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Research Article

# The Dark side of Gravity and LENR

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**Abstract**

A previous article paved the way from a dark gravity theory (DG) toward LENR. This article is intended to go beyond the conceptual foundations (which will only be briefly summarized), and to provide a more technical detailed road map. An important revision of the theory was also made necessary by the recent direct detection of gravitational waves by Ligo. Finally, justifications will be given for adopting a slightly modified view of the process that triggers the formation of micro lightning balls, those enigmatic objects being produced in association with (and arguably responsible for) LENR, as we have recently identified the key role being played by a local increase of the density of electrons by various methods including a high luminosity beam (pulse) of electrons on a target.


*Keywords:* Anti-gravity, Field discontinuities, Janus field, LENR, Negative energies, Time reversal

## 1. Introduction

As a reminder, in this introduction we shall list the main conceptual steps toward Dark Gravity and main achievements of the theory referring the reader to our previous article [18] for a more in-depth presentation.

- In the 1970s, due to the increasing difficulties in trying to reach a coherent theory of quantum gravity, many theorists were led to doubt that the gravitational field was the metric describing the geometrical properties of space–time itself. Rather we should perhaps rehabilitate the old view of a nondynamical space–time with metric $\eta_{\mu\nu}$ beyond the field $g_{\mu\nu}$, the latter remaining merely, for all fields minimally coupled to it, the prism through which the space and time intervals (inherently nondeformable) are seen deformed.
- But all attempts toward theories involving both $g_{\mu\nu}$ and $\eta_{\mu\nu}$ to hopefully facilitate quantization, were strongly conflicting with accurate tests of the equivalence principle and were progressively abandoned. Those attempts however missed a crucial point: in presence of $\eta_{\mu\nu}$, $g_{\mu\nu}$ 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.

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- The action (thus the equations derived from it) must be invariant under the permutation of $g_{\mu\nu}$ and $\tilde{g}_{\mu\nu}$. This 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.

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

  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.
- It results from the derived equations that the only interaction allowed between our side *F* fields and $\tilde{F}$ fields of the dark side of the DG universe is Anti-gravity (readily readable from Eq. (1) involving an inverse matrix $g^{-1}$ )
- This is the only kind of theory enabling Anti-gravity (negative energy sources for gravity) in a stable way.
- A negative energy is just the energy of an ordinary field as seen from the other side of gravity. All fields living on the same side of gravity see each other as positive energy fields (but this sign is then merely a matter of convention).
- The fundamental symmetry linking the two faces of the Janus field $g_{\mu\nu}$ and $\tilde{g}_{\mu\nu}$ is actually time reversal. This is most easily checked in DG cosmological solutions but also in the gravific energy reversal when the observer changes sides under time reversal. This time reversal is really understood as a genuine discrete symmetry in a gravitational context and does not apply to our field through a general coordinate transformation.
- According special relativity alone, time reversal was the natural way to transform a positive into negative energy. However, a less obvious anti-unitary time reversal operator was elected in QFT, which avoided the regeneration of negative energies but not any removal nor reinterpretation of those states which from the beginning have been solutions of all our relativistic field equations. In DG, QFT negative energy solutions and a Unitary time reversal can now be rehabilitated.
- The well known instability issues between interacting positive and negative energy fields are trivially solved for nongravitational interactions which are forbidden between F and $\tilde{F}$ fields. Moreover even the new anti-gravitational interaction is stable as first advocated by JP Petit [3,7,8] (no runaway), the precursor and first explorer of Dark Gravity, and more recently Hossenfelder [4].

## 2. Solving the Equations for a Cosmological Solution

### 2.1. The scalar-tensor cosmological field

For a cosmological solution, both $g_{\mu\nu}$ and $\tilde{g}_{\mu\nu}$ must be homogeneous and isotropic, and given a flat nondynamical space–time with its Minkowskian metric entering in Eq. (1), this is only possible provided the spatial curvature parameter $k = 0$ in both faces of the FRW Janus field. We leave as an open option for the future the less natural case of a static nondynamical but curved space–time in which case $g_{\mu\nu}$, $\tilde{g}_{\mu\nu}$ and the metric of space–time will share the same *k* and, for the scale factor, the same solutions as in the flat case since *k* terms will be found to cancel out from the equations. So far we just note that the already tested with good accuracy, perfect flatness of our universe, can be considered a prediction of DG (without any need for inflation) since there is no reason why the nondynamical space–time itself should be curved in DG.

The next step is to try the Janus FRW ensatz and solve the equations for the scale factor $a(t)$. One finds that only a static field can satisfy all the equations which would appear a dead end for a DG theory trying to describe the expansion history of the universe. However, it turns out that the theory is easily saved if the elements of the cosmological field are required to be tied together and cannot be varied independently. This is the case if our field needed to describe cosmological expansion is built from a scalar $\Phi$ and we can write $g_{\mu\nu} = (-A, A, A, A) = \Phi\eta_{\mu\nu}$ and $\tilde{g}_{\mu\nu} = (-1/A, 1/A, 1/A, 1/A) = \frac{1}{\Phi}\eta_{\mu\nu}$. Quite naturally, we shall call this field a scalar-tensor Janus field.

The form taken by this homogeneous field could be further justified based on discrete space–time symmetry arguments, [2], Section 6. Moreover, we will later argue that this field has to be genetically homogeneous, i.e $\Phi$ is from birth required to be the spatially independent $\Phi(t)$, ensuring it cannot be perturbed in anyway because we will need to avoid any adverse scalar contribution to the radiation of gravitational waves.

Another independent Janus field will thus be required later to describe local gravity, a field where all elements will be allowed to vary independently as usual but then a field forced to remain asymptotically static to satisfy all the equations.

But for now, we are left with only one fundamental scalar equation to be satisfied by our scale factor $a(t) = 1/\tilde{a}(t)$ in $\Phi(t) = A(t) = a^2(t)$ instead of the two Friedman equations in GR so we avoid the equation which in case $k = 0$ in GR implies that the universe density is constrained to be the critical density. In DG, having no such constraints to be satisfied by our densities we no longer need Dark Matter to fill any missing mass at the cosmological scale. Our fundamental cosmological single equation obtained by requiring the action to be extremal under any variation of $\Phi(t) = a^2(t)$ is:

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

### 2.2. Cosmology

We investigated in details the solutions of this cosmological equation and have shown that DG is able to reproduce the same scale factor expansion evolution as obtained within the standard LCDM Model. This is all summarized in Fig. 1. This expansion implies that the dark side of the universe is in contraction and was already dominated by radiation

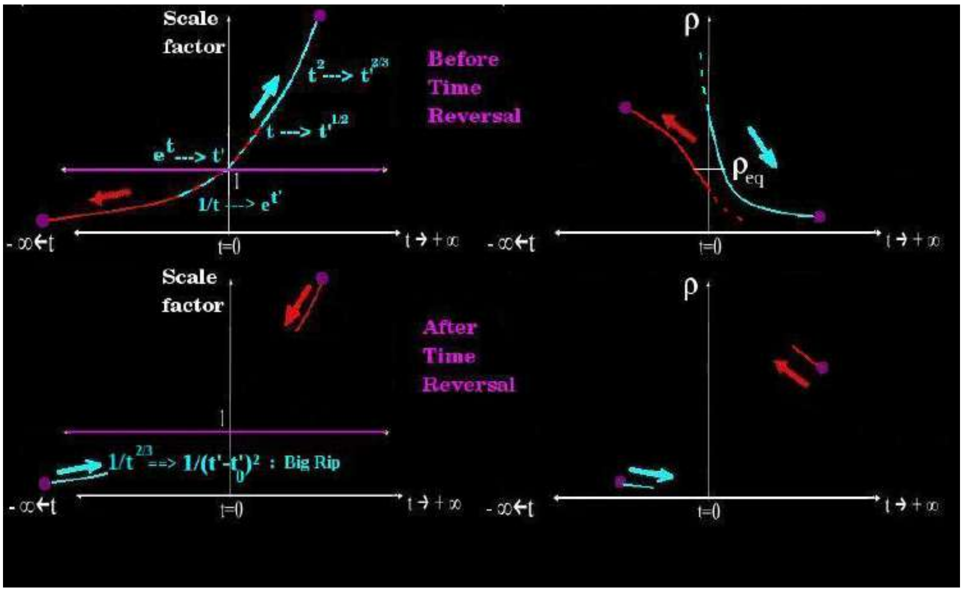


**Figure 1.** Evolution laws and time reversal of the conjugate universes, our side in blue.

at the time of our side nucleosynthesis. Otherwise a nonvanishing source $\tilde{\rho} - 3\tilde{p}$ from the Dark side would have implied a quite different evolution from LCDM and very different fractions for the light elements following Big-Bang Nucleosynthesis, which is completely excluded. The reason why the radiative era evolution $t'^{1/2}$ (the solutions first obtained in conformal time $t$ are straightforwardly translated into standard cosmological time $t'$ evolution laws) and subsequent decelerated evolution $t'^{2/3}$ in the cold era on our side are the same as in LCDM is simple: provided our side scale factor $a(t)$ dominates the inverse scale factor $\tilde{a}(t) = 1/a(t)$ and provided $\tilde{\rho} - 3\tilde{p}$ vanishes as well during our side hot era, dark side terms can be neglected in our cosmological equation which reduces to a cosmological equation known to be valid within GR (Figs. 1–3).

The very new feature of this history is that we are now also able to account for the recent acceleration of the universe without a cosmological constant in DG, assuming a discrete transition, genuine permutation of the conjugate scale factors which occurred about the transition redshift $z_{\text{tr}} = 0.7$. Such transition is a very peculiar but also very natural feature of a theory where the discrete nature of the time reversal symmetry is really accounted for. We understand that the huge discontinuous transition itself did not produce an observable effect at the time it occurred. In particular the densities are the same just before and just after the transition. This seems to conflict with the usual understanding that the densities vary when the scale factor varies, the exact behaviour being deduced from the free fall equations. However the free fall equation simply does not apply to the time reversal process itself that instantaneously exchanges the roles of the conjugate scale factors. On the contrary our current understanding is that all physical quantities (matter and radiation properties) remain the same in such transition so that in our cosmological equation (3) it is only the terms that depend explicitly on the scale factors that are modified.[a]

So neither the Hubble factors (the scale factor is transformed into its inverse and at the same time the infinitesimal dt is also transformed into $-\mathrm{d}t$ so that $\dot{a}/a$ is invariant) nor densities did experience any discontinuity at the transition however the subsequent evolution now started to be driven by the dominant $\tilde{a}(t)$ term on the left-hand side of our cosmological equation.

On the right-hand side of our cosmological equation, let us stay open minded and consider two alternatives. The conjugate side now should have reached huge densities after contracting by a $\simeq 10^9$ factor between Big Bang Nucleosynthesis and now (remember we don't need to care about the instantaneous discontinuous permutation itself since it does not modify the densities). Thus $\tilde{\rho} - 3\tilde{p}$ still zero is normally expected in a radiation dominated phase so that $\rho - 3p \simeq \rho \propto 1/a^3(t)$ drives the evolution...

In this case our cosmological equation simplifies

$$\tilde{a}^2 \frac{\ddot{\tilde{a}}}{\tilde{a}} \propto \frac{1}{\tilde{a}}. \tag{4}$$

With solution $a(t) \propto t^{-2/3}$ which translates into an accelerated expansion regime $(t' - t'_0)^{-2}$ with a Big Rip at future time $t'_0$.

Another possibility is the one represented in Fig. 2 where a mother Universe lost contact with its conjugate and split into two new baby conjugate universes about a new re-normalized $\eta$ background at a reset time origin $t_0$. If this happened during the cold matter dominated era (for instance between $z = 1000$ and now), this scenario is interesting because now our conjugate side universe might not be extremely different from our side since the two originated recently from a same mother. Following this scenario, right now this recently born conjugate universe can be both in

[a] We shall investigate later discontinuities in space, e.g. what happens when light or a body crosses the frontier between two regions where different regimes of the scale factor take place, one expanding and one contracting for instance. In this particular case of a discontinuity in space rather than in time, the body does not experience time reversal crossing it, so the equation of free fall applies (wave equations can always be solved in presence of potential discontinuities: forces are undefined but potential barriers and their effects are well defined, remind the square potentials of our basic QM courses) and new effects are expected that will be the subject of forthcoming sections.

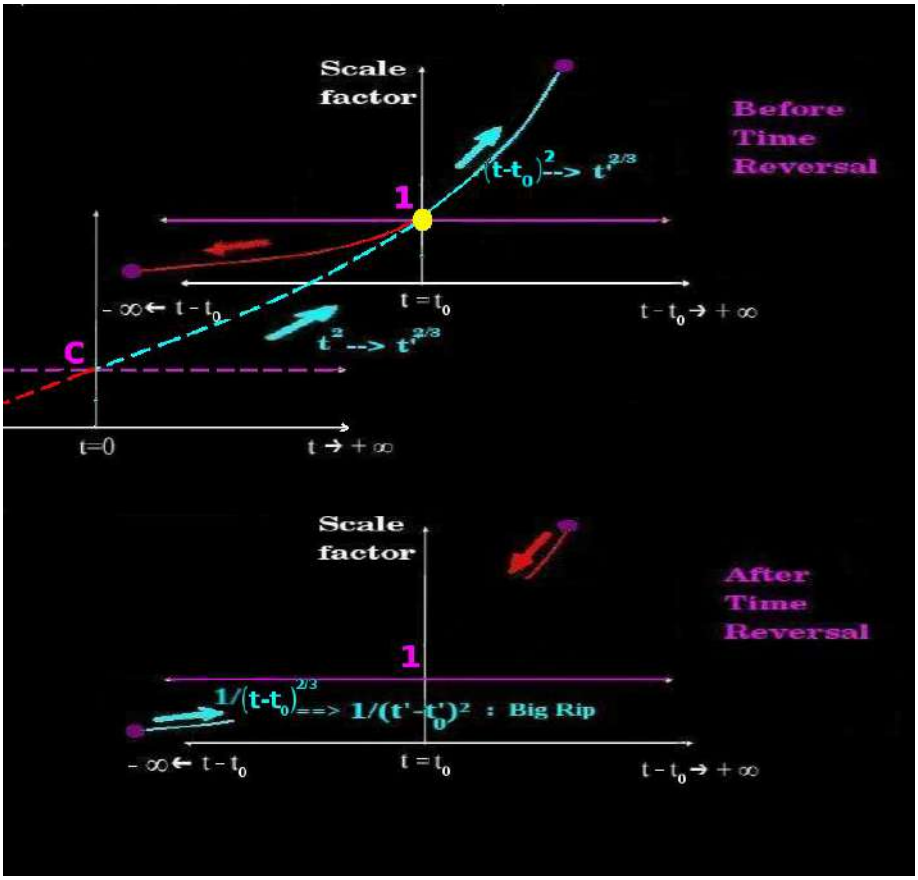


**Figure 2.** Universe splitting giving birth to a new couple of conjugate universes, our side in blue.

a matter dominated era or radiation dominated era if it had enough time between the yellow point where it started to contract and the purple point of time reversal in Fig. 2.

The equation of state can be such that $\tilde{\rho} - 3\tilde{p}$ is $\propto 1/(\tilde{a}^{3+\delta}(t))$ with $0 < \delta < 1$ , $\delta = 0$ corresponding to a cold matter dominated era and $\delta = 1$ to a state not far from matter radiation equality. More radiation dominated (fast increasing $\delta > 1$) would eventually result again in a negligible $\tilde{\rho} - 3\tilde{p}$ so we are back to the Big Rip of our first case when our side $\rho - 3p \simeq \rho \propto 1/a^3(t)$ drives the evolution. In case $0 < \delta < 1$ the conjugate side can momentarily drive the evolution all the easier as $a^4(\rho - 3p) \ll \tilde{a}^4(\tilde{\rho} - 3\tilde{p})$ for $a(t) \ll \tilde{a}(t)$. Then our cosmological equation simplifies in a different way:

$$\tilde{a}^2 \frac{\ddot{\tilde{a}}}{\tilde{a}} \propto \tilde{a}^{1-\delta}. \tag{5}$$

With solution $a(t) \propto t^{-2/(1+\delta)}$ which translates into an accelerated expansion regime $t'^{2/(1-\delta)}$.

Constraining the age of the universe to be the same as in LCDM is the easiest way to ensure that there will be no noticeable departure between our and the LCDM cosmological history insofar as we are not looking at the fine details of the recent transition between decelerated and accelerated regime. In case of a discrete transition applying everywhere simultaneously we could derive the following formula relating the transition redshift to the power $\alpha$ of the recent accelerated expansion law $t'^{\alpha}$.

$$z_{\rm tr} = \left(\frac{2/3-\alpha}{1-\alpha}\right)^{\alpha} - 1. \tag{6}$$

Then one could check that our predicted $\alpha = 2/(1-\delta)$ in the second case gives $0.33 < z_{\rm tr} < 0.78$ for $0 < \delta < 1$ in good agreement with the best current estimation $z_{\rm tr} = 0.67 \pm 0.1$ [17]. In the first case $\alpha = -2$ gives $z_{\rm tr} = 0.27$ which, we notice, is quite close to $z_{\rm tr} = e^{1/3} - 1 \approx 0.4$ corresponding to a modified fictitious LCDM cosmology with a discontinuous transition between 100 % cold dark matter and 100 % $\Lambda$ dominated universe.

We probably cannot assume that the transition redshifts were everywhere exactly the same due to local inhomogeneities so that integrated over large regions, the resulting transition is likely to be observed significantly smoothed by this dispersion of $z_{\rm tr}$. The mean transition redshift is very sensitive to this since the LCDM very smooth transition well fits the data with $z_{\rm tr} \approx 0.7$ while a discrete transition would imply $z_{\rm tr} = e^{1/3} - 1 \approx 0.4$ as we already noticed.

The good agreement in the second case particularly for a small $\delta$, seems to imply a small dispersion of $z_{\rm tr}$ while in the first case or radiation dominated second case a much larger dispersion implying a very progressive and smoothed transition on the mean is required, a scenario which probably will be more difficult to discriminate from the very progressive LCDM transition between matter and Lambda dominated expansion.

Another lesson of the previous analysis is that with a possible succession of time reversals and rebirths of universes, particularly if the rebirth is originating from a finite sub-region of a mother universe (maybe a giant black-hole), the equality between matter and antimatter, which presumably was a starting point, can be completely lost in a given couple of conjugate universes and the fraction of baryons over photons can also be quite arbitrary on both sides.

Notice then that when we say that the conjugate side was in a radiative era at the time of our side BBN, this does not necessarily mean that it was very dense: on the contrary it could have been a very low energy density universe where the fraction of photons over baryons was and has remained much greater than on our side.

## 3. Local Gravity

Another Janus field and its own separate Einstein–Hilbert (E–H) action are required to describe local gravity because it cannot be mixed with our previous cosmological scalar-tensor field in the same E–H action without reintroducing an additional unwanted equation for the latter.

We can summarize what we learned from solving the equations for this field in the isotropic case.

- Our new Janus field for local gravity can only satisfy the equations provided it is asymptotically Minkowskian (as we already noticed in Section 2). This ensures that any global evolution is exclusively driven by our previous cosmological tensor-scalar field.
- We found a couple of static isotropic conjugate solutions in vacuum of the form $g_{\mu\nu} = (B, A, A, A)$ and $\tilde{g}_{\mu\nu} = (1/B, 1/A, 1/A, 1/A)$

$$A = \mathrm{e}^{\frac{2MG}{r}} \approx 1 + 2\frac{MG}{r} + 2\frac{M^2G^2}{r^2}, \tag{7}$$

$$B = -\frac{1}{A} = -\mathrm{e}^{\frac{-2MG}{r}} \approx -1 + 2\frac{MG}{r} - 2\frac{M^2G^2}{r^2} + \frac{4}{3}\frac{M^3G^3}{r^3} \tag{8}$$

  perfectly suited to represent the field generated outside an elementary 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: no more black hole!

- 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.
- The exponential form of the metric implies that a trivial superposition principle allows us to combine the field generated by a mass $M_1$ and the field generated by a mass $M_2$ at the same place: gravity is linear in the argument of the exponential. We did not already figure out all the implications of this result which we believe is of fundamental importance. We know about great theoretical efforts that were undertaken toward a modified theory of gravity just to get this kind of solution instead of the Schwarzschild GR one [26].

## 4. Gravitational Waves, Sound Waves and Vacuum Energy

### 4.1. Gravitational waves

Let us introduce a plane wave perturbation $h_{\mu\nu}$ with its counterpart $\tilde{h}_{\mu\nu}$. Then, up to a redefinition of the gravitational constant *G* by a factor two (the same as for the equations of the $B = -1/A$ isotropic static field of Section 3), the linearized equations could be the same in GR and DG. Indeed, without such redefinition here we have:

$$2\left(R^{(1)}_{\mu\nu} - \frac{1}{2}\eta_{\mu\nu}R^{(1)\lambda}_{\lambda}\right) = -8\pi G(T_{\mu\nu} - \tilde{T}_{\mu\nu}). \tag{9}$$

We know that the physical degrees of freedom for these plane waves are quadrupolar (spin 2) and could well account for the recent direct observation of gravitational waves by Ligo. The apparent problem is that this equation is also valid to second order in the perturbation $h_{\mu\nu} = -\tilde{h}_{\mu\nu}$ because one just needs to add a quadratic term $t_{\mu\nu} - \tilde{t}_{\mu\nu}$ on the right-hand side standing for the energy–momentum of the gravitational field itself which has two cancelling contributions since $t_{\mu\nu} = \tilde{t}_{\mu\nu}$ to second order in small plane wave perturbations. This does not mean that there is no wave. Indeed the Linearized Bianchi identities are still obeyed on the left-hand side and it therefore follows the local conservation law:

$$\frac{\partial}{\partial x^{\mu}}(T^{\mu\nu} - \tilde{T}^{\mu\nu} + t^{\mu\nu} - \tilde{t}^{\mu\nu}) = 0, \tag{10}$$

where the indices were raised with $\eta$. The interpretation could be the following: for any wave radiated on our side which energy carried away by $t^{\mu\nu}$ was lost by $T^{\mu\nu}$ there is of course the accompanying wave on the conjugate side with the same energy $\tilde{t}^{\mu\nu} = t^{\mu\nu}$ carried away implying a back-reaction effect on whatever is the content of $\tilde{T}^{\mu\nu}$: $\partial_\mu T^{\mu\nu} = \partial_\mu \tilde{T}^{\mu\nu}$. It results that the following conservation equations might be separately verified:

$$\partial_\mu(T^{\mu\nu} + t^{\mu\nu}) = 0, \tag{11}$$

$$\partial_\mu(\tilde{T}^{\mu\nu} + \tilde{t}^{\mu\nu}) = 0. \tag{12}$$

In the first equation, we have exactly the same definition of $t_{\mu\nu}$ as in GR while in Eq. (9) the coupling is $G/2$ instead of *G* in GR. Then for the same strength of gravity (implying a redefinition of *G* in the equations of the $B = -1/A$ field of Section 3) we expect a radiated power divided by 2 in DG relative to GR.

One could imagine trying to get the correct emission of GW thanks to a separate Einstein–Hilbert action just for our quadrupolar plane waves with a twice larger coupling but this is extremely unnatural Ad-Hoc and most probably nonsensical to separately handle in this way the GW modes and those of the static local field.

A more appealing possibility is if a compact source of mass M on our side generates by its anti-gravitational effect, a matter depleted region, e.g. a "hole" in the conjugate side distribution of matter-energy (resulting in an effective mass $-M$ there in static equilibrium with *M* on our side) which effect would be equivalent to exactly doubling the source term in Eq. (9) to help us exactly recover the same prediction as in GR without redefining *G*.

Another idea would maybe help this to work, e.g. get the exact $-M$ effective mass on the conjugate side in any case. The DG theory for the first time allows us to speculate about the vacuum being populated by a network of point fundamental masses with alternating masses plus or minus $m_0$, because such picture is then granted to be stable. The masses could be very big provided they are close to each over (small pitch of the network) without having ever been noticed experimentally. Then a given body immersed on our side in such false vacuum would attract the positive plus $m_0$ on our side and repel the negative minus $m_0$ of the conjugate side resulting in the actual effective mass that we do measure for this body (we shall investigate in the next section another very different and unrelated kind of vacuum polarisation effect determined by vacuum quantum fluctuations). Because of this vacuum gravitational polarisation effect, any massive body might (further investigation needed) actually be considered as a pair of mass $+M$ on our side and almost exactly effective $-M$ (depleted vacuum region) on conjugate side resulting in the total effective gravific mass *2M* so we do not need any redefinition of *G* to recover the same predictions as in GR for both gravitational waves radiation and the local static field! Moreover the mass $+M$ on our side and $-M$ effective mass counterpart on the conjugate side free fall in exactly the same way in any external gravitational field because the behaviour of $-M$ is the same as that of an Archimedian Bubble: it falls in the opposite way, so this extension of the theory appears fully consistent!

Finally, we might consider an unconventional boundary condition for our fields being asymptotically Minkowskian up to a normalisation constant, e.g. $C\eta_{\mu\nu}$ far from sources (this would not matter in GR). Then for $C \gg 1$ we are back to GR for local gravity because all terms depending on the conjugate field become negligible. Moreover $C\eta_{\mu\nu}$ might be conceived as a frozen state of our tensor scalar field. This option is much less appealing because we might lose our beloved exponential static solution at the same time. Eventually, following this last approach, depending on the local *C* value, 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.

Anyway, stability is granted since those waves and the fields they directly couple to either on our or the conjugate side carry the same sign of the energy.

### 4.2. Gravity of the vacuum energy

It is well known that the vacuum energy arises as a cosmological constant term which we shall denote $\Lambda$. In the absence of gravitational or electromagnetic sources, there is also no reason why such term should differ on our and conjugate side of the Janus field, so the related energy momentum tensors simply are:

$$T^{\mu\nu}_{vac} = \Lambda g^{\mu\nu}, \qquad \tilde{T}^{\mu\nu}_{vac} = \Lambda \tilde{g}^{\mu\nu} \tag{13}$$

and the corresponding source term in the DG equation:

$$\sqrt{g}T^{\mu\nu}_{vac} - \sqrt{\tilde{g}}\tilde{T}^{\rho\sigma}_{vac}\eta_{\tau\rho}\eta_{\lambda\sigma}g^{\tau\mu}g^{\lambda\nu} = \sqrt{g}\Lambda g^{\mu\nu} - \sqrt{\tilde{g}}\Lambda g^{\mu\nu} \tag{14}$$

naturally vanishes when $g_{\mu\nu} = \eta_{\mu\nu}$. This is already an impressive result!

However, this might not be the case in general, not only because of the nonvanishing $\sqrt{g} - \sqrt{\tilde{g}} = \sqrt{g} - \frac{1}{\sqrt{g}}$ factor but also because of an expected vacuum "polarisation" induced by any local concentration of mass: then $\Lambda$ gets replaced by a polarized $\Lambda f_p(g)$ on our side and anti-polarized $\Lambda f_p(\tilde{g}) = \Lambda / f_p(g)$ on the conjugate side. Therefore the source term in the DG equation becomes proportional to $F(g) - 1/F(g)$ where $F(g) = \sqrt{g} f_p(g)$ so that a condition for a vanishing vacuum contribution to gravity anywhere is $f_p(g) = \frac{\sqrt{\eta}}{\sqrt{g}}$ ($f_p(g)$ needs to be a scalar) which does not seem unreasonable.

So the solution to the worse discrepancy between observation and the General Relativity theory (the vacuum energy contribution to gravity should be huge everywhere which does not appear to be the case) is really now at hand in DG. By the way let us note that a theory without any polarization effect but with an effective action of the kind $\int \mathrm{d}^4x\sqrt{\eta}\Lambda ln(g/\eta)$ on both sides of the Janus field would equally lead to a vanishing vacuum contribution to the gravitational field.

### 4.3. Acoustic waves

On the very hot conjugate side of our universe (but maybe not so dense if at the beginning of its contraction the conjugate side was almost empty and dominated by photons) not only gravitational but also acoustic waves (as the waves that left their imprint on the CMB) can propagate. The effect of those sound waves can also indirectly be detected from our side as they modify the local density of the fluid and therefore its local gravity felt on our side according the Janus field. Interferometers are also able to detect such longitudinal (acoustic like) waves as these do not expand/contract the two arms in the same way.

## 5. The Unified DG Theory

### 5.1. DG actions

Eventually the theory splits up into two parts, one with total action made of a E–H 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 E–H action for the asymptotically Minkowskian Janus Field $g_{\mu\nu}$ for local gravity (which perturbations $h_{\mu\nu}$ and $\tilde{h}_{\mu\nu}$ can account for the detected gravitational waves) added again to SM actions for F and $\tilde{F}$ type fields respectively minimally coupled to $g_{\mu\nu}$ and $\tilde{g}_{\mu\nu}$.

Our efforts did not allow us to merge the two Janus fields into one, neither in a single E–H action, as we already saw, nor in a single SM source action. This is because when we vary $g_{\mu\nu}$ in its E–H action, this field must also be alone in a SM action and not combined either in an additive or multiplicative way with $\Phi\eta_{\mu\nu}$ because globally there must be an exact cancellation between positive and negative gravific effects from both sides for $g_{\mu\nu}$ to remain asymptotically Minkowskian while introducing $\Phi\eta_{\mu\nu}$ in a SM source action would obviously break the equilibrium.

We thus have two separate theories: one theory that describes the generation of the homogeneous $\Phi\eta_{\mu\nu}$ and also how matter and radiation fields "feel" the effects of this field and one theory that describes the generation of local gravity $g_{\mu\nu}$ and gravitational waves and also how matter and radiation fields react to this gravity. Now the question is: is it possible to merge the theories by merely adding the SM and E–H Actions for $\Phi\eta_{\mu\nu}$ to the SM and E–H Actions for the asymptotically Minkowskian $g_{\mu\nu}$ ?

Following this way is technically feasible (see Section 9): we need to vary the matter and radiation fields in both SM actions these belong to in order to get their equations of motion. One finds violations of the Weak Equivalence Principle, and also strongly excluded expansion effects of orbital planetary periods relative to atomic periods in the solar system. Trying to cure this by varying the electromagnetic coupling according the scalar $\Phi(t)$ (as in Section 9) is not a solution because it would severely conflict with other strong constraints on the time variation of the fine structure constant. Thus, though we eventually have a good candidate for a unified theory, the latter is not suited to correctly describe all aspects of gravity in the inner part of the solar system at least during the last decades.

In GR because expansion effects and local gravity are described in the same field, it was possible to derive that local gravity in the solar system completely cancels the effect of the background expansion: in other words the solar system is not expanding which is confirmed by various tests showing for instance that planetary periods are not drifting relative to atomic clock periods.

In DG we have two separate fields which implies that wherever the homogeneous scalar–tensor field applies it will hardly be possible to avoid the related expansion effects: this is for instance what we get in the solar system in our unified theory candidate where we merely add the actions of the two fields.

The only possible solution not to conflict with observational constraints which do not see expanding planet trajectories, is therefore to admit that $\Phi\eta_{\mu\nu}$ was absent at least in the inner part of the solar system during the last decades. But even more it might be that $\Phi\eta_{\mu\nu}$ is always totally absent in the vicinity of mass concentrations and is only discontinuously switched on far away from those gravity sources.

This way DG mimics GR again: no effect of expansion on small scales, but progressively taking place for GR when reaching the largest scales and discretely reappearing in DG at some distance from masses. This implies the existence of genuine field discontinuities at the frontier between zones where the asymptotically Minkowskian $g_{\mu\nu}$ applies alone and zones where $\Phi\eta_{\mu\nu}$ and $g_{\mu\nu}$ are most probably both active and their dynamics could well be described within our unified theory candidate.

To make the argument more simple, let us neglect local gravity and thus approximate our asymptotically Minkowskian $g_{\mu\nu}$ by $\eta_{\mu\nu}$ in the inner part of the solar system. Of course not to lose the cosmological redshift the transition must not be between this $\eta_{\mu\nu}$ and, in the same coordinate system, the outside $\Phi\eta_{\mu\nu}$ where photons spent most of the time during their cosmological trip. On the contrary, understanding that $\eta_{\mu\nu}$ is the metric in standard cosmological time coordinate the transition must be between this $\eta_{\mu\nu}$ and $\Phi\eta_{\mu\nu}$ as well expressed in standard cosmological time coordinate. This means that such new kind of spatial transition discontinuity (between $\eta_{\mu\nu}$ and $\Phi\eta_{\mu\nu}$ expressed in standard time rather than the previously encountered kind of discontinuity between $\Phi\eta_{\mu\nu}$ and $\Phi^{-1}\eta_{\mu\nu}$) now only affects the spatial elements of the metric: small speed matter can freely cross such discontinuity without any noticeable effects while on the contrary light will see a real potential barrier when crossing it.

### 5.2. Alternating theories

An as well interesting alternative would make appeal to discontinuities in time rather than in space. We are naturally led to consider a possible alternating between the two theories, i.e. that the time is divided in pairs of slots with durations $T_g$ and $T_\Phi$, one for the asymptotically Minkowskian dynamics and one for the homogeneous field dynamics. This kind of time quantization is facilitated by what we have understood about discontinuities in time as having no effect by themselves and allowing now to jump not only between $\Phi\eta_{\mu\nu}$ and $\Phi^{-1}\eta_{\mu\nu}$ but also between $\Phi\eta_{\mu\nu}$ and $g_{\mu\nu}$. So maybe $\Phi\eta_{\mu\nu}$ and the related expansion effects were momentarily absent in the inner part of the solar system, in a recent past including a few decades because it was switched off as it is periodically switched on and off and is therefore able to account on the mean for the redshift on cosmological time scales.

## 6. Spatial Discontinuities and the Pioneer Effect

### 6.1. Spatial discontinuities

We have already considered two kinds of discontinuities in time (between $\Phi\eta_{\mu\nu}$ and $\Phi^{-1}\eta_{\mu\nu}$ or between $\Phi\eta_{\mu\nu}$ and $g_{\mu\nu}$) and also spatial discontinuities (between $\Phi\eta_{\mu\nu}$ and $g_{\mu\nu}$). We now shall investigate possible spatial discontinuities of a second kind, e.g. between $\Phi\eta_{\mu\nu}$ and $\Phi^{-1}\eta_{\mu\nu}$. Indeed, one single solution $a(t)$ for the scale factor might not be at work everywhere on a given side of the universe. Some regions might instead be evolving according to the other solution $1/a(t)$ implying that the conjugate background (scalar–tensor) metrics exchange their roles from one to the neighbour region but then also a genuine discontinuity of this background field at their common frontier. The background field is a two valued field that can only jump from one value to the other T-conjugate one: this is another far reaching

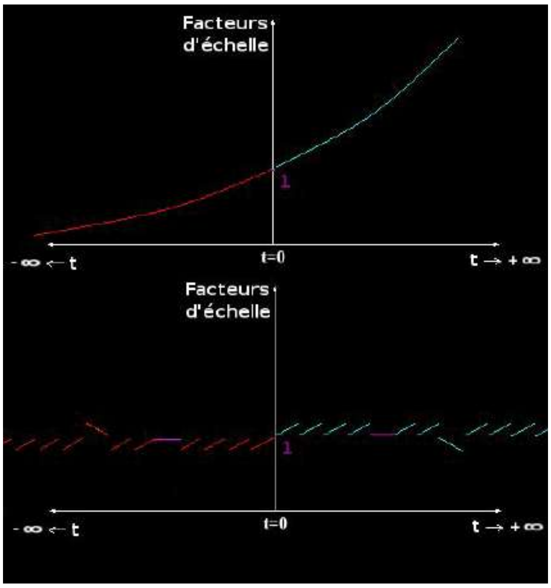


**Figure 3.** Periodic time resets of the conjugate universes, our side in blue.

consequence of the fact that this scalar-tensor field is "genetically" space independent and cannot smoothly vary in space as would any other usual field because of an inhomogeneous source.[b] As we already noticed in our previous article, the discontinuities do not necessarily imply huge potential barriers even though the scale factors have varied by many orders of magnitude between BBN and now. This is because time reversal but also time resets have no effect by themselves as we already explained in a previous section so that the two expansions pictured in top and bottom of Fig. 3 could be actually indistinguishable as for the total cosmological redshifts these imply as long as the evolutions in the continuous phases would be the same (this is not the case in Fig. 3 because in the bottom plot the evolution also had steady and contracting phases, which is also a possibility). On the other hand, the evolution represented at the bottom of Fig. 3 with its periodic resets implies that the conjugate scale factors might remain close to each other so that the implied potential barrier would not necessarily be huge from one region to the neighbour one and the related effects when crossing it might even remain unnoticed in some cases.

### 6.2. The Pioneer Effect

#### 6.2.1. *Introduction*

One might wonder why we are still interested in the Pioneer effect after the final verdict by Wikipedia: "The apparent anomaly was a matter of tremendous interest for many years, but has been subsequently explained (in 2012) by an

[b] As we already stressed in previous articles [24], being discontinuous with perhaps global rather than local factors triggering those discontinuities, we have a promising framework to explore the roots of the as well discontinuous and nonlocal rules of quantum mechanics though on the other hand the instantaneous nonpropagated nature of the local gravitational field is now much less obvious than we believed it to be, there being quadrupolar waves to propagate it (maybe!, it is left as an open question whether the quadrupolar propagating modes (pure plane wave hypothesis, no $1/r$ dependency ) and isotropic mode (timeless in DG as in GR, according to the Birkhoff theorem ) are eventually independent degrees of freedom or not).

anisotropic radiation pressure caused by the spacecraft's heat loss."

The problem is that the spacecraft asymmetric radiation estimated contribution to the anomaly had been shown to be much too small by Anderson [15] taking into account the details of the spacecraft which was specifically designed to keep the radiation as symmetric as possible. On the contrary one finds that all recent "detailed" simulations, in one way or another had to modify the structural properties of the spacecraft just to obtain the desired result: a much larger asymmetry of the radiation. My own detailed analysis is available in [24] (and [25] only in french sorry). Anderson himself is of course not convinced and has again, last summer, published an attempt to explain the Pioneer anomaly and its sudden onset after Saturn encounter by fundamental physics [16], relating it to the cosmological expansion just as we do (but not in the same way). He claims that the "thermal contribution to the anomaly can be approximately modeled to give almost only $\approx 12\%$": that's quite an accurate number isn't it?! ... and discussed at length in the conclusion of the publication.

#### 6.2.2. *Our theoretical explanation*

Above formula (16) of Ref [15] there is a CHASMP frequency drift being mentioned which value is half the usually admitted Pioneer effect, followed by the ambiguous comment: half way only. This has even led the author of [14] to interpret that the Pioneer anomaly was actually a $H_0$ instead of $2H_0$ drift in time rate. The ambiguity for us is the following: did they actually measure a $H_0$ Pioneer effect on a half way only (implying the Pioneer clock was not locked on the earth clock, contrary to what is asserted several times in the article [15]) from which they deduced the two way $2H_0$ frequency drift assuming it was a Doppler effect or did they really measure the $2H_0$ effect on the complete two way and then deduced from that, again assuming its really an anomalous Doppler effect, the half way value (that would be extremely strange because then there is absolutely no point mentioning this half way value as they do!).

For us, the effect has nothing of a Doppler effect and is actually due to a drift in time of the Pioneer free (unlocked) clock relative to earth clocks so there is an ambiguity because the two above interpretations can be translated into either a $H_0$ frequency drift in time of Pioneer clock relative to earth clock in the first (one way measurement) case and a $2H_0$ frequency drift in time in the second (two way measurement) case.

In the following we shall explain how we could explain both a $2H_0$ and a $H_0$ (more straightforward) rate for the drift. We tend to more believe in the $H_0$ drift because it is more natural in our theoretical framework, but we must still consider the $2H_0$ alternative possibility.

Suppose we can compare ticks of two identical clocks separated by a field discontinuity (with conformal metric assumed on both sides): in one region times accelerates as $a(t)$ and in the other region times decelerates as $1/a(t)$ so from the point of view of one clock the other will be seen to accelerate or decelerate at a rate equal to twice $H_0$. This is exactly (quantitatively) equal to the usually admitted $2H_0$ Pioneer frequency drift effect! Now if in one region times accelerates as $a(t)$ and in the other region the cosmological background is stationary, from the point of view of one clock the other will be seen to accelerate or decelerate at a rate equal to $H_0$. This second case is more appealing for us because the region where there is no background effect would be the inner part of the solar system (where we find our earth clocks) where indeed various precision tests have shown that expansion or contraction effects on orbital periods are excluded. Obtaining a $2H_0$ Pioneer frequency drift effect without conflicting with such observational constraints is less obvious but we are going to show that it's possible as well. After all we don't know for sure which one of the two above interpretations is correct so we are obliged to consider the two cases. The interpretation of the sudden onset of the Pioneer anomaly after Saturn encounter is also straightforward if this is where the spacecraft crossed the discontinuity of the field at the frontier between the two regions. The discontinuity absolute effect itself would have remained unnoticeable if the two scale factors are close (as we explained earlier) and only the relative drift in time started to be measurable.

We feel sorry for the experts but we prefer to present here a much detailed derivation for the beginners in GR. Hereafter subscript P refers to Pioneer and subscript E to the Earth. In the conformal time *t* coordinate system we write the metrics:

$$\begin{aligned} \mathrm{d}\tau_{\mathrm{P}}^2 &= a^2(t)(\mathrm{d}t_{\mathrm{P}}^2 - (\mathrm{d}x_{\mathrm{P}}^2 + \mathrm{d}y_{\mathrm{P}}^2 + \mathrm{d}z_{\mathrm{P}}^2)) \Rightarrow \mathrm{d}t_{\mathrm{P}} = \frac{1}{a(t)}\mathrm{d}\tau_{\mathrm{P}}, \\ \mathrm{d}\tau_{\mathrm{E}}^2 &= a^{-2}(t)(\mathrm{d}t_{\mathrm{E}}^2 - (\mathrm{d}x_{\mathrm{E}}^2 + \mathrm{d}y_{\mathrm{E}}^2 + \mathrm{d}z_{\mathrm{E}}^2)) \Rightarrow \mathrm{d}t_{\mathrm{E}} = a(t)\mathrm{d}\tau_{\mathrm{E}} \end{aligned} \tag{15}$$

for rest clocks ($\mathrm{d}x = \mathrm{d}y = \mathrm{d}z = 0$), from which follows considering two successive ticks of identical clocks ($\mathrm{d}\tau_{\mathrm{P}} = \mathrm{d}\tau_{\mathrm{E}}$):

$$\frac{\mathrm{d}t_{\mathrm{E}}}{\mathrm{d}t_{\mathrm{P}}} = a^2(t) = \frac{f_{\mathrm{P}}}{f_{\mathrm{E}}} \Rightarrow \frac{\dot{f}_{\mathrm{P/E}}}{f_{\mathrm{P/E}}} = 2\frac{a\dot{a}}{a^2} = 2\frac{\dot{a}}{a}, \tag{16}$$

where $f_{\mathrm{P/E}}$ and $\dot{f}_{\mathrm{P/E}}$ are the frequency and frequency derivative of the Pioneer clock as measured from Earth, i.e. taking as reference an Earth clock. Of course this expression is valid in conformal time coordinate *t*.

We want the expressions in standard time coordinate $t'$ because this is the one we use to get the Hubble cosmological parameter. On earth we have

$$\begin{aligned} \mathrm{d}\tau^2 &= \mathrm{d}t'^2 - a'^{-2}(t')(\mathrm{d}x^2 + dy^2 + \mathrm{d}z^2) \\ &= g'_{\mu\nu}\mathrm{d}x'^{\mu}dx'^{\nu} \\ &= g_{\mu\nu}\mathrm{d}x^{\mu}\mathrm{d}x^{\nu} \\ &= a^{-2}(t)(\mathrm{d}t^2 - (\mathrm{d}x^2 + \mathrm{d}y^2 + \mathrm{d}z^2)); \end{aligned} \tag{17}$$

however, using this same $t'$ that puts the earth metric in standard form, the Pioneer metric would have a quite different form, neither standard nor conformal. Anyway we now just need

$$\frac{f'_{\mathrm{P}}}{f'_{\mathrm{E}}} = \frac{\mathrm{d}t'_{\mathrm{E}}}{\mathrm{d}t'_{\mathrm{P}}} = \sqrt{\frac{g'_{00\mathrm{P}}}{g'_{00\mathrm{E}}}} = \sqrt{\frac{\left(\frac{\partial t}{\partial t'}\right)^2 g_{00\mathrm{P}}}{\left(\frac{\partial t}{\partial t'}\right)^2 g_{00\mathrm{E}}}} = \sqrt{\frac{g_{00\mathrm{P}}}{g_{00\mathrm{E}}}} = \frac{\mathrm{d}t_{\mathrm{E}}}{\mathrm{d}t_{\mathrm{P}}}. \tag{18}$$

This transformation of coordinate is very well known and very simplified because only the time is transformed. So the frequency ratio is still the same as it was in conformal coordinate ...

$$\frac{f'_{\mathrm{P}}}{f'_{\mathrm{E}}} = a^2(t) \tag{19}$$

but now we just would like to express it in the new $t'$ coordinate. This is an easy task because the space–space metric elements are invariant under such time transformation, for instance:

$$a^2(t) = -\frac{1}{g_{11}} = -\frac{1}{g'_{11}} = a'^2(t'). \tag{20}$$

Eventually

$$\frac{f'_{\mathrm{P}}}{f'_{\mathrm{E}}} = a'^2(t') \Rightarrow \frac{\dot{f'}_{\mathrm{P/E}}}{f'_{\mathrm{P/E}}} = 2\frac{a'\dot{a'}}{a'^2} = 2\frac{\dot{a'}}{a'}, \tag{21}$$

where of course all derivatives now are relative to the standard time $t'$.

Now beware that our scale factor is not $a'(t')$ but $1/a'(t')$ in Eq. ( 17) so an increasing $a'(t')$, needed to obtain the Pioneer blue shift, a positive $2(\dot{a'}/a')$, describes a contracting universe with respect to earth reference clocks. This is even better understood coming back to the conformal coordinate system where Eq. (15) makes it clear that earth clocks time intervals are increasing while Pioneer clocks time intervals are decreasing relative to constant photon periods in this coordinate system. In other words, as seen from Pioneer the universe is expanding (cosmological photons are red shifted) whereas as seen from earth the universe is instead contracting (cosmological photons are blue shifted). Yet we know that from earth we see that the universe has been expanding for billion years. What the Pioneer effect tells us is that this has not always been the case, because at least at the time the Pioneer effect was registered the universe is contracting relative to earth clocks rather than expanding. Only the Dark Gravity theory and its discrete symmetries allow that, because discrete jump from an expanding to a contracting solution are naturally expected to occur either globally or locally, when the conjugate metric exchange their roles. Eventually

$$\frac{\dot{f}'_{\mathrm{P}}}{f'_{\mathrm{E}}} = 2\frac{\dot{a}'}{a'} = -2H'_{00} = 2H'_0, \tag{22}$$

where $H'_{00}$ refers to the instantaneous recent Hubble factor at least valid during the last decades while $H'_0$ is the cosmological Hubble parameter as we get it from an SNs magnitude-redshift fit for instance. They are opposite as the result of a transition $a'(t') \to 1/a'(t')$.

However, one concern remains. We already noticed that no expansion/contraction effect has been active in the inner part of the solar system during the past decades. So neither of the two metrics in Eq. (15) are actually acceptable in the inner part of the solar system.

This problem is easily solved and to simplify the argument we neglect, hereafter, the nonrelevant local gravitational fields. The problem is solved because the metric in the inner part of the solar system is actually $g_{\mu\nu} \approx \eta_{\mu\nu}$ alone as we explained earlier (which trivially avoids expanding orbits) and the cosmological effects are only switched on outside of this zone with a discrete transition from $\eta_{\mu\nu}$ to the metric of $\mathrm{d}\tau^2 = \mathrm{d}t'^2 - a(t')^2\mathrm{d}\sigma^2$. The important point here is that this $\eta_{\mu\nu}$ is already expressed in standard time coordinate so rest clocks from both sides of such new kind of discontinuity are obviously not drifting with respect to each other since no scale factor applies to temporal elements of both metrics. The only possible effects, Shapiro delay and deflection for photons crossing such discontinuity, are irrelevant here (these are more interesting in case of a huge discontinuity surrounding a black hole candidate because most of its radiation might be reflected, allowing the hole to remain as black as in GR but without any event horizon).

Let us emphasize that this $\eta_{\mu\nu}$ has nothing to do with the stationary solution of our scalar-tensor field which is $\eta_{\mu\nu}$ in conformal rather than standard time! Again, this $\eta_{\mu\nu}$ is an approximated expression of our asymptotically Minkowskian field $g_{\mu\nu}$. Now, after the discontinuity between asymptotically Minkowskian and scalar-tensor field, as a second step we can switch the very different kind of discontinuity between the expanding and contracting solutions of the scalar-tensor field: this is just what we did above to get the Pioneer effect.

This reasoning in two steps and with two successive discontinuities allows us to understand more easily how we can get the 2 $H_0$ acceleration flipping directly between $\eta_{\mu\nu}$ (earth side) and $a^2(t)\eta_{\mu\nu}$ of Eq. (15) (Pioneer side) expressed in the same time $t'$ (see Eq. (17)), that puts the $a^{-2}(t)\eta_{\mu\nu}$ metric (rather than the $a^2(t)\eta_{\mu\nu}$ metric) in a standard form.

This means that we are able to both account for the acceleration of Pioneer clock at a rate $2H_0$ relative to earth clocks even though the latter clocks and actually all the inner part of the solar system encompassed by the discontinuity are not submitted to any scale factor effect as required by observational constraints!

Now if the pioneer anomaly was actually $\dot{f}_{\mathrm{P}}/f_{\mathrm{E}} = H_0$ instead of $2H_0$ everything is more simple because this rather means that we have a direct transition from $\eta_{\mu\nu}$ (earth side) to $a^2(t)\eta_{\mu\nu}$ of Eq. (15) (Pioneer side) now both already in conformal time t, rather than a transition from $\eta_{\mu\nu}$ in standard time $t'$ and $a^2(t)\eta_{\mu\nu}$ transformed to the $t'$ time coordinate as we just explained above to get the $2H_0$ effect. Moreover, $\eta_{\mu\nu}$ in this case ($H_0$ effect), and still neglecting local gravitational fields, could as well be interpreted as a stationary solution of our scalar-tensor (background) field.

#### 6.2.3. *PLL issues*

A last but not least issue is that in principle a Pioneer spacecraft should behave as a mere mirror for radio waves even though it includes a frequency multiplier. This is because its re-emitted radio wave is phase locked to the received wave so one should not be sensitive to the own free speed of the Pioneer clock.

Our interpretation of the Pioneer effect is thus that either all data were actually collected in open loop mode (kind of conspiracy theory since, to obtain correct Doppler data, this anyhow implies manipulations at the level of raw data that was not documented, which then prevented any theoretical convincing explanation of the Pioneer effect. Notice that the open loop mode is anyway mandatory to get the $H_0$ Pioneer effect rather $2H_0$) or there was a failure of on board PLLs to specifically "follow" a Pioneer like drift in time.

The latter interpretation makes sense since we never studied before how the scale factor varies on short time scales: it might be that it only varies on very rare and short time slots but much more rapidly (with much bigger Hubble factor) so that integrated on longer durations we recover the mean known $H_0$. This behaviour would produce high frequency components in the spectrum which might have not passed a low pass filter in the PLL, resulting in the on board clocks not being able to follow those sudden drifts and keep locked. Only when the integrated total drift of the phase would reach a threshold level, this system would "notice" that something went wrong, perhaps resulting in those instabilities and loss of lock (?) that one can notice in the Doppler fit residues (Fig. 9 of Ref. [15]). Indeed (from now on we give up the primes in our notations) for a $f = 2.29$ GHz clock, $\dot{f} = f.2a_{\mathrm{P/c}} = 1.2 \times 10^{-8}$ Hz/s where $a_{\mathrm{P}}$ is the anomalous acceleration in the most usual (not our) interpretation of the Pioneer effect, and we used formula (15) of Ref. [15]. A loss of lock seems to be happening at least twice a year as we can see in Fig. 9 of Ref. [15]. On half a year the Pioneer effect reaches $a$ 0.15 Hz total drift ( $a \approx 13$ degrees phase shift) which might be close to or greater than the suspected threshold. The inability to keep lock also makes sense if the PLL system was actually designed specifically not to keep lock on a Pioneer type drift in time which were not so difficult to theoretically anticipate: any local effect of the cosmological expansion could only possibly arise if one could compare free clock speeds as we have explained in details above ... so it's hard to believe that no solar system mission attempted to do this given the major theoretical issues, and given that the deep space environment is very helpful for the necessary on-board clock stability to be granted.

## 7. From Field Discontinuities to LENR

### 7.1. Reminder

We have so far encountered discontinuities in time and discontinuities in space. The latter type can also further be divided into two kinds: the first kind is a discontinuity between a zone where the local tensor field applies alone and another zone where the scalar-tensor homogeneous field is also switched on. We are going here to focus on the second kind of spatial discontinuities, those between the different possible solutions of our homogeneous scalar–tensor field which of course imply potential barriers able to accelerate massive particles crossing them (the energy gained or lost is proportional to their mass) so these could be new sources of energy for LENR phenomena. However these are totally transparent to light or other massless particles. We have already paved the way to LENR in details in a previous article. We refer the reader to this article [18] (see also [9,10,12,13] and references therein for experimental evidences related to "strange objects" produced in association with LENR) and will now focus on what is new in our understanding of the mechanism that is responsible for the apparition of a micro-ball lightning (mbl).

What remains true here is that the source term in Eq. (3) determines whether the background (scalar–tensor field) chooses the $a(t)$ evolution or the $1/a(t)$ evolution. It just depends on which contribution is the greater, our side or the conjugate side one. If we are in a vast region dominated by the conjugate side source term then a local concentration of energy on our side, as soon as it locally exceeds the conjugate side one, triggers the background flip in this region to the other regime, producing a discontinuity at the surface frontier between the external area where the conjugate side still dominates and the internal one which is enclosed by the discontinuity. Notice also that it is only the nonkinetic sources of energies that contribute to our source terms which tend to vanish in the ultra-relativistic limit. We then proposed that the universal trigger be a concentration of charges implying a local increase of the electrostatic energy because such form of static energy could better fill the available space than rest mass energy of nucleons confined inside a very small volume at the center of atoms.

### 7.2. Electronic density is the trigger

However, because the nucleons rest mass is by far the dominant form of energy it certainly implies discontinuities near the surface of these nucleons or nuclei. There however, the discontinuous low potentials (less than 10 eVs) are completely insignificant relative to the energies at work involving the strong interactions. The question is therefore: what could increase the density of static energy outside of the nuclei to pull the discontinuities out of these, and hopefully enough far away to allow them to encompass not even a single atom but many atoms? The electrostatic energy was indeed a candidate for that but the electronic density of energy as implied by the electrons rest masses is much greater and is also able to fill the volume of an atom or several atoms: this is what an electron wave function does if it truly represents the electron rest mass spread over a volume. Moreover, this form of energy can really become dominant over the conjugate side one thanks to a local concentration of electrons, because most of the conjugate side content is ultra-relativistic and has a very reduced contribution as we already noticed. However conjugate side fluctuations may play an important role by indirectly favouring more or less LENR. Those fluctuations could also be related to the local conjugate side production of a large number of matter-anti-matter pairs near their production threshold where these are nonrelativistic and can contribute to the source. This is an argument for understanding the sometimes very unpredictable and capricious character of LENR if, as we believe, LENR is made possible by the production of mbls.

### 7.3. Best experimental methods

So now the game for LENR hunters would be to find the best way to increase or make fluctuate the local density of electrons, not inside the atoms where it is imposed by the individual potential well of each nucleus, but rather at their periphery to pull out the discontinuities out of the atoms and let them encompass many atoms.

We believe that all methods allowing the system to reach the highest local pressures, the better in an impulsive way, should be helpful to achieve this. Electrical discharges are also another way to bring for a short time a large number of electrons in a small volume before these escape because of their mutual repulsion. Another way is to throw a beam packet with a very large number of electrons (impulse) onto a target: the results obtained already 10 years ago by this method was very impressive and have supported almost all features of our mbl theory [19], including the production of extremely exotic nuclei with thousands of nucleons! Plasma discharges have also given impressive results showing transmutations, unexplained energy release and big lightning balls with a substructure appearing to involve many much smaller lightning balls [22,23]. The needed super-compression might also be obtained in Z-pinch and other discharge experiments where anomalies have indeed been reported [20].

### 7.4. The stability issue

The next question is: is the mbl produced by such a local increased density of electrons, stable? As we explained in our previous article [18], the discontinuous potential barrier is completely negligible for electrons so it does not ensure the stability of an mbl which origin is a concentration of electrons. It depends however on how electrons escape the mbl then: is the electron density going to drop uniformly or much faster near the surface of the mbl? In the first case many discontinuities will eventually appear, each to encompass each individual atom (just as many islands may remain when sea level rises at the place there was a single larger island) and the mbl will soon disappear in this way. In the second case the discontinuity will start to push the nuclei against each other up to the point where the electrons cannot escape because they must compensate the nuclei positive charge concentration by their own negative charges: at this point the mbl is auto-stabilized because the concentration of electrons that gave birth to it is maintained by the concentration of nuclei.

### 7.5. The mbl collapse

Also notice that such mbls where positive and negative charges densities are increased together are not necessarily very charged (net charge) on the contrary to mbls produced by electrical discharges where there is a dominant concentration of one type of charge. Anyway our slow and fast collapse scenarios for mbls [18] must be revised since there is now nothing such as a slow or fast neutralization of an mbl to make it collapse. A collapse would now most probably be driven by the conditions prevailing on the conjugate side if they modify the balance between the two source terms in Eq. (3). The rapidity of such collapse remains crucial to predict which transmutations and nuclear reactions will be allowed. A too fast collapse will heat the content of the mbl too fast and it will lose its nuclei before these can fuse or participate to any nuclear reactions. To be more quantitative we can consider as an exercise a mbl which radius is initially one micrometer and which content is hydrogen at 2000 K and density nearly stp (we cannot exclude such low density mbls for instance in case a fluctuation in the distribution of matter energy on the conjugate side, or a local increase of electrostatic energy density on our side was the trigger). During a first phase of the collapse dividing the radius by 10 (volume by 1000), the density remains lower than the condensed Hydrogen density. Because the initial thermal energy of the mbl is $10^{-11}$ J and its radiative power according the Stefan–Boltzman law starts from $10^{-5}$ W and will decrease by a factor 100 as the mbl size gets reduced by 10, the mbl could dissipate its energy in 1 $\mu$s unless its collapse is much faster than this time. In this fast collapse case, instead the temperature might rise adiabatically as $T \propto 1/R^{3(\gamma-1)} = 1/R^{1.2}$ and the mbl would see its temperature increased by a factor 16, and the mean kinetic energy per nucleus allows the Hydrogen to escape the mbl that soon disappears in this way.

As a second exercise, we can consider a mbl with initially already the density of condensed matter, for instance Ni at again 2000 K and 1 $\mu$m radius. Now the initial thermal energy of the mbl is $\approx 3 \times 10^{-8}$ J which could be dissipated in 3 ms. But now the compression of the condensed matter is expected to be converted in elastic energy (a form of electrostatic internal energy) rather than thermal energy so the temperature might not increase as in the gas case for a fast adiabatic compression. This is fortunate for the stability of the mbl but it remains true that a collapse much shorter than a millisecond would not allow the mbl to dissipate its initial thermal energy radiatively: moreover, after suddenly collapsing by a factor 10, the mbl now needs as much as 0.3 s to radiatively dissipate this energy.

The lesson from the two previous exercises is that the initial content and density of the mbl does matter.

Now beyond a factor 10 compression level if the mbl is still alive, we are now crushing densities beyond those of condensed matter and the temperature can more easily remain stable so that the mbl itself has good chance to remain stable up to much higher densities needed both to help trigger nuclear reactions and thermalize their radiation products.

In a slow collapse of an mbl with a large number of nuclei, the nuclei remain cold and at some point their wave functions will overlap, and a collective, new many body kind of nuclear process is expected to be triggered. Because this is a reaction involving a large number of degrees of freedom, it is not unnatural, as in any system with many degrees of freedom, to see a continuously evolving nuclear process with very progressive energy exchanges taking place as there is a collective re-arrangement of the nucleons between nuclei (According L. Urutskoev [11] this might explain the difference between short duration experiments giving a small energy release per nuclei involved in transmutations as in his own discharge experiments, while longer experiments, à la Rossi, would produce much larger time integrated energy releases.) Continuous here means that each step of the process would involve a small energy release, which is possible as the mass difference between a many body input and many body output to a reaction can almost be made as small as we like. Thus what is crucial for such process to proceed in this way is both the extreme density AND extreme coldness of the state of matter reached at the end of the mbl collapse and actually only mbls can reach such state: stars and the primordial universe are both extremely dense but also extremely hot and for instance it will take many billions of years for white dwarf to cool down to such room temperatures while a micrometer object can radiate away its heat much more effectively. The cold temperature is presumably very important because it is the parameter that ensures that two body collisions and their huge nuclear energy releases will not be triggered before reaching the state where the nuclei wave functions all largely overlap (large Heisenberg extension is related to the small mean kinetic energy) each other and presumably begin to behave as a whole intricate entity! Of course this is still a very qualitative picture at this stage, and should be hopefully confirmed by detailed analysis and computations by nuclear physics experts: hopefully because the experimental evidence is already there and overwhelming (Ref. [19] for instance)!

### 7.6. Remarks concerning lowest energy experiments trying to generate heat

Eventually in an experiment which impulse energies are too small so that mbls are hardly produced and a too small number of them is able to reach the density conditions for nuclear fusion, it is better to increase as much as possible the number of sites where high pressures are reached in condensed matter or where micro electrical discharges could take place. For example huge local pressures (GPa) can be reached locally in silicium platelets and cracks [21] after the Silicium was submitted to a 32 keV Hydrogen ions beam so a beam is an effective method to create high pressure spots to favour the generation of mbls in materials. This most probably contributes effectively to the impressive LENR anomalies obtained in various low energy beam (in Japan for instance) or discharge experiments.

For low energy experiments it also makes sense to feed the mbls with the lightest fuels such as hydrogen isotopes which according the usual laws of nuclear physics have an enhanced probability to fuse, well before the conditions could be reached to obtain other less favored reactions. It remains an open question whether, in order to produce heat, it's more interesting to trigger two body reactions which high energy radiation products are efficiently thermalized in the ultra-dense mbl or many body reactions with a much lower and more progressive energy release. But let us keep in mind that the first nuclear reactions taking place can lead to premature disintegration of the mbl and prevent it to reach the conditions for other kind of reactions.

### 7.7. Tritium and Helium 3

One more feature difficult to explain in LENR experiments able to trigger hydrogen fusion into He4 is the observation of tritium while He3 is absent. The ultra-dense medium inside an mbl as we understand it might be the key to the enigma because it leads to a medium populated with high Heisenberg energy electrons. Those are able to transform protons belonging to various nuclei into neutrons through the weak interaction. We believe that for instance most He3 nuclei could be effectively transformed into tritium when the 19 keV needed energy can be provided by the electrons. The same kind of process starting from a heavier nuclei (nickel for instance) involving a chain of fusions with protons, each followed by weak transformation of those protons into neutrons would also allow to explain the chain of nickel transmutations leading to heavier Ni isotopes observed in the Rossi reactor according to the Lugano report.

## 8. Conclusion

We have reviewed the genesis of the DG theory along with some of its most important results in cosmology, but also described how the gravitational waves and the Pioneer effect can be understood within this new framework. Let us stress that the Pioneer effect remains ambiguous and has been interpreted by some as a clock acceleration with rate $H_0$ rather than $2H_0$. DG can explain both quite simply and naturally but a rate $H_0$ is even more straightforwardly obtained. A last part was devoted to an important revision of the mechanism that we believe is responsible for the apparition of micro lightning balls appearing to be strongly correlated with LENR effects in many kind of experiments.

## 9. Annex: Matter and radiation field equations: the two metric case

In the following, we want to see what kind of equations we could get assuming our radiation and matter fields at the same time minimally couple to both our homogeneous cosmological field and asymptotically Minkowskian field in their respective separate actions. We by the way applied a "somewhat questionable trick" to get the same expansion effect on gravitationally and electromagnetically bound system, otherwise this would not be natural. We remain in the conformal time coordinate system and adopt the conventions of [6].

As in [6], p. 358, formula (12.1.6), we take the matter (particle with mass $m$ and charge $e$) and radiation (EM vector potential $A_\mu$) action as:

$$I_M = -m\int \mathrm{d}p\frac{\mathrm{d}\tau(p)}{\mathrm{d}p} - \frac{1}{4}\int \mathrm{d}^4x\sqrt{g}F_{\mu\nu}(x)F^{\mu\nu}(x) + e\int \mathrm{d}p\frac{\mathrm{d}x^\mu(p)}{\mathrm{d}p}A_\mu(x(p)) \tag{23}$$

and vary the dynamical variable $x(p)$ and $A_\mu$ following the same steps as in [6], p. 359, but keeping $p$ as the integration variable. First varying $x(p)$ we eventually get the action variation

$$\begin{aligned}\delta I_M = &\int \mathrm{d}p g_{\mu\lambda}(x(p))\left(-m\frac{\mathrm{d}p}{\mathrm{d}\tau(p)}\left[\frac{\mathrm{d}^2x^\mu(p)}{\mathrm{d}p^2} + \Gamma^\mu_{\rho\sigma}(x(p))\frac{\mathrm{d}x^\rho(p)}{\mathrm{d}p}\frac{\mathrm{d}x^\sigma(p)}{\mathrm{d}p}\right]\right)\delta x^\lambda(p)\\ &+ e\int \mathrm{d}p g_{\mu\lambda}(x(p))\frac{\mathrm{d}x^\rho(p)}{\mathrm{d}p}F^\mu_\rho(x(p))\delta x^\lambda(p).\end{aligned} \tag{24}$$

But now suppose the same matter and radiation fields are also minimally coupled to another $\bar{g}_{\mu\nu}$ in $\bar{I}_M$ which variation $\delta\bar{I}_M$ we need to add to the previous $\delta I_M$. With the same integration variable:

$$\begin{aligned}\delta\bar{I}_M = &\int \mathrm{d}p\, \bar{g}_{\mu\lambda}(x(p))\left(-m\frac{\mathrm{d}p}{\mathrm{d}\bar{\tau}(p)}\left[\frac{\mathrm{d}^2x^\mu(p)}{\mathrm{d}p^2} + \bar{\Gamma}^\mu_{\rho\sigma}(x(p))\frac{\mathrm{d}x^\rho(p)}{\mathrm{d}p}\frac{\mathrm{d}x^\sigma(p)}{\mathrm{d}p}\right]\right)\delta x^\lambda(p)\\ &+ e\int \mathrm{d}p\, \bar{g}_{\mu\lambda}(x(p))\frac{\mathrm{d}x^\rho(p)}{\mathrm{d}p}\bar{F}^\mu_\rho(x(p))\delta x^\lambda(p).\end{aligned} \tag{25}$$

Now $\bar{g}_{\mu\nu}$ is nothing but our scalar tensor $a^2(t)\eta_{\mu\nu}$ and $g_{\mu\nu}$ our local field. If we want to study the first order effects of the scale factor a(t) we can certainly approximate $\bar{g}_{\mu\lambda}$ by $a^2 g_{\mu\lambda}$ and $\mathrm{d}\bar{\tau}(p)$ by $a\,\mathrm{d}\tau(p)$. Eventually changing the integration variable from $p$ to $\tau$, requiring a vanishing total action variation gives us the equation of motion for our particle:

$$(1+a)\frac{\mathrm{d}^2x^\mu(p)}{\mathrm{d}p^2} + (\Gamma^\mu_{\rho\sigma}(x(p)) + a\bar{\Gamma}^\mu_{\rho\sigma}(x(p)))\frac{\mathrm{d}x^\rho(p)}{\mathrm{d}p}\frac{\mathrm{d}x^\sigma(p)}{\mathrm{d}p} = \frac{e}{m}\frac{\mathrm{d}x^\rho(p)}{\mathrm{d}p}(F^\mu_\rho(x(p)) + a^2\bar{F}^\mu_\rho(x(p))), \tag{26}$$

where we eventually renamed $\tau$ into $p$ again. Did you see the "trick"? Anyway there is no doubt that such equations could more rigorously be obtained by introducing extra scalar coefficients $\Phi = a^2(t)$ where we need them in the actions ... however there is also no doubt this would be at the price of violating constraints on the secular variation of the fine structure constant.

Now varying $A_\mu(x)$ we eventually get the total action variation

$$\int \mathrm{d}^4x \left(\frac{\partial}{\partial x^\mu}[\sqrt{g}F^{\mu\nu}(x)] + e\int \mathrm{d}p\,\delta^4(x-x(p))\frac{\mathrm{d}x^\nu(p)}{\mathrm{d}p}\right)\delta A_\nu(x)$$
$$+\int \mathrm{d}^4x \left(\frac{\partial}{\partial x^\mu}[\sqrt{\bar{g}}\bar{F}^{\mu\nu}(x)] + e\int \mathrm{d}p\,\delta^4(x-x(p))\frac{dx^\nu(p)}{\mathrm{d}p}\right)\delta A_\nu(x) \quad (27)$$

and with $\bar{g}_{\mu\nu} = a^2(t)\eta_{\mu\nu}$, $\sqrt{\bar{g}}\bar{F}^{\mu\nu}(x) = F_{\mu\nu}(x)$ we see that the derived Maxwell equations will not be sensitive to the scale factor as expected in conformal time coordinate. We again require the action variation to vanish to get:

$$\frac{\partial}{\partial x^\mu}[\sqrt{g}g^{\mu\rho}g^{\nu\sigma}F_{\rho\sigma}(x) + \eta^{\mu\rho}\eta^{\nu\sigma}F_{\rho\sigma}(x)] = -2e\int \mathrm{d}p\,\delta^4(x-x(p))\frac{\mathrm{d}x^\nu(p)}{\mathrm{d}p}. \quad (28)$$

However, this equation violates the Weak Equivalence Principle in gravitational redshift experiments so this is already a dead end.

Now our purpose is to only investigate the effect of the scale factor in Eq. (26) for the case $a(t) \gg 1$ to see if at least something interesting could happen in this sector. Then:

$$\frac{\mathrm{d}^2x^\mu(p)}{\mathrm{d}p^2} + (\frac{1}{a}\Gamma^\mu_{\rho\sigma}(x(p)) + \bar{\Gamma}^\mu_{\rho\sigma}(x(p)))\frac{\mathrm{d}x^\rho(p)}{\mathrm{d}p}\frac{\mathrm{d}x^\sigma(p)}{dp} = \frac{e}{m}\frac{\mathrm{d}x^\rho(p)}{\mathrm{d}p}(\frac{1}{a}F^\mu_\rho(x(p)) + a\bar{F}^\mu_\rho(x(p))) \quad (29)$$

with $F_{\rho\nu} = (\partial_\rho A_\nu - \partial_\nu A_\rho)$ where $A_\mu = (V(r), 0, 0, 0)$. The free fall equations of motion in the plane $\theta = \pi/2$ and in the slow velocity approximation read:

$$\frac{\mathrm{d}^2r}{\mathrm{d}p^2} + \frac{1}{2a}\frac{B'}{A}\left(\frac{\mathrm{d}t}{\mathrm{d}p}\right)^2 + 2\frac{\dot{a}}{a}\frac{\mathrm{d}r}{\mathrm{d}p}\frac{\mathrm{d}t}{\mathrm{d}p} = \frac{q}{m}\frac{V(r)'}{a(t)}\left(\frac{1}{A}+1\right)\frac{\mathrm{d}t}{\mathrm{d}p},$$

$$\frac{\mathrm{d}^2\phi}{\mathrm{d}p^2} + 2\frac{\dot{a}}{a}\frac{\mathrm{d}\phi}{\mathrm{d}p}\frac{\mathrm{d}t}{\mathrm{d}p} + \left(\frac{A'}{aA}+\frac{2}{r}\right)\frac{\mathrm{d}r}{\mathrm{d}p}\frac{\mathrm{d}\phi}{\mathrm{d}p} = 0,$$

$$\frac{\mathrm{d}^2t}{\mathrm{d}p^2} + \frac{B'}{aB}\left(\frac{\mathrm{d}r}{\mathrm{d}p}\right)\left(\frac{\mathrm{d}t}{\mathrm{d}p}\right) + \frac{\dot{a}}{a}\left(\frac{\mathrm{d}t}{\mathrm{d}p}\right)^2 = \frac{q}{m}\frac{V(r)'}{a(t)}\left(\frac{1}{B}+1\right)\frac{\mathrm{d}r}{\mathrm{d}p}.$$

We integrate the second equation after dividing it by $\mathrm{d}\phi/\mathrm{d}p$

$$\frac{\mathrm{d}}{\mathrm{d}p}\left[\ln\left(\frac{\mathrm{d}\phi}{\mathrm{d}p}\right) + \ln A^{1/a} + \ln a^2 + 2\ln r\right] = 0 \;\Rightarrow\; \frac{\mathrm{d}\phi}{\mathrm{d}p} \propto \frac{1}{a^2r^2}$$

keeping only the leading $a(t)$ term (we could as well have switched off the local gravity).

We then perform the integration of the third equation:

$$\frac{\mathrm{d}t}{\mathrm{d}p}\frac{\mathrm{d}}{\mathrm{d}p}\left(\ln\frac{\mathrm{d}t}{\mathrm{d}p} + \ln B + \ln a\right) = \frac{q}{m}\frac{\mathrm{d}V}{a(t)\mathrm{d}p}\left(\frac{1}{B}+1\right) \quad (30)$$

or defining $u = a(t)(\mathrm{d}t/\mathrm{d}p)$ and keeping only leading term in $a(t)$:

$$u\frac{\mathrm{d}}{\mathrm{d}p}(\ln u) \approx \frac{2q}{m}\frac{\mathrm{d}V}{\mathrm{d}p} \quad (31)$$

hence now

$$\frac{\mathrm{d}t}{\mathrm{d}p} = \frac{2}{a(t)}\left(\frac{q}{m}V(r)+1\right) \propto \frac{1}{a(t)},$$

which allows us to get

$$\dot{\phi} \approx \frac{1}{ar^2}$$

We could again have switched off local gravity and electromagnetism to get this result. The first equation in the small speed limit and using

$$\frac{\mathrm{d}}{\mathrm{d}t}\left(\frac{\mathrm{d}t}{\mathrm{d}p}\right) = -\frac{\dot{a}}{a}\frac{\mathrm{d}t}{\mathrm{d}p}$$

gives

$$\begin{aligned}
&\frac{\mathrm{d}}{\mathrm{d}t}\left[\frac{\mathrm{d}t}{\mathrm{d}p}\frac{\mathrm{d}r}{\mathrm{d}t}\right]\frac{\mathrm{d}t}{\mathrm{d}p} + \frac{1}{2}\frac{B'}{aA}\left(\frac{\mathrm{d}t}{\mathrm{d}p}\right)^2 + 2\frac{\dot{a}}{a}\dot{r}\left(\frac{\mathrm{d}t}{\mathrm{d}p}\right)^2 = \frac{q}{m}\frac{V(r)'}{a(t)}\left(\frac{1}{A}+1\right)\frac{\mathrm{d}t}{\mathrm{d}p} \\
&\Rightarrow \left[\ddot{r} - \frac{\dot{a}}{a}\dot{r}\right] + \frac{1}{2}\frac{B'}{aA} + 2\frac{\dot{a}}{a}\dot{r} \approx \frac{q}{m}V(r)'.
\end{aligned}$$

Eventually,

$$\ddot{r} \approx \frac{q}{m}V'(r) - \frac{1}{2}\frac{B'}{A} - \frac{\dot{a}}{a}\dot{r}.$$

Thanks to our "trick" (for which again we surely could elaborate a rigorous version thanks to our "always available when needed" scalar field), the effects of expansion are the same on electromagnetic or gravitationally bound systems and, for circular orbits, produce a drift of their periods relative to periods of free electromagnetic waves which are constant in our conformal coordinate system: therefore the universe is correctly expanding. In standard cosmological time, on the contrary, light periods would of course expand as usual relative to constant gravitational and electromagnetic periods. However we again emphasize that in this case we most probably cannot avoid WEP violations and also large, already ruled out, evolution of the fine structure constant. Eventually the lesson is that at least in the inner part of the solar system during the last decades, our homogeneous field was not active in any way. On the other hand, wherever our homogeneous field is switched on gravitationally bound system will expand (relative to atoms) in the same way whatever the scale (stellar systems, galaxies, and of course larger scale structures). Trying to avoid this would produce variations of the fine structure constant.

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