Coherent and Conventional Gravidynamic Quantum 1/f Effects

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***Abstract*—The connection between conventional and coherent quantum gravidynamic (QGD) Q1/fE is evaluated by comparing terms in the hamiltonian. It allows the calculation of QGD quantum 1/f noise from its components, the conventional and coherent Q1/fE. The weight of these components are 1/(1+s") and s"/(1+sa). Here s"=N'r$_s$, where r$_s$ is the Schwarzschild radius of the particles of mass m in a beam, stream, or jet. N' is the number of particles per unit length of the beam.**

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

I. Introduction

The quantum theory [1]-[9] of fundamental 1/f noise is a new aspect of quantum mechanics, in-troduced in 1975 as an infrared divergence pheno-menon. It is also a decoherence phenomenon, present in many forms. The QED form describes the fundamental 1/f noise in the materials, devices and systems of electro-physics, electronics, mi-croelectronics, nanotechnology, sensors and phase noise in HF or UHF devices and systems, or high stability frequency standards. The quantum gravidynamic (QGD) form replaces photons by gravitons and describes it in macroscopic and mesoscopic streams of matter, with terrestrial and cosmic implications. The quantum lattice-dynamic (QLD) form describes it in electric currents in 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 sur-face as infraquanta. In general, the quantum 1/f noise is always present when a current of any nature has infrared-divergent (IRD) coupling to a system of massless, environment-forming, infra-quanta. The quantum 1/f noise (Q1/fN) contains in all its forms both, the conventional and cohe-rent Quantum 1/f Effects (Q1/fE).

The conventional Q1/fE (derived for QGD below) 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 as $\nu=(2\alpha/3\pi)(\Delta\mathbf{v}/c)^2$, and also gives the spectral density of fractional fluctuations in this “physical cross section or process rate” 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 fluctuations in current are thus

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

The derivation assumes that the phases of the bremsstrahlung energy loss components were randomized by ***decoherence***. Here α= e^2/h,′ 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.

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 is not an energy eigenstate, therefore a nonstationary state, and the ensuing fractional current fluctuations have a universal spectrum

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

$S_{\delta j/j} = 2Gm^2/\pi fNch,'$ in QGD. (2)

In the usual (QED) case, the resulting Q1/fN is roughly evaluated simply, according to 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, experiment showed that it worked very well in practice, in the QED case, as we see from early publications of F.N. Hooge and Aldert van der Ziel [8], as well as from many other measurements 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

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

The QGD-Q1/fN is

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

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 their reduced mass is μ. 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 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 kinetic energy" of the stream of electrically neutral particles (or bodies) of average mass m, on one hand, and their bare-particle kinetic energy $mv^2/2$ 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 in the QED case

$$s_e = [\int B^2 d\tau/8\pi]/[N'mv^2/2]$$

$$= \{[4e^2J^2/8\pi c^2][\int 2\pi r dr/r^2]\}/\{N'mv^2/2\}$$

$$= [e^2N'^2v^2 \ln((r/R_0)]/[\int 2\pi r dr/r^2]$$

$$= 2N'r_e \ln(r/R_0) \approx 2N'r_e \quad (5)$$

Here J ist the electric current, B 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 set 1.

In general relativity there is also an analog **vxg**/c of the magnetic field vector B, as the field generated from the acceleration of gravity **g** by motion of the particle with velocity **v**. We obtain for the QGD case

$$s'' = s_g = [\int(\mathbf{v}\mathrm{x}\mathbf{g}/c)^2 d\tau/8\pi G]/[N'mv^2/2]$$
$$= \{(4Gm^2N'^2v^2/N'mv^2/2)\int 2\pi r dr/r^2\}/[N'mv^2/2]$$

$$= 2(GN'm/c^2)\ln(r/R_0) \approx 2GN'm/c^2 = N'r_s. \quad (6)$$

Here we introduced the Schwarzschild radius r_s 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'.

The QGD Q1/fN can be easily verified in macroscopic streams of matter in any state of aggregation, both on earth and in cosmos..

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. However, in the non-relativistic limit, this time the infrared exponent □A is replaced by the GQ1/fE infrared exponent

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

where θ is the scattering angle of the particles in the center-of-mass reference system, with **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]

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

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 characteristic center of mass energy of the interaction considered. Note that all virtual phonons must be included, so λ is actually zero and 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 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 $\beta \ll 1$. 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

$$(\varepsilon_1/\Lambda)^{\beta} = (\varepsilon_0/\Lambda)^{\beta}\left[1 + \beta\int_{\varepsilon_0}^{\varepsilon_1}(\varepsilon/\varepsilon_0)^{\beta}\, d\varepsilon/\varepsilon\right] \quad (10)$$

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 then 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 $\phi+\gamma(\varepsilon)$, we obtain the scattering amplitude

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

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 a random phase of this resulting einselected state, which reflects the uncertainty of the moment of graviton emission and the initial phase of the gravitonic mode of the universe, as well as the interaction with the environment, causing decoherence. Therefore, if the incoming beam of particles or matter is described by a plane wave $\exp[i(\mathbf{pr})]$ in units with h,′ =c =1, the scattered spherical wave will be a stochastic mixture

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

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 e completely in favor of q in the integration. The latter has replaced here right away the corresponding summation over **q**, that is originally present.

We obtain for the resulting 2-particle "einselected" state a classically correlated system, a mixture of 2 pure states for each ε,

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

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"

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

$$= 1 + \int_{\varepsilon o}^{\varepsilon 1}|\rho_\varepsilon|^2 d\varepsilon/\varepsilon + \int_{qo}^{q1}|\rho_q|^2\cos[q(r_2-r_1)]dq/q \quad (15)$$

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

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

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 **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

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

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

IV. Discussion

Eq. (18) gives the spectrum of the conventional gravidynamic quantum 1/f effect. This effect, with

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

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. Together with the coherent gravidynamic Q1/fE, it determines the total gravi-dynamic 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 [8] and important in engineering. In general, epistemologically or conceptually, fun-damental 1/f noise is the result of nonlinearity combined with a special type of homogeneity [9], [10].

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