# Dynamic sources, Dynamic Multi-folds, and General Relativity Lense-Thirring and Frame Dragging Effects

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**Abstract**

*In a multi-fold universe, gravity emerges from entanglement through the multi-fold mechanisms. As a result, gravity-like effects appear in between entangled particles, whether they are real or virtual. Long range, massless gravity results from entanglement of massless virtual particles. Entanglement of massive virtual particles leads to massive gravity contributions at very smalls scales. Multi-folds mechanisms also result into a spacetime that is discrete, with a random walk fractal structure, and non-commutative geometry, which is Lorentz invariant, and where spacetime nodes, and particles, can be modeled with microscopic black holes. All these recover General Relativity (GR) at large scales, and semi-classical model remain valid till smaller scale than usually expected. Gravity can therefore be added to the Standard Model (SM) resulting into what we define as $SM_G$. This can contribute to resolving several open issues with the Standard Model without new Physics other than gravity, as well as to open issues with the Standard Cosmological Model*

*The paper discusses how multi-folds apply when sources of gravity, or the center of mass of entangled systems, are dynamically moving: multi-folds mechanisms remain the same but using the evolving center of mass. As a result gravity, or gravity-like, contributions are to be vectorially integrated over the retarded multi-fold spacetime location that can contribute to a point at a certain time (spacetime location), instead of all the multi-folds for all directions. It is illustrated in the case of a rotating sphere as source of gravity: we recover the Lense-Thirring results with its centripetal, Coriolis and axial contributions. The analysis allows us to settle contradictory, and incorrect, results encountered in the literature. It also shows how non-linearity of General Relativity (GR) appears in the multi-fold mechanisms, something that may not have been obvious to all in the original papers.*

*The ability for the multi-fold mechanisms to explain such GR effects help better understand these effects, but more importantly, it is another way to illustrate and validate that multi-folds recover GR and GR recovers the multi-folds.*

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## 1. Introduction

In a multi-fold universe [1,15-17,29], gravity emerges from entanglement through the multi-fold mechanisms. As a result, gravity-like effects appear in between entangled particles [1,31,32], whether they are real or virtual. Long range, massless gravity results from entanglement of massless virtual particles [1,32]. Entanglement of massive virtual particles leads to massive gravity contributions at very smalls scales [1,33]. It is at the base of the E/G Conjecture [31], and the main characteristics of the multi-fold theory [29]. Multi-folds mechanisms also result in a spacetime that is discrete, with a random walk fractal structure, and a non-commutative geometry that is Lorentz invariant, and where spacetime nodes and particles can be modeled with microscopic black holes [1,4,5,7,23,34,35]. All these recover General Relativity (GR) at large scales, and semi-classical model remain valid till smaller scales than usually expected. Gravity can therefore be added to the Standard Model (SM) resulting into

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what we define as $SM_G$: the SM with gravity effects non-negligible at its scales. This can contribute to resolving several open issues with the Standard Model without New Physics[2] other than gravity added to SM, and with the standard cosmological model [1-92,103-132,*138-194*]. These considerations hint an even stronger relationship between gravity and the Standard Model, as finally shown in [30]. (*Note added on January 21, 2025: Note that, in this paper, references in italic were added on January 21, 2025*).

Among the multi-fold $SM_G$ discoveries, the apparition of an-always in-flight, and hence non-interacting, right-handed neutrinos, coupled to the Higgs boson is quite notable. It is supposedly always around the Higgs boson, due to chirality flips by gravity of the massless Weyl fermions [1,56], induced by 7D space time matter induction and scattering models, and hidden behind the Higgs bosons or field at the entry points and exit points of the multi-folds. Massless Higgs bosons modeled as minimal microscopic black holes mark concretized spacetime locations. They can condensate into Dirac Kerr-Newman soliton Qballs to produce massive and charged particles [1,68], thereby providing a microscopic explanation for a Higgs driven inflation, the electroweak symmetry breaking, the Higgs mechanism, the mass acquisition and the chirality of fermions and spacetime; all resulting from the multi-fold gravity electroweak symmetry breaking. Above it, massless Higgs boson create massless particles through patterns of random walk matching the 7D induced solitons. The multi-fold theory has also concrete implications on New Physics like supersymmetry, superstrings, M-theory and Loop Quantum Gravity (LQG) [1,15-28,*138*].

The multi-fold paper [1] proposes contributions to several open problems in physics, like the reconciliation of General Relativity (GR) with Quantum Physics, explaining the origin of gravity proposed as emerging from quantum (EPR- Einstein Podolsky Rosen) entanglement between particles, detailing contributions to dark matter and dark energy, and explaining other Standard Model mysteries without requiring New Physics beyond the Standard Model other than the addition of gravity to the Standard Model Lagrangian ($SM_G$). All this is achieved in a multi-fold universe that may well model our real universe, which remains to be validated.

With the proposed model of [1], spacetime and Physics are modeled from Planck scales to quantum and macroscopic scales, and semi-classical approaches appear valid till very small scales. In [1], it is argued that spacetime is discrete, with a random walk-based fractal structure, fractal/fractional and noncommutative at, and above Planck scales (with a 2-D behavior and Lorentz invariance preserved by random walks till the early moments of the universe). Spacetime results from past random walks of particles. Spacetime locations and particles can be modeled as microscopic black holes (Schwarzschild for photons and concretized spacetime coordinates, and metrics between Reissner Nordström [2], and Kerr Newman [3] for massive, and possibly charged, particles – the latter being possibly extremal). Although possibly surprising, [1] recovers results consistent with others (see [68], and references therein), while also being able to justify the initial assumptions of black holes from the models of gravity or entanglement in a multi-fold universe. The resulting gravity model recovers General Relativity at larger scale, as a 4D process, with massless gravity, but also with massive gravity components at very small scales, which make gravity non-negligible at these scales. Semi-classical models also turn out to work well till way smaller scales than usually expected.

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[2] Conventional physicists may argue it is New Physics. We consider that it isn't because no new particles or interactions are introduced. We just add gravity, as we know it should be, and multi-fold mechanisms and let conventional Physics unfold with the considerations. It does change conventional results or explanations, usually with same observables, and it does live in a discrete spacetime etc. as a result of conventional analysis of these consequences. We also do not cover stable field effects like Skyrmions [183], that we prefer to see as a collective effect for the theory. Besides the SM particles, there are other collective solutions/solitons in gauge theories. They have behaviors as particles but they are quasi-particles composed of collective effects of a large set of particles. We see them as Qballs or patterns that can appear by multi-fold space time matter induction and scattering, under specific circumstances, nothing more. They are topological solitons and can appear in a BEC, as expected with massless Higgs boson condensates [188,189].

Multi-folds are encountered in GR at Planck scales [12,13] and in Quantum Mechanics (QM) if different suitable quantum reference frames (QRFs) are to be equivalent relatively to entangled, coherent or correlated systems [14]. This shows that GR and QM are different facets of something that they cannot well model: multi-folds.

Considering results as in [13], and our answers to so many open issues with the $SM_G$ as discussed for example in [1-92,103-132,*138-194*], we can then argue that these conclusions could apply to our real universe, especially considering how the multi-fold mechanisms recover GR [1,13], and can be encountered in GR at Planck scales, with the spacetime reconstruction [1,7,13], and with the top-down-up-and-upper derivation of the multi-fold theory [13].

As discussed [1,13,*160*] show that GR contains multi-folds and that the multi-fold theory recovers GR through different paths, e.g., from multi-fold attractive effective potentials [1,*160*], from multi-fold spacetime reconstruction [1, *160*], from the top-down-up-and-upper derivation[13] and from the thermodynamic of the graph black hole [1, *160*]. [1, *160*] includes a short section on frame dragging [92], however, based on questions and feedback received, the figure in [1,*160*] was not well understood by several readers. It was indeed not the clearest, and for sure possibly confusing. Here, this paper will take a better angle, instead of trying to just reuse and reexplain that figure better.

We start from a short discussion on how the multi-fold mechanisms and their kinematic and dynamic evolve when the entangled particle center of mass non-trivially moves. It is an important explicit additional recipe to the multi-folds for those who did not infer it from [1,*160*], where we did not explicitly call out these important variations. It is for us the most important outcome: the dynamic behaviors of multi-fold when sources behave dynamically. *Note added on January 22, 2025: the relationship to the multi-fold mechanisms is then positioned in [139].*

As a result, we can redraw the frame dragging picture for a rotating cylinder [1,*160*], rotating sphere or rotating empty spherical shell. We will focus on a rotating sphere, to be able to discuss other related papers [93,94]. Based on these results we see the recover the Lense-Thirring results [94], point out sign confusions in the Thirring paper [93] and in another paper [96], and explain the axial force, and its sign discussed in [94,96] and references therein. We also recover the frame dragging effect from [1,*160*], but now better explained in terms of multi-folds. Part of the model relies on the relativistic increases of mass due to rotation, while avoiding speaking of the controversial relativistic mass. We reuse that result to also discuss other effects mentioned by Einstein in [95].

# 2. Dynamic multi-fold behaviors for dynamic sources

We refer the reader to [1,15-17,29,*139,160*] for the details of the multi-fold mechanisms. In most of the examples in [1,*160*], the center of mass of entangled particles is static or inertial. Also, the sources of gravity, (mass / energy are similarly represented), for massive and massless cases, are typically static or inertial. Of course they do not have to be as discussed here.

## 2.1 Multi-folds between entangled particles

Let us consider entangled particles with a generic trajectory of the center of mass / centroid. It is illustrated in figure 1.

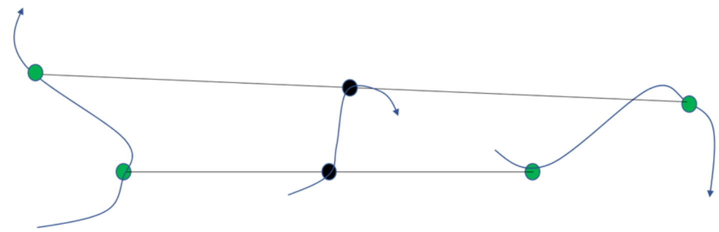

*Figure 1: The green particles are entangled (the one on the left with the one on the right). At a given time, the multi-folds à la [1] are tangents to the center of mass, which we take as the geometrical meaning called centroid in English (center of geometric mass in other languages), marked in black. As the particles move, the centroid evolves. The line between entangled particles is the axis of the multi-fold mechanisms [1,139,160].*

Figure 1 matches the real particle entanglement cases.

In figure 2, test particles as the yellow ones will feel an attractive potential towards the corresponding centroid, in $r^{-2}$, where r is the distance to the corresponding centroid.

It is possible that different times may contribute to same spacetime location of a test particles, i.e., at a given time, contributions can come from spacetime position of a pair of particles, and from different particles. That will be especially true when looking at the mechanisms that generate gravity.

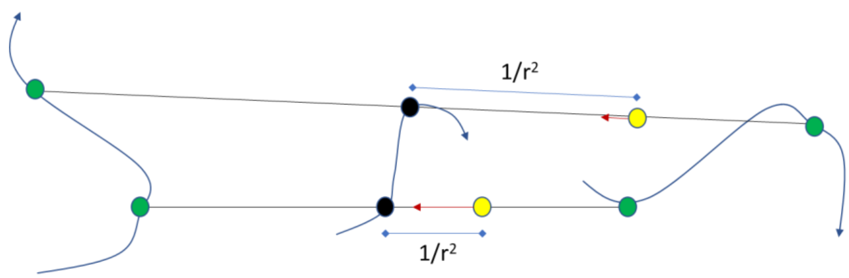


*Figure 2: Test particles (yellow) are added to figure 1. They cross the support of the multi-folds. Following [1], each test mass feels an attractive potential towards the corresponding centroid and in $1/r^2$, where r is the distance to the centroid.*

Just as in [1,*139,160*], entanglement continues to generate gravity-like fluctuations as in [1,31,32]. In the future it may become observable at some point within (macroscopic) quantum material [1,32]. Dark matter effect continue to be good candidates explained, at least in part, with such effects [1,6,10,38-42,63,90].

## 2.2 Gravity emergence form entangled pairs of virtual particles and anti-particles

The same reasoning immediately extends to pairs of entangled virtual particles and antiparticles as shown in figure 3. There, the source may evolve around a complex trajectory. In addition, the mass of the source may also change due to external input, or changes of its energy à la mass energy equivalence.

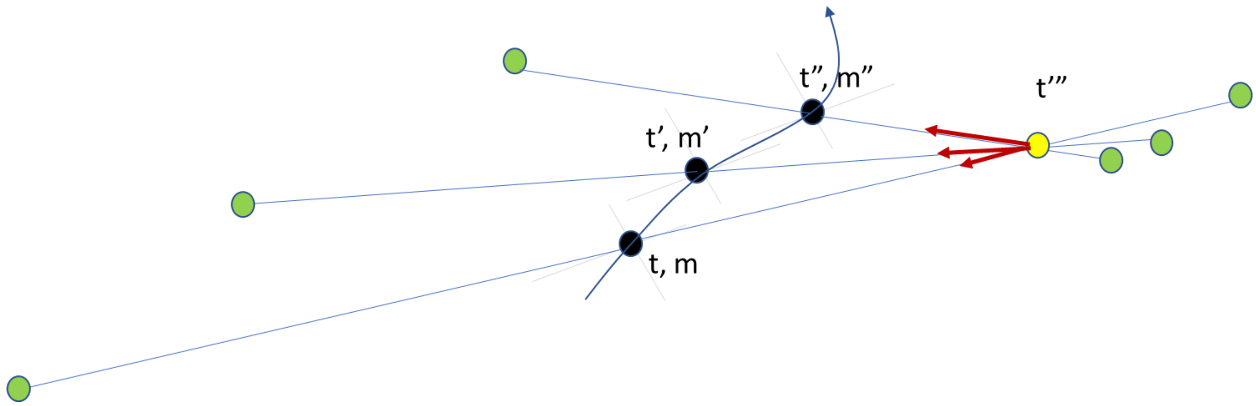


*Figure 3: A source of gravity (mass or energy) evolving in time (different positions and possibly evolving mass) is shown in black. It emits pairs of entangled virtual particles and antiparticles. It generates gravity-like attractive potentials contributions in $1/r^2$. At the differences of the examples from [1], the multi-folds from the past do not simply aligned leading to an aggregated contribution in 1/r. Integrations may involve multiple spacetime locations and at a given time, it is a vector composition (integration).*

These effects also illustrate that multi-fold gravity will be non-linear, as is GR and in alignment with GR recovery from [1,13,*160*].

## 3. Lense-Thirring effects and Rotational Frame Dragging

Thirring [93], then Lense-Thirring [94], studied the effect of rotating bodies, respectively a spherical shell and a solid sphere, on spacetime, and a nearby test mass. The result, at GR scales, is usually known as the Lense-Thirring effect or frame dragging effect [92,98].

The effect is explained in figure 4, which is our promised improved picture.

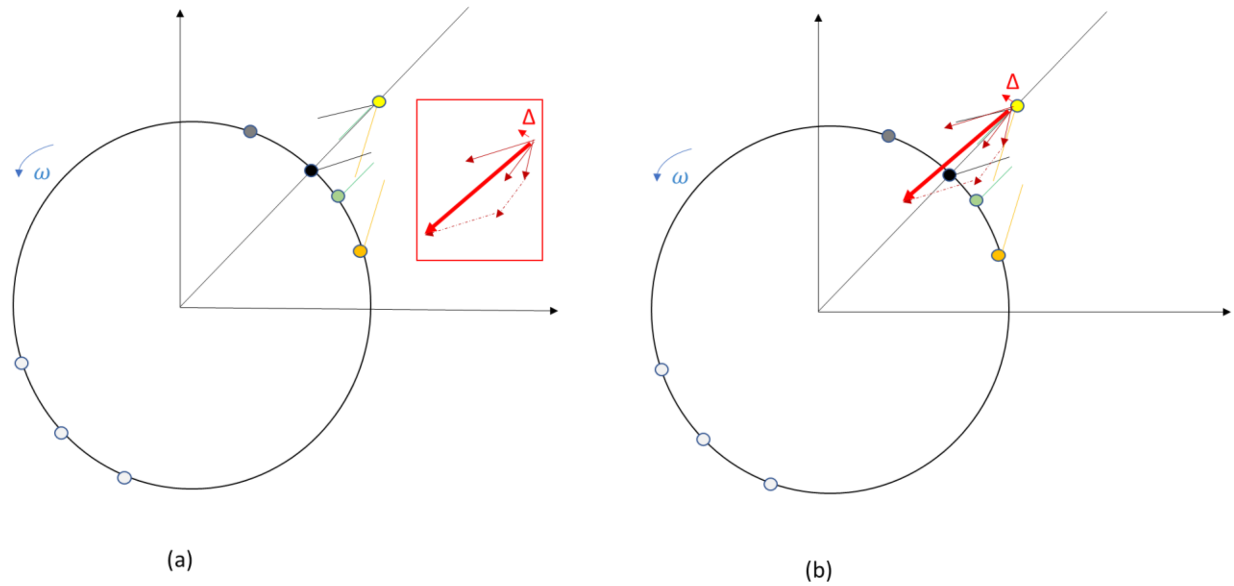


*Figure 4: Illustrates a rotating solid sphere (or spherical shell) and a test particle (yellow). The view is of the equatorial plane seen from the axis of rotation. The points on the sphere contribute to the effects of multi-folds associated to pairs of entangled virtual particles and antiparticles from the past that affect the spacetime location of the test particle. Here, the test particle moves radially towards the center. This ensures that the rotation in (x,y) plane creates an additional tangential force (because multi-fold at a point come from the past), and so they are weaker on the side of the rotating sphere that has yet to pass the radial line between sphere center and test mass and stronger on the other side, especially for an object moving towards center radially. Besides there is a centripetal component. (a) focuses on the dynamics of the multi-folds and shows pictorially the vectorial summation of the attractive effective potentials. Δ indicates the frame dragging contribution. b) superposes the vectorial sum onto the test particle. Source sin the sphere further away have way smaller effects and do not matter in computation here.*

If $r \rightarrow \infty$, then (15) in [94] gives an oscillator that tends to zero. The effect is maximum near the rotating body, where y (or x) is an oscillator with frequency tending to $\propto \omega$. It can be seen from figure 4: when $r \rightarrow \infty$, the justification of the asymmetry between the left and right side disappears. Near the sphere, as r → radius of the sphere, the only relevant contribution comes form the moving black particle: the effect results into a tangential move at speed $Radius_{Sphere} \cdot \omega$. Frame dragging can be seen as the move of an inertial frame of references as rotating at ω, near the sphere then at rotation speed decreasing further away. It has been experimentally observed as precession effects [92,98].

Along the axial (e.g., z) vertical direction, a component always exist towards the equatorial plane (and towards the center of the sphere). This is due to usual gravity attraction, and the fact that as the sphere rotates, the equatorial region speeds up more and gains more mass as its energy increases.

The direction of effects match the classical Coriolis direct of Coriolis and Centripetal effects, as for the rotating sphere in [99], along with an additional axial contribution that includes additional terms due to the relativistic mass increase, e.g., when (x,y,z) = (0,0,z). It all makes sense.

We note that (22) in [93], even if for a spherical shell instead of a solid sphere, does not contain a sign error vs. our result, and [94] (Formula (15)) for the effects in the (x,y) plane. Indeed, [93] is for the inside of the spherical shell (rotating hollow sphere). In such a case the radial component will be centrifugal, as discussed in section 4.1. The component along the axial direction is also correct. It matters because [96] suggest flipping that sign, on the basis on the Mach principle, and seemingly confusing that [93] and [94] are respectively for the inside and outside of the sphere (shell). We do not agree with [96][3]. Yes, it would have been great to explain black hole jets with an outbound force, however it simply is not what happens and jets can be tentatively explained via (twisted) magnetic fields due to accretion of charged particles and plasma physics, albeit we are not sure, nor does the explanation holds always for pulsars and neutrons stars. As entry points, check [100-102,133-137]. Accordingly, the effects of frame dragging on the magnetic fields, created by the rotating matter in the accretion region (and in orbit close to the rotating black hole's horizon), is to rotate and mangle/twist them, resulting into electric fields and currents along the pole axis: the jets. This process to extract rotational energy from the rotating black hole is known as the Blandford-Znajek Process [133,134]. The jet is then launched [135], collimated [136] and accelerated via a combination of magnetic, radiative and thermal acceleration specific to each black hole case [137]. As we can see, no need or relevant impact of gravity, contrary to what [96] seems to hint.

# 4. Einstein's other use cases: Linear Frame Dragging, Static Mass increase and all that

One can find in [95] additional examples of related effects, published by Einstein in 1921.

## 4.1 Rotating inside a spherical shell

Einstein shows that, within a rotating hollow sphere, one finds a Coriolis force aligned with the direction of rotation and a centrifugal force [95]. Of course, if we repeat the analysis of figure 4, as shown in figure 5.

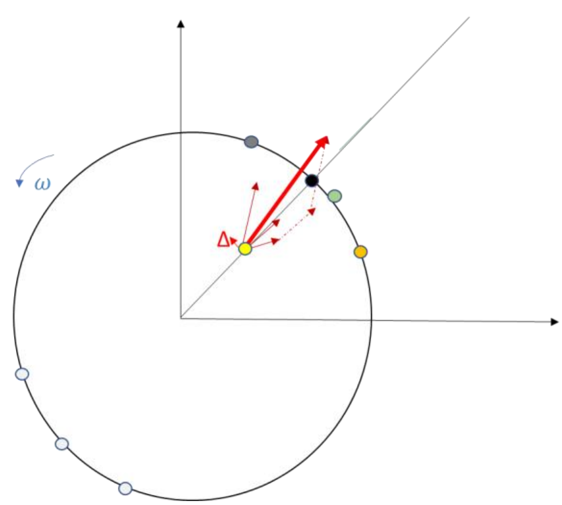


*Figure 5: It shows that there is a similar Coriolis effect on a test mass within a rotating spherical shell. On the other hand, the radial resulting force is centrifugal.*

It is fully explained and aligned with dynamic multi-fold effects.

[3] Of course, we would have loved to see it being correct.

## 4.2 Linear Frame Dragging

Consider a (linearly) accelerated source. Einstein shows that in GR, masses are accelerated in the direction of the acceleration. This is immediately explains with figure 6, that we will let the reader describe and justify as an exercise.

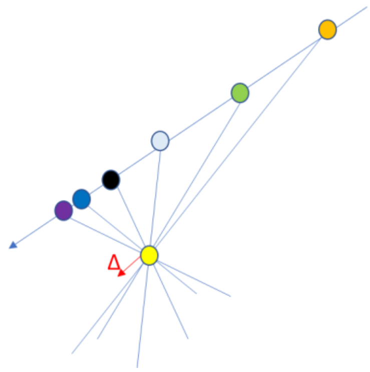

*Figure 6: The color dots represented an accelerated source (at regular time interval). The yellow dot is a test mass. The reader should be able to apply the reasoning so far and multi-fold mechanisms of [1,139,160] to determine that the resulting force has a component along the direction of acceleration.*

## 4.3. Increased mass of a source

If the mass of the source increases, we already saw (e.g., section 3) that it increases attraction due to the multi-fold gravity and mechanisms of [1,*160*]. As a result potential energy of a test mass increase, a key aspect of multi-folds [1,97], and therefore it can be equivalently modeled as a mass increase of the mass of the test particle mass, via the energy to mass relationship, when considering the movement of the test particle, or the attractive force that it feels increases. As a result its inertia to any other effects increases [1,43,*160*].

## 4.4. Recovering the three effects described by Einstein in [95]

Sections 4.1 to 4.3 recover the three effects predicted by Einstein in [95], as stated page 100 of the 1950 edition (and missing in most other editions).

# 5. Non-linear effects

We can see that in all these cases, the multi-fold effective potential is no more just the result of integrating over r, contributions in $r^{-2}$. Instead one needs to integrate over the history of past (retarded) effective potentials in $r^{-2}$, and consider changes of energy, and therefore mass of the sources. This also implies back reaction to the motions of all the masses involved.

These result into the non-linear effects well known in GR.

Remember also that in multi-fold gravity, there are also massive contributions, only relevant at very small scales, with neutrinos behaving as ~ massless [1,13].

## 6. Conclusions

The paper shows and explains with multi-fold mechanisms the effects of dynamic sources: complex entanglement motion of the geometrical center of mass of entangled particles, and dynamic behavior of mass / energy and therefore gravity sources.

It allows us to simply recover and motivate qualitatively the Lense-Thirring and frame-dragging effects of GR and other dynamic behavior predicted by Einstein [95]. As such it confirms and illustrates our past claims that the multi-fold theory recovers GR and GR contains multi-folds [1,13,15-17,29,*160*]. It also shows how non-linear effects appear in multi-folds. We also clarified some sign confusions in some of the related papers. As a result, gravity is not responsible for the jets emitted by rotating black holes, bur frame dragging is probably one of the elements that contribute to their creation.

The work explicitly completes the prescription for the multi-fold effects provided in [1,*160*], where we only mentioned that gravity effects were based on the (history) of all radiated virtual particles, but we had shown such history only in simple cases where the integration over r was immediate. Here, when we have dynamic moves, it is no more the case.

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