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Frederic Henry-Couannier

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## DISCRETE SYMMETRIES AND GENERAL RELATIVITY, THE DARK SIDE OF GRAVITY

FREDERIC HENRY-COUANNIER

*CPPM, 163 Avenue De Luminy, Marseille 13009 France.  
 henry@cppm.in2p3.fr*

Received ..

Revised ..

The parity, time reversal and space/time exchange invariant actions, equations and their conjugated metric solutions are obtained in the context of a general relativistic model modified in order to take into account discrete symmetries. The equations are not covariant however the predictions of the model, in particular its Schwarzschild metric solution in vacuum, only start to differ from those of General Relativity at the Post-Post-Newtonian order. No coordinate singularity (black hole) arises in the privileged coordinate system where the energy of gravity is found to vanish. Vacuum energies cancel as gravitational sources and a flat universe accelerated expansion phase is obtained without resorting to inflation nor a cosmological constant. The Pioneer anomalous blue-shift is a straightforward outcome. The context is promising to help us elucidate several outstanding enigmas such as flat galactic rotation curves or the universe voids. A wave solution is obtained leading to the same binary pulsar decay rate as observed and predicted in GR.

*Keywords:* Negative energy; time reversal, tachyon.

### 1. Introduction

We might summarize the point of view developed in Ref. 1 as follows: any physicist would agree that symmetries are fundamental in contemporary physics. They both allow to constrain the form assumed by the actions and the properties of the basic objects such as fields from which the actions are built and the phenomenology is derived. If we miss some fundamental symmetry of mother nature or misunderstand the way it works, the physical world description we will derive might be either totally wrong or in the best case incomplete. As is well known, a discrete operator such as the time reversal one in Quantum Field Theory may be either unitary or anti-unitary. The anti-unitary choice for it is the conventional one, and the commonly accepted derived picture undoubtedly constitutes an important part of our culture. However, our starting point in Ref. 1 was to take serious the other mathematical possibility for the time reversal operator, e.g. that it be unitary and see how far we could follow this theoretical option. Then a very different conception of time reversal arises together with negative energy fields. However, at some point we found that

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there is no way to reach a coherent description in flat space-time. But fortunately, we know that the complete picture should include gravity and this, as we shall show, naturally allows us to achieve our primary goal: understand time reversal and by the way the negative energy representations of the Lorentz group. The reader is referred to Ref. 1 for our investigation of negative energies and time reversal restricted to QFT in flat space-time but an interesting analysis can also be found in Ref. 2.

## 2. Negative Energies in Quantum Field Theory

Let us gather the main information we learned from our investigation in Ref. 1 of negative energies in Relativistic QFT indicating the the correct theoretical framework for handling them should be found in a modified GR.

- Theoretical Motivations

In second quantification, all relativistic field equations admit genuine negative energy field solutions creating and annihilating negative energy quanta. Unitary time reversal links these fields to the positive energy ones. The unitary choice, usual for all other symmetries in physics, also allows us to avoid the well known paradoxes associated with time reversal. Positive and negative energy fields vacuum divergences we encounter after second quantization are unsurprisingly found to be exactly opposite. The negative energy fields action must be maximised. However, there is no way to reach a coherent theory involving negative energies in flat-spacetime. Indeed, if positive and negative energy scalar fields are time reversal conjugated, also must be their Hamiltonian densities and actions. This is only possible in the context of GR thanks to the metric transformation under discrete symmetries.

- Phenomenological Motivations

In a mirror negative energy world whose fields remain non coupled to our world positive energy fields, stability is insured and the behavior of matter and radiation is as usual. Hence, it is just a matter of convention to define each one as a positive or negative energy world. Otherwise, If they interact gravitationally, promising phenomenology is expected. Indeed, many outstanding enigmas indicate that repelling gravity might play an important role in physics: flat galactic rotation curves, the Pioneer effect, the flatness of the universe, acceleration and its voids, etc... But negative energy states never manifested themselves up to now, suggesting that a barrier is at work preventing the two worlds to interact except through gravity.

- A Modified GR to Circumvent the Main Issues

A trivial cancellation between vacuum divergences is not acceptable since the Casimir effect shows evidence for vacuum fluctuations. But the positive and negative energy worlds could be maximally gravitationally coupled in such a way as to produce at least exact cancellations of vacuum energies gravitational effects. Also, a generic catastrophic instability issue arises whenever quantum positive and negative energy fields are allowed to inter-

act. If we restrict the stability issue to the modified gravity, this disastrous scenario is avoided. Finally, allowing both positive and negative energy virtual photons to propagate the electromagnetic interaction, simply makes it disappear. The local gravitational interaction is treated very differently in our modified GR so that this unpleasant feature is also avoided.

- Outlooks

A left-handed kinetic and interaction Lagrangian can satisfactorily describe all known physics (except mass terms which anyway remain problematic in modern physics). This strongly supports the idea that the right handed chiral fields might be living in another world (where the 3-volume reversal under parity presumably would make these fields acquire a negative energy density) and may provide as shown in Ref. 1 an interesting explanation for maximal parity violation observed in the weak interaction.

If the connection between the two worlds is fully reestablished above a given energy threshold, then loop divergences naturally would get cancelled thanks to the positive and negative energy virtual propagators compensation. Such reconnection might take place through a new transformation process allowing particles to jump from one metric to the conjugated one presumably at places where the conjugated metrics meet each other.

### 3. Conjugated Worlds Gravitational Coupling

From Ref. 3 we learn that if a discrete symmetry (Parity or/and Time reversal) transforms the general coordinates, this will not affect a scalar action however if the inertial coordinates  $\xi^\alpha$  are also transformed in a non-trivial way:

$$\xi^\alpha \rightarrow \tilde{\xi}^\alpha, \quad (1)$$

non-trivial in the sense that in general  $\tilde{\xi}^\alpha \neq \xi^\alpha$ , our metric terms will be affected and our action is not expected to be invariant under P or T. Having two conjugated inertial coordinate systems, we can build, following the usual procedure, two discrete symmetry reversal conjugated metric tensors:

$$g_{\mu\nu} = \eta_{\alpha\beta} \frac{\partial \xi^\alpha}{\partial x^\mu} \frac{\partial \xi^\beta}{\partial x^\nu}, \quad \tilde{g}_{\mu\nu} = \eta_{\alpha\beta} \frac{\partial \tilde{\xi}^\alpha}{\partial x^\mu} \frac{\partial \tilde{\xi}^\beta}{\partial x^\nu}. \quad (2)$$

This means that there exists a coordinate system where the discrete symmetry applies in the trivial way (for instance  $x^0 \rightarrow -x^0$  in case of time reversal) transforming the conjugated metrics into one another. We postulate that this coordinate system is such that  $\tilde{g}_{\mu\nu}$  identifies with  $g^{\mu\nu}$ , a non covariant relation making this frame a privileged one. Then, we should distinguish between those fields following the geodesics of  $\tilde{g}_{\mu\nu}$  and the others following the geodesics of  $g_{\mu\nu}$ . We first build the total action: sum of usual  $I_{RG}$  and the new conjugated one  $\tilde{I}_{RG}$ . The conjugated actions are separately general coordinate scalars and adding the two pieces is necessary to obtain a discrete symmetry reversal invariant total action. In this system, varying our action, applying the extremum action principle and making use of the

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relation  $\delta g^{\rho\kappa}(x) = -g^{\rho\mu}(x)g^{\nu\kappa}(x)\delta g_{\mu\nu}(x)$  would lead us to a modified Einstein equation (with  $c = 1$ ) :

$$-8\pi G \left( \sqrt{g(x)}T_{\rho\sigma} - \sqrt{g^{-1}(x)}\tilde{T}^{\rho\sigma} \right) = \sqrt{g(x)} \left( R_{\rho\sigma} - \frac{1}{2}g_{\rho\sigma}R \right) - \sqrt{g^{-1}(x)} \left( R^{\rho\sigma} - \frac{1}{2}g^{\rho\sigma}R \right) \Big|_{g^{\rho\sigma} \rightarrow g_{\rho\sigma}, g_{\rho\sigma} \rightarrow g^{\rho\sigma}}. \quad (3)$$

This equation, only valid as it stands in our privileged working coordinate system, is not general covariant and not intended to be so. Indeed, it follows from both an extremum principle of our general covariant and discrete symmetry invariant action and a noncovariant relation between one metric and its discrete symmetry reversal conjugated. The straightforward interpretation of the Left hand side is that fields living in the reversed metric world are seen from our world as negative energy density fields but living in the conjugated metric prevents them from interacting with our world fields except through gravitation. However coupling in this traditional way metric fields with matter and radiation fields assumes implicitly that we treat and understand in the same way both directions of the bidirectional talk between matter and gravity. We shall show why this is not always possible and in general (there will be a noticeable exception) will give up the matter action, keeping only the purely gravitational action  $I_G + \tilde{I}_G$ . The derived equation is neither unic nor valid in such a general form as above. Indeed, symmetry requirements will a priori determine two possible simplified forms for the conjugate metrics in the privileged coordinate system.

#### 4. Isotropy and Space/Time Exchange

The isotropy condition for both conjugated metrics determines their general form:

$$d\tau^2 = B(r, t)dt^2 + A(r, t)dx^2, \quad d\tilde{\tau}^2 = \frac{1}{B(r, t)}dt^2 + \frac{1}{A(r, t)}dx^2. \quad (4)$$

We now want to investigate the space/time exchange symmetry in order to understand the tachyonic Lorentz group representation. Indeed, the natural symmetry linking tachyons to bradyons is the transformation reversing the metric signature, hence, following Ref. 11 12 13 transforming space-like coordinates into time-like ones (we call it x/t symmetry). This can be achieved by Wick rotating them and leads us to introduce the flipped signature conjugated metric:  $\hat{g}_{\mu\nu}(r, t) = -g_{\mu\nu}(r, t)$ . More generally, it is natural to allow our metrics to be complex, the phases corresponding to rotations in the complex plane continuously transforming into one another these conjugated metrics. The trivial B=A=C Euclidian form manifestly involves time and space coordinate in a symmetrical way, whatever the function C(r,t):

$$d\tau^2 = C(r, t) (dt^2 + dx^2), \quad (5)$$

$$d\tilde{\tau}^2 = \frac{1}{C(r, t)} (dt^2 + dx^2). \quad (6)$$

But in general we really need the inverse metric to restore the space/time symmetry. Indeed, the most general expression being

$$d\tau^2 = C(r, t) \left( \frac{1}{A(r, t)} dt^2 + A(r, t) dx^2 \right), \quad (7)$$

$$d\tilde{\tau}^2 = \frac{1}{C(r, t)} \left( A(r, t) dt^2 + \frac{1}{A(r, t)} dx^2 \right). \quad (8)$$

only the presence of  $C(r, t)$  breaks down the space / time symmetry so that in general, as we already noticed, such term is not allowed and the conjugated metrics verify  $A(r, t) = B^{-1}(r, t)$ . However, in the special case where A is a pure phase with angle:  $\theta(r, t) = \pi/2$  it is possible to keep the  $C(r, t)$  term and respect the space/time symmetry thanks to the opposite conjugated metric  $\hat{g}_{\mu\nu}(r, t) = -g_{\mu\nu}(r, t)$ . Then we have four conjugated metrics:

- $g_{\mu\nu}$
- $\tilde{g}_{\mu\nu} = g_{\mu\nu}^{-1}$
- $\hat{g}_{\mu\nu} = -g_{\mu\nu}$
- $\tilde{\hat{g}}_{\mu\nu} = \hat{g}_{\mu\nu}$

Explicitely:

$$\begin{aligned} d\tau^2 &= C(r, t) [dt^2 - dx^2] \\ d\tilde{\tau}^2 &= \frac{1}{C(r, t)} [dt^2 - dx^2] \\ d\hat{\tau}^2 &= C(r, t) [dx^2 - dt^2] \\ d\tilde{\hat{\tau}}^2 &= \frac{1}{C(r, t)} [dx^2 - dt^2] \end{aligned}$$

Thus we could show that appart from the trivial B=A form we only have two kinds of metrics: the "euclidian" ones satisfying B=1/A and the Minkowskian ones with B=-A. Of course, in the above formula, thanks to an additional global  $\theta = \pi/2$  phase, C(r,t) thus the Minkowskian metric can be real. Therefore, in case the metric elements are pure phases, the inverse metric is nothing but the complex conjugated metric and a first  $\theta = \pi/2$  phase rotation can transform the Euclidian into imaginary Minkowskian ones which under the additional  $B = A = C(r, t) = 1/i$  phase rotation reduce to our two real space/time conjugated stationary worlds.

$$\begin{aligned} d\tau^2 &= d\tilde{\tau}^2 = [dt^2 - dx^2] \\ d\hat{\tau}^2 &= d\tilde{\hat{\tau}}^2 = [dx^2 - dt^2] \end{aligned}$$

Then, if we allow modulus terms, two couples of time reversal conjugated non-stationary worlds will emerge as we shall show. We will thus have conjugated tachyonic/bradyonic worlds as well as positive/negative energy worlds.

## 5. The Complex Metrics and their Variations

In the following sections we will require that either the metric elements are a priori linked by  $A(r, t) = -B(r, t)$  or  $A(r, t) = B^{-1}(r, t)$  so that a single degree of freedom

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eventually remains and we shall investigate the form of its solution in each case. The metric elements being related can no longer be varied independently. Therefore, given any tensor  $T_{\mu\nu}$  and for real metric elements making use of  $\frac{\delta g_{i'i'}}{\delta g_{ii}} = \frac{g_{i'i'}}{g_{ii}}$  and  $\frac{\delta g_{tt}}{\delta g_{ii}} = \frac{g_{tt}}{g_{ii}}$  in case B=-A, a typical action variation will be proportional to a scalar trace:

$$\delta g_{rr} T^{rr} + \delta g_{tt} T^{tt} + \delta g_{\theta\theta} T^{\theta\theta} + \delta g_{\phi\phi} T^{\phi\phi} = \frac{\delta g_{rr}}{g_{rr}} T$$

while in case B=1/A,  $\frac{\delta g_{i'i'}}{\delta g_{ii}} = \frac{g_{i'i'}}{g_{ii}}$  and  $\frac{\delta g_{tt}}{\delta g_{ii}} = -\frac{g_{tt}}{g_{ii}}$  and the additional minus sign gives us a modified trace:

$$T_{B=1/A} = g_{rr} T^{rr} + g_{\theta\theta} T^{\theta\theta} + g_{\phi\phi} T^{\phi\phi} - g_{tt} T^{tt}$$

But in case the metric is complex, so are the variations. The real and imaginary parts of the variation will generate two independent equations. The previous treatment applies to the modulus for a real variation but not an imaginary one if we want to keep the inverse relation between conjugate metrics. In this case we also need the relation between the relative real variations of the (inverse) conjugate metrics needed to obtain the gravitational equation in term of the components of a single metric:  $\frac{\delta \tilde{g}_{xx}}{g_{xx}} = -\frac{\delta g_{xx}}{g_{xx}}$

For a pure phase instead, the variation can be the purely imaginary one if we define the conjugate metric to be the complex conjugated one. Then, the conjugate metric variations are opposite in such a way that  $\delta \tilde{g}_{xx} = -\delta g_{xx}$  and  $\delta g_{i'i'} = \delta g_{ii} = \pm \delta g_{tt}$  for phase metrics for B=-A and B=1/A respectively. Eventually, we will find ourselves with two equations of gravity: one for the modulus and one for the phase in both cases. The moduli describe homogeneous and isotropic backgrounds for both conjugate metrics which necessarily implies their spatial flatness and r independence. The phases describe the perturbations over this background. The conjugate metric solutions should transform into one another under  $r \rightarrow -r$  and  $t \rightarrow -t$ .

## 6. B=1/A, The Phase: The Schwarzschild Solution

With B=1/A pure phase metric elements, defining g to be the modulus of the metric determinant, its squareroot simplifies and we obtain the following equation in vacuum:

$$R_{B=1/A} - \tilde{R}_{B=1/A} = 0$$

with  $\tilde{R} = R_{A \rightarrow 1/A}$ . This yields:

$$4 \frac{A''}{A} - 4 \left( \frac{A'}{A} \right)^2 + 8 \frac{A'}{Ar} = 0$$

We easily get the unic static phase solution

$$1/B = A = e^{\frac{2iMG}{r}} \quad (9)$$

This euclidian metric is not appropriate to get the geodesics followed by test masses. Rather should we first perform a Wick rotation of the spatial coordinates  $r \Rightarrow ir$  to obtain the real Minkowskian metric with components B, -A satisfying:

$$\Rightarrow A = e^{\frac{2MG}{r}} \approx 1 + 2\frac{MG}{r} + 2\frac{M^2G^2}{r^2}, \quad (10)$$

$$\Rightarrow B = \frac{1}{A} = e^{-\frac{2MG}{r}} \approx 1 - 2\frac{MG}{r} + 2\frac{M^2G^2}{r^2} - \frac{4}{3}\frac{M^3G^3}{r^3}. \quad (11)$$

different from the GR one though in good agreement up to Post-Newtonian order. No black hole type singularity arises in our isotropic system. The phenomenology is simple: objects living in the same metric attract each other. Objects living in different metrics repel each other, as if the object living in the conjugate metric contributes as a negative energy source from the point of view of our metric. The conjugate metrics can be transformed into one another through  $r \rightarrow -r$  or  $M \rightarrow -M$ . We could show in Ref. 1 that a left-handed Lagrangian could satisfactorily describe all known physics (at least kinetic and interaction terms) and provide an interesting explanation for maximal parity violation. This strongly supports the idea that the right handed chiral fields are living in another metric and acquire thanks to the 3-volume reversal a negative energy density. Eventually, because the solution is unpropagated in the privileged coordinate system (was Newton right ?) the usual stability issues reviewed in Refs. 5–8 are avoided. The instability is usually seen in the phenomenology of a positive energy mass interacting with a negative energy mass through an interaction propagated by positive energy virtual interaction particles. The negative energy object is being attracted by the positive energy object, the latter being repulsed by the former. They then accelerate together for ever this resulting in an obviously instable picture. But here the gravitational interaction of two masses living in different metrics exhibits no such instability since they just repel each other. Yet, from the point of view of one of the two metrics, this is really the interaction between a positive energy mass and a negative energy mass.

Postulating the existence of many comoving coordinate systems, each system being defined relative to its source with the gravitational interaction being instantaneous only in the source frame is expected to potentially generate severe causality violations. Thus, may be we should prefer considering that there exists a unic privileged coordinate system (for instance the one where the CMB appears isotropic). But there are still many possible isotropy centers and in each one we would apply the above treatment to get its Schwarzschild solution in a static form even for a moving source relative to the privileged system (as if we were taking a photo and considering that the stationary picture we get is all we need to derive the solution). But then another issue is the impossibility to span 3d-space with isotropic elementary volumes so that having determined the energy momentum tensor of a source distribution inside a given (necessarily non isotropic) 3d-space cell and computed its trace, we must recover isotropy by postulating that this source cell trace con-



tribution is concentrated in a point. We thus have two modes of spacetime: the continuous one where we shall have to define an energy momentum tensor for our sources and a discret one allowing to get our Schwarzschild solution for each individual cell. Eventually, in the privileged coordinate system we can divide any source distribution into cells having a mass point source (isotropic and static) behaviour where the above Schwarzschild treatment always applies in vacuum.

We can compute gravitational energy following the standard method using the pseudo-energy momentum tensor. It vanishes for each individual metric solution thanks to the relation  $B=1/A$  in the privileged coordinate system. However the pseudo energy-momentum tensor does not happen to be meaningful out of the privileged coordinate system. Indeed, in our framework this object is not even a Lorentz tensor. Combining multiplicatively the various euclidian metrics (this is strongly suggested by the exponential form of the solution) before getting by an additional Wick rotation the final Minkowskian metric preserves in any case the relation  $B=1/A$  in vacuum (out of the discrete network of pointlike sources) satisfied by the final solution and insures that there is no gravitational energy even for an extended perfectly continuous matter and radiation distribution. The weak equivalence principle is obviously not menaced since once the metric field solution is established, matter and radiation will have to follow its geodesics as in GR. But, because of the non covariance of our equation, a violation of the strong equivalence principle arises at the PPN level for a point-like source. For an extended distribution, gravitational energy, since it vanishes, of course falls in the same way as any other form of energy in a gravitational field and this case does not menace the strong equivalence principle more than in the point-like source case.

Also our metric solution can still (as in GR) be exported by a Lorentz transformation into any frame moving at constant velocity relative to the privileged frame so that this transformation alone should not introduce any additional discrepancy with GR. If any, violations of local lorentz invariance only arise in the form taken by the metric in the initial privileged coordinate system where even for a moving source the metric is diagonal (no expected gravitomagnetism effect in the privileged frame where the source is moving but after Lorentz transformation gravitomagnetism arises in the source comoving frame!). At last, let us stress that the Post-Newtonian formalism considering extended source distributions and propagated metric solutions does not apply here.

## 7. $B=-A=h$ : The Phase: Gravitational Waves

The metric a priori takes the form:

$$d\tau^2 = h(r, t) [dx^2 - dt^2]$$

$$d\tilde{\tau}^2 = h^*(r, t) [dx^2 - dt^2]$$

And the left hand side of our modified Einstein equation yields:

$$R - \tilde{R} = 6 \left( h'' - \ddot{h} + 2\frac{h'}{r} - h'^2 + \dot{h}^2 \right)$$

Then, we easily obtain the evolution equation for  $h$ :

$$6 \left( \square^2 h + \dot{h}^2 - h'^2 \right) = n\pi G \delta T$$

For a generic impulse source term  $\delta T = \frac{\delta(r)\delta(t)}{A}$ ,  $h(r,t)$  is the classical plane wave solution of  $\square^2 h(r,t) = n\pi \frac{G}{6} \delta(r)\delta(t)$  making  $\dot{h}^2 - h'^2$  vanish so that the energy carried by the wave is not a source for gravity. As required, the conjugate metrics transform into one another through time and space reversal. Any linear and normalised superposition of such plane waves is also solution of the equation except on small space-time scales relative to the wavelength where the superposition of an ingoing and outgoing waves with the same frequency produces a Zitterbewegung of  $\dot{h}^2 - h'^2$ , a perturbation appearing as a source term in the moduli equation and suspected to be at the origin of the birth of times: the birth of a couple of time reversal conjugated universes which scale factors are the evolving moduli as we shall show in a next section.

We shall now show that we predict the same energy lost through gravitational waves radiation of the binary pulsar as in GR in good agreement with the observed decay of the orbit period. We follow Weinberg's computation of the power emitted per unit solid angle and adopt the same notations. For any extended non relativistic source the solution is the retarded potential:

$$h(x, t) = n\pi \frac{-G}{4\pi} \frac{1}{6} \int d^3x' \frac{\delta T_{00}(x', t - |x - x'|)}{|x - x'|}$$

The radial momentum component of our gravitational wave energy momentum tensor reads:

$$T_{r0} = \frac{1}{n\pi G} \sum_{\sigma=0,3} \frac{\partial R}{\partial \left( \frac{\partial A_\sigma}{\partial r} \right)} \frac{\partial A_\sigma}{\partial t} = \frac{1}{n\pi G} \frac{\partial R}{\partial \left( \frac{\partial h}{\partial r} \right)} \frac{\partial h}{\partial t}$$

where,

$$\forall \sigma, A_\sigma = h = \sum_{\omega, k} h(\omega, k) e^{i(\omega t - kr)} + h^*(\omega, k) e^{-i(\omega t - kr)}$$

$$\langle T_{r0}(\omega, k) \rangle = \frac{6}{n\pi G} (-2) \langle h' \dot{h} \rangle_{\omega, k} = \frac{6}{n\pi G} 4\omega^2 |h(\omega, k)|^2$$

Thus the power emitted per unit solid angle in the direction  $k$  is:

$$\begin{aligned} \frac{dP}{d\Omega}(\omega, k) &= r^2 \langle T_{r0}(\omega, k) \rangle = r^2 \frac{24}{n\pi G} \omega^2 |h(\omega, k)|^2 \\ &= \frac{dP}{d\Omega}(\omega, k) = 24 \frac{\omega^2}{n\pi G} \left( n\pi \frac{-G}{4\pi} \frac{1}{6} \right)^2 \delta T_{00}^2(\omega, k) \\ &= \frac{n}{24} \frac{\omega^2 G}{\pi} \delta T_{00}^2(\omega, k) \\ &= \frac{2}{\pi} G \omega^2 \delta T_{00}^2(\omega, k) \\ &= \frac{G \omega^6}{2\pi} k_i k_j k_l k_m D_{ij}(\omega) D_{lm}(\omega) \end{aligned}$$

Where  $n$  has been given the numerical value 48 taking account of the fact that in the Newtonian limit our equation  $6\Box^2 h = 48\pi G\delta T$  must give again  $\nabla^2 g_{00} = -8\pi GT_{00}$  (the same straightforward reasoning allows to determine  $n$  in all the other gravitational equations of the theory!). Then following Weinberg, we may write in terms of the moment of inertia Fourier transforms in the observer coordinate system:

$$P = \frac{2}{15}G\omega^6 \left[ (D_{ii}(\omega))^2 + 2D_{ij}(\omega)D_{ij}(\omega) \right]$$

$$P = \frac{2}{15}G\omega^6 12D_{11}^2(\omega)$$

For a rotating body with angular speed  $\Omega$ , equatorial ellipticity  $e$ , moment of inertia  $I$  in the rotating coordinates,  $\omega = 2\Omega$ ,  $D_{11}(\omega) = \frac{eI}{4}$  and the radiated power reads:

$$P = 2\frac{12}{15}G64\Omega^6 e^2 \frac{I^2}{16} = \frac{32}{5}G\Omega^6 e^2 I^2$$

as in General Relativity. The main difference is that our gravitational wave is found to propagate pure monopole modes linked by  $-g_{00} = g_{11} = g_{22} = g_{33} = A$ . But these cannot be excited independently whatever the source configuration since we have the single degree of freedom  $A(r,t)$ . Quantifying the  $h$  field must generate a new gravitational propagated interaction in addition to the Schwarzschild non propagated solution we obtained in the previous section. We cannot add its potential to the exponential Schwarzschild one since these would severely conflict with observations. Thus the two solutions do not cohabit. Rather the Schwarzschild solution is valid up to a critical distance (related to the value of the quantum of gravitational energy carried by the waves) where the other one takes over.

## 8. B=-A: The Modulus: Cosmology

The gravity for moduli, i.e. global gravity (this is cosmology) only depends on time. Indeed, there also exists a global privileged coordinate system where a couple of time reversal conjugated purely time dependent solutions can be derived from a new couple of conjugated actions. The existence of a time reversal conjugate universe was also suggested a long time ago in Ref. 8. Notice that even if we did not impose the B=-A condition, the only possible privileged coordinate system with both metrics spatially homogeneous and isotropic would be a flat Cartesian one. When B=-A, our equation for gravity now reads:

$$\sqrt{A^4}R - \frac{1}{\sqrt{A^4}}\tilde{R} = 0$$

with  $\tilde{R} = R_{A \rightarrow 1/A}$ . For a cosmological homogeneous source we will get purely time dependent background solutions and can keep only the time derivatives leading in the cold-cold regime to:

$$3A \left( -\frac{\ddot{A}}{A} + \frac{1}{2} \left( \frac{\dot{A}}{A} \right)^2 \right) - \frac{3}{A} \left( \frac{\ddot{A}}{A} - \frac{3}{2} \left( \frac{\dot{A}}{A} \right)^2 \right) = 0$$

The solutions such that the right hand side always vanishes describe worlds where only light can live (null trace). Its trivial  $A=1$  stationary solution thus describes a self conjugated light world. A mass perturbation  $\delta(t)$  (as a superposition of ingoing and outgoing GW) is needed for the birth of times to take place and see a couple of universes start evolving. The background matter worlds have simple evolution laws in the particular ranges  $A \ll 1, A \approx 1, A \gg 1$ . Indeed, the scale factor evolution is then driven (here nondimensional time unit is used) by the following differential equations in the three particular domains:

$$a \ll 1 \Rightarrow \ddot{a} \propto \frac{3 \dot{a}^2}{2 a} \Rightarrow a \propto 1/t^2 \text{ where } t < 0, \quad (12)$$

$$a \approx 1 \Rightarrow \ddot{a} \propto \frac{\dot{a}^2}{a} \Rightarrow a \propto e^t, \quad (13)$$

$$a \gg 1 \Rightarrow \ddot{a} \propto \frac{1 \dot{a}^2}{2 a} \Rightarrow a \propto t^2 \text{ where } t > 0. \quad (14)$$

We can check that  $t \rightarrow -t$  implies  $1/t^2 \rightarrow t^2$  but also  $e^t \rightarrow e^{-t}$  thus  $A \rightarrow 1/A, B \rightarrow 1/B$  when  $t$  reverses as required. Let us stress that the couple of cosmological metric solutions does not imply any local gravitational interaction between objects but only a global one between the two conjugated universes as in Ref. 9. A striking and very uncommon feature is that the evolution of the scale factor is mostly driven by the gravitational energy exchange between the coupled universes almost independently of the universes matter and radiation content. In particular, the observed flatness can no longer be translated into the usual estimation  $\Omega_m = 1$  from the WMAP data. The  $t^2$  evolution is one of the very few possibilities. Thus, we are most probably living in a constantly accelerating universe. Our and the conjugated universe crossed each other and time reversal occurred at their birthtime. At last, not only our universe is accelerated without any need to a cosmological constant or dark energy component but it is flat and undergoes a primordial exponential acceleration without inflation. The vanishing of cosmological constant terms provided

$$d^4 \xi(x) \Lambda = d^4 \tilde{\xi}(x) \tilde{\Lambda}. \quad (15)$$

appears to be only a local issue (for our Schwarzschild solution)

## 9. $B=1/A$ : The Modulus: Pioneer Effect and Pseudo-Horizon

### 9.1. The Pioneer Effect

When  $B=1/A$ , our equation for the background takes a very simple form:

$$\frac{3}{2} \left( B - \frac{1}{B} \right) \left( \frac{\dot{B}}{B} \right)^2 = 0$$

implying  $1=B=1/A$ . However, the unit element here remains to be defined. We require the unit element to be such that an object at rest ( $dx=0$ ) will not feel any gravitational discontinuity when passing from the  $B=1/A$  regime to the  $B=-A$

regime. Thus the B element must be the same for both  $B=-A$  and  $B=1/A$  metrics. At a particular distance from a massive body, the cosmological metric flips locally from a  $A=-B$  solution to a  $A=-1/B$  solution. This results in the photons being redshifted compared to wavelengths emitted by atomic references in the  $A=-B$  expanded regime (it is more accurate to say that the reference periods contract while the photon keeps unaffected) while they will be blue shifted with exactly the same magnitude as compared to the same references in the  $A=-1/B$  regime (it is more accurate to say that the reference periods still contract while the photon periods contract twice more) . Then, perhaps we should not be surprised to receive the photons from an object at several Astronomical Units as are the Pioneer aircrafts slightly blue-shifted, an effect which according to Ref. 10 has been measured to a very good precision with the expected magnitude. The space-space metric component discontinuity when passing from the  $B=-A$  to the  $B=-1/A$  regime might transmit part of the photons and reflect the others as a genuine gravitational mirror.

## 9.2. *The Black Hole Horizon*

Our exponential solution tells us that there is no more BH singularity in our theory. However a test mass approaching the Schwarzschild radius of a massive body at rest with respect to the global coordinate system is propagating in a modulus and phase originating superposition:

$$d\tau^2 = \frac{1}{A(r)R(t)^2} dt^2 - A(r)R(t)^2 dx^2. \quad (16)$$

But for a strong enough gravitational field, e.g probably not much below the Schwarzschild radius thanks to the exponential regime, the  $A(r)$  term is expected to "cross" the scale factor term so that the  $r/t$  symmetry ( hence a more stable configuration) of the euclidian metric could be restored. Reaching this radius the test mass would be transfered in the Euclidian world or possibly via an extra rotation in the  $r/t$  conjugated light world. As well as a genuine black hole horizon this mechanism would account for the absence of thermonuclear bursts from BH candidates.

## 10. Phenomenological Outlooks

We now show that the new context may hopefully provide a very powerfull alternative to dark matter models and a seductive common explanation to various outstanding enigmas after carefull study of the postulated mechanisms.

### 10.1. *An Alternative to Dark Matter*

It is very tempting to interpret the universe voids as being filled with invisible matter living in the conjugate metric and repelling our matter at the frontier of what eventually appears to us as empty bubbles. On the other hand a massive

structure in our metric repels the matter living in the conjugate metric creating there an attracting void for our structure which might help to explain the flat galaxy rotation curves and other gravitational lensing effects.

### 10.2. Large Scale Structure Formation and the Early Universe

Of course, the large scale structure formation and evolution as well as nucleosynthesis would need to be completely revisited in this new context where the game rules are drastically modified. We now have to consider:

- The interactions between conjugated density fluctuations favoring the gravitational collapse.
- The absence of gravitational horizon up to a given distance which would account for the large scale homogeneity of the CMB.
- A slower expanding rate in the past thanks to the accelerated regime.
- A twice older universe ( $2/H_0=28$  billion years) to be compared with the oldest galaxies ages ( $z=5$ )  $\approx 17$  billion years in quite a good agreement with the oldest stars ages while providing more time for galaxy formation.

Our hope is to be as successful as the standard model in cosmology while avoiding ad-hoc hypothesis and adjustable parameters such as a cosmological constant, cold dark matter, inflation...

## 11. Conclusion

We could settle down here the foundations for a modified theory of gravitation. This theory is essentially general relativity enriched to take into account the fundamental discrete symmetries involved in the structure of the Lorentz group. Eventually, we find that this allows to solve many long lasting theoretical issues such as negative energies and stability, QFT vacuum divergences and the cosmological constant but also leads to very remarkable phenomenological predictions: Locally, the disagreement with GR only arises at the PPN level and black holes disappear. Globally (this is cosmology), a constantly accelerating necessarily flat universe in good agreement with the present data is a natural outcome of the model. At last, we could also show that the space/time exchange symmetry allows to derive a gravitational wave solution leading to the observed decay of the binary pulsar orbital period and to clarify the status of tachyonic representations.

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