \int dt \left(1 - \frac{\mathbf{v}_R^2}{c^2}\right)^{1/2}, \tag{26}$$

with $\mathbf{v}_R$ given by (15). So the trajectory will be independent of the mass of the object, corresponding to the equivalence principle. Under a deformation of the trajectory $\mathbf{r}_0(t) \to \mathbf{r}_0(t) + \delta\mathbf{r}_0(t)$, $\mathbf{v}_0(t) \to \mathbf{v}_0(t) + \dfrac{d\delta\mathbf{r}_0(t)}{dt}$, and we also have

$$\mathbf{v}(\mathbf{r}_0(t) + \delta\mathbf{r}_0(t), t) = \mathbf{v}(\mathbf{r}_0(t), t) + (\delta\mathbf{r}_0(t).\nabla)\mathbf{v}(\mathbf{r}_0(t)) + ... \tag{27}$$

Then

$$\begin{aligned}
\delta\tau &= \tau[\mathbf{r}_0 + \delta\mathbf{r}_0] - \tau[\mathbf{r}_0] \\
&= -\int dt\, \frac{1}{c^2}\mathbf{v}_R.\delta\mathbf{v}_R \left(1 - \frac{\mathbf{v}_R^2}{c^2}\right)^{-1/2} + ... \\
&= \int dt \frac{1}{c^2}\left(\mathbf{v}_R.(\delta\mathbf{r}_0.\nabla)\mathbf{v} - \mathbf{v}_R.\frac{d(\delta\mathbf{r}_0)}{dt}\right)\left(1 - \frac{\mathbf{v}_R^2}{c^2}\right)^{-1/2} + ... \\
&= \int dt \frac{1}{c^2}\left(\frac{\mathbf{v}_R.(\delta\mathbf{r}_0.\nabla)\mathbf{v}}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} + \delta\mathbf{r}_0.\frac{d}{dt}\frac{\mathbf{v}_R}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}}\right) + ... \\
&= \int dt\, \frac{1}{c^2}\delta\mathbf{r}_0 \,.\left(\frac{(\mathbf{v}_R.\nabla)\mathbf{v} + \mathbf{v}_R \times (\nabla \times \mathbf{v})}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} + \frac{d}{dt}\frac{\mathbf{v}_R}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}}\right) + ...
\end{aligned} \tag{28}$$

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

$$\frac{d}{dt}\frac{\mathbf{v}_R}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} = -\frac{(\mathbf{v}_R.\nabla)\mathbf{v} + \mathbf{v}_R \times (\nabla \times \mathbf{v})}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}}. \tag{29}$$

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

$$\frac{d\mathbf{v}(\mathbf{r}_0(t), t)}{dt} = \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}_0.\nabla)\mathbf{v}, \tag{30}$$

we obtain

$$\frac{d}{dt}\frac{\mathbf{v}_0}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} = \mathbf{v}\frac{d}{dt}\frac{1}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}} + \frac{\frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}.\nabla)\mathbf{v} + (\nabla \times \mathbf{v}) \times \mathbf{v}_R}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}}. \tag{31}$$

Then in the low speed limit $v_R \ll c$ we obtain

$$\frac{d\mathbf{v}_0}{dt} = \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}.\nabla)\mathbf{v} + (\nabla \times \mathbf{v}) \times \mathbf{v}_R, \tag{32}$$

which agrees with the fluid flow form suggested in (6) for zero vorticity ($\nabla \times \mathbf{v} = 0$), but introduces a new vorticity effect for the gravitational acceleration. The last term in (32) is relevant to the 'frame-dragging' effect and to the Allais eclipse effect. Hence (31) is a generalisation of (6) to include Lorentzian dynamical effects, for in (31) we can multiply both sides by the rest mass m_0 of the object, and then (31) involves

$$m(\mathbf{v}_R) = \frac{m_0}{\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}}, \tag{33}$$

the so called 'relativistic' mass, and (31) acquires the form

$$\frac{d}{dt}(m(\mathbf{v}_R)\mathbf{v}_0) = \mathbf{F}, \tag{34}$$

where $\mathbf{F}$ is an effective 'force' caused by the inhomogeneities and time-variation of the flow. This is essentially Newton's 2nd Law of Motion in the case of gravity only. That m_0 cancels is the equivalence principle, and which acquires a simple explanation in terms of the flow. Note that the occurrence of $1/\sqrt{1 - \frac{\mathbf{v}_R^2}{c^2}}$ will lead to the precession of the perihelion of elliptical planetary orbits, and also to horizon effects wherever $|\mathbf{v}| = c$: the region where $|\mathbf{v}| < c$ is inaccessible from the region where $|\mathbf{v}| > c$. Also (26) is easily used to determine the clock rate offsets in the GPS satellites, when the in-flow is given by (9). So the fluid flow dynamics in (19) and (25) and the gravitational dynamics for the matter in (29) now form a closed system. This system of equations is a considerable generalisation from that of Newtonian gravity, and would appear to be very different from the curved spacetime formalism of General Relativity. However we now show that General Relativity leads to a very similar system of equations, but with one important exception, namely that the 'dark matter' 'quantum-foam' dynamics is missing from the Hilbert-Einstein theory of gravity.

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, in Sect.**??**.

4 General Relativity and the In-Flow Process

Eqn.(26) involves various absolute quantities such as the absolute velocity of an object relative to the quantum foam and the absolute speed c also relative to the foam, and of course absolute velocities are excluded from the General Relativity (GR) formalism. However (26) gives (with $t = x_0^0$)

$$d\tau^2 = dt^2 - \frac{1}{c^2}(d\mathbf{r}_0(t) - \mathbf{v}(\mathbf{r}_0(t), t)dt)^2 = g_{\mu\nu}(x_0)dx_0^\mu dx_0^\nu, \tag{35}$$

which is the Panlevé-Gullstrand form of the metric $g_{\mu\nu}$ [13, 14] for GR. We emphasize that the absolute velocity $\mathbf{v}_R$ has been measured, and so the foundations of GR as usually stated are invalid. Here we look closely at the GR formalism when the metric has the form in (35), appropriate to a velocity field formulation of gravity. In GR the metric tensor $g_{\mu\nu}(x)$, specifying the geometry of the spacetime construct, is determined by

$$G_{\mu\nu} \equiv R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = \frac{8\pi G}{c^2}T_{\mu\nu}, \tag{36}$$

where $G_{\mu\nu}$ is the Einstein tensor, $T_{\mu\nu}$ is the energy-momentum tensor, $R_{\mu\nu} = R^{\alpha}_{\mu\alpha\nu}$ and $R = g^{\mu\nu}R_{\mu\nu}$ and $g^{\mu\nu}$ is the matrix inverse of $g_{\mu\nu}$. The curvature tensor is

$$R^{\rho}_{\mu\sigma\nu} = \Gamma^{\rho}_{\mu\nu,\sigma} - \Gamma^{\rho}_{\mu\sigma,\nu} + \Gamma^{\rho}_{\alpha\sigma}\Gamma^{\alpha}_{\mu\nu} - \Gamma^{\rho}_{\alpha\nu}\Gamma^{\alpha}_{\mu\sigma}, \tag{37}$$

where $\Gamma^{\alpha}_{\mu\sigma}$ is the affine connection

$$\Gamma^{\alpha}_{\mu\sigma} = \frac{1}{2}g^{\alpha\nu}\left(\frac{\partial g_{\nu\mu}}{\partial x^{\sigma}} + \frac{\partial g_{\nu\sigma}}{\partial x^{\mu}} - \frac{\partial g_{\mu\sigma}}{\partial x^{\nu}}\right). \tag{38}$$

In this formalism the trajectories of test objects are determined by

$$\Gamma^{\lambda}_{\mu\nu}\frac{dx^{\mu}}{d\tau}\frac{dx^{\nu}}{d\tau} + \frac{d^2x^{\lambda}}{d\tau^2} = 0, \tag{39}$$

which is equivalent to extremising the functional

$$\tau[x] = \int dt\sqrt{g^{\mu\nu}\frac{dx^{\mu}}{dt}\frac{dx^{\nu}}{dt}}, \tag{40}$$

with respect to the path $x[t]$. This is precisely equivalent to (26).

In the case of a spherically symmetric mass M the well known solution of (36) outside of that mass is the external-Schwarzschild metric

$$d\tau^2 = (1 - \frac{2GM}{c^2r})dt^2 - \frac{1}{c^2}r^2(d\theta^2 + \sin^2(\theta)d\phi^2) - \frac{dr^2}{c^2(1 - \frac{2GM}{c^2r})}. \tag{41}$$

This solution is the basis of various experimental checks of General Relativity in which the spherically symmetric mass is either the sun or the earth. The four tests are: the gravitational redshift, the bending of light, the precession of the perihelion of Mercury, and the time delay of radar signals.

However the solution (41) is in fact completely equivalent to the in-flow interpretation of Newtonian gravity. Making the change of variables $t \to t'$ and $\mathbf{r} \to \mathbf{r}' = \mathbf{r}$ with

$$t' = t + \frac{2}{c}\sqrt{\frac{2GMr}{c^2}} - \frac{4GM}{c^2}\tanh^{-1}\sqrt{\frac{2GM}{c^2r}}, \tag{42}$$

the Schwarzschild solution (41) takes the form

$$d\tau^2 = dt'^2 - \frac{1}{c^2}(dr' + \sqrt{\frac{2GM}{r'}}dt')^2 - \frac{1}{c^2}r'^2(d\theta'^2 + \sin^2(\theta')d\phi'^2), \tag{43}$$

which is exactly the Panlevé-Gullstrand form of the metric $g_{\mu\nu}$ [13, 14] in (35) with the velocity field given exactly by the Newtonian form in (9). In which case the geodesic equation (39) of test objects in the Schwarzschild metric is equivalent to solving (31). This choice of coordinates corresponds to a particular frame of reference in which the test object has velocity $\mathbf{v}_R = \mathbf{v} - \mathbf{v}_0$ relative to the in-flow field $\mathbf{v}$, as seen in (26). This results shows that the Schwarzschild metric in GR is completely equivalent to Newton's inverse square law: GR in this case is nothing more than Newtonian gravity in disguise. So the so-called 'tests' of GR were nothing more than a test of the geodesic equation, where most simply this is seen to determine the motion of an object relative to an absolute local frame of reference - the quantum foam frame.

It is conventional wisdom for practitioners in General Relativity to regard the choice of coordinates or frame of reference to be entirely arbitrary and having no physical significance: no observations should be possible that can detect and measure $\mathbf{v}_R$. This 'wisdom' is based on two beliefs (i) that all attempts to detect $\mathbf{v}_R$, namely the detection of absolute motion, have failed, and that (ii) the existence of absolute motion is incompatible with the many successes of both the Special Theory of Relativity and of the General Theory of Relativity. Both of these beliefs are demonstrably false, see [8, 10].

The results in this section suggest, just as for Newtonian gravity, that the Einstein General Relativity is nothing more than the dynamical equations for a velocity flow field $\mathbf{v}(\mathbf{r}, t)$. Hence the non-flat spacetime construct appears to be merely an unnecessary artifact of the Einstein measurement protocol, which in turn was motivated by the mis-reporting of the results of the Michelson-Morley experiment [8, 12]. The putative successes of General Relativity should thus be considered as an insight into the fluid flow dynamics of the quantum foam system, rather than any confirmation of the validity of the spacetime formalism, and it was this insight that in [8, 10] led, in part, to the flow dynamics in (19) and (20). Let us therefore substitute the metric

$$d\tau^2 = g_{\mu\nu}dx^\mu dx^\nu = dt^2 - \frac{1}{c^2}(d\mathbf{r}(t) - \mathbf{v}(\mathbf{r}(t), t)dt)^2, \tag{44}$$

into (36) using (38) and (37). This metric involves the arbitrary time-dependent velocity field $\mathbf{v}(\mathbf{r}, t)$. The various components of the Einstein tensor are then found to be

$$\begin{aligned} G_{00} &= \sum_{i,j=1,2,3} v_i \mathcal{G}_{ij} v_j - c^2 \sum_{j=1,2,3} \mathcal{G}_{0j} v_j - c^2 \sum_{i=1,2,3} v_i \mathcal{G}_{i0} + c^2 \mathcal{G}_{00}, \\ G_{i0} &= -\sum_{j=1,2,3} \mathcal{G}_{ij} v_j + c^2 \mathcal{G}_{i0}, \qquad i = 1, 2, 3. \end{aligned}$$

$$G_{ij} = \mathcal{G}_{ij}, \qquad i,j = 1,2,3. \tag{45}$$

where the $\mathcal{G}_{\mu\nu}$ are given by

$$\begin{aligned}
\mathcal{G}_{00} &= \frac{1}{2}((trD)^2 - tr(D^2)), \\
\mathcal{G}_{i0} &= \mathcal{G}_{0i} = -\frac{1}{2}(\nabla \times (\nabla \times \mathbf{v}))_i, \qquad i = 1,2,3. \\
\mathcal{G}_{ij} &= \frac{d}{dt}(D_{ij} - \delta_{ij} trD) + (D_{ij} - \frac{1}{2}\delta_{ij} trD) trD \\
&\quad -\frac{1}{2}\delta_{ij} tr(D^2) - (D\Omega - \Omega D)_{ij}, \qquad i,j = 1,2,3.
\end{aligned} \tag{46}$$

In vacuum, with $T_{\mu\nu} = 0$, we find from (36) and (45) that $G_{\mu\nu} = 0$ implies that $\mathcal{G}_{\mu\nu} = 0$. This system of equations is thus very similar to the in-flow dynamics in (19) and (20), except that in vacuum GR, for the Panlevé-Gullstrand metric, demands that

$$((trD)^2 - tr(D^2)) = 0. \tag{47}$$

This simply corresponds to the fact that GR does not permit the 'dark matter' effect, namely that $\rho_{DM} = 0$, according to (14), and this happens because GR was forced to agree with Newtonian gravity, in the appropriate limits, and that theory also has no such effect. As well in GR the energy-momentum tensor $T_{\mu\nu}$ is not permitted to make any reference to absolute linear motion of the matter; only the relative motion of matter or absolute rotational motion is permitted.

It is very significant to note that the above exposition of the GR formalism for the Panlevé-Gullstrand metric is exact. Then taking the trace of the $\mathcal{G}_{ij}$ equation in (46) we obtain, also exactly, and again using the identity in (17), and in the case of zero vorticity, and outside of matter so that $T_{\mu\nu} = 0$,

$$\frac{\partial}{\partial t}(\nabla.\mathbf{v}) + \nabla.((\mathbf{v}.\nabla)\mathbf{v}) = 0, \tag{48}$$

which is the Newtonian 'velocity field' formulation of Newtonian gravity outside of matter. This should have been expected as it corresponds to the previous observation that 'Newtonian in-flow' velocity field is exactly equivalent to the external Schwarzschild metric. So again we see the extreme paucity of new physics in the GR formalism: all the key tests of GR are now seen to amount to a test *only* of $\delta\tau[x]/\delta x^\mu = 0$, when the in-flow field is given by (46), and which is nothing more than Newtonian gravity. Of course Newtonian gravity was itself merely based upon observations within the solar system, and this was too special to have revealed key aspects of gravity. Hence, despite popular opinion, the GR formalism is based upon very poor evidence. Indeed there is only one definitive confirmation of the GR formalism apart from the misleading external-Schwarzschild metric cases, namely the observed decay of the binary pulsar orbital motion, for only in this case is the metric non-Schwarzschild, and therefore non-Newtonian. However the new theory of gravity also leads to the decay of orbits, and on the grounds of dimensional analysis we would expect comparable predictions. So GR is not unique in predicting orbital decay.

5 The 'Dark Matter' Effect

We now make more explicit the 'dark matter' effect in a form that will be extensively analysed in the following sections. Restricting the flow dynamics to that of a matter system approximately at rest with respect to the quantum foam system, and also neglecting vorticity effects, (19) and (20) simplify to (11), with the key $C(\mathbf{v})$ term defined in (12). In this case we have

$$\mathbf{g} = \frac{\partial \mathbf{v}}{\partial t} + (\mathbf{v}.\nabla)\mathbf{v}, \tag{49}$$

and then (11) gives

$$\nabla.\mathbf{g} = -4\pi G\rho - C(\mathbf{v}) = -4\pi G\rho - 4\pi G\rho_{DM}, \tag{50}$$

after writing the new term as $C(\mathbf{v}) = 4\pi G\rho_{DM}$, with

$$\rho_{DM}(\mathbf{r}) = \frac{\alpha}{32\pi G}((trD)^2 - tr(D^2)). \tag{51}$$

So we see that ρ_{DM} would act as an effective matter density, and it is demonstrated later that it is the consequences of this term which have been misinterpreted as 'dark matter'. Note however ρ_{DM} is not positive definite. We see that this effect is actually the consequence of quantum foam effects within the new proposed dynamics for gravity, and which becomes apparent particularly in spiral galaxies. With $\nabla\times\mathbf{v} = 0$ we can write $\mathbf{v} = \nabla u$, and (11) has the form

$$\nabla^2\left(\frac{\partial u}{\partial t} + \frac{1}{2}(\nabla u)^2\right) = -4\pi G\rho - C(\nabla u(\mathbf{r})). \tag{52}$$

Then noting (23) we see that (52) has the non-linear integro-differential equation form

$$\frac{\partial u(\mathbf{r},t)}{\partial t} = -\frac{1}{2}(\nabla u(\mathbf{r},t))^2 + \frac{1}{4\pi}\int d^3r' \frac{C(\nabla u(\mathbf{r}',t))}{|\mathbf{r}-\mathbf{r}'|} - \Phi(\mathbf{r},t), \tag{53}$$

where Φ is the Newtonian gravitational potential

$$\Phi(\mathbf{r},t) = -G\int d^3r' \frac{\rho(\mathbf{r}',t)}{|\mathbf{r}-\mathbf{r}'|}. \tag{54}$$

Hence the Φ field acts as the source term for the velocity potential. Note that in the Newtonian theory of gravity one has the choice of using either the acceleration field $\mathbf{g}$ or the velocity field $\mathbf{v}$. However in the new theory of gravity this choice is no longer available: the fundamental dynamical degree of freedom is necessarily the $\mathbf{v}$ field, again because of the presence of the $C(\mathbf{v})$ term, which obviously cannot be written in terms of $\mathbf{g}$. If we were to ignore time-dependent behaviour (53) gives

$$|\mathbf{v}(\mathbf{r})|^2 = \frac{2}{4\pi}\int d^3r'\frac{C(\mathbf{v}(\mathbf{r}'))}{|\mathbf{r}-\mathbf{r}'|} - 2\Phi(\mathbf{r}). \tag{55}$$

This non-linear equation clearly cannot be solved for $\mathbf{v}(\mathbf{r})$ as its direction is not specified. This form makes it clear that we should expect gravitational waves, but certainly not waves travelling at the speed of light as c does not appear in (53). Note that (53) involves 'action-at-a-distance' effects, as there is no time-delay in the denominators. This was a feature of Newton's original theory of gravity. Here it is understood to be caused by the underlying quantum-foam dynamics (QHFT) which reaches this classical 'flow' description by ongoing non-local and instantaneous wavefunctional collapses, as discussed in [8]. Contrary to popular belief even GR has this 'action-at-a-distance' feature, as the reformulation of GR via the Panlevé-Gullstrand metric leads also to an equation of the form in (52), but with the $C(\mathbf{v})$ term absent.

6 Gravitational Waves

Newtonian gravity in its original 'force' formalism (2) does not admit any wave phenomena. However the completely equivalent 'in-flow' formalism in (6) and (8) does admit wave phenomena. For the simpler case of zero vorticity, and so permitting the velocity potential description, and also neglecting the 'dark matter' term $C(\mathbf{v})$, then (53) becomes

$$\frac{\partial u}{\partial t} + \frac{1}{2}(\nabla u)^2 = -\Phi. \tag{56}$$

and

$$\mathbf{g} = \frac{\partial \nabla u}{\partial t} + \frac{1}{2}\nabla(\nabla u)^2, \tag{57}$$

which together reproduce (3), even when the flow is time-dependent. Suppose that (56) has for a static matter density a static solution $u_0(\mathbf{r})$ with corresponding velocity field $\mathbf{v}_0(\mathbf{r})$, and with corresponding acceleration $\mathbf{g}_0(\mathbf{r})$. Then we look for time dependent perturbative solutions of (56) with $u = u_0 + \overline{u}$. To first order in $\overline{u}$ we then have

$$\frac{\partial \overline{u}(\mathbf{r},t)}{\partial t} = -\nabla\overline{u}(\mathbf{r},t).\nabla u_0(\mathbf{r}). \tag{58}$$

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

$$\mathbf{v}(\mathbf{r},t) = \mathbf{v}_0(\mathbf{r}) - A\mathbf{k}\sin(\mathbf{k}.\mathbf{r} - w(\mathbf{k},\mathbf{r})t). \tag{59}$$

But are these wave solutions physical, or are they a mere artifact of the in-flow formalism? First note that the wave phenomena do not cause any gravitational effects, because the acceleration field is independent of their existence; whether they are present or not does not affect $\mathbf{g}(\mathbf{r})$. This question is equivalent to asking which of the fields $\mathbf{v}$ or $\mathbf{g}$ is the fundamental quantity. As we have already noted the velocity field $\mathbf{v}$ and these wave phenomena have already been observed [8, 11, 12]. Indeed it is even possible that the effects of such waves are present in the Michelson-Morley 1887 fringe shift data. This would imply that the real gravitational waves have actually been observed for over 100 years.

Within the new theory of gravity these waves do affect the acceleration field $\mathbf{g}$, via the new $C(\mathbf{v})$ term. Numerical studies have shown these wave effects, and that even when the 'dark matter' effect is retained this wave phenomena persists. The observational evidence is that these gravitational waves are apparently present in the Milky Way and local galactic cluster, as revealed in the analysis of data from at least three distinct observations of absolute motion effects [12].

7 Frame-Dragging Effect as an In-Flow Vorticity Effect

Here we briefly note that (25) and the vorticity dependent term in (32) together explain the frame-dragging effect. For the case where $\mathbf{v}_R$ is determined solely by the rotation of the earth (25) gives, outside of the earth, the dipole form

$$\omega(\mathbf{r}) = -4\frac{G}{c^2}\frac{3(\mathbf{r}.\mathbf{L})\mathbf{r} - r^2\mathbf{L}}{2r^5}, \tag{60}$$

where $\mathbf{L}$ is the angular momentum of the earth, and $\mathbf{r}$ is the distance from the centre of the earth. Here spherical symmetry of the earth is assumed. When used in (32) the precession of a spinning sphere, caused by the $\omega \times \mathbf{v}_R$ term where here $\mathbf{v}_R$ is used to describe the rotation of the sphere, may be used to detect the vorticity in (60), as in the Gravity Probe B. This effect has always caused interpretational problems in General Relativity: what system is it that acts as a frame of reference in defining the rotation of the earth? Answers usually invoked some Machian explanation, namely that the rotation was defined relative to the universe as a whole. In the velocity-field formalism for gravity the rotation is relative to the local quantum-foam substratum, and the rotation of the earth is affecting the in-flow component to the extent that it slightly drags the in-flow, that is, it imparts some of its rotation to the in-flow, as described by the above vorticity. In GR the vorticity field ω is known as the 'gravitomagnetic' field, because of its role in the Lorentz-like velocity-dependent acceleration in (32). The expression for the vorticity in (25) would also appear to have contributions from the absolute linear motion of the earth. Such an effect can be tested by the Gravity Probe B as the test-sphere spin-precession would then be different in both magnitude and direction.

8 Gravitational Anomalies

There are numerous gravitational anomalies, including not only the spiral-galaxy 'dark matter' effect and problems in measuring G, but as well there are others that are not well-known in physics, presumably because their existence is incompatible with the Newtonian or the Hilbert-Einstein gravity theories.

The most significant of these anomalies is the Allais effect [15]. In the 1950's Allais conducted a long series of experiments using a paraconical pendulum, which can be thought of as a Foucault pendulum with a short arm length and a special pivot mechanism. These observations revealed pendulum precession effects that are distinct from the Foucault pendulum precession, which mainly manifests in the case of a very long pendulum, associated with the position of the moon, but with a magnitude very much larger than the well-known tidal effects. However in June 1954 Allais reported that the paraconical pendulum exhibited peculiar movements at the time of a solar eclipse. Allais was recording the precession of the pendulum in Paris. Coincidentally during the 30 day observation period a partial solar eclipse occurred at Paris on June 30. During the eclipse the precession of the pendulum was seen to be disturbed. Similar results were obtained during another solar eclipse on October 29 1959. There have been other repeats of the Allais experiment with varying results.

Another anomaly was reported by Saxl and Allen [16] during the solar eclipse of March 7 1970. Significant variations in the period of a torsional pendulum were observed both during the eclipse and as well in the hours just preceding and just following the eclipse. The effects seem to suggest that an "apparent wavelike structure has been observed over the course of many years at our Harvard laboratory", where the wavelike structure is present and reproducible even in the absence of an eclipse.

Again Zhou and Huang [17] report various clock anomalies occurring during the solar eclipses of September 23 1987, March 18 1988 and July 22 1990 observed using atomic clocks.

Another anomaly is of course the 'dark matter' effect associated with the rotational velocities of objects in spiral galaxies. This anomaly led to the introduction of the 'dark matter' concept - but with no such matter ever having been detected, despite extensive searches. This anomaly was compounded when recently observations of the rotational velocities of objects within elliptical galaxies was seen to require very little 'dark matter'. Of course this is a simple consequence of the new theory of gravity, as we shall see.

All these anomalies, including the g anomaly in Sect.9 and others such as the the solar neutrino flux deficiency problem were clearly indicating that gravity has aspects to it that are not within the prevailing theories.

9 The Borehole g Anomaly and the Fine Structure Constant

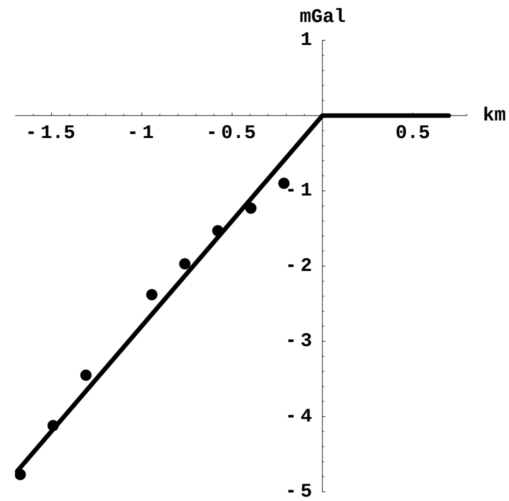

Figure 1: The data shows the gravity residuals for the Greenland Ice Cap [22] Airy measurements of the $g(r)$ profile, defined as $\Delta g(r) = g_{Newton} - g_{observed}$, and measured in mGal (1mGal $= 10^{-3}$ cm/s^2), plotted against depth in km. Using (71) we obtain $\alpha^{-1} = 139 \pm 5$ from fitting the slope of the data, as shown.

Stacey and others [18, 19, 20, 21] have found evidence for non-Newtonian gravitation from gravimetric measurements (Airy experiments) in mines and boreholes. The discovery was that the measured value of g down mines and boreholes became greater than that predicted by the Newtonian theory, given the density profile $\rho(r)$ implied by sampling, and so implying a defect in Newtonian gravity, as shown in Fig.1 for the Greenland Ice shelf borehole measurements. The results were interpreted and analysed using either a value of G different to but larger than that found in laboratory experiments or by assuming a short range Yukawa type force in addition to the Newtonian 'inverse-square law'. Numerous experiments were carried out in which g was measured as a function of depth, and also as a function of height above ground level using towers. The tower experiments [23, 24] did not indicate any non-Newtonian effect, and so implied that the extra Yukawa force explanation was not viable. The combined results appeared to have resulted in confusion and eventually the experimental effect was dismissed as being caused by erroneous density sampling. However the new theory of gravity predicts such an effect, and in particular that the effect should manifest within the earth but not above it, as was in fact observed. The effect predicted is that $d\Delta g(r)/dr$ should be discontinuous at the boundary, as shown in Fig.1. Essentially this effect is caused by the new $C(\mathbf{v})$ term in the in-flow theory of gravity.

When the matter density and the flow are both spherically symmetric and stationary in time (11) becomes, with $v' \equiv dv/dr$,

$$2\frac{vv'}{r} + (v')^2 + vv'' = -4\pi G\rho(r) - 4\pi G\rho_{DM}(r), \tag{61}$$

and then

$$\rho_{DM}(r) = \frac{\alpha}{32\pi G}\left(\frac{v^2}{2r^2} + \frac{vv'}{r}\right). \tag{62}$$

Eqn.(61) may be written in a non-linear integral form

$$v^2(r) = \frac{8\pi G}{r}\int_0^r s^2\left[\rho(s) + \rho_{DM}(s)\right] ds + 8\pi G\int_r^\infty s\left[\rho(s) + \rho_{DM}(s)\right] ds, \tag{63}$$

which follows from evaluating

$$|\mathbf{v}(\mathbf{r})|^2 = 2G\int d^3r'\frac{\rho(r') + \rho_{DM}(r')}{|\mathbf{r} - \mathbf{r}'|}. \tag{64}$$

in the case of spherical symmetry and a radial in-flow.

First consider solutions to (63) in the perturbative regime. Iterating once we find

$$\rho_{DM}(r) = \frac{\alpha}{2r^2}\int_r^\infty s\rho(s)ds + O(\alpha^2), \tag{65}$$

so that in spherical systems the 'dark matter' effect is concentrated near the centre, and we find that the total 'dark matter'

$$M_{DM} \equiv 4\pi\int_0^\infty r^2\rho_{DM}(r)dr = \frac{4\pi\alpha}{2}\int_0^\infty r^2\rho(r)dr + O(\alpha^2) = \frac{\alpha}{2}M + O(\alpha^2), \tag{66}$$

where M is the total amount of (actual) matter. Hence to $O(\alpha)$ $M_{DM}/M = \alpha/2$ independently of the matter density profile.

When the matter density $\rho(r) = 0$ for $r \geq R$, as for the earth, then we also obtain, to $O(\alpha)$, from (6) and (63) Newton's 'inverse square law' for $r > R$

$$g(r) = \begin{cases} -\dfrac{(1+\frac{\alpha}{2})GM}{r^2}, & r > R, \\ -\dfrac{4\pi G}{r^2}\displaystyle\int_0^r s^2\rho(s)ds - \dfrac{2\pi\alpha G}{r^2}\displaystyle\int_0^r\left(\int_s^R s'\rho(s')ds'\right)ds, & r < R, \end{cases} \tag{67}$$

and we see that the effective Newtonian gravitational constant in (67) is $G_N = (1 + \frac{\alpha}{2})G$ which is different to the fundamental gravitational constant G in (11). The result in (67), which is different from that of the Newtonian theory ($\alpha = 0$) has actually been observed in mine/borehole measurements [18, 19, 22] of $g(r)$, though of course there had been no explanation for the effect, and indeed the reality of the effect was eventually doubted. The gravity residual [18, 19, 22] is defined as

$$\begin{aligned} \Delta g(r) &\equiv g(r)_{Newton} - g(r)_{observed} & (68) \\ &= g(r)_{Newton} - g(r). & (69) \end{aligned}$$

The 'Newtonian theory' assumed in the determination of the gravity residuals is, in the present context,

$$g(r)_{Newton} = \begin{cases} -\dfrac{G_N M}{r^2}, & r > R, \\ -\dfrac{4\pi G_N}{r^2}\displaystyle\int_0^r s^2\rho(s)ds, & r < R, \end{cases} \quad (70)$$

with $G_N = (1+\frac{\alpha}{2})G$. Then $\Delta g(r)$ is found to be, to 1st order in α and in $R-r$, i.e. near the surface,

$$\Delta g(r) = \begin{cases} 0, & r > R, \\ -2\pi\alpha G_N \rho(R)(R-r), & r < R. \end{cases} \quad (71)$$

which is the form actually observed [18, 19, 22]. So outside of the spherical earth the Newtonian theory and the in-flow theory are indistinguishable, as indicated by the horizontal line, for $r > R$, in Fig.1. However inside the earth the two theories give a different dependence on r, due to the 'dark matter' effect within the earth.

Gravity residuals from a borehole into the Greenland Ice Cap were determined down to a depth of 1.5km [22]. The ice had a density of $\rho(R) = 930$ kg/m^3, and from (71), using $G_N = 6.6742\times10^{-11}$ m^{3}s^{-2}kg^{-1}, we obtain from a linear fit to the slope of the data points in Fig.1 that $\alpha^{-1} = 139 \pm 5$, which equals the value of the fine structure constant $\alpha^{-1} = 137.036$ to within the errors, and for this reason we identify the α constant in (11) as being the fine structure constant.

The so called fine structure constant α was introduced into physics by Sommerfeld in 1916. Sommerfeld extended the Bohr theory of atoms to include elliptical orbits and the relativistic dependence of mass on speed. The result for a typical energy difference is

$$E_{nk} = -\frac{mc^2\alpha^2 k}{2n^2}\left(1 + \frac{\alpha^2}{n^2}\left(\frac{n}{k} - \frac{3}{4}\right)\right). \quad (72)$$

We see that the leading term contains α^2, as well as the second term which introduces another α^2. It is because of its presence in this second order term that α is called the fine structure constant, though that is really a misnomer, for α determines also the Bohr energies, as is seen once we compare the atomic energy levels with the rest mass energy of the electron, as in (72). The occurence of α in the self-interaction dynamics of space implies that the stochastic processing in the information-theoretic *process physics*, see [8], involves a probability measure that not only manifests in this spatial dynamics but also manifests in Quantum Electrodynamics, where there α is a measure of the probablity for a charged particle to emit or absorb a photon. Clearly we are seeing evidence of a deep unification of fundamental physics.

10 Measurements of G and the Fine Structure Constant

As already noted Newton's Inverse Square Law of Gravitation may only be strictly valid in special cases. The theory that gravitational effects arise from inhomogeneities in the quantum foam flow implies that there is no 'universal law of gravitation' because the inhomogeneities are determined by non-linear 'fluid equations' and the solutions have no form which could be described by a 'universal law'. Fundamentally there is no generic fluid flow behaviour. The Inverse Square Law is then only an approximation, with large deviations seen in the case of spiral galaxies. Nevertheless Newton's gravitational constant G will have a definite value as it quantifies the effective rate at which matter dissipates the information content of space.

From these considerations it follows that the measurement of the value of G will be difficult as the measurement of the forces between two of more objects, which is the usual method of measuring G, will depend on the geometry of the spatial positioning of these objects in a way not previously accounted for because the Newtonian Inverse Square Law has always been assumed, or in some case a specified change in the form of the law has been used. But in all cases a 'law' has been assumed, and this may have been the flaw in the analysis of data from such experiments. This implies that the value of G from such experiments will show some variability as a systematic effect has been neglected in analysing the experimental data. So experimental measurements of G should show an unexpected contextuality. As well the influence of surrounding matter has also not been properly accounted for. Of course any effects of turbulence in the inhomogeneities of the flow has presumably also never even been contemplated. The first measurement of G was in 1798 by Cavendish using a torsional balance. As the precision of experiments increased over the years and a variety of techniques used the disparity between the values of G has actually increased [49]. Fig.2 shows the results from precision measurements of G over the last 60 years. As can be seen one indication of the contextuality is that measurements of G produce values that differ by nearly 40 times their individual error estimates. In 1998 CODATA increased the uncertainty in G, shown by the dotted line in 2, from 0.013% to 0.15%.

Note that the relative spread $\Delta G_N/G_N \approx O(\alpha)$, as we would now expect. Essentially the different Cavendish-type laboratory experiments used different matter geometries and, as we have seen, the geometry of the masses has an effect on the inflow, and so on the measured force between the masses. Only for the borehole-type experiments do we have a complete analytic analysis, in Sect.9, and an ocean measurement is of that type, and experiment [25] gives a $G_N = (6.677 \pm 0.013) \times 10^{-11}$

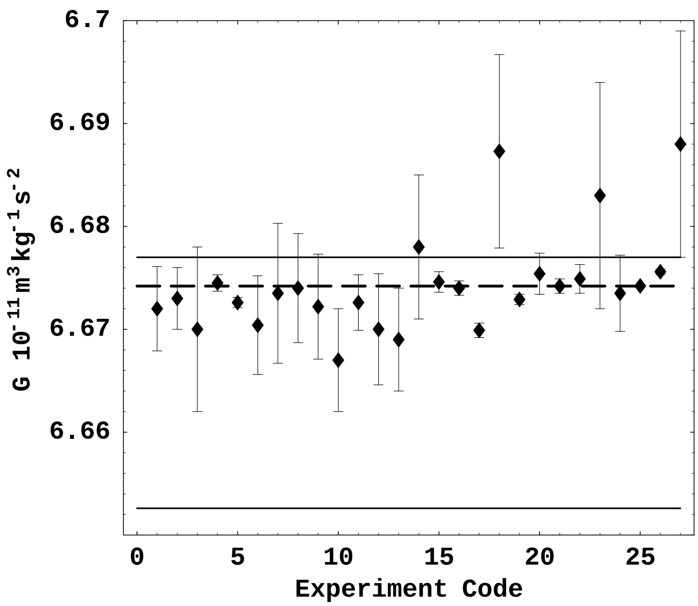

Figure 2: Results of precision measurements of G published in the last sixty years in which the Newtonian theory was used to analyse the data. These results show the presence of a systematic effect, not in the Newtonian theory, of fractional size $\Delta G/G \approx \alpha/4$. The upper horizontal line shows the value of G from ocean Airy measurements [25], while the dotted line shows the current CODATA G value. The lower horizontal line shows the value of G after removing the 'dark matter' effects from the [25] G value.
Experiment Codes: 1: Gaithersburg 1942 [26], **2:** Magny-les-Hameaux 1971 [27], **3:** Budapest 1974 [28], **4;** Moscow 1979 [29], **5:** Gaithersburg 1982 [30], **6-19:** Fribourg Oct 84, Nov 84, Dec 84, Feb 85 [31], **10:** Braunschweig 1987 [32], **11:** Dye 3 Greenland 1995 [33], **12:** Gigerwald Lake 1994 [34], **13-14:** Gigerwald lake19 95 112m, 88m [35], **15:** Lower Hutt 1995 MSL [36], **16:** Los Alamos 1997 [37], **17:** Wuhan 1998 [38], **18:** Boulder JILA 1998 [39], **19:** Moscow 1998 [40], **20:** Zurich 1998 [41], **21:** Lower Hutt MSL 1999 [42], **22:** Zurich 1999 [43], **23:** Sevres 1999 [44], **24:** Wuppertal 1999 [45], **25:** Seattle 2000 [46], **26:** Sevres 2001 [47], **27:** Lake Brasimone 2001 [48].

$m^2s^{-2}kg^{-1}$, shown by the upper horizontal line in Fig.2. From that value we may extract the value of the 'fundamental gravitational constant' G by removing the 'dark matter' effect: $G \approx (1 - \frac{\alpha}{2})G_N = (6.6526 \pm 0.013) \times 10^{-11}$ $m^2s^{-2}kg^{-1}$, shown by the lower horizontal line in Fig.2, compared to the current CODATA value of $G_N = (6.6742 \pm 0.001) \times 10^{-11}$ $m^2s^{-2}kg^{-1}$, which is contaminated with 'dark matter' effects. Then in the various experiments, without explicitly computing the 'dark matter' effect, one will find an 'effective' value of $G_N > G$ that depends on the geometry of the masses. A re-analysis of the data in Fig.2 using the in-flow theory is predicted to resolve these apparent discrepancies. Examples of how the quantum-foam fluid-flow theory of gravity alters the analysis of data from Cavendish-type experiments are given in Sect.20, and in general the 'dark matter' effects are of order α.

11 Gravitational Attractors - New Black Holes

Here we consider a new phenomena which is not in either the Newtonian or Einsteinian theories of gravity, namely the existence of gravitational attractors. Such an attractor may exist by itself or it may be accompanied by matter, as in the case of planets, stars, globular clusters and galaxies, both elliptical and spiral. As we have seen in Sect.9 the existence of such an attractor at the centre of the earth is suggested by the borehole g anomaly data. Here we develop the general theory of these attractors. Indeed they are apparently a common occurrence. Up to now the effects of these 'attractors' in globular clusters, quasistellar objects (QSO) and galaxies have been interpreted by astronomers as general relativity 'black holes', but only by default as no other phenomenon was until now known which could account for the strong gravitational effects observed at the centres of these systems. These attractors are self-sustaining quantum foam in-flows, and their behaviour is determined solely by the fine structure constant: they are quantum foam in-flow singularities where the quantum-foam is destroyed, together with any matter that happnes to in-fall. So to that extent they are classical manifestations of quantum gravity. These attractors have an event horizon where the in-flow speed reaches the speed of light, and within this horizon the speed increases without limit to an infinite speed at a singular point. In-falling matter can produce radiation from the heating effects associated with this in-fall.

However the existence of these in-flow singularities does not require that they be formed by the collapse of matter, and they need not have matter at their centres, so in many respects they differ from the 'black holes' of general relativity. They also differ from these 'black holes' in that their gravitational acceleration $g(r)$ is not given by Newton's inverse square law. It is suggested here that along with matter and radiation, that they formed the third component of the universe, apart from space itself. And that they played a key role in the formation of certain gravitationally collapsed systems, such as spiral galaxies, and that the long range nature of their acceleration field $g(r)$ explains the apparent relatively rapid formation of such structures in the early universe.

Here we first consider the special case of a one-parameter class of matter-free spherical attractors, and then the case when the attractor is associated with matter. In this case the attractor may be minimal or non-minimal, with the distinction determined by whether or not the attractor produces a long-range acceleration field, as for the non-minimal attractors. We also consider a class of non-spherical attractors, but the non-sphericity produce only short range effects. For the case of spherical attractors we determine the size of the event horizon. For globular clusters we can then predict the minimum mass of the central attractor and compare that with the total mass of the cluster. This ratio is shown to be equal to $\alpha/2$, and this prediction is in agreement with the observations of the M15 and G1 globular clusters. Hence the globular clusters supply a striking confirmation of the new theory of gravity and its attractors. In Sect.20 we show that these attractors may be experimentally studied in Cavendish-style laboratory gravitational experiments, and so provide the opportunity for the first laboratory quantum gravity experiments and indeed laboratory black hole experiments.

There will be at least a minimal attractor within the sun which can also be detected by analysing the neutrino flux and its energy spectrum, as these attractors produce central gravitational forces very different from the Newtonian theory, which is an essential input into current stellar dynamics.

12 Spherical Gravitational Attractors

Here we reveal the one-parameter class of spherical attractors in the absence of matter. For a spherically symmetric in-flow $v(r,t)$ the basic in-flow equation (11) has the form

$$\frac{\partial v'}{\partial t} + vv'' + \frac{vv'}{r} + (v')^2 + \frac{\alpha}{2}\left(\frac{v^2}{2r^2} + \frac{vv'}{r}\right) = 0, \tag{73}$$

where $v' = \partial v(r)/\partial r$. For a stationary flow this equation becomes linear in $f(r)$ where $v(r) = \sqrt{f(r)}$

$$\frac{f''}{2} + \frac{f'}{r} + \frac{\alpha}{2}(\frac{f}{2r^2} + \frac{f'}{2r}) = 0. \tag{74}$$

The general solution of this homogeneous equation is

$$f(r) = \frac{K}{r} + \frac{\beta}{r^{\alpha/2}}, \tag{75}$$

where K and β are arbitrary constants. The effective 'dark matter' density (62) is then

$$\rho_{DM}(r) = \frac{\alpha\beta}{16\pi G}(1 - \frac{\alpha}{2})\frac{1}{r^{2+\alpha/2}}, \tag{76}$$

which essentially has the $1/r^2$ dependence, as seen in spiral galaxies and discussed later. Note that the K term does not contribute to ρ_{DM}. However the K term is not a solution of (11) for a stationary flow. The reason for this is somewhat subtle. By direct computation we would appear to obtain that

$$\nabla^2 \frac{1}{|\mathbf{r}|} = \frac{1}{2}\frac{d^2}{dr^2}\frac{1}{r} + \frac{1}{r}\frac{d}{dr}\frac{1}{r} = 0, \tag{77}$$

which is used in finding the K term part of (75). But in fact the correct result is

$$\nabla^2 \frac{1}{|\mathbf{r}|} = -4\pi\delta^{(3)}(\mathbf{r}). \tag{78}$$

This is confirmed by applying the divergence theorem

$$\int dV \nabla.\mathbf{w} = \int d\mathbf{A}.\mathbf{w}, \tag{79}$$

with $\mathbf{w} = \nabla(1/|\mathbf{r}|)$ for a spherical region. The RHS of (79) gives -4π independent of the radius of the sphere. So the LHS must have a delta-function distribution at $\mathbf{r} = \mathbf{0}$, as in (78). Hence the K term should not be present in (75). Essentially for this term to appear the RHS of (11) would have to have a $-4\pi\delta^{(3)}(\mathbf{r})$ term corresponding to a point mass. However by definition all of the matter density is included in $\rho(\mathbf{r})$, and in the present case there is no matter present at all. However for the β term the result is different. By direct computation we find that

$$\nabla^2 \frac{1}{|\mathbf{r}|^\alpha} = -\frac{\alpha(1-\alpha)}{r^{2+2\alpha}}. \tag{80}$$

Using the divergence theorem again but now with $\mathbf{w} = \nabla(1/|\mathbf{r}|^\alpha)$ we find that (79) is satisfied, and so no delta-function distribution is needed on the RHS of (80). Hence the correct general solution of (74) is

$$f(r) = \frac{\beta}{r^{\alpha/2}}, \tag{81}$$

which defines a one-parameter class of spherically symmetric attractors. The gravitational acceleration produced by this in-flow is

$$g(r) = \frac{1}{2}\frac{df(r)}{dr} = -\frac{\alpha\beta}{4r^{1+\alpha/2}}, \tag{82}$$

which decreases slowly with distance, compared to Newton's inverse square law. Because these attractors can be independent of matter they would have arisen in the early universe during the formation of space itself. Once matter had cooled to the recombination temperature of about 3000^oK, these attractors would have played a key role in the formation of the first stars and the galaxies. This attractor has a spatial in-flow with a speed singularity at $r = 0$. There is a spherical event horizon, where $v = c$, at $r_H = (\frac{\beta}{c^2})^{2/\alpha}$. Hence the attractor acts as a 'black hole', but very much unlike the 'black hole' in general relativity. The universe would have had these attractors as primordial black holes from the very beginning.

13 Minimal Attractor for a Uniform Density Sphere

Now consider the gravitational attractors that are formed by the presence of matter. Here the quantum foam in-flow associated with the matter appears to trigger a non-Newtonian in-flow at the centre of the matter distribution. Now for a spherically symmetric matter density and a spherically symmetric in-flow $v(r,t)$ the basic in-flow equation (11) has the form

$$\frac{\partial v'}{\partial t} + vv'' + \frac{vv'}{r} + (v')^2 + \frac{\alpha}{2}\left(\frac{v^2}{2r^2} + \frac{vv'}{r}\right) = -4\pi G\rho(r), \tag{83}$$

Again for a stationary in-flow this equation becomes linear in $f(r)$ where $v(r) = \sqrt{f(r)}$

$$\frac{f''}{2} + \frac{f'}{r} + \frac{\alpha}{2}(\frac{f}{2r^2} + \frac{f'}{2r}) = -4\pi G\rho(r). \tag{84}$$

Define the particular 'matter dependent' solution of this inhomogeneous equation to be $f_m(r)$. Then the general solution of (73) is the sum of this particular solution and the solutions of the homogeneous equation,

$$f(r) = \frac{\beta}{r^{\alpha/2}} + f_m(r), \tag{85}$$

where β is again an arbitrary constant. The effective 'dark matter' density (62) is now

$$\rho_{DM}(r) = \frac{\alpha\beta}{16\pi G}(1 - \frac{\alpha}{2})\frac{1}{r^{2+\alpha/2}} + \frac{\alpha}{2}(\frac{f_m}{2r^2} + \frac{f'_m}{2r}). \tag{86}$$

Let us now consider the solution of (84) for a piece-wise constant matter density, in particular for a sphere of radius R of uniform density ρ:

$$\rho(r) = \rho, \quad 0 < r < R; \quad \rho(r) = 0, \quad r > R. \tag{87}$$

The solution of (84) is then found to be, in each region,

$$f(r) = \begin{cases} \dfrac{\beta}{r^{\alpha/2}} - \dfrac{16\pi\rho G r^2}{3(4+\alpha)}, & 0 < r < R, \\ \dfrac{K}{r} + \dfrac{\overline{\beta}}{r^{\alpha/2}}, & r > R, \end{cases} \tag{88}$$

where in general β and $\overline{\beta}$ have different values. As well the K term is permitted in the external region. Indeed for a non-stepwise density the K term would arise as the asymptotic or the 'matter dependent' solution $f_m(r)$. The complete solution is obtained by ensuring that $f(r)$ and $f'(r)$ are continuous at $r = R$, which is required of the 2nd order differential equation. Let us first consider the critical case where the gravitational attractor does not extend beyond the sphere, i.e. $\overline{\beta} = 0$. This shall result in what is defined here to be a 'minimal attractor'. Then we find that

$$\beta = \frac{16\pi\rho G R^{2+\alpha/2}}{(1-\alpha/2)(4+\alpha)}, \tag{89}$$

$$K = 16\pi\rho G R^3 \frac{2+\alpha/2}{3(1-\alpha/2)(4+\alpha)} = 2(1+\frac{\alpha}{2}+O(\alpha^2)\ )MG, \tag{90}$$

where M is the total matter content of the sphere. Then for the 'dark matter' density we obtain

$$\rho_{DM}(r) = \begin{cases} \dfrac{\alpha\beta}{16\pi G}(1-\dfrac{\alpha}{2})\dfrac{1}{r^{2+\alpha/2}} - \dfrac{\alpha\rho}{4+\alpha} = \dfrac{\alpha\rho}{4}\left(\left(\dfrac{R}{r}\right)^{2+\alpha/2} - 1\right), & 0 < r < R, \\ 0, \quad r > R. \end{cases} \tag{91}$$

which agrees with (65), to $O(\alpha)$, for a uniform matter density.

Eqn.(90) gives the external gravitational acceleration

$$g(r) = -\frac{(1+\frac{\alpha}{2}+O(\alpha^2)\ )MG}{r^2}, \quad r > R, \tag{92}$$

in agreement with (67). So for this case the system would produce Keplerian orbits for small test objects in orbit about this sphere. So the perturbative analysis in Sect.9 gave rise to a minimal attractor. For such a uniform density sphere the in-flow speed $v(r)$, matter density $\rho(r)$ and 'dark matter' density $\rho_{DM}(r)$, and the acceleration $-g(r)$ are plotted in the left column of Fig.3, including the special case $\alpha = 0$ which gives the Newtonian gravity results. Shown in the right hand column of Fig.3 are the corresponding results for a spherical shell with the same total mass M, as the sphere. In general the new theory predicts a gravitational attractor at the centre of all matter distributions. For the case of a spherical system the effective mass of the attractor is $M_{DM} = \alpha M/2$, as measured by the external gravitational acceleration in (92). Note that for the minimal attractor the in-flow is uniquely determined by the matter density, apart of course from time-dependent behaviour. The minimal attractor is caused by the matter induced in-flow, and as such is not the result of a primordial attractor.

14 Non-Minimal Attractor for a Uniform Density Sphere

Now consider the more general case of a non-minimal attractor for which the non-Newtonian acceleration field (82) extends beyond the matter density. These attractors have a primordial origin, and would have played a critical role in the formation of the matter system from a gas cloud. In the non-minimal case with $\overline{\beta} > 0$, we

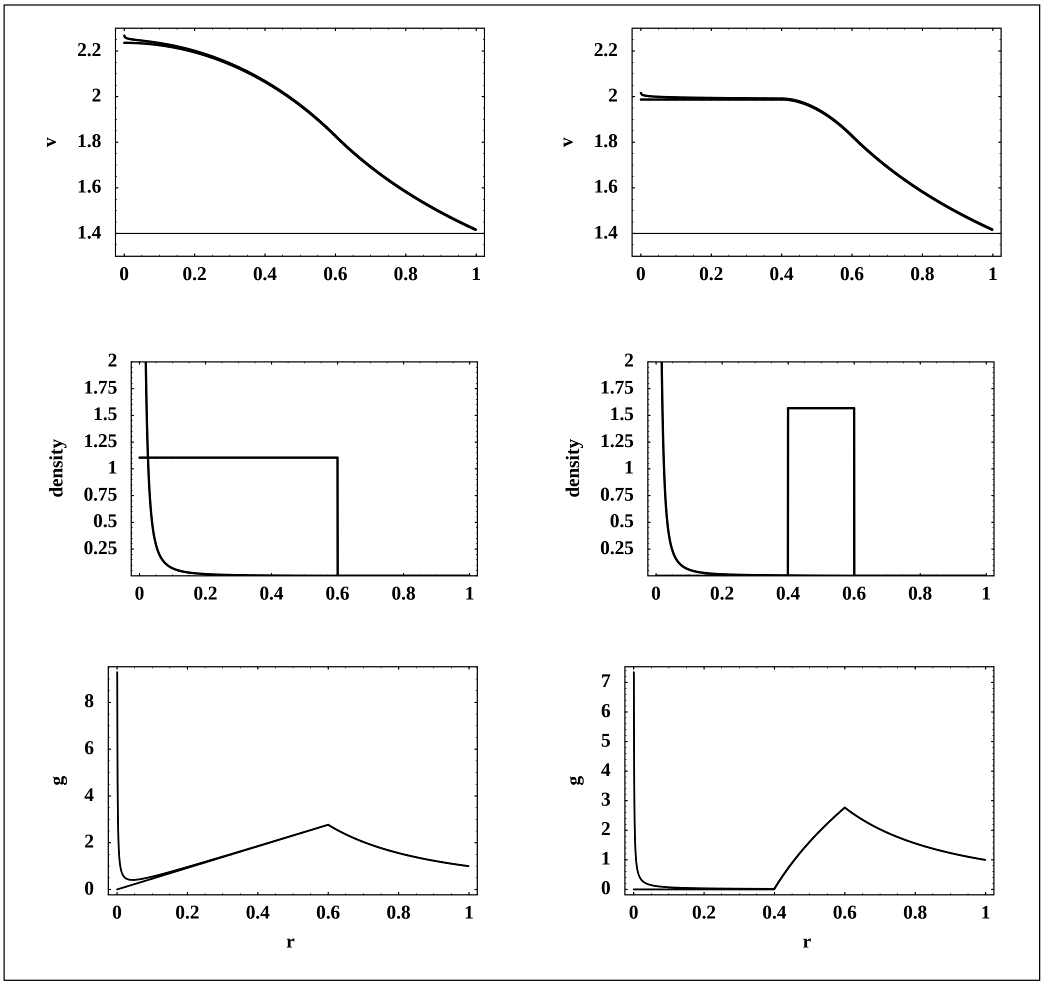

Figure 3: Solutions of (84) for a uniform density sphere (on the left), and for a spherical shell (on the right). The upper plots show the in-flow speeds for both Newtonian gravity and for the new theory of gravity, which displays the increase in speed near the attractor at $r = 0$. The middle plots are the matter density profiles, with the 'dark matter' density peaking at $r = 0$. The lower plots show the gravitational acceleration $|g(r)|$, with again a comparison of the Newtonian gravity and the new theory, which shows large accelerations near the attractor at $r = 0$.

find solutions parametrised by M and an arbitrary valued $\overline{\beta}$. Again for a sphere of uniform density as in (87) and with regional solutions as in (88), matching $f(r)$ and $f'(r)$ at $r = R$ gives

$$\beta = \overline{\beta} + \frac{16\pi\rho G R^{2+\alpha/2}}{(1-\alpha/2)(4+\alpha)}, \tag{93}$$

$$K = 16\pi\rho G R^3 \frac{2+\alpha/2}{3(1-\alpha/2)(4+\alpha)} = 2(1 + \frac{\alpha}{2} + O(\alpha^2)\ )MG. \tag{94}$$

Hence the value of K is unchanged from the minimal case, while the value of β is simply increased by $\overline{\beta}$ from the minimal case. Then for the 'dark matter' density we obtain

$$\rho_{DM}(r) = \begin{cases} \dfrac{\alpha\overline{\beta}}{16\pi G}(1-\dfrac{\alpha}{2})\dfrac{1}{r^{2+\alpha/2}} + \dfrac{\alpha\rho}{4}\left(\left(\dfrac{R}{r}\right)^{2+\alpha/2} - 1\right), & 0 < r < R, \\ \dfrac{\alpha\overline{\beta}}{16\pi G}(1-\dfrac{\alpha}{2})\dfrac{1}{r^{2+\alpha/2}}, & r > R. \end{cases} \tag{95}$$

Then the external velocity in-flow is

$$v(r) = \sqrt{\frac{K}{r} + \frac{\overline{\beta}}{r^{\alpha/2}}}, \quad r > R, \tag{96}$$

and the external gravitational acceleration is given by

$$g(r) = -\frac{(1 + \dfrac{\alpha}{2} + O(\alpha^2)\ )MG}{r^2} - \frac{\alpha\overline{\beta}}{4r^{1+\alpha/2}}, \quad r > R, \tag{97}$$

which asymptotically is dominated by the non-Newtonian second term, which essentially decreases like $1/r$. The first term is of course Newton's Inverse Square Law. In this non-minimal attractor case we have a superposition of a minimal attractor, with its strength given by the results in Sect.13, and an independent vacuum attractor with strength $\overline{\beta}$. This happens because in the case of a static spherically symmetric system the flow equation is linear. Of course in a physical situation these two components would interact because the matter density would respond to the total gravitational acceleration. Here we have ignored this dynamical effect.

One important consequence of this form for $g(r)$ is that asymptotically Kepler's orbital laws are violated. For circular orbits the centripetal acceleration relation $v_O(r) = \sqrt{rg(r)}$ gives the orbital speed to be

$$v_O(r) = \left(\frac{M + M_{DM}}{r} + \frac{\alpha\beta}{4r^{\alpha/2}}\right)^{1/2}, \tag{98}$$

which gives an extremely flat rotation curve. Such rotation curves are well known from observations of spiral galaxies.

15 Non-Spherical Gravitational Attractors

The in-flow equation (11) also has stationary non-spherical attractors of the form

$$\mathbf{v}(\mathbf{r}) = \frac{\mathbf{r}}{r}\left(\frac{\beta}{r^{\alpha/2}} + \frac{q}{r^{\gamma}}\cos(\theta) + ...\right)^{1/2}, \tag{99}$$

where θ is the angle measured from some fixed direction, and where

$$\gamma = \frac{2+\alpha+\sqrt{36-4\alpha+\alpha^2}}{4} \approx 2 + \frac{\alpha}{6}. \tag{100}$$

So the non-spherical term falls off quickly with distance.

16 Fractal Attractors

In the early universe there would have been primordial gravitational attractors of various strengths, as defined by their β values. It is unknown what spectrum of β values would have occurred. These would initially have all been devoid of matter agglomerations, that is they would be 'bare' attractors, because of the high temperatures. Each such attractor represents an in-flow of space which would have been in competition with the overall growth of space, as described previously. Each such attractor would have a region of influence, beyond which its flow field and consequently its gravitational field would be cancelled by that of other attractors. That is, the in-flow would be confined to that region. Clearly attractors with larger β values would have larger regions of influence. Hence space would be demarcated into a cellular form. However within each such cellular region there would be smaller attractors, and within their regions, further smaller attractors. We would then expect a fractal cellular structure: cells within cells and so on. This form is predicted by the emergent geometry of the gebit structure, as discussed in [8, 9], and so we appear to be seeing the linking of the bottom-up approach, from the information-theoretic ideas, with the top-down phenomenological description of space and gravity, that has arisen from generalising the flow formalism of both Newtonian gravity and General Relativity. This fractal cellular structure is consistent with the in-flow equation. Each cell would respond gravitationally to the gravitational field of the cell in which it is effectively embedded. Presumably attractors can merge, though this has not been analysed so far. Over time one would then expect that extremely strong and spatially extended attractors would arise. As the universe cooled and the plasma recombined to form a neutral gas, that gas would have been rapidly attracted by the long range gravitational fields. Detailed studies of the dynamics of this system of fractal attractors is required, as it is this system that determined the matter distribution of the universe, though as well we need to take account of possible vortex systems, as discussed later.

17 Globular Cluster Black Holes

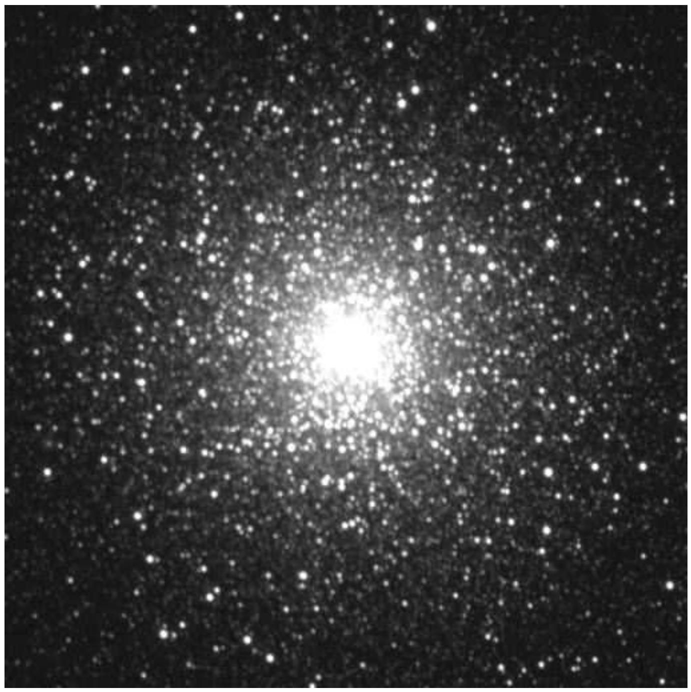

Figure 4: Globular cluster M15 in the constellation Pegasus, about 40,000 light years away, contains some 30,000 stars. M15 is one of some 150 known globular clusters that form a halo surrounding the Milky Way. The core is tightly packed. The new theory of gravity implies that this and other clusters have a minimal attractor, a black hole, at the centre of mass $M_{DM} = \frac{\alpha}{2}M$.

Astronomers using the Hubble Space Telescope announced [50, 51] that they had discovered evidence for intermediate mass black holes (IMBH), with masses from 100 to tens of thousands of solar masses. They believed that they had already established the existence of stellar black holes with masses from a few to ten solar masses. Stellar black holes were believed to be formed by the collapse of the cores of giant stars. But two of the Milky Way globular clusters, M15 and G1, suggested the existence of medium sized black holes. M15, shown in Fig.4, is in the constellation Pegasus, while G1 is near the Andromeda Galaxy. These clusters are some of the nearly 150 known globular clusters that form a halo surrounding the Milky Way. It is believed that the rising density of stars towards the centre had resulted in a collapse of the core, leaving an IMBH. Using the motion of stars within the clusters the mass of the cluster and of the 'black hole' were determined. In General Relativity the mass of such a black hole would depend on how many stars had been drawn into

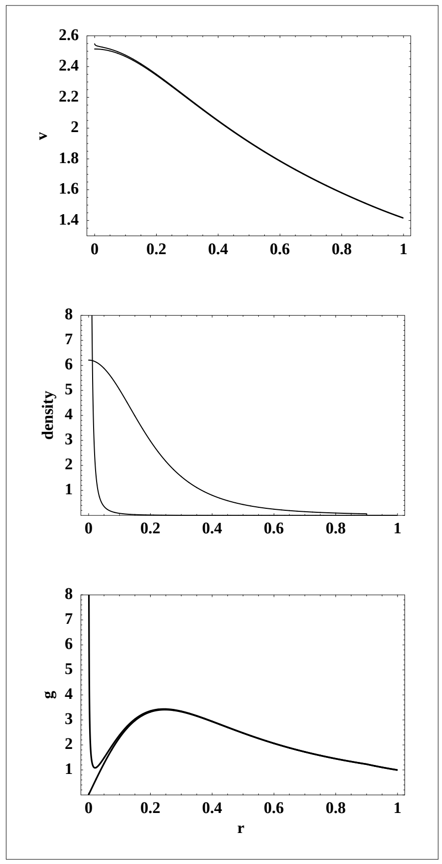

Figure 5: Assuming a matter density profile falling off like $1/(r^2+b^2)^2$, appropriate for a globular cluster, the in-flow speed was computed from the in-flow equation, as shown in the upper plot, which is larger than the 'Newtonian in-flow' speed near $r=0$, as also shown in the plot. The difference becomes very large for small r, but this is not shown in the plot. The matter density and the effective 'dark matter' density are shown in the middle plot. The lower plot shows the gravitational acceleration, with the strong peak at $r=0$ caused by the induced minimal attractor. The effective mass of the attractor is given by $M_{DM}=\alpha M/2$ to good accuracy. A non-minimal attractor would give even larger effects near $r=0$.

the black hole, and that is not predictable without generating some scenario for the dynamical history of the globular cluster. However in the new theory of gravity we must have at least a minimal gravitational attractor, whose mass is computable, and is given to sufficient accuracy by the perturbative result. So the globular clusters M15 and G1 give an excellent opportunity to test the presence of the attractor and its effective mass.

Numerical solutions of (61) for a typical cluster density profile are shown in Fig.5 and revealed that indeed the central 'dark matter' attractor has a mass accurately given by the perturbative result $M_{DM}/M = \alpha/2 = 0.00365$. For M15 the mass of the central 'black hole' was found to be [50] $M_{DM} = 1.7^{+2.7}_{-1.7} \times 10^3 \mathrm{M}_\odot$, and the total mass of M15 was determined [52] to be $4.9 \times 10^5 \mathrm{M}_\odot$. Then these results together give $M_{DM}/M = 0.0035^{+0.011}_{-0.0035}$ which is in excellent agreement with the above prediction. For G1 we have [51] $M_{DM} = 2.0^{+1.4}_{-0.8} \times 10^4 \mathrm{M}_\odot$, and $M = (7 - 17) \times 10^6 \mathrm{M}_\odot$. These values give $M_{MD}/M = 0.0006 - 0.0049$, which is also consistent with the above $\alpha/2$ prediction.

However there is one complication in this analysis. The determination of the 'black hole' mass followed from stochastic modelling of the motion of the inner stars, which was compared with the motion of those stars as revealed by the HST. In that modelling the gravitational acceleration caused by the 'black hole' would have been described by Newton's inverse square law form: $g(r) \sim 1/r^2$. However the attractor produces a gravitational acceleration of the form: $g(r) \sim 1/r^{1+\alpha/2}$. Hence to test the attractor explanation it is necessary for the stochastic modelling to be repeated using this modified force law. Nevertheless that the attractor explanation gives masses consistent with the observations and modelling is very encouraging. The attractor explanation is independent of the dynamical history of the globular cluster. Observations of other clusters should confirm that they all have the same mass ratio $M_{DM}/M = \alpha/2$. Of course there is an event horizon associated with the attractor, and to that extent we can continue to describe the attractor as a 'black hole', though one very different from that of General Relativity.

18 Galactic Rotation Curves and Gravitational Attractors

Consider the case of a spiral galaxy with a non-spherical rotating matter distribution. For spiral galaxies the new theory of gravity implies that their central black holes are large non-minimal primordial attractors. Then the non-inverse square law acceleration of such an attractor, in (97), would have caused a vary large in-fall speed for the surrounding matter, unlike the Newtonian-like gravitational in-fall which would result from the matter alone without a primordial attractor. Such a large in-fall speed would almost certainly result in a large angular momentum for the matter, resulting in the rotating flat disk so charactersitic of spiral galaxies. Then by the same argument we see that non-rotating elliptical galaxies are formed by a gravitational in-fall mechanism that does not have a central primordial black hole, or at least only a very small one. Hence elliptical galaxies should not display the extreme 'dark matter' effect that follows from the presence of a central non-minimal attractor, as is apparent now from a recent analysis of elliptical galaxies [53]. As well the region of influence of a primordial attractor will determine the total amount of matter that it can attract to form a spiral galaxy, and so there will be a relationship between the total 'dark matter' content of a spiral galaxy and its luminosity. On the other hand for elliptical galaxies the central attractors are simply a consequence of the matter induced in-flow, resulting in a minimal attractor, so their central black hole mass should be related to their total matter content by the same relationship as for the globular clusters, with some correction for their non-sphericity, which in general also permits more than one such black hole.

For the case of spiral galaxies we need to use numerical techniques, but beyond a sufficiently large distance the in-flow, due then mainly to the primordial attractor, will have spherical symmetry, and in that region we may use (61) and (62) with $\rho(r) = 0$. Then as already analysed the in-flow has the form, on re-parametrising (96),

$$v(r) = \overline{K}\left(\frac{1}{r} + \frac{1}{R_S}\left(\frac{R_S}{r}\right)^{\frac{\alpha}{2}}\right)^{1/2}, \tag{101}$$

where $\overline{K}$ and R_S are arbitrary constants in the $\rho = 0$ region, but where the value of $\overline{K}$ is determined by matching to the solution in the matter region. Here R_S characterises the length scale of the non-perturbative non-minimal attractor part of this expression, and $\overline{K}$ depends on α and G and details of the matter distribution. The galactic circular orbital velocities of stars etc may be used to observe this process in a spiral galaxy and from (49) and (101) we obtain a replacement for the Newtonian 'inverse square law',

$$g(r) = \frac{\overline{K}^2}{2}\left(\frac{1}{r^2} + \frac{\alpha}{2rR_S}\left(\frac{R_S}{r}\right)^{\frac{\alpha}{2}}\right), \tag{102}$$

in the asymptotic limit. From (102) the centripetal acceleration relation $v_O(r) = \sqrt{rg(r)}$ gives a 'universal rotation curve'

$$v_O(r) = \frac{\overline{K}}{2}\left(\frac{1}{r} + \frac{\alpha}{2R_S}\left(\frac{R_S}{r}\right)^{\frac{\alpha}{2}}\right)^{1/2}. \tag{103}$$

Because of the α dependent part this rotation-velocity curve falls off extremely slowly with r, as is indeed observed for spiral galaxies. Of course it was the inability of the Newtonian and Einsteinian gravity theories to explain these observations that

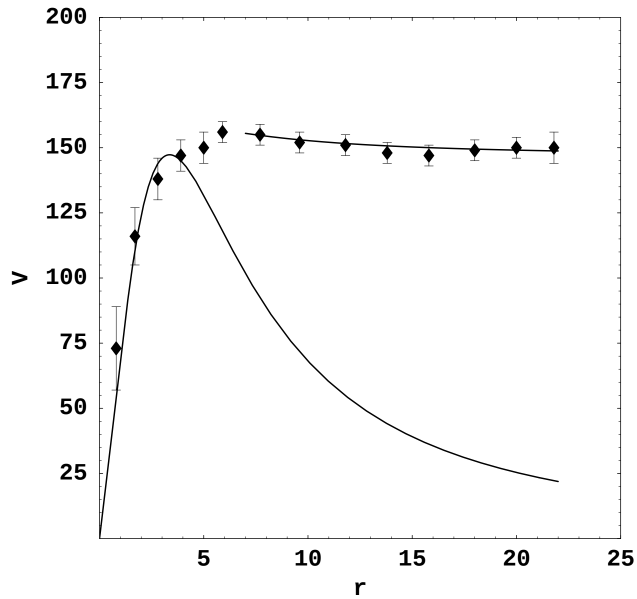

Figure 6: Rotation-velocity curve plot for the spiral galaxy NGC3198, with v in km/s, and r in kpc/h. Complete curve is rotation curve expected from Newtonian theory of gravity or the General Theory of Relativity for an exponential disk, which decreases asymptotically like $1/\sqrt{r}$. The incomplete curve shows the asymptotic form from (103).

led to the notion of 'dark matter'. It is possible to illustrate the form in (103) by comparing it with rotation curves of spiral galaxies. Fig.6 shows the rotation curve for the spiral galaxy NGC3198. Persic, Salucci and Stel [54] analysed some 1100 optical and radio rotation curves, and demonstrated that they are describable by the empirical universal rotation curve (URC)

$$v_O(x) = v(R_{opt})\Bigg[\left(0.72+0.44\text{Log}\frac{L}{L_*}\right)\frac{1.97x^{1.22}}{(x^2+0.78^2)^{1.43}} + 1.6\text{e}^{-0.4(L/L_*)}\frac{x^2}{x^2+1.5^2(\frac{L}{L_*})^{0.4}}\Bigg]^{1/2}, \quad (104)$$

where $x = r/R_{opt}$, and where R_{opt} is the optical radius, or 85% matter limit. The first term is the Newtonian contribution from an exponential matter disk, and the 2nd term is the 'dark matter' contribution. This two-term form also arises from the in-flow theory, as follows from (55). The form in (103) with $\alpha = 1/137$ fits, for example, the high luminosity URC, for a suitable value of R_S, which depends on the luminosity, as shown by one example in Fig.7. For low luminosity data the observations do not appear to extend far enough to reveal the asymptotic form of the rotation curve, predicted by (103).

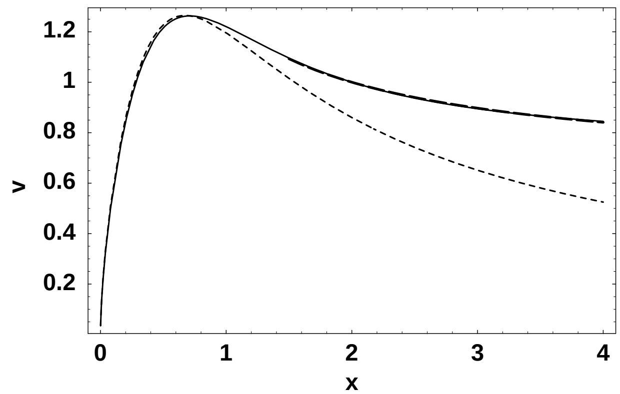

Figure 7: Spiral galaxy rotation velocity curve plots, with $x = r/R_{opt}$. Solid line is the Universal Rotation Curve (URC) for luminosity $L/L_* = 3$, using the URC in (104), Ref.[54]. Short dashes line is URC with only the matter exponential-disk contribution, and re-fitted to the full URC at low x. Long dashes line, which essentially overlaps the solid line for $x > 1.5$, is the form in (103) for $\alpha = 1/137$ and $R_S = 0.01R_{opt}$.

As already noted in (95) the effective 'dark matter' density for these non-minimal attractors falls off, essentially, like $1/r^2$, as astronomers had deduced from observations of the rotation curves of spiral galaxies. This leads to the following expression for the total 'dark matter' within radius R

$$M_{r<R} = 4\pi \int_0^R \rho_{DM}(r) r^2 dr = \frac{\alpha\beta R^{1-\alpha/2}}{4G}, \tag{105}$$

which increases almost linearly with R. It is this expression that explains the observations that the total amount of 'dark matter' exceeds the real amount of matter, as revealed by its luminosity, by often an order of magnitude.

19 Stellar Structure

The structure of stars is very much based on the assumption that the Newtonian theory of gravity is sufficiently accurate. This leads to the Solar Standard Model (SSM) in the case of the sun. However the new theory of gravity predicts at least a minimal gravitational attractor at the centres of stars, with an associated event horizon. This quantum-foam in-flow singularity causes the gravitational acceleration to be very different to that from the Newtonian theory, as already illustrated by a number of cases. Bahcall and Davis started an exploration of the sun by means of neutrinos [55, 56], with that work resulting in the solar neutrino anomaly, namely that all experiments, exploring different portions of the solar neutrino spectrum, reported a flux less than that predicted. The solar neutrino flux is determined by the physical and chemical properties of the sun, such as density, temperature, composition and so on. The current interpretation of the solar neutrino anomaly is in terms of the neutrino masses and mixing leading to oscillations of ν_e into active (ν_μ and/or ν_τ) or sterile neutrino, ν_s.

Because of the gravitational attractor effect one of the key equations in the SSM, the equation for hydrostatic equilibrium,

$$\frac{dP(r)}{dr} = -\rho(r)g(r) = -\frac{G\rho(r)m(r)}{r^2}, \tag{106}$$

where $P(r)$ is the hydrostatic pressure, $\rho(r)$ is the matter density and $m(r)$ is the matter within radius r, must be changed to

$$\frac{dP(r)}{dr} = -\frac{G\rho(r)m(r)}{r^2} - \frac{2\pi\alpha\rho(r)G}{r^2}\int_0^r \left(\int_s^R s'\rho(s')ds'\right) ds, \tag{107}$$

from (67) to $O(\alpha)$ terms. Towards the centre of the star this equation is dominated by the α dependent term. We can illustrate this for the simple case of uniform density. In this case (106) gives

$$P(r) = \frac{2\pi G\rho^2(R^2 - r^2)}{3}, \tag{108}$$

where R is the radius of the star, and where $P(R) = 0$, giving a finite pressure at the centre $r = 0$. However (107) becomes

$$\frac{dP(r)}{dr} = -\frac{4}{3}\pi G\rho^2 r - \pi\alpha\rho^2 G(\frac{R^2}{r} - \frac{r}{3}), \tag{109}$$

with solution

$$P(r) = \frac{2\pi(1 + \alpha/4)G\rho^2(R^2 - r^2)}{3} + \pi\alpha G\rho^2 R^2 \ln(\frac{R}{r}), \tag{110}$$

which reveals a logarithmic pressure singularity at the centre. In a more realistic modelling this effect would probably be even more pronounced, as the density would increase there as a consequence of such a pressure increase. Existing stellar structure codes need modification in order for this effect to be explored, and for any signature of the effect on the neutrino flux revealed. Because there is an event horizon at the centre of stars, essentially a black hole effect, though one very different from that of general relativity, an additional source of energy, and hence heating is available, namely the radiation from matter falling into this black hole. This would, even by itself, increase the temperature of the central region of stars.

Radiometric data from the Pioneer 10/11, Galileo, and Ulysses spacecraft indicated an apparent anomalous, constant, acceleration acting on the spacecraft with a magnitude of $\sim 8.5 \times 10^{-8}$ cm/s^2 directed towards the sun [59]. For Pioneer 10/11 the acceleration was 8.56×10^{-8} cm/s^2 at 30 AU, while at 60 AU it was 8.09×10^{-8}

cm/s^2. If there was a non-minimal gravitational attractor associated with the sun, we would expect an anomalous acceleration directed towards the sun, but decreasing like $1/r$. However the Pioneer 10/11 data does not indicate any such decrease, and so we conclude that (i) there is no evidence yet for such a non-minimal attractor, and (ii) that the new theory of gravity does not offer an explanation for this anomalous acceleration.

20 Laboratory Quantum Gravity Experiments

Quantum gravity effects are really just quantum-foam in-flow effects. As discussed in Sect.10 such effects have been manifest in ongoing attempts to measure G over the last 60 years. There they showed up as $O(\alpha)$ unexplained systematic effects. The new theory of gravity has two fundamental constants α and G, and clearly one cannot measure one of these alone. These G measurement experiments basically measure the force between two test masses as a function of separation distance. Using the linearity of the Newtonian theory of gravity the computation of these forces involves a vector sum of the forces between the individual mass points in the different test masses. However in the new theory there is a non-linearity whose magnitude is determined by α.

Assuming a stationary in-flow the velocity field is given by

$$|\mathbf{v}(\mathbf{r})|^2 = \frac{2}{4\pi}\int d^3r' \frac{C(\mathbf{v}(\mathbf{r}'))}{|\mathbf{r}-\mathbf{r}'|} - 2\Phi(\mathbf{r}). \tag{111}$$

with the *ansatz* that the direction of $\mathbf{v}(\mathbf{r})$ is the same as the direction of $\mathbf{g}(\mathbf{r})$, where this gravitational acceleration is given by

$$\mathbf{g}(\mathbf{r}) = \frac{1}{2}\nabla(\mathbf{v}^2(\mathbf{r})). \tag{112}$$

It is easier to see the effects of the non-linearity of the 'dark matter' term by computing and displaying this matter density in those cases relevant to a Cavendish-type laboratory experiment in which both α and G are measured together. In Fig.8 is shown the 'dark matter' density for two spheres for the cases of two separation distances. Here we have ignored the inhomogeneity of the in-flow of the earth. When the spheres are well separated the 'dark matter' effect occurs at the centre of each sphere, but as they are brought together the non-linearity of the effect causes the 'dark matter' density to become essentially polarised, this 'dark matter' polarisation is evident in Fig.8, that is, in each mass it moves away from the centre, and there is also a small region of 'dark matter' that forms outside and between the two spheres. Because of this non-linear polarisation effect the net force between the two spheres is not describable by the Newtonian theory. However the leading effect is that the 'dark matter' mass depends on the geometry of the masses used. The deviations from the Newtonian theory then permit the experimental determination of α from

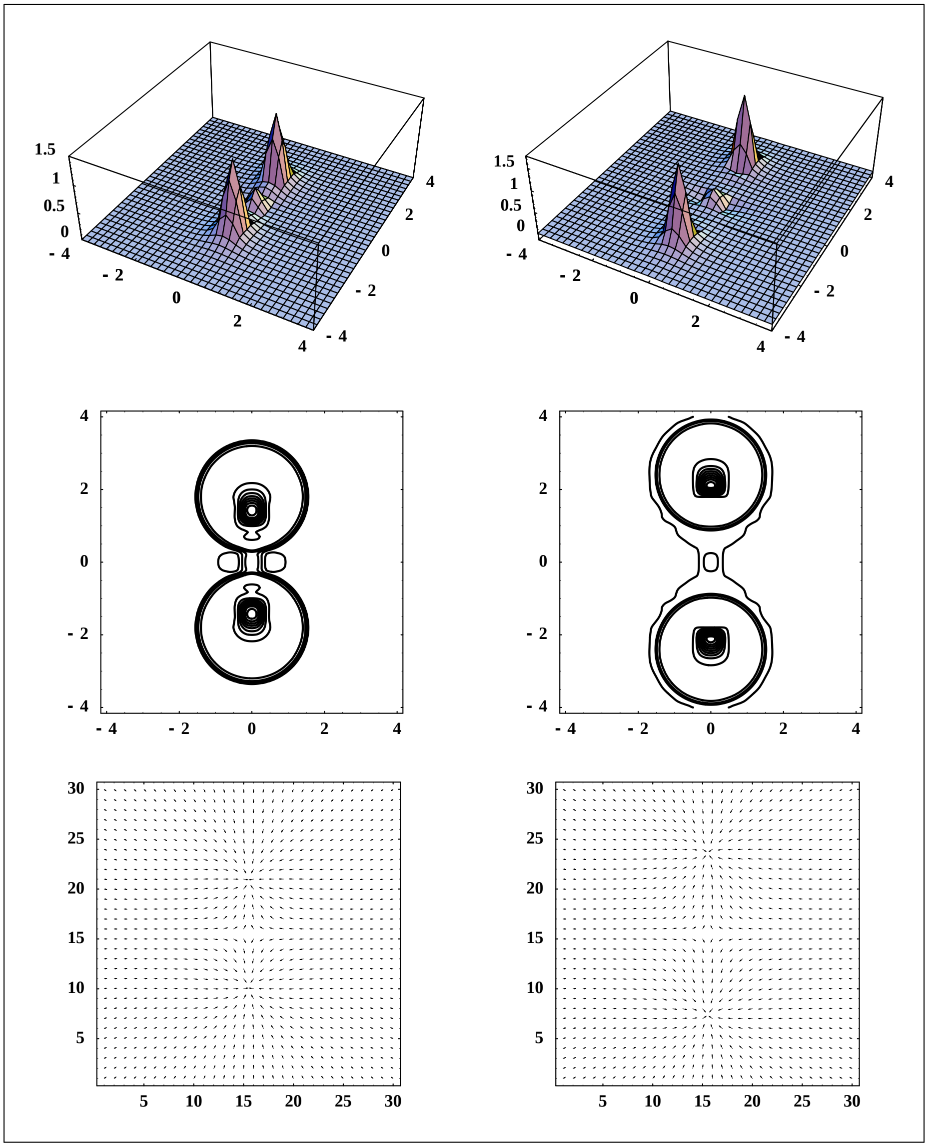

Figure 8: Cavendish experiment with two spheres, each of radius 1.5, and with uniform density. On the left the separation of the centres is 3.6, while on the right the separation is 4.8. The upper plots show the 'dark matter' density distributions of the gravitational attractors, as also shown in the middle contour plots. The contour plots clearly reveal the 'polarisation' effect of the 'dark matter' density, which is greater for smaller separations. In each case the ratio of the total 'dark matter' to the total mass is 0.0045. The lower plots show the in-flow velocity fields. These are quantum gravity effects that are detectable in laboratory experiments.

such an experiments. This effect is a key prediction and provides a critical test of the new theory. An analysis of the data requires numerical solutions of the flow fields for each configuration of the masses in such an experiment. The magnitude of the 'dark matter' mass is $\approx \alpha/2$, i.e. 0.3%, but the main observable effect is the dependence of this mass on the geometry of the objects, which experiment suggests is at the 0.1 % level.

21 Conclusions

We have seen that the solar system was too special to have revealed key aspects of gravity. These only become evident when Newtonian gravity is re-formulated in terms of a velocity in-flow field. A generalisation of that formalism leads to an explanation of the so-called 'Dark Matter' effect. The most significant aspect of this work is the discovery that the magnitude of the 'dark matter' spatial self-interaction dynamics is determined by the fine structure constant α, while Newton's gravitational constant G only determines the interaction of space with matter. It has been shown how the values of α and G together may be determined in Cavendish-type laboratory experiments. Also significant is the discovery that this new theory of gravity leads to gravitational attractors - a new form of black hole, and whose properties are determined by the value of α and not G. As a consequence we saw how these attractors explain the observed globular cluster black hole masses, and similarly the necessity for black holes in galaxies. We also saw that primordial non-minimal black holes explain both the origin and nature of spiral galaxies, particularly their rotational behaviour. This new theory of gravity has its origins in the information-theoretic *Process Physics*, which offers as well an explanation and unification of the quantum nature of space and matter, and their classicalisation [8]. That work implies that the occurrence of α in the new classical description of gravity is indicative of the underlying quantum processes of space, that space is a complex quantum-information theoretic system, and at that level it is not geometric. The results herein imply that we have the first evidence of quantum aspects of gravity.

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