COSMOLOGICAL DARK ENERGY THROUGH NEUTRINO OSCILLATIONS AND QUANTUM MECHANICS

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Abstract.

We argue that the present classical formalism of neutrino oscillations is just approximate (cf. PDG 2006), thus still requiring various second-order corrections : internal kinetic dispersion from internal mass dispersion ; curing Lorentz invariance violation between different mass eigenstates, in transitions of the kind $m_1 \Rightarrow m_2$, through energy shifts $(m_2^2 - m_1^2)/(2p)$, made salient in phase factors ; so, necessary transfers of quadri-impulsion with any medium, even "vacuum" ; so, evidence of ethereal "dark energy" of purely weak essence, within vacuum oscillations ; actual violation of some deeply rooted principles of "quantum mechanics" (corpuscular elementarity, orthogonality of eigenstates amplitudes, Wigner's rules of super-selection, Heisenberg's relations of uncertainty) ; strict non-hermiticity of the Hamiltonian operator, involving finite proper lifetimes ; neutrino mass matrices duly of the "CKM" type, as for quarks ; "ubiquity" concept and existence of "probability waves", instead of matter waves, giving serious credibility to the paradoxical lemma of intense radiation from the vicinity of so-called "black holes"

and "pulsars" (so, faking genuine "white wells"). Spontaneous individual birth of zero-mass neutrinos (not by pairs, from Lorentz invariance !) might explain the paradoxical excess of "dark energy" over "dark mass", overwhelming at cosmological scales.

KEY WORDS : neutrino oscillations, kinematical dispersion, energy shifts, Lorentz invariance, quadri-momentum transfer, orthogonality of amplitudes, non-hermiticity, super-selection rules, relations of uncertainty, dark matter, pulsars, black holes, white wells, probability waves, ubiquity, dark energy.

(I) INTRODUCTION.

The present experimental status of neutrino oscillation, though not yet fully coherent in interpretation, broadly enforces the idea that neutrinos should have masses and display something akin to oscillations, as expected, whatever may be the underlying theoretical mechanisms at stake, the proper number and nature of actual neutrinos.

Change of flavour, indeed, seems to be significantly revealed in results, simultaneously from soft solar and hard atmospheric (cosmic rays) neutrinos, on one side, and still with earth-created reactor neutrinos, in the complementary side [cf. refs. 1 to 9]. However, controversial recent data [10] and quizzical LSND versus KARMEN results cast a shade about relevant interpretations ! The MiniBooNE1 experiment positively concludes that the LSND3 results are incompatible with mere standard oscillation of neutrinos, through some recent announcement [10] (on April 11, 2007, in Press Release from Fermilab).

Some Revision of the formalism may be in order, the more so as the compatibility equation for 3 species of neutrinos, as it seems, cannot really be satisfied : $\Delta m_{12}^2 + \Delta m_{23}^2 + \Delta m_{31}^2 \neq 0$!

So, the simplest neutrino formalism, as in standard usage, indeed, does not seem to be quite relevant. Among possible ways (existence of a fourth species of neutrinos, of sterile ones …), we merely propose an analytical re-examination of the classical formalism, as stated by B. Kayser [1], for instance.

(II) FORMALISM REVISITED

(a) KINETIC MASS DISPERSION

Contrary to the past in the Standard Model, it is now fully admitted that some neutrinos should have masses.

We shall so start from the universally accepted classical statements, as presented in [1]. But for better physical clarity, we shall use matrix notations.

We note : ν_ℓ $(\ell = e , \mu , \tau \ \ldots)$ as the ν flavour (eigen-)states ,

and : M_k $(k = 1 , 2 , 3 \ldots)$ as the ν mass eigenstates, associated.

We condense the flavour states in the vector : $F = {}^t(\nu_e , \nu_\mu , \nu_\tau \ \ldots)$,

and the mass eigenstates in the vector : $M = {}^t(M_1 , M_2 , M_3 \ \ldots)$.

The flavour states are written as linear combinations of the mass eigenstates :

$F = V.M$, where V is the unitary leptonic matrix.

The time evolution for a mass eigenstate M_k, in its very proper rest frame, is obtained through a Shrödinger-like equation, with a hermitian Hamiltonian :

$$M_k(\tau_k) = e^{-im_k\tau_k} M_k(0)$$ (τ_k being the lifetime of M_k in its rest frame)

Thus, in time evolution : $M = \Phi . M(0)$, for the set of eigenstates, with Φ being the unitary diagonal phase matrix :

$$\Phi_{kq} = \delta_{kq} . e^{-im_k\tau_k}) .$$

Now, the phase invariant in Lorentz transformation, from the rest frame to the laboratory frame, is written :

$$\Phi_k = e^{-im_k.\tau_k} = e^{-i(E_k.t - P_k.L)}$$

However, the common ultra-relativistic approximation generalised in [1] :

$E_k = p_k + m^2/(2.p_k)$ cannot be systematically accepted, actually, as being illegitimate in some cases (for soft solar neutrinos ≈ 1- 2 eV, as far as masses of the order of ≈ 1 eV/c^2 are not yet experimentally excluded [8] ; actually, some KATRIN experiment looking for 2 eV/c^2 neutrinos should give results in 2009). Under such reservations, we are lead to the form : $\Phi_k = \exp[-i.m^2_k.L/(2.p_k)]$ defining the diagonal unitary matrix $\Phi(t) = \{\Phi_{kk'} = \delta_{kk'} \Phi_k\}$.

We go then to the laboratory frame for all mass eigenstates, starting from their respective, different, rest frames. According to Kayser [1] , a unique boost might be manageable for all states, using some "average" lab. E energy ≈ $<P_k>$; thus yielding :

$$F(t) = V(t) . M(t) = V(t) . \Phi(t) . V^{-1}(t) . F(0)$$

or, if one likes, $\nu_{\ell}(L) = \Sigma_{\ell'} [\Sigma_k V_{\ell k} . \exp[-im^2_k.L/(2E)] . V^{-1}_{k \ell'}] \nu_{\ell'}(0)$

(using such simpler matrix forms should, now, make things physically obvious).

Clearly, this is just a rough approximation in calculations (in particular, concerning the crucial Φ phase matrix : using distinct Lorentz transformations, corresponding to the various mass eigenstates, results would actually be much less simple and straightforward).

We shall then conclude that a second-order correction is necessary, in the formalism : some kinematic dispersion should still be algebraically added, in the laboratory, to the components of the mass eigenstates, meaning full spatial extension in time for the whole wave function. We shall later discuss physical implications of this practical point, in connection with still further ones.

The deep physical reason is obvious : you cannot have both butter and the money of butter, in handling. As far as you attempt to impose, effectively, internal kinetic scattering through neutrino masses, within the wave function, you must still have to expect full kinematic dispersion, and, thus, physical momentum dispersion of theirs, reflecting it unavoidably! And such spatial opening should be, both, longitudinal and transversal, for observable effects.

(b) "VIOLATION" OF LORENTZ INVARIANCE AND "DARK MATTER"

The formalism supposes possible transitions between mass eigenstates of the type $m_1 \rightarrow m_2$ **, with mass/energy internal shifts, duly expressed in the phase terms, through the squared-mass splittings :**

$$½ (m_2^2 / p_2) - ½ (m_1^2 / p_1) \approx ½ (m_2^2 - m_1^2) / E$$

So, the fundamental squared-mass splitting actually reflects no less than mass shift, or transition, and is thus violating Lorentz invariance, apparently !

That is not at all meaningless or physically exceptional : for instance, the usual γ materialization of energetic photons (> 1 Mev/c), which might seem to violate Lorentz invariance, does actually proceed through direct quadri-momentum transfer with the medium (and so, not in vacuum, of course, where this should be impossible: and indeed, it does not occur… at least for photons !).

So, this formalism is genuinely not manageable for "absolute vacuum" as medium : practicable medium should actually allow energetic transfers to enable neutrino oscillation, for (squared-) mass transitions.

This is new evidence of the existence of some "ethereal dark matter", endowed with necessary "dark energy", within the apparently pure "vacuum" traversed, as far as oscillation does really occur for cosmic neutrinos, as hinted precisely by present experimental data.

This fake vacuum thus acting as medium on ν oscillations, but not in γ materializations, paradoxically, suggests that "dark matter" associated has some "weak nature", ignoring electro-magnetic-interactions, but endowed with weak interactions.

On the other side, this is an extra piece of evidence of some indispensable "kinematical dispersion", within the neutrino wave packet, of physical inference, because of the quadri-momentum transfers involved (and, thus, meant in addition to the kinematical internal dispersion, from mass self-scattering, as above studied).

(c) ORTHOGONALITY OF EIGENSTATES AMPLITUDES

Since effective mass (or energy), in the rest frame, constitutes a physical observable of real stance, it is well known that the corresponding amplitudes for distinct mass eigenstates should absolutely be orthogonal. And so, interference should actually be zero, for no oscillation … as far as the Hamiltonian operator is hermitian, indeed, as duly supposed in the academic treatment, described in [1], and yielding real eigenvalues (real masses) !

Therefore, we must abandon such a usual hermiticity requirement for the Hamiltonian (a priori not at all compulsory!): consequently, mass (or energy) should now be complex in the rest frame, for any eigenstate.

Concretely, finite widths and finite lifetimes should, so, absolutely occur.

Instead of any m_k , as above, we must then have $[m_k - i\,\Gamma_k / 2]$, as Hamiltonian eigenvalue, meaning addition of some relevant Γ_k width.

Accordingly, the lifetimes of the distinct mass (or energy) eigenstates should likewise be finite, and even perhaps small, in the neutrino rest frame ; and so, even though the Lorentz relativity boosting factor, which should usually be extremely large, may still currently simulate infinite neutrino lifetimes, in the "laboratory" frame of the usual world, through any actual observations.

In other words, the non-hermiticity of the Hamiltonian must absolutely be imposed in order to avoid quantic orthogonality of the amplitudes, and thus merely to enable the underlying interference, involving oscillations. And just as actual neutrino "masses", thus resulting in complex quantum derivation, can strictly no longer be regarded as purely real, the overall neutrino mass matrix so developed should, unavoidably, assume a form of the "C.K.M." type, likewise in reflection (henceforth, analogous to the quark mass matrix).

(III) PHYSICAL CONSEQUENCES

The former considerations have various far-reaching consequences, in the physical world.

Quantum Mechanics must, firstly, be reconsidered in its whole, since deeply rooted principles might be violated.

(a) WIGNER'S SUPER-SELECTION RULES , AND CORPUSCULAR ELEMENTARITY

The fundamental concept of particle elementarity is, thus, abandoned for the neutrino. And consequently, the well-known requirement of the so-called Wigner's super-selection rules, in related principle, can no longer apply (any elementary particle should always be an eigenstate of such quantum numbers as mass).

So, standard Quantum Mechanics, in usual classical stance, is violated. More concretely, the kinematical dispersion in time evolution, which has been highlighted at various levels, implies a special fan opening of the quantum wave function, on the whole, at least for neutrinos ; and thus, potentially, an indefinite extension, both longitudinally and transversally.

In the long run, gradual estrangement of components is thus predictable. This point is of the utmost importance, as we shall see.

(b) PROBABILITY WAVES

Accordingly, an extra orthogonality factor between neutrino amplitudes, now from sheer spatial splitting, is therefore imposed to the mass eigenstates. Indeed, since kinetic dispersion implies divergence in motion, on macroscopic scale, progressive space separation of the wave components seems unavoidable, to the point of splitting, eventually meaning irreducible orthogonality.

At first, the interference at stance in the oscillation mechanism should be progressively dampened, from separation of wave packets, thus meaning gradual reduction of the oscillation, and sheer disappearance, in the long run.

Wave components being thus spatially scattered, the very conception of real "MATTER" must be reconsidered : accordingly, we should then have to think in terms of "UBIQUITY" and "PROBABILITY WAVES", rather, instead of "matter waves".

This result could somehow stand fundamental in the field of "QUANTUM GRAVITY".

Far from being misleading at all, indeed, it might even provide some possible paradoxical interpretation to the amazing sheer radiation from the vicinity of some so-called "black holes", as cosmologically suggested : indeed, some part of the probability waves can accordingly fall into a black hole, whereas another part might paradoxically still avoid it (through accretion, possibly), thus seriously faking a "white well", intensely radiating.

Similar considerations, obviously, might still be applied to various "pulsars", or "neutron stars", which are said to be intensely radiating, possibly emitting ultra-high energy cosmic rays, although they are patently gravitational prisons. Indeed, even an extremely high magnetic field ($\approx 10^8$ Tesla), occasionally, rotating like a dynamo, should not possibly arouse such radiations from (neutronic) "neutral matter" (whatever has been said) :

and so, not because of insufficiency of the electric field thus created, but because there is nearly nothing to extract! If it could, through unlikely ionisation of neutronic matter inside the "pulsar", the acceleration energy obtained would be drastically diminished in extraction, by the paramount gravitational energy, first to be vanquished.

NOTA. In practice, such a phenomenon of "ubiquity", through splitting in probability waves, also presents an enormous advantage on the experimental ground, since it implies finite probability transitions, definitely, from dampening oscillations. Formerly, indeed, practical study was hugely impeded by the "infinitesimal" character of transition probabilities in neutrino oscillations, often to be theoretically expected.

(c) HEISENBERG'S RELATIONS OF UNCERTAINTY

Neutrinos should however be close to elementarity in structure, admittedly, in any case, although not being quite standard particles, strictly speaking, in the spirit of Wigner's early quantum mechanics.

Therefore, neutrinos should have a restricted number of internal freedom degrees (N). Accordingly, genuine Heisenberg's relations of uncertainty should still strictly apply in symbolic form, involving equalities of the kind :

$$\Delta p.\Delta x = N.\hbar/2$$ **(where N is small, as an integer number).**

Accordingly, such a product must keep finite, a priori, and even severely restricted by such majoration. However, this statement looks quite paradoxical, since it clearly contradicts expectations of our framing views. And indeed, we have seen that there must be indefinite spatial opening of the wave (turning to "probability waves", in the long run), in the regular case.

Because of the various dispersion kinematical terms (as highlighted), the Δp kinetic uncertainties should still keep at least finite, whereas the Δx terms of spatial extension must necessarily keep growing in time (but not indefinitely, however, because of finite proper lifetimes, as we saw). So, the product, being almost ever increasing, should eventually get exceedingly large, then violating the former bond.

And so, obviously, Heisenberg's relations of uncertainty must be strongly violated, in their genuine form !

Such a statement is merely an unavoidable reflection of the release of Wigner's elementarity, for neutrinos. It is the main conceptual source for the physical "ubiquity" axiom, and probability waves.

(IV) CONCLUSION.

On the whole, Quantum Mechanics must be fully reconsidered, with the advantage of regularly accounting for various intense, otherwise paradoxical, radiations reported from the vicinity of some "black holes" and "pulsars".

For instance, quite intense X radiations have been duly reported from some black holes labelled "GRO J1655-40" (in Scorpius) and "Cygnus X-1" (in Cygnus), both located at about 8000 ly, with still amazing jets of matter at quite relativistic velocities, observed and attributed to the former one [11].

(a) DARK MATTER

In summary, some points of the classical neutrino oscillation formalism, as stated in [1], have been discussed. We conclude that various corrections of second-order should be added, as it seems ; then, extra kinematical dispersion, in particular, should somewhat disturb experimental predictions.

We also conclude that the Hamiltonian operator can by no way be kept hermitian, and that apparent violation of Lorentz invariance, through mass transitions, should unavoidably reflect some kinematical exchanges (of quadri-momentum) through crossing of the medium, whatever it may be, even the so-called "vacuum", thus seen as spurious.

In this way, we find thus still direct evidence for the presence and action of some necessary ethereal "dark energy", be it massive or massless, in "vacuum" oscillations, and weakly interacting with neutrinos (but not with photons, for lack of γ materializations, and thus probably devoid of any possible electro-magnetic interactions).

Although uneasily accountable in the common physical frame, because of the enormous Lorentz relativistic boosting factor, finite proper lifetimes, as well as finite widths, are still predictable for oscillating neutrinos, in the rest frames. And accordingly, the neutrino mass matrix should be of the "C.K.M." quark type.

Most importantly, we arrive at the necessary concept of "UBIQUITY", clearly supported by various observational evidences , meaning "probability waves", occasionally splitting, instead of standard "matter waves".

(b) DARK ENERGY

What about "dark energy", that is nowadays quite precisely estimated, and said to be more than three times larger than "dark mass" ? That is amazing : because they should be almost undistinguishable from each other, at first, merely on mechanical grounds in standard views. Conversely, if "dark mass" were included in "dark energy", as it is natural, the ratio would even get larger than four !

Indeed, restricting ourselves to Special Relativity, as in the limited scope of our Milky Way, it is obvious that there values should be nearly identical (up to pointless normalization factors), as far as isotropy in radiation/diffusion is supposed, meaning zero momentum on the whole: $M^2 = E^2 - P_{av}{}^2 = E^2$ **, so** $M \cong E$ **(??).**

Now, on cosmological scale, from red-shift inferences, there is obviously a paramount loss of energy, in furtherance. However, such "dark energy" in excess looks quite quizzical on its own, leading to a real fundamental dilemma. Indeed, we can either admit that energy, merely, is not at all conserved, in actual facts, which is perfectly natural in General Relativity … or not ! with still some conservative spirit (that seems to prevail almost unanimously !), and that energy conservation must still be enforced at any price. But then, "dark energy" should get still much more elusive than "dark matter", and largely independent of it !

Indeed, lengthening of the photon wavelength, according to the Hubble expansion law, associated to cell dilation, leads to some $1/R^4$ decrease of energy density for photon, and roughly similar decrease should occur, for instance, for neutrinos … and even for the gravitational linking energy between all galaxies. So, why maintaining energy conservation in a non-Euclidean cosmic world ? Axiomatically, there is no forcible or practical reason for it !

The point is that it might be as difficult to distinguish both concepts in General Relativity as in Special Relativity : for instance, the usual Robertson-Walker metric, for any isotropic diffusion of materially vectorized energy loss, would likewise maintain such a strict identity/equivalence between mass and energy, be it "dark" or not.

In any case, beyond the simple "loss" status, authentic "dark energy" cannot properly exist without some kind of support, be it particle vector or not ; so that it must absolutely be localized beyond "dark mass" itself. Therefore, we propose an elusive vector as a solution, empirically quite invisible in the usual approaches, but still endowed with proper "dark" energy : it has the advantage of reconciling both viewpoints (be it the genuine energy conservation in elusive form ; or conversely, non-classical energy loss and so non-conservation).

Then, spontaneous creation of just individual neutrinos (not by pair !), occurring through cosmic friction, might be the real case : their individual mass should thus be zero, or so (necessarily, because of local Lorentz invariance), their momentum being finite, anyhow, thus in retrieval of the paramount excess of "dark energy" over "dark mass", as expected. Now, their zero masses would supposedly escape gravitational effects, being therefore unaccountable as dark mass, while constituting some part of the "ethereal dark matter" at stake, as above studied.

Remark. Actually, the usual hypothesis of cosmic pair creation of neutrinos, with opposite momenta, is now absolutely discarded, as necessarily violating local Lorentz invariance, in any case.

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