Coherent and Conventional Gravidynamic Quantum 1/f Effects and Indirect Observation of Gravitons in Artesian Fountains

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***Abstract*—Just like in electrodynamics, the gravitational (gravidynamic) *coherent* quantum 1/f effect (Q1/fE) is a fluctuation property of large matter currents, caused by their interaction with their own field, and by decoherence. The same causes yield also the gravitational *conventional* Q1/fE as a property of scattering cross sections and process rates of material particles. We derive the conventional quantum gravidynamic (QGD) Q1/fE, and apply the larger, coherent QGD Q1/fE in Sec. IV to an artesian fountain as an example, obtaining an 11 cm observable quantum-gravitational effect, in the height fluctuations. These are macroscopic quantum fluctuations based on gravidynamic decoherence; They are single-particle effects, observable, like diffraction, only with many particles. Easy to measure, they display directly, for the first time, the quantum nature of gravity and prove the existence of gravitons in our daily experience, also determining the coherence volume. Just like *mobility*, *conductivity* and *resistivity* are defined for electrons in semiconductors, we can again define for the imagined diffusion of similar light neutral particles through a lattice of atoms in a gravitational field, a diffusional mobility, diffusional conductivity and resistivity. These new quantities will be subject to a "diffusional" form of the conventional gravidynamic Q1/fE. The connection between conventional and coherent QGD diffusional quantum 1/f effects is estimated by comparing terms in the hamiltonian. It allows the calculation of QGD quantum 1/f noise in a hypothetical diffusion flow (e.g., percolation of water) with finite drift speed, like electric current in semiconductors. Usually, no such "diffusion" occurs, no such connection is present. Both the coherent and conventional effects are present then, independently.**

Keywords*—Fundamental 1/f noise, gravidynamic 1/f noise, quantum 1/f noise, conventional quantum 1/f effect, coherent quantum 1/f effect, gravitonic quantum noise, diffusional connection between quantum 1/f effects

I. Introduction

The quantum theory of fundamental 1/f noise [1]-[9] is a new aspect of quantum mechanics, introduced in 1975 as an infrared divergence (IRD) phenomenon [1]. It is also a decoherence [8] phenomenon, present in many forms. Its quantum electrodynamic (QED) form describes the fundamental 1/f noise of electric currents in the materials, devices and systems of electro-physics, electronics, microelectronics, nanotechnology, sensors and phase noise in HF or UHF devices and systems, or in high stability frequency standards. The quantum gravidynamic (QGD) form [11] of quantum 1/f (Q1/f) noise replaces photons by gravitons and describes it in macroscopic streams of matter, with terrestrial and cosmic implications. The quantum lattice-dynamic (QLD) form describes it in electric currents through ferroelectric materials like $BaSr(TiO_3)_2$ or bulk GaN, with piezo-phonons replacing the photons as infra-quanta. The Fermi-sphere quantum 1/f noise, present, e.g. in contact noise at a metallic surface, has electron-hole pairs at the Fermi surface as infra-quanta. In general, the quantum 1/f noise is always present, when a current of any nature has IRD coupling to a system of massless, environment-forming, infra-quanta, i.e., ultra-low frequency quanta.

For the special case of "gravitational diffusion /conduction," of imagined light neutral particles of mass similar to the electron's, the QGD Quantum 1/f Noise (Q1/fN), like the QED case, combines both, the conventional and coherent Quantum 1/f Effects (Q1/fE) in a new, different, way.

The conventional Q1/fE is a property of the physical cross sections σ and process rates Γ of quantum mechanics (QM), a new aspect of QM. In QED, e.g., the well-known infrared catastrophe caused by the IRD gives the number of emitted infra-photons per scattered electron as $\nu= (2\alpha/3\pi f)(\Delta\mathbf{v}/c)^2$, and also gives the spectral density of fractional fluctuations in this "physical cross section σ or process rate Γ" of the process considered, as $S_{\delta\sigma/\sigma} =2\nu/Nf$. N is the number of particles in the beam section (or length portion) used in order to define the notion of current. The resulting QED conventional Q1/fE fluctuations in current are thus

$$S_{\delta j/j} =(1/Nf)](4\alpha/3\pi)(\Delta\mathbf{v}/c)^2. \qquad (1)$$

Here $(\Delta\mathbf{v}/c)^2=4(v^2/c^2)\sin^2(\theta/2)$, where θ is the scattering angle for σ. The corresponding conventional QGD-Q1/fE, derived below, is given by

$$S_{\delta j/j} =(1/Nf)]\ [(8G/5c^5\hbar\ )\mu^2v^4\sin^2\theta_c]. \qquad (1')$$

Here in both cases, the derivation assumes that the phases of the bremsstrahlung energy loss components were randomized by ***decoherence***, i.e, by interaction with the environment Here $\alpha= e^2/\hbar c =1/137$ is the fine structure constant, $\Delta\mathbf{v}/c$ the vector velocity change (in units of the speed of light) of the electrons in the (e.g., scattering or tunneling, etc.) process considered, and N the number of carriers defining the current whose fluctuations are considered. G is the constant of universal gravitation, $m/2\leq\mu<m$ is the reduced mass of the particles of mass m which emerge from a scattering

process on a scattering center of larger or equal mass, and here θ is their scattering angle in the center of mass system of reference.

The coherent Q1/fE is a property of any current, caused by the coherent state of the (photonic, gravitonic, etc.) field of a physical particle. This field is not in an energy eigenstate, therefore the whole particle is in a nonstationary state, and the ensuing fractional current fluctuations have a universal 1/f spectrum

$$S_{\delta j/j} = 2\alpha/\pi fN \text{ in QED, and} \qquad (2)$$

$$S_{\delta j/j} = 2Gm^2/\pi fN\hbar c = 2\beta_{coh}/\pi fN \text{ in QGD.} \qquad (2')$$

Here $\alpha = e^2/\hbar c$ is the fine structure constant and $\beta_{coh} = Gm^2/\hbar c$, with G the constant of universal gravitation. In the usual (QED) case, for the coexistence of the coherent and conventional Q1/f effects in semiconductors, the resulting Q1/fN is roughly evaluated simply, using the weights $1/(1+s)$ and $s/(1+s)$ of the corresponding terms in the hamiltonian. Combining the conventional and coherent contributions with these weights of $1/(1+s)$ and $s/(1+s)$, where s is the coherence parameter, is in fact a very rough and heuristic approximation. However, many experiments showed that it worked very well in practice, in the QED case, as we see from early publications of F.N. Hooge (referred to in [10] for coherent Q1/fE) and Aldert van der Ziel [10], as well as from many other measurements by other authors on larger samples where s is not very small. This coherence parameter is $s = 2r_oN'$, i.e., the number of carriers along the current, contained in a slice of thickness $r_o = e^2/mc^2$, known as the classical radius of the electron, perpendicular to the current direction. Here N' is the number of carriers per unit length and m the mass of the electron or any current carrier. The QED-Q1/fN is thus

$$S_{\delta j/j} = [1/Nf(1+s)][(4\alpha/3\pi)(\Delta\mathbf{v}/c)^2 + 2s\alpha/\pi] \qquad (3)$$

The total difusional QGD-Q1/fN for particles of mass m percolating through a hypothetical crystal lattice points of mass M is then

$$S_{\delta j/j} = [1/Nf(1+s'')][(8G/5\hbar c^5)\mu^2 v^4 \sin^2\theta + 2s'' Gm^2/\pi\hbar c], \qquad (4)$$

where θ is the scattering angle of the particles of mass m in the center-of-mass reference system, with relative velocity v of the particles, and reduced mass $\mu = (m+M)/mM$. Here $s'' = 2N'GM/c^2 = N'r_s$, evaluated below, is the coherence parameter introduced by us like the parameter s for electromagnetic Q1/fE and also like s' for the piezoelectric Q1/fE. N' is again the number of particles per unit length and $r_s = 2GM/c^2$ is here their Schwarzschild radius, with G the constant of universal gravitation.

II. Evaluation of the QGD Coherence Parameter s''

The evaluation of s'' is done for the first time explicitly in this paper. The derivation proceeds similar to the earlier derivations of s and s'. The s'' parameter is defined as the *ratio* between the "gravitational field's coherent collective contribution to the drift kinetic energy" of the stream of electrically neutral particles (or bodies) of average mass m and drift (average) velocity v on one hand, and their bare-particle drift kinetic energy $mv^2/2$ (of the diffusive, or percolation, motion) on the other hand. The former scales with the square number of particles per unit length, like the magnetic energy in QED. The latter scales as the number of particles. This ***ratio*** is similar to the ratio of these energy terms in the QED case

$$\begin{aligned} s &= [\textstyle\int B^2 d\tau/8\pi]/[N'mv^2/2] \\ &= \{[4e^2J^2/8\pi c^2][\textstyle\int 2\pi r dr/r^2]/[N'mv^2/2] \\ &= 2N'(e^2/mc^2)\ln(R_0/r) \approx 2N'r_e \end{aligned} \qquad (5)$$

Here J is the current of carriers of mass m and charge e, $B = 2J/r$ its magnetic field, and R_0 is the radius of the electric circuit, a cut-off for the logarithmic divergence. The logarithm is of the order unity and is set 1. We introduced the classical radius $r_e = e^2/mc^2 = 2.8\ 10^{-13}$ cm of the electron.

In general relativity there is also an analog $\mathbf{v}_x\mathbf{g}/c$ of the magnetic field vector B, as the field generated from the particle's own gravitational field $g = -2GN'v/r$ in cross product with its drift velocity $\mathbf{v}$. This is not a relativistic invariant calculation. It is done in the local frame. We obtain for the QGD case

$$\begin{aligned} s'' = s_g &= [\textstyle\int (\mathbf{v}_x\mathbf{g}/c)^2 d\tau/8\pi G]/[N'mv^2/2] \\ &= \{(4Gm^2N'^2v^2/N'mv^2/2)\textstyle\int 2\pi r dr/r^2\}/[N'mv^2/2] \\ &= 2(GN'm/c^2)\ln(r/R_0) \approx 2GN'm/c^2 = N'r_s. \end{aligned} \qquad (6)$$

Here we introduced again the Schwarzschild radius $r_s = 2Gm/c^2$ of the particles of mass m in the beam, stream, or jet.

This completes our evaluation of s'', also denoted by s_g, and is very similar with the evaluations of s, and s'.

While Eqs. (1') and (2') are always applicable in macroscopic streams of matter in any state of aggregation, both on earth and in cosmos, the QGD Q1/fN, Eq. (4) is not applicable, and could be verified only if, e.g., "dark matter" would be, unlikely, like a solid in which matter would move like electrons in a semiconductor or metal made of "dark matter!" We have just formally extended here the practically important formalism developed for QED and QLD. However, a fundamentally different approach to the nature of dark matter will be presented in a future paper.

III. Derivation of the Conventional QGD Q1/fE

The derivation of the conventional QGD Q1/fE is similar to the derivation [1]-[4] of the conventional Q1/fE in QED, by calculating the bremsstrahlung, this time of gravitons. In the non-relativistic limit the infrared exponent αA is thus replaced by the GQ1/fE infrared exponent

$$\beta = \beta_{conv} = (8G/5\pi c^5\hbar)\mu^2 v^4 \sin^2\theta, \qquad (7)$$

where θ is the scattering angle of the particles in the center-of-mass reference system, with $\mathbf{v}$ being the relative velocity of the particles that scatter on each other, and their reduced mass being μ. G is the constant of universal gravitation.

The rate $\Gamma_{\alpha\beta}{}^{o}$ of an arbitrary interaction or transition from state α to β, which changes the momentum of a beam of particles or of a stream of matter, is subject to gravitonic infrared radiative corrections. The corrections due to virtual gravitons of small energy $\lambda<\varepsilon<\Lambda$ that boomerang back, yield a rate [1]

$$\Gamma'_{\beta\alpha}(\lambda,\Lambda) = (\lambda/\Lambda)^{\beta}\Gamma_{\beta\alpha}{}^{o}. \quad (8)$$

Here λ is an arbitrarily small cutoff, used to display the infrared divergences, while Λ is an energy chosen to be about an order of magnitude below the charcteristic center of mass energy of the interaction considered. Note that all virtual phonons must be included, so λ is actually zero and so, the rate computed without allowing any energy loss caused by bremsstrahlung of real photons is zero. Eq. (8) was obtained by summing up the series of virtual graviton diagrams defining the matrix element of the process, into an exponential function of a logarithmically divergent integral. Eq (8) gives the squared module of this matrix element.

Including also the real gravitons, we notice that the series of diagrams exponentiates again, but only at the level of the process rate [1]. Neglecting the influence of the thermal radiation background, we obtain for the (e.g. scattering) interaction process with gravitonic bremsstrahlung energy losses $>\lambda$, but below a certain limit ε_1, the rate

$$\Gamma_{\beta\alpha}(<\varepsilon_1) = (\varepsilon_1/\lambda)^{\beta}\Gamma'_{\beta\alpha} = (\varepsilon_1/\Lambda)^{\beta}b(\beta)\Gamma_{\beta\alpha}{}^{o} \approx (\varepsilon_1/\Lambda)^{\beta}\Gamma_{\beta\alpha}{}^{o}. \quad (9)$$

Here the function $b(\beta) = 1 - \pi^2\beta^2/12 + \ldots \approx 1$, since $\beta<<1$. The derivation of an equation replacing Eq. (9) is done in [5] in the presence of a thermal radiation background. However, the result is a convolution involving Eq. (9) as one of its factors, which indicates that the spontaneous and induced transitions are statistically independent. This has been used to prove [6]-[7] that the quantum 1/f result remains unaffected in the presence of a thermal radiation background of infraquanta. The background only contributes a statistically independent white noise term, just as it happens in the electromagnetic (QED) case. Since we are interested in the 1/f noise part, this consideration justifies the neglect of the thermal-radiation-background-induced stimulated emission and absoption processes in the final result obtained below.

In Eq. (9) we can use the identity

$$(\varepsilon_1/\Lambda)^{\beta} = (\varepsilon_o/\Lambda)^{\beta}[1 + \beta\int_{\varepsilon o}^{\varepsilon 1}(\varepsilon/\varepsilon_o)^{\beta}d\varepsilon/\varepsilon. \quad (10)$$

We interpret $\varepsilon_o<\varepsilon_1$ as the graviton detection threshold, which is not less than the reciprocal noise measurement time times Planck's constant. Multiplied by $\Gamma_{\alpha\beta}{}^{o}$, the first term in rectangular brackets yields the elastic scattering rate, while the second term gives the bremsstrahlung scattering rate with energy loss up to ε_1. Corresponding scattering matrix elements could be defined as the square root of these rates. Restoring also the phases, say ϕ and $\phi+\gamma(\varepsilon)$, where $\gamma(\varepsilon)$ is a random phase introduced subsequently by decoherence, we obtain the scattering amplitudes

$$a=(\varepsilon_o/\Lambda)^{\beta/2}[b(\beta)\Gamma_{\beta\alpha}{}^{o}]^{1/2}\exp(i\phi), \ \& \ a\rho_\varepsilon\exp[i\gamma(\varepsilon)]d\varepsilon/\varepsilon^{1/2}, \quad (11)$$

for scattering without and with gravitonic bremsstrahlung respectively, where

$$\rho_\varepsilon= (\beta)^{1/2}(\varepsilon/\varepsilon_o)^{\beta/2}. \quad (12)$$

Here $\gamma(\varepsilon)$ is the random phase of this resulting einselected [8] state, which reflects the interaction with the environment that causes decoherence. Therefore, if the incoming beam of particles or matter is described by a plane wave $\exp[i(\mathbf{pr})]$ in units with $\hbar=c=1$, the scattered spherical wave will be a stochastic mixture

$$\psi = ae^{ipr}\{1 +\int_{\varepsilon o}^{\varepsilon 1} \rho_\varepsilon e^{-iqr}\exp[i\gamma(\varepsilon)]d\varepsilon/\varepsilon^{1/2}\}, \quad (13)$$

because $\gamma(\varepsilon)$ is a random phase for each ε. Here, considering stationary states, the momentum magnitude loss $q=Mc(k/K)= M(\varepsilon/K)$ is necessary for energy conservation in the Bremsstrahlung process. Thus, q is an equivalent parameter for $ck= \varepsilon$, with $d\varepsilon/\varepsilon=dq/q$, and we can also eliminate ε completely in favor of q in the integration. The latter has replaced here right away the corresponding summation over $\mathbf{q}$, that is originally present.

We obtain for the resulting 2-particle "einselected" state a classically correlated system, from two single-particle states for each ε,

$$\Psi = a\exp[ip(r_1+r_2)\{1+\int_{\varepsilon o}^{\varepsilon 1}\rho_\varepsilon\exp[i\gamma(\varepsilon)-iqr_1]d\varepsilon/(2\varepsilon)^{1/2} +\int_{\varepsilon o}^{\varepsilon 1} \rho_\varepsilon\exp[i\gamma(\varepsilon)-iqr_2]d\varepsilon/(2\varepsilon)^{1/2}\}. \quad (14)$$

By module squaring and averaging over the phases, we can thus write the autocorrelation function in space or time, as well as in "space and time"

$$<|\Psi|^2> =1 +\int_{\varepsilon o}^{\varepsilon 1} |\rho_\varepsilon|^2d\varepsilon/\varepsilon +\int_{\varepsilon o}^{\varepsilon 1} |\rho_\varepsilon|^2\cos[q(r_2-r_1)]d\varepsilon/\varepsilon$$

$$= 1 +\int_{\varepsilon o}^{\varepsilon 1} |\rho_\varepsilon|^2d\varepsilon/\varepsilon +\int_{q o}^{q 1} |\rho_q|^2\cos[q(r_2-r_1)]dq/q \quad (15)$$

$$= 1 +\int_{\varepsilon o}^{\varepsilon 1} |\rho_\varepsilon|^2d\varepsilon/\varepsilon +\int_{\varepsilon o}^{\varepsilon 1} |\rho_\varepsilon|^2\cos[\varepsilon\tau]d\varepsilon/\varepsilon \quad (16)$$

$$= 1 +\int_{\varepsilon o}^{\varepsilon 1} |\rho_\varepsilon|^2d\varepsilon/\varepsilon +\int_{\varepsilon o}^{\varepsilon 1} |\rho_\varepsilon|^2\cos[\varepsilon\theta]d\varepsilon/\varepsilon. \quad (17)$$

Here $\varepsilon=\omega$ is the frequency, τ is the correlation time, and $\theta = t-r/v$ is the parameter describing the propagation of quantum 1/f fluctuations along the beam, or stream of matter, in the outgoing radial direction $\mathbf{r}$. The fractional spectral density of conventional gravidynamical quantum 1/f fluctuations in concentration or current j is given by the Wiener Khitchine theorem as the third term divided by the constant term

$$<(dj/j)^2> = (2/N)[|\rho_\varepsilon|^2/\varepsilon]/[1 +\int_{\varepsilon o}^{\varepsilon 1} |\rho_\varepsilon|^2d\varepsilon/\varepsilon] =(2/N\,\varepsilon)\beta(\varepsilon/\varepsilon_o)^{\beta} = (2/N\omega)\beta(f/f_o)^{\beta}. \quad (18)$$

Here $f=\omega/2\pi$ is the frequency, and N=2 is the number of particles that define the notion of current $j=v|\psi|^2$. Eqs. (10 and (18) give the spectrum

$$\beta=\beta_{conv} = (8G/5\pi\hbar c^5)\mu^2 v^4 \sin^2\theta, \quad (19)$$

of the conventional gravidynamic quantum 1/f effect. This effect contains Planck's constant in the denominator and is at the angulation line of quantum mechanics and general relativity. This is the most fundamental form of quantum chaos, the quantum manifestation of classical, general relativistic, turbulence. It is a fundamental aspect of quantum mechanics, which can be used to define quantum mechanics as the actual form taken by the process of metrogenesis [9]. Together with the coherent gravidynamic Q1/fE, it determines the total gravidynamic quantum 1/f noise that is observable. All forms of quantum 1/f noise represent the main part, ontologically the most basic, of fundamental 1/f noise, verified experimentally [10] and important in engineering. In general, epistemologically or conceptually, fundamental 1/f noise is the result of nonlinearity combined with a special type of homogeneity [11], [12]. Q1/f noise is then a special form.

IV. Experimental Verification

Consider a rigid horizontal pipe, 10m long, of 10 cm^2 cross section, with water flowing in the pipe at 4m/s, draining water from a huge reservoir at 10 cm^2 $\times$400 cm/s =4 liter/s. The end of the pipe is bent 90^o upwards, ending with a nozzle of 2.5 cm^2 cross section and, with water pressure having decreased to atmospheric pressure, projects the water vertically up at 16 m/s, creating an artesian fountain. We show that the resulting 13.6 m height of the jet can exhibit coherent gravidynamic Q1/f fluctuations of about 11 cm in height. Indeed, the spectral density of the fluctuations is given by the coherent (second) term in the rectangular brackets of Eq. (4), with no diffusion control, i.e., without the weight factor s"/(1+s"),

$$S_{\delta j/j} =(1/Nf)2Gm^2/\pi\hbar c \quad (20)$$

Considering coherence parcels of 1 mg water, we get $N=10^8$ parcels in the pipe. Larger parcels give larger noise. With $G=6.6741\times10^{-8}\ cm^3g^{-1}s^{-2}$, in CGS units:

$S_{\delta j/j}=(2/10^8\pi f)6.67\times10^{-8}10^{-6}/3\cdot10^{10}10^{-27}=1.4\ 10^{-5}/f$ (21)

Since $h=(1600cm/s)^2/1960cm/s^2=1306$ cm, from $v^2=2gh$ the spectrum of fractional height fluctuations of the fountain is four times larger than $S_{\delta j/j}$:

$$dh/h=2dv/v=2dj/j:\ S_{\delta h/h} =5.6\ 10^{-5}/f =C/f.$$

The Allan two-sample variance 2Cln2 =Cln4 is thus

$$<(\delta h/h)^2>_A=5.6\ 10^{-5}\ln 4=7.76\ 10^{-5};$$
$$<\delta h/h>_A=8.8\ 10^{-3}.\ \ \delta h_A= 13\ m\ 8.8\ 10^{-3}.= 11.4\ cm. \quad (22)$$

V. Discussion

This simple calculation supplements the manuscript LM700 submitted by this author to Phys. Rev. Letters on December 12, 1975. It has not been accepted for publication yet, since any 1/f noise "could have been caused by fish in the water." No serious flaw was ever found. It was then included in our Conference Proceedings [13]. That paper applied the conventional QGD Q1/fE to a vertical circular column of water with a 1 m diameter, or jet, moving with 10 m/s and deflected to 90^o on a free-rolling conveyer belt. Considering a mass of 100 Kg scattered coherently, it yielded $S_{\delta j/j}$= 2.47 10^{-11}/f, or 6.36 10^{-8}/f for a hydroelectric plant.

Compared to QED, the 10^{43} times smaller gravitational coupling is overcompensated by the squared Avogadro number, because masses can aggregate. Careful experiments on artesian fountains, on hydroelectric plants, and other water flows can better determine the coherence volume for gravitational radiation, assumed here to be 1g. Our evaluation shows that gravitons of infra-quantum energies may shape the easily observable macroscopic distribution of matter in time and space, particularly when no other causes of fluctuations are apparent. This is just like the complete verification of the modulation of electrical currents by photons in QED Q1/fN by electronics, microelectronics and time-keeping. Single gravitons will cause a simple harmonic, sinusoidal, dependence. It is a new approach to weak-field quantum gravity. The latter was recently the subject of ingenious, delicate, experiments trying again to demonstrate the quantum nature of weak-field gravity, gravitational quantum entanglement, and the existence of gravitons [14], [15]. It is, however, not yet addressing actual quantum gravity, which governs strong gravitational fields and the inner dynamics of black holes, beyond the apparent singularity. Conceptually, it is also the subject of our jointly submitted paper [9].

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