The Dark side of Gravity vs MOND/DM

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This article continues the exploration of the Dark Gravity Theory which foundations and some consequences we have detailed in two previous articles.

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1. Introduction

In the presence of a flat non dynamical background $\eta_{\mu\nu}$, it turned out that the usual gravitational field $g_{\mu\nu}$ has a twin $\tilde{g}_{\mu\nu}$. The two being linked by

$$\tilde{g}_{\mu\nu} = \eta_{\mu\rho}\eta_{\nu\sigma}\left[g^{-1}\right]^{\rho\sigma} = \left[\eta^{\mu\rho}\eta^{\nu\sigma}g_{\rho\sigma}\right]^{-1} \tag{1}$$

are just the two faces of a single field (no new degrees of freedom) that we called a Janus field [1,2,5,10]. See also [3,6,7,4] for alternative approaches to Anti-gravity with two metric fields.

The action treating these two faces of the Janus field on the same footing should be invariant under the permutation of $g_{\mu\nu}$ and $\tilde{g}_{\mu\nu}$ which is achieved by simply adding to the usual GR and SM (standard model) action, the similar action with $\tilde{g}_{\mu\nu}$ in place of $g_{\mu\nu}$ everywhere.

$$\int d^4x(\sqrt{g}R + \sqrt{\tilde{g}}\tilde{R}) + \int d^4x(\sqrt{g}L + \sqrt{\tilde{g}}\tilde{L}) \tag{2}$$

where R and $\tilde{R}$ are the familiar Ricci scalars built from g or $\tilde{g}$ as usual and L and $\tilde{L}$ the Lagrangians for respectively SM F type fields propagating along $g_{\mu\nu}$ geodesics and $\tilde{F}$ fields propagating along $\tilde{g}_{\mu\nu}$ geodesics. This theory symmetrizing the roles of $g_{\mu\nu}$ and $\tilde{g}_{\mu\nu}$ is DG and we also explained at length why it allows to rehabilitate and understand time reversal and negative energies (thus anti-gravity) while avoiding any kind of theoretical instabilities.

2. Global gravity

2.1. *The scalar-tensor cosmological field*

We found that an homogeneous and isotropic solution is necessarily flat. However, it is also static so that the only way to save cosmology in the DG framework is to introduce a tensor-scalar Janus field built from a scalar Φ such that $g_{\mu\nu} = \Phi\eta_{\mu\nu}$ and $\tilde{g}_{\mu\nu} = \frac{1}{\Phi}\eta_{\mu\nu}$. Then our fundamental cosmological single equation obtained by requiring the action to be extremal under any variation of $\Phi(t) = a^2(t)$ is:

$$a^2\frac{\ddot{a}}{a} - \tilde{a}^2\frac{\ddot{\tilde{a}}}{\tilde{a}} = \frac{4\pi G}{3}(a^4(\rho - 3p) - \tilde{a}^4(\tilde{\rho} - 3\tilde{p})) \qquad (3)$$

Moreover this field is understood to be genetically homogeneous e.g. the spatially independent $\Phi(t)$ at any scale and sourced by the mean expectation value of the usual sources averaged over space rather than the sources themselves. So there are no scalar waves associated to this field and there is also no scale related to a loss of homogeneity as in GR.

Another independent Janus field will thus be required to describe all other aspects of gravity with all it's usual degrees of freedom, but a field forced to remain asymptotically static to satisfy all the equations.

2.2. *Cosmology*

The expansion of our side implies that the dark side of the universe is in contraction. Provided dark side terms can be neglected, our cosmological equation reduces to a cosmological equation known to be valid within GR. For this reason it is straightforward for DG to reproduce the same scale factor expansion evolution as obtained within the standard LCDM Model at least up to the Lambda dominated era in case we want to avoid a cosmological constant term.

A discrete transition is a natural possibility within a theory involving truly dynamical discrete symmetries. If this transition occurred as a genuine permutation of the conjugate scale factors, understood to be a discrete transition which modifies all terms explicitly depending on $a(t)$ but not the densities and pressures themselves in our cosmological equation (this was already discussed in our previous article but an additional argument for that will be given later), it could trigger the recent acceleration of the universe. This was demonstrated in previous articles assuming the dark side was already dominated by radiation at the time of our side nucleosynthesis so that our side source $\rho - 3p \simeq \rho \propto \frac{1}{a^3(t)}$ in the cold era has driven the evolution up to now, eventually resulting, following the discrete transition, in a recent accelerated expansion regime $(t' - t'_0)^{-2}$ in standard time coordinate with a Big Rip at future time t'_0.

But there is an alternative possibility: following the transition the dark side source might momentarily have started to drive the evolution as far as $a^4(\rho - 3p) \propto a << \tilde{a}^4(\tilde{\rho} - 3\tilde{p}) \propto Const$ for $a(t) << Const << \tilde{a}(t)$ would have been satisfied. Then our cosmological equation simplifies in a different way:

$$\tilde{a}^2\frac{\ddot{\tilde{a}}}{\tilde{a}} \propto Const \qquad (4)$$

with solution $a(t) \propto 1/t$ which translates into an exponentially accelerated expansion regime $e^{t'}$ in standard time coordinate.

In the Big Rip scenario, constraining the age of the universe to be the same as in LCDM the predicted transition redshift is $z_{tr} = 0.27$ in case it occurred everywhere simultaneously but the mean transition redshift should be significantly increased by an expected dispersion of transition redshifts due to inhomogeneities which should also smooth the observed transition between decelerated and accelerated expansion after averaging over large regions and makes the theory difficult to discriminate from the very progressive LCDM transition. The mean transition redshift is indeed very sensitive to a smoothing. For instance the LCDM very smooth transition well fits the data with $z_{tr} \approx 0.7$ while a fictitious LCDM discrete transition between a purely CDM and a purely Lambda driven expansion regime would imply $z_{tr} \approx 0.4$ for the same constrained age of the universe. This last scenario of course also corresponds to our exponentially accelerated expansion case if it occurred everywhere simultaneously and again the smoothing effect would make it even harder to discriminate from the real LCDM transition.

3. Local gravity

3.1. *The isotropic case*

Another Janus field and it's own separate Einstein Hilbert action are required to describe local gravity with isotropic solution in vacuum of the form $g_{\mu\nu} = (B, A, A, A)$ and $\tilde{g}_{\mu\nu} = (1/B, 1/A, 1/A, 1/A)$

$$A = e^{\frac{2MG}{r}} \approx 1 + 2\frac{MG}{r} + 2\frac{M^2G^2}{r^2} \tag{5}$$

$$B = -\frac{1}{A} = -e^{\frac{-2MG}{r}} \approx -1 + 2\frac{MG}{r} - 2\frac{M^2G^2}{r^2} + \frac{4}{3}\frac{M^3G^3}{r^3} \tag{6}$$

perfectly suited to represent the field generated outside an isotropic source mass M. This is different from the GR one, though in good agreement up to Post-Newtonian order. It is straightforward to check that this Schwarzschild new solution involves no horizon. The solution also confirms that a positive mass M in the conjugate metric is seen as a negative mass -M from its gravitational effect felt on our side.

3.2. *Gravitational Waves*

The linearized equations look the same as in GR except for the additional dark side source term:

$$2(R^{(1)}_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}R^{(1)\lambda}_{\lambda}) = -8\pi G(T_{\mu\nu} - \tilde{T}_{\mu\nu}) \tag{7}$$

however this equation is also valid to second order in the perturbation $h_{\mu\nu} = -\tilde{h}_{\mu\nu}$ because the quadratic term $t_{\mu\nu} - \tilde{t}_{\mu\nu}$ on the right side standing for the energy-momentum of the gravitational field itself has two cancelling contributions since $t_{\mu\nu} = \tilde{t}_{\mu\nu}$ to second order in small plane wave perturbations. The Linearized Bianchi identities are still obeyed on the left hand side and it therefore follows the local conservation law:

$$\frac{\partial}{\partial x^{\mu}}(T^{\mu\nu} - \tilde{T}^{\mu\nu} + t^{\mu\nu} - \tilde{t}^{\mu\nu}) = 0 \tag{8}$$

Our new interpretation is that any radiated wave will both carry away a positive energy in $t^{\mu\nu}$ as well as almost the same amount of energy with negative sign in $-\tilde{t}^{\mu\nu}$ resulting in a total vanishing radiated energy at least to second order. Thus the DG theory, so far appears to be dramatically conflicting with both the indirect and direct observations of gravitational waves.

Actually, we shall show in a forthcoming section that the theory is naturally extended in such a way that we can both expect an isotropic solution approaching the GR Schwarzschild one with it's black hole horizon as well as the same gravitational wave solutions (including the production rate) as in GR but also, whenever some particular yet to be defined conditions are reached, the above DG solutions, with a vanishingly small production of gravitational waves and an exponential Schwarzschild solution without horizon. Both will be limiting cases of a more general solution.

4. The unified DG theory

4.1. *Actions and space-time domains*

Eventually the theory splits up into two parts, one with total action made of a Einstein Hilbert action for our scalar-tensor homogeneous and isotropic Janus field added to SM actions for F and $\tilde{F}$ type fields respectively minimally coupled to $\Phi\eta_{\mu\nu}$ and $\Phi^{-1}\eta_{\mu\nu}$. The other part of the theory has an Einstein Hilbert (EH) action for the asymptotically Minkowskian Janus Field $g_{\mu\nu}$ for local gravity added again to SM actions for F and $\tilde{F}$ type fields respectively minimally coupled to $g_{\mu\nu}$ and $\tilde{g}_{\mu\nu}$.

The two theories must remain completely separate. Indeed, to remain asymptotically static, $g_{\mu\nu}$ must be isolated from the scale factor effect. But also as announced earlier the scalar field is spatially independent at all scales so admits only perfectly homogeneous sources. So a unified theory cannot be obtained by mixing the local and global gravity in an action. However it's still possible to add the following global and local actions, being understood that no dynamical field is shared between them. This means that even for the sources, the average background and perturbations are different dynamical fields, the former in the global L and $\tilde{L}$, the latter in the local L and $\tilde{L}$. Later this total action will be helpful to establish a non trivial connection between global and local gravity.

$$\int_{Global} d^4x(\sqrt{g}(R+L) + \sqrt{\tilde{g}}(\tilde{R}+\tilde{L}))+ \tag{9}$$

$$\int_{Local} d^4x(\sqrt{g}(R+L) + \sqrt{\tilde{g}}(\tilde{R}+\tilde{L})) \tag{10}$$

From this fact one must be careful not to draw the too rapid conclusion that global and local gravity never apply at the same place and time so that only an alternating of the two would remain conceivable. Indeed it would be difficult in this case to find out non arbitrary rules linking the unconnected successive time slots of both global and local evolutions. Moreover, this would require the introduction of arbitrary parameters for the global and local slots durations.

On the other hand considering the global and local physics of those actions running in parallel totally decoupled and uninterrupted leads to another issue. We need to understand then how clocks and rods can both feel the effect of global expansion and local gravity being now understood that those clocks and rods do not even appear in the global Lagrangians L and $\tilde{L}$ above just because as we already noticed only the averaged perfectly homogeneous over the whole universe, perfect fluid densities and pressures are there.

Our proposal for solving this problem is that the asymptotic local static gravity is actually only a constant piecewise function of time rather than rigorously the stationary $\eta_{\mu\nu}$. In other words it is rather $C\eta_{\mu\nu}$ which asymptotic value C is piecewise constant, being periodically discontinuously updated to $a(t)$ and can therefore follow the evolution of $a(t)$ through a series of fast discrete transitions on a regular basis. Eventually, clocks and rods coupling to local gravity only but never coupling directly to $a(t)$, can still feel the effects of the continuous global expansion indirectly thanks to this mechanism. At the same time, this helps understanding how clocks and rods can remain insensitive to discrete transitions of the scale factor itself such as the one responsible for the cosmological transition to global acceleration if our mechanism does not roll up those transitions to the local field asymptotic value. We shall soon understand better how relevant is this asymptotic value within DG (no obvious peer within GR).

Another issue is that gravity in the inner part of the solar system as we know it from thorough studies during the last decades exclude that global gravity applied to clocks and rods without being strongly attenuated. Indeed, it would otherwise lead to strongly excluded expansion effects of orbital planetary periods relative to atomic periods: the gravitational constant G would seem to vary at a rate similar to H_0 which is not the case. GR solves this problem because it predicts that significant expansion effects only take place on scales beyond those of galaxy clusters. At the contrary, the theory involving the physics of the global action above would produce expansion effects with the same magnitude at all scales if the asymptotic value C of local fields was following everywhere the scale factor $a(t)$ evolution as we explained above. Therefore this driving mechanism did not apply to local gravity in the inner part of the solar system at least during the last decades. This is the only possible solution not to conflict with observational constraints: no evidence of expanding planet trajectories so far. This implies the existence of frontiers between spacetime domains where the local field is the asymptotically Minkowskian local $g_{\mu\nu}$ (for instance in the inner part of the solar system during the last decades) and others where the $g_{\mu\nu}$ asymptotic value C is driven by the scale factor from the global $\Phi\eta_{\mu\nu}$

according our above mechanism.

4.2. *Space-time domains and the Pioneer effect*

The following question therefore arises: suppose we have two identical clocks exchanging electromagnetic signals between one domain submitted to the expanding $a(t)$ in $\Phi\eta_{\mu\nu}$ (still through our indirect mechanism) and another without such effect. Electromagnetic periods and wavelengths are not affected in any way during the propagation of electromagnetic waves in the conformal coordinate system where we wrote our cosmological equation even when crossing the inter-domain frontier. Through the exchange of electromagnetic signals, the period of the clock decreasing as $a(t)$ can then directly be tracked and compared to the static clock period and should be seen accelerated with respect to it at a rate equal to the Hubble rate H_0. Such clock acceleration effect indeed suddenly appeared in the radio-wave signal received from the Pioneer space-crafts but with the wrong magnitude by a factor two: $\frac{\dot{f}_P}{f_E} = 2H_0$ where f_P and f_E stand for Pioneer and earth clocks frequencies respectively. This is the so called Pioneer anomaly [89]. The interpretation of the sudden onset of the Pioneer anomaly just after Saturn encounter would be straightforward if this is where the spacecraft crossed the frontier between the two regions. The region not submitted to global expansion (at least temporarily) would therefore be the inner part of the solar system where we find our earth clocks and where indeed various precision tests have shown that expansion or contraction effects on orbital periods are excluded during the last decades. Only the origin of the factor 2 discrepancy between theory and observation remains to be elucidated in the following sections.

4.3. *Cyclic expanding and static regimes*

We know from cosmology that, still in the same coordinate system, earth clocks must have been accelerating at a rate H_0 with respect to still standing electromagnetic periods of photons reaching us after travelling across cosmological distances: this is just the so called cosmological redshift. However, according our above analysis this was not locally the case at least during the last decades which did not manifest any cosmological effect in the inner part of the solar system.

This necessarily implies that earth clocks must have been submitted to alternating static and expanding regimes. It just remains to assume (further justification will be provided in a forthcoming section) that through cosmological times, not only earth clocks but also all other clocks in the universe, spent exactly half of the time in the expanding regime and half of the time in the static regime, in a cyclic way. It follows that the instantaneous expansion rate $2H_0$ of our global field as deduced from the Pioneer effect is twice bigger than the average expansion rate (the average of $2H_0$ and zero respectively in the expanding and static halves of the cycle) as measured through a cumulative redshift over billions of years.

In our previous article we presented a very different more complicated and less natural explanation on how we could get the needed factor two which we do not support anymore. This article also discussed the possibility of field discontinuities at the frontier between regions with different expansion regimes, and likely related effects in LENR experiments. Those discontinuities do not necessarily imply huge potential barriers even though the scale factors have varied by many orders of magnitude between BBN and now. At the contrary they could be so small to have remained unnoticed as far as our cycle is short enough to prevent some regions to accumulate a too much drift relative to others.

5. Frontier dynamics

Our next purpose is to understand the physics that governs the location of frontier surfaces between regions identified in the previous sections.

Consider the gravitational field total action in a space-time domain where our driving mechanism from global to local gravity does not apply :

$$\int_{Global} d^4x(\sqrt{g}R + \sqrt{\tilde{g}}\tilde{R}) + \tag{11}$$

$$\int_{Local} d^4x(\sqrt{g}R + \sqrt{\tilde{g}}\tilde{R}) \tag{12}$$

where in the global (resp local) actions the gravitational field is $\Phi\eta_{\mu\nu}$ (resp $g_{\mu\nu}$). We want to determine the frontier surface of this domain at the time t the local field asymptotic value is reset to the scale factor beyond this surface (not in our domain). Considering the frontier to be stationary between two such successive updates, the frontier position is determined at any time. To this end we extend the extremum action principle. Not only the total action should be extremum under any infinitesimal field variations which as we all know allows to get the field equations but also the total action at t (hence with a $\delta(x_0 - t)$ factor in each integral) is required to be extremum e.g. stationary under any infinitesimal displacement of the surface at the frontier of the action validity domain. But the displaced surface might only differ from the original one near some arbitrary point, so that requiring the action variation to vanish actually implies that the total integrand should vanish at this point and therefore anywhere on the surface. Eventually, anywhere and at any time at the domain surface boundary we have:

$$(\sqrt{g}R + \sqrt{\tilde{g}}\tilde{R})_{global} + (\sqrt{g}R + \sqrt{\tilde{g}}\tilde{R})_{local} = 0 \tag{13}$$

This equation is merely a constraint relating local gravity to global gravity at the surface and it can be further simplified remembering that at the present time we could neglect term 1 because our side scale factor is negligible compared to the dark side scale factor. We assume g is also negligible relative to $\tilde{g}$ for local gravity.

Though this is not expected in the weak field approximation we will justify this crucial point in the forthcoming section. Considering that we are in vacuum on our side, the dark side fluid source term is dominant in the local field equation which can therefore be approximated and contracted by $\tilde{g}_{\mu\nu}$ to get $\tilde{R} = 8\pi G\tilde{T} = 8\pi G(\tilde{\rho} - 3\tilde{p})$ which is nothing but a GR equation, the Einstein equation for the dark side gravity.

Replacing $\tilde{R}$ by this expression in the equation relating local to global gravity, we get:

$$(\sqrt{\tilde{g}}\tilde{R})_{global} = -8\pi G\sqrt{\tilde{g}_{local}}(\tilde{\rho} - 3\tilde{p}) \tag{14}$$

By the way $\tilde{\rho} - 3\tilde{p}$ does not vanish exactly as long as there are massive particles in the fluid. This expression varies like the densities and pressures themselves which are here constant because we are dealing with the pressure and density in the local gravitational field alone so it is static rather than varying as $1/\tilde{a}^4$. But the lhs is $\tilde{a}^2\frac{\ddot{\tilde{a}}}{\tilde{a}}$ which according to our cosmological equation is constant in the exponential acceleration scenario and varies as $a = \frac{1}{\tilde{a}}$ in the Big Rip scenario. Therefore, in the external gravity of a massive spherical body which radial a-dimensional potential is $\Phi(r) = -GM/rc^2$ we are led to:

$$a^{\gamma}(t) \propto e^{\frac{2MG}{rc^2}} \tag{15}$$

with $\gamma = 1$ for the Big Rip and 0 for the exponential acceleration.

This equation relating physical observables was obtained here in the conformal coordinate system and must also be valid in standard time coordinate. It is valid to PN order being understood that the local gravitational field is here the weak field PN approximation of the GR Schwarzschild solution rather than a DG Schwarzschild solution as we shall show in the next section. This equation I=J implies $\dot{I}/I = \dot{J}/J$ so that:

$$\gamma 2H_0 = -2\frac{d\Phi}{dr}\frac{dr}{dt} \tag{16}$$

here taking into account that the instantaneous Hubble factor is actually $2H_0$ as we explained earlier.

The latter equation tells us that the frontier between the two domains is drifting at speed $\frac{dr}{dt} = \frac{H_0}{-\Phi'(r)}$ in the Big Rip Scenario whereas it is fixed in the exponentially accelerated scenario.

The Big Rip option is therefore our favorite because it could involve a characteristic period, the time needed for the scale factor to scan $e^{\frac{2MG}{r}}$ from the asymptotic value to the deepest level of the potential at which point a new scan cycle is started except that this time the two regions will have exchanged their roles about the moving frontier. In other words if for a given cycle the expanding region is the outer one and the static region the inner one, the next cycle will be with the inner part expanding and the outer part static. After two such complete cycles any area will have spent exactly the same total time static and expanding at $2H_0$ resulting in the promised average H_0. A Geogebra animation in [11] helps visualizing the evolution of the local potential over one complete cycle. Notice that the scale factor, as shown in the animation, also needs periodical resets because it's mean evolution rate is twice the evolution rate of C.

It is worthy of special mention that then the total time to scan the potential well of our sun which is the deepest at the sun surface is about the same as the equinox precession period. Betting on a driving mechanism that might along many cycles lead to synchronize the two phenomena, we can estimate H_0 from the precession of the equinoxes cycle and get $H_0 = 80,56 \pm 0.01(km/sec)/Mpc$ to be compared with the best precision "recent" cosmological measurement of $H_0 = 73.03 \pm 1.79(km/sec)/Mpc$. Therefore, according this interpretation, the present value would be greater by four standard deviations than the cosmological one over the two last billion years (300 SNe Ia at $z < 0.15$ having a Cepheid-calibrated distance) which itself exceeds by three standard deviations the one predicted by LCDM from Planck data. This is noteworthy because an unexpectedly high recent acceleration could of course be the signature of our Big Rip scenario.

6. Unconventional asymptotic values

After many cycles of successive static and expanding phases, the local field asymptotic value is everywhere going to be very different from it's initial C=1 value. This also implies that the new asymptotic values of the local field and its conjugate will be very different. This is also going to be our justification for having neglected g relative to $\tilde{g}$ even for weak fields, in the previous section.

Given that $g^{C\eta}_{\mu\nu} = Cg^{\eta}_{\mu\nu}$ and $\tilde{g}^{\eta/C}_{\mu\nu} = \frac{1}{C}\tilde{g}^{\eta}_{\mu\nu}$ where the $< g^{\eta}, \tilde{g}^{\eta} >$ Janus field is asymptotically Minkowskian it is straightforward to rewrite the local DG Janus Field equation now satisfied by this asymptotically Minkowskian Janus field after those replacements. Hereafter we omit all labels specifying the asymptotic behaviour for better readability and only write the time-time equation.

$$C\sqrt{g}\frac{G_{tt}}{g_{tt}} - \frac{1}{C}\sqrt{\tilde{g}}\frac{\tilde{G_{tt}}}{\tilde{g}_{tt}} = -8\pi G(C^2\sqrt{g}\rho - \frac{1}{C^2}\sqrt{\tilde{g}}\tilde{\rho}) \tag{17}$$

Where $G_{\mu\nu} = R_{\mu\nu} - \frac{1}{2}g_{\mu\nu}R$ and ρ is as usual the energy density for matter and radiation. The tilde terms again refer to the same tensors except that they are built from the corresponding tilde (dark side) fields. Then for $C >> 1$ we are back to a GR like equation ($G_{tt} = -8\pi GC\rho g_{tt}$) for local gravity from sources on our side because all terms depending on the conjugate field become negligible on the left hand side of the equation while the local gravity from sources on the dark side is attenuated by the huge $1/C^4$ factor (in the weak field approximation, $G_{tt} = 8\pi G\frac{\tilde{\rho}}{C^3}$). Once we get $g^{C\eta}_{\mu\nu}$ we can of course absorb the C constant by the adoption of a new coordinate system and redefinition of G, so for $C >> 1$ we are back to GR (with its Horizon in the Schwarzschild solution and it's gravitational waves) except that on the dark side everything will feel the effect of the anti-gravitational field from bodies on our side amplified by the same huge factor relative to the gravity produced by bodies on their own side.

Of course the roles are exchanged in case $C << 1$. Then the GR equation is valid on the dark side ($\tilde{G}_{tt} = -\frac{8\pi}{C} G\tilde{\rho}\tilde{g_{tt}}$) while the anti-gravity we should feel from the dark side is enhanced by the huge $1/C^4$ factor relative to our own gravity (given in the weak field approximation by solving $\tilde{G}_{tt} = 8\pi G C^3 \rho$ for $\tilde{g}_{\mu\nu}$ from which we derive immediately our side $g_{\mu\nu}$ of the Janus field). Here is our promised justification for having assumed that the local gravitational field was the weak field PN approximation of the GR Schwarzschild solution rather than a DG Schwarzschild solution in the previous section.

Only in case C=1 do we recover our local Dark gravity, with no significant GW radiations and no Black Hole horizon and also a strength of gravity ($G_{tt} = -4\pi G\rho$) reduced by a factor 2C relative to the above GR gravity ($G_{tt} = -8\pi GC\rho$) as a consequence of two geometrical terms adding up on the lhs of the equations.

It's important to stress that the phenomenology following from different asymptotic behaviours of the two faces of the Janus field here has no peer within GR in which a mere coordinate transformation is always enough to put the gravitational field in an asymptotically Minkowskian form in which a redefinition of the gravitational constant G gives back the usual gravitational potentials. This would still be possible in DG for one face of the Janus field but not for both at the same time. The new physics emerges from their relative asymptotic behaviour which can't be absorbed by any choice of coordinate system.

Eventually, depending on the local C value in a given space-time domain, a departure from GR predictions could be expected or not both for the gravitational waves radiated power and the local static gravitational field e.g. depending on the context, we could get either exponential elements or the GR Schwarzschild solution for the static isotropic gravity; and get either no gravitational waves at all or the same radiated power as in General Relativity.

Because clock and rods submitted to local gravity also indirectly felt the effects of global expansion through our quantized evolution of C, if we could test gravity over the past cycles we would necessarily detect that it's strength was different and has changed in the same proportion as the scale factor itself. Current test in the solar system and in some strong field binary systems constrain relative variations of G at levels much lower than H_0 however what we need in the inner part of the solar system is either an instantaneous test in the expanding regime (so far inaccessible because we are apparently currently in the stationary half cycle) or a test for multi-millennial variations hence necessarily over much longer time scales than the cycle period to exclude or not a mean variation at the Hubble rate.

7. The MOND phenomenology

We derived in a former section the speed $\frac{dr}{dt} = \frac{H_0}{-\Phi'(r)}$ at which our local vs global frontier sitting at an isopotential between internal and external regions should radially propagate in the potential well of a given body. From this formula the speed of light $\frac{dr}{dt} = c$ is reached for an acceleration of gravity that equals cH_0. This appears to be nothing but the MOND acceleration and the corresponding radius nothing but the MOND radius beyond which gravity starts to be anomalous in galaxies. We are therefore tempted to postulate that to prevent the frontier discontinuities from propagating faster than the speed of light something must be happening at the MOND radius. Our best guess is that the local Janus field asymptotic C and $\frac{1}{C}$ exchange their roles there, which, as we explained in the previous section would result in the gravitational field from the Dark side in the region beyond the MOND radius to be enhanced by a huge factor C^4. Then even a slightly under-dense state of the highly radiative fluid on the dark side would result in an anti-anti-gravitational force on our side and would be difficult to discriminate from the effect of a Dark Matter hallow!

8. Back to Black-Holes and gravitational waves

Let's consider the collapse of a massive star which according to GR should lead to the formation of a Black Hole. As the radius of the star approaches the Schwarzschild radius the metric becomes singular there so the process lasts an infinite time according to the exterior observer. If the the local fields both outside and inside the star have huge asymptotic C values, we already demonstrated that the gravitational equations are GR like. We postulate however that the metric actually never becomes singular at the Schwarzschild radius but instead when the metric reaches some threshold, the inner region (the volume defined by the star itself) global and local fields are reset to Minkowski and C=1. Therefore this is where and when the DG solution is triggered avoiding thereby the GR black hole Horizon but producing in place a huge discontinuity in the vicinity of the Schwarzschild Radius. At the center of the star, the two faces of the Janus field will get very close to each other just because C=1 and because this is where the star potential vanishes. These are the required conditions to allow the transfer of the star matter to the conjugate side there all the more since the pressure is huge. This effect along with the strength of gravity being reduced by a factor 2C for DG relative to GR might eventually stop the collapse whenever the conditions are reached for the stability of a neutron star.

The resulting object having no horizon is in principle still able to radiate light. It must also have lost a significant part of its initial mass content transferred to the dark side and also much of its gravific mass because of the 2C reduction factor. Something new however is that the discontinuity itself should have a contribution to the total mass and this might lead to pseudo BHs much more massive than we believed them to be.

Although we have seen that DG does not allow significant Gravitational Waves radiation from the inner region, considering that the discontinuity itself is gravific and can radiate as any accelerating body according the GR laws in the outer region, we are sure to avoid any conflict with all the observational evidence from GWs emitted by "black holes". Shocks and matter anti-matter annihilation at the discontinuity which we remember is also a bridge toward the Dark side and it's anti-matter fluid, could also produce further GWs radiation which would be much less natural from a regular GR Black Hole.

9. The Wave function Collapse

The Black Hole discontinuity of the previous section, which lies at the frontier between GR and DG domains, behaves as a wave annihilator for incoming GW waves and a wave creator for outgoing waves. This is a fascinating remark because this makes it the only known mechanism for creating or annihilating waves à la QFT or even may be explain the very nature of a wave function collapse which is also a QM well known process completely irreducible to classical wave physics because it is non local, and in fact just as non local as our transition from GR $C >> 1$ to DG, C=1 in the inside domain. The latter transition is non local because it is first of all driven by a transition of our global field which by construction ignores distances.

10. Stability issues

Generic instability issues arise again when C is not anymore strictly equal to one. This because the positive and negative energy terms do not anymore cancel each other as in the DG C=1 solution. Gravitational waves are emitted either of positive or negative (depending on C being less or greater than 1) energy whereas on the source side of the equation we have both positive and negative energy source terms. Whenever two fields (here the gravitational field and some of the matter and radiation fields) carry energies with opposite sign, the vacuum instability is unavoidable even at the classical level and the problem is even worsen by the massless property of the gravitational field.

We are therefore led to understand that whenever C becomes different from 1, the Local Janus field $< g^C, \tilde{g}^{1/C} >$ needs to split in two independent Janus fields $< f^C, \tilde{f}^{1/C} >$ and $< h^C, \tilde{h}^{1/C} >$ (superscripts C and 1/C still denote asymptotic values) and we are tempted to consider the following actions running in parallel and decoupled (in which we omit asymptotic behaviour superscripts for better readability).

$$\int_{Local} d^4x \sqrt{f} R_f + \sqrt{f} L_f \tag{18}$$

$$\int_{Local} d^4x \sqrt{\tilde{h}} R_{\tilde{h}} + \sqrt{\tilde{h}} \tilde{L}_{\tilde{h}} \tag{19}$$

to avoid $\tilde{L}_{\tilde{f}}$ and L_h terms in the first and second action respectively which ensures that we will not end up with source terms carrying an energy opposite to the energy of gravitational waves in any of the two actions. The permutation symmetry is now between f and $\tilde{h}$. This is a bit silly however because we lost $\tilde{f}$ and h and anti-gravity in that new game. But this is just an intermediary step because we can actually recover easily the conjugates of the Janus fields along with anti-gravity if matter and radiation are actually coupled to a combination of f and h instead of f alone in the first action, and equivalently to a combination of $\tilde{f}$ and $\tilde{h}$ rather than $\tilde{h}$ alone in the second action.

The composite metrics are denoted and defined by $[fh]_{\mu\nu} = \eta^{\rho\sigma} f_{\mu\rho} h_{\nu\sigma}$ and $[\tilde{f}\tilde{h}]_{\mu\nu} = \eta^{\rho\sigma} \tilde{f}_{\mu\rho} \tilde{h}_{\nu\sigma}$.

$$\int_{Local} d^4x \sqrt{f} R_f + \sqrt{[fh]} L_{[fh]} \tag{20}$$

$$\int_{Local} d^4x \sqrt{\tilde{h}} R_{\tilde{h}} + \sqrt{[\tilde{f}\tilde{h}]} \tilde{L}_{[\tilde{f}\tilde{h}]} \tag{21}$$

Being understood that f is only dynamical in the first action and $\tilde{h}$ in the second action, stability is still granted because even though our side matter and radiation fields in L feel the anti gravitational effect of matter and radiation fields from $\tilde{L}$ through h and reciprocally through $\tilde{f}$ the gravitational field f is only sourced by matter and radiation fields coupled to f (and not $\tilde{f}$) and spectator h in the first action and equivalently the gravitational field $\tilde{h}$ is only sourced by matter and radiation fields coupled to $\tilde{h}$ (and not h) and spectator $\tilde{f}$ in the second action.

We can gain more insight about what's new by varying the first action with respect to $f_{\mu\nu}$ to get :

$$\sqrt{f} G_f^{\mu\nu} \delta f_{\mu\nu} + 8\pi G \sqrt{[fh]} T_{[fh]}^{\mu\sigma} \eta^{\nu\rho} h_{\rho\sigma} \delta f_{\mu\nu} = 0 \tag{22}$$

In the perfect fluid case, after some replacements we find this leads to the equation :

$$\sqrt{f} G_f^{\mu\nu} = -8\pi G \sqrt{[fh]} T_f^{\mu\nu} \Rightarrow G_f^{\mu\nu} = -8\pi G \sqrt{h} T_f^{\mu\nu} \tag{23}$$

For instance the time-time equation for C asymptotic f and h fields yields that the asymptotically Minkowskian part in the weak field approximation is solution of $G_{f\,tt} = -8\pi G C^3 \rho$ while we find $G_{\tilde{h}\,tt} = -8\pi G C^{-3} \tilde{\rho}$ following the same method and recover a previous section conclusion (but now in a framework without any instabilities) that the gravity from the dark side is damped with respect to gravity from our side but now by an even greater factor $1/C^6$. And of course the situation again gets reversed for $C < 1$.

11. Conclusion

New developments of DG not only seem to be able to solve the tension between the theory and gravitational waves observations but also provide a renewed and reinforced understanding of the Pioneer as well as a recent cosmological acceleration greater than expected. An amazing unifying explanation of MOND/Dark Matter phenomenology seems also at hand. The outlook for a wave-function collapse new mechanism also appears promising on an unprecedented scale.

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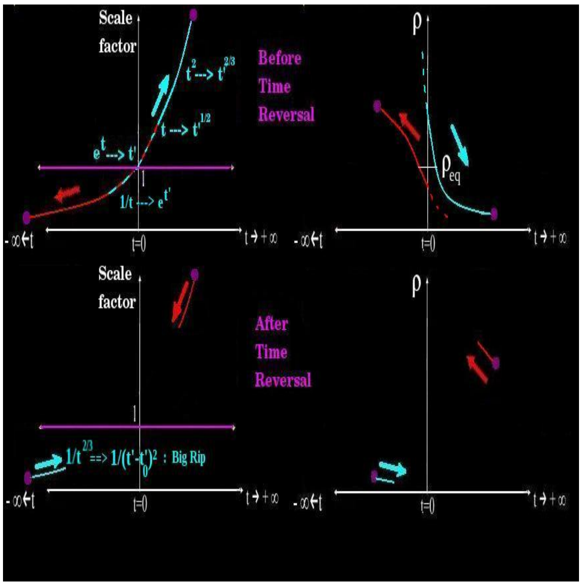

Fig. 1. Evolution laws and time reversal of the conjugate universes, our side in blue