On binary pulsars and the force of gravity

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Abstract
The energy-momentum budget of the astrophysical systems can be studied by the exact local conservation equation derived by Landau and Lifshitz. We show that a similar equation is valid for the Einstein-Cartan gravity. We reanalyze a binary pulsar system using the Landau-Lifshitz conservation equation and show that the orbital period change rate can be completely understood as a curvature backreaction process. Taking into account the detailed theoretical and observational research of relativistic binary pulsar systems, especially the system of Hulse and Taylor, we conclude that general relativity and astrophysical observations rule out the existence of gravitational radiation. We comment upon the LIGO GW events and their alternative explanation, as well as the recent pulsar timing arrays data.

1 Introduction and motivation

The force of gravity represents for physicists the most intriguing and challenging fundamental interaction to be studied and understood. This is partly because gravity is the first established universal interaction, but still without a clear correspondence to other fundamental interactions.

In this paper we intend to clarify the issue of gravity waves. There is a common belief that gravity waves are inevitable consequence of Einstein’s General Relativity (GR). The usual argument for their existence relies on the energy loss observed in the binary systems. In the next three sections we shall prove the opposite, i.e. the nonexistence of gravity waves, using the local conservation equations.

Further sections will discuss wave equations, similarities and distinctions between fundamental interactions, and their phenomenology. Our reasoning and results are summarized in the last section.
2 Local conservation equation of Landau and Lifshitz in GR

There are a few ways to derive the field equations of the GR found in the literature \[1, 2\] (with our convention \[1\]: \[\eta_{ij} = \text{diag}(+1, -1, -1, -1)\]):

\[
G_{ij} = \kappa T_{ij},
\]

\[
G_{ij} \equiv R_{ij} - \frac{1}{2} R g_{ij}, \quad \kappa \equiv 8\pi G N c^{-4}. \tag{1}
\]

However, it is important to stress the unavoidable presence of the integrability conditions (Bianchi identities) valid for the tensors of the field equations:

\[
\nabla_k G^k_i = \nabla_k T^k_i = 0, \tag{2}
\]

\[
\nabla_i G^k_j = \partial_i G^k_j + \Gamma^k_{im} G^m_j - \Gamma^m_{ij} G^k_m,
\]

\[
\Gamma^k_{im} \equiv \left\{ \begin{array}{c}
    \begin{array}{c}
        k \\
        i \quad m
    \end{array}
\end{array} \right\} = \text{Christoffel symbol.}
\]

Since the Bianchi identities represent conservation equations in the curved spacetime, it could be physically advantageous to search for the local conservation equations with ordinary partial derivatives. Landau and Lifshitz \[1\] accomplished this task using both GR field equations and Bianchi identities:

\[
\frac{\partial}{\partial x^k} \left[ (-g) (T^{ik} + t^{ik}) \right] = 0, \tag{3}
\]

\[
g = \text{det}(g_{ij}),
\]

\[
t^{ik} = \frac{1}{2\kappa} \left( 2\Gamma^m_{im} \Gamma^p_{np} - \Gamma^p_{ip} \Gamma^m_{mn} - \Gamma^m_{in} \Gamma^p_{mp} \right) (g^j_i g^{km} - g^{jk} g^{im})
\]

\[
+ g_{ij} g^{mn} \left( \Gamma^k_{ip} \Gamma^m_{mn} + \Gamma^k_{im} \Gamma^p_{mn} - \Gamma^m_{np} \Gamma^p_{im} - \Gamma^m_{im} \Gamma^p_{np} \right) + g_{im} g^{np} \left( \Gamma^i_{ln} \Gamma^k_{np} - \Gamma^i_{lm} \Gamma^k_{np} \right).
\]

This remarkable exact equation relates ordinary derivatives of the quantities \((-g)T_{ij}\) and \((-g)t_{ij}\) that are not tensors with respect to the general coordinate transformations (even \(g\) is not a scalar, but only a scalar density), but are tensors with respect to the Lorentz transformations. The immediate consequence of this equation is the existence of the conserved quantities \[1\]:

\[
P^i = P^i(T) + P^i(t) = \text{const.}, \tag{4}
\]

\[
P^i(T) = c^{-1} \int (-g) T^{i0} dV, \quad P^i(t) = c^{-1} \int (-g) t^{i0} dV.
\]
The weak field version of this local conservation equation is derived in Weinberg’s textbook [2].

The local conservation equation is crucial for discussions on relativistic astrophysical systems.

3 Local conservation equation in the Einstein-Cartan gravity

The inclusion of the rotational degrees of freedom into the relativistic theory of gravity leads to the Einstein-Cartan (EC) theory of gravity [3, 4]. We wish to explore whether the EC gravity implies a similar local conservation equation as GR. Below we present field and conservation equations of the EC gravity [5]:

\[
G^{ij} = \kappa (\sigma^{ij} + \nabla_k (\tau^{ijk} - \tau^{jki} + \tau^{kij})) ,
\]

\[
T^{ij} = \kappa \tau^{ijk} ,
\]

\[
\nabla_j G^i_j = T^k_{jl} R^j_{kl} ,
\]

\[
\Gamma^k_{ij} = \left\{ \begin{array}{c} k \\ i \\ j \end{array} \right\} + S^k_{ij} - S^k_{ji} + S^k_{ij} ,
\]

\[
T^k_{ij} = S^k_{ij} + \delta^k_j S^l_{il} - \delta^k_i S^l_{jl} ,
\]

\[
\nabla_k \tau^{ijk} = \nabla_k \tau^{ijk} + 2 S^l_{kl} \tau^{ijk} ,
\]

\[
\nabla_i \psi_j = \nabla_i \psi_j + 4 S^k_{(ij} \psi_{k)} , (ij) \equiv \frac{1}{2} (ij + ji) ,
\]

\[
\sigma^{ij} = 2 \left[ \text{det}(-g_{ij}) \right]^{-1/2} \frac{\delta \mathcal{L}}{\delta g_{ij}} , S^k_{ij} = \text{torsion tensor} ,
\]

\[
\tau^{ijk} = \text{spin - angular momentum tensor} .
\]

Owing to a solely algebraic relation between spin-angular momentum of matter and torsion of spacetime, it is possible to write the field equation with the effective energy-momentum tensor that contains relevant terms with the spin-angular momentum tensor:

\[
G^{ij} (\Gamma = \{ \}) = \kappa T^{ij}_{\text{EC}} ,
\]

\[
T^{ij}_{\text{EC}} = \sigma^{ij} (\tau) - \kappa F^{ij} (\tau) ,
\]

\[
F^{ij} (\tau) = 4 \tau^k_{[i} \tau^{jl}_{,k]} + 2 \tau^k_{ijkl} \tau^{l_{,j}} - \tau^k_{ijkl} \tau^{l_{,j}}
\]

\[
- \frac{1}{2} g^{ij} (4 \tau^k_{m[i} \tau^m_{l]k]} + \tau^m_{kl} \tau^{m_{,kl}}) ,
\]

\[
\sigma^{ij} = \sigma^{ji} , F^{ij} = F^{ji} , [ij] \equiv \frac{1}{2} (ij - ji) .
\]

Using the Bianchi identity for the Einstein’s tensor in Riemannian spacetime, the local conservation equation in the EC gravity follows immediately:
Thus, if the EC gravity appears to be the proven theory of gravity, one can apply the local conservation equation whenever it is necessary.

4 Binary systems

The discovery of the binary pulsar B1913+16 by Hulse and Taylor [6] represents a milestone in astrophysics because relativistic binary pulsar systems are perfect laboratories to study general relativity. In the past decades, very detailed calculations were performed in the post-Newtonian approximation, with all possible relativity corrections to measurables (see, for example, [7], [8], [9] and references therein).

However, it seems that one important part of the calculations is not included into the analysis of a relativistic binary system. Namely, the backreaction of the spacetime curvature on the observables of a binary bound system is not elucidated properly.

The metric can be defined in the following form [1]:

\[ g_{ij} = \eta_{ij} + h_{ij}. \]

It is suitable for the treatment of an isolated bound system if we assume that \( h_{ij} \) vanishes at infinity.

The calculation of the energy flow in the direction of the \( x \) axis shows the following [note that: \( h_{ij}(t - x/c)\)]:

\[ t^{01} = \frac{1}{2\kappa}\left[ (\frac{\partial h_{22}}{\partial t})^2 + (\frac{\partial h_{23}}{\partial t})^2 \right], \quad T^{01} = -t^{01} + \frac{1}{\kappa} \frac{\partial}{\partial x} \left[ h_{22} \frac{\partial h_{22}}{\partial x} + h_{23} \frac{\partial h_{23}}{\partial x} \right]. \]

The term with the total derivatives vanishes after integration, not affecting the local conservation equation. The components \( h_{ij} \) are proportional to the second partial derivative in the time variable of the quadrupole moment of the system \( h_{ij} \propto \frac{\partial^2 D_{ij}}{\partial t^2} \) [1]. The averaging procedure described in [1] leads to the well known energy loss of the binary systems [10].

Thus, the orbital period change rate due to the “curvature backreaction” is, after averaging over one period of the motion [7, 10, 1]:

\[ \dot{P}_b = f(P_b, e, m_p, m_c), \]

\[ f(P_b, e, m_p, m_c) = -\frac{192\pi G^{5/3}}{5} \left( \frac{P_b}{2\pi} \right)^{-5/3}(1 - e^2)^{-7/2} \]

\[ \times \left( 1 + \frac{73}{24} e^2 + \frac{37}{96} e^4 \right) m_p m_c (m_p + m_c)^{-1/3}, \]
\( e = \text{eccentricity, } m_{pc} = \text{mass of the pulsar; companion.} \)

However, we now know from the local Landau-Lifshitz conservation equation that the kinetic energy loss is compensated by the potential energy gain (Eq.(4)):

\[
\delta E(T^{ik}; \text{kinetic energy}) + \delta E(t^{ik}; \text{potential energy}) = 0.
\]

Small changes of the quadrupole gravity potentials cannot substantially influence the calculation of the quadrupole moments of the system.

Evidently, there is no energy for gravitational waves. The energy loss is evaluated in the center of mass Lorentz system. We can evaluate both the kinetic energy loss and the potential energy gain in some other Lorentz system, but according to the local conservation of energy, their sum always vanishes.

5 Wave equation

The waves in theoretical physics represent the solutions of the wave equations, i.e. the equations that describe the time evolution of waves in the Minkowski spacetime. For example, the field equations in GR (or EC gravity) could be represented in a form similar to the wave equations; see ref. [11], where in his notation Eq.(5.2b) has the following form:

\[
(-\partial_t^2 + \nabla^2)\tilde{h}^{\alpha\beta} = -16\pi\tau^{\alpha\beta},
\]

\[
\tau^{\alpha\beta} = (-g)(T^{\alpha\beta} + t^{\alpha\beta}_{LL}) + (16\pi)^{-1}[\tilde{h}^{\alpha\mu}_{\cdot\mu} \tilde{h}^{\beta\nu}_{\cdot\nu} - \tilde{h}^{\alpha\beta}_{\cdot\mu\nu} \tilde{h}^{\mu\nu}_{\cdot\nu}],
\]

\[
\tilde{h}_{jk}(x) = 16\pi \int G^+_{jk-pq}(x, x')\tau_{pq}(x')d^4x'.
\]

Obviously, this is an integral equation for \( \tilde{h}_{jk} \), not the wave equation (see also [12]). One can perform the weak field approximation ending in the wave equation but the resulting equation does not belong to the theory invariant under the general coordinate transformations [2]; Eq.(10.1.10) in Weinberg’s notation:

\[
(\nabla^2 - \frac{\partial^2}{\partial t^2})h_{\mu\nu} = -16\pi G S_{\mu\nu}.
\]

However, we have to affiliate to the approximate field equation the corresponding approximate Bianchi identity. We know from the preceding sections that the curvature feedback is always present, owing to the Landau-Lifshitz conservation equation, preventing the propagation of the energy in the form of the tensor wave.
6 GR and EC gravity vs. intrinsic local gauge interactions

The electromagnetic, weak and strong interactions differ substantially from the GR because they are confirmed to be the intrinsic unitary local gauge symmetries. On the other hand, the GR (or the EC gravity) are based on spacetime symmetries that cannot propagate in the form of local tensor waves, because of the integrability conditions (Bianchi identities).

Conformal and discrete symmetries play somewhat different roles in the nonsingular and causal $SU(3) \times SU(2) \times U(1)$ BY theory of ref. [13] than in the nonsingular EC gravity.

The six dimensional conformal space of the conformal symmetry is perfectly suitable for the conformal $SU(3)$ unification of all the observed $SU(3) \times SU(2) \times U(1)$ local gauge forces [13]: $8 \times 6 = 8 \times 4 + 3 \times 4 + 4 = gauge\, degrees\, of\, freedom$. Trace anomaly (or the divergence of the dilatational current) and Wick’s theorem help us in generating the elementary particle masses [13].

The violation of the discrete symmetries by weak interactions is strongly connected with the $SU(2)$ global anomaly and the topology of the unitary symmetries in the conformal space [13].

On the other hand, the four dimensional spacetime is the lowest dimensional spacetime for which the conformal (Weyl) tensor does not vanish [2]. The conformal tensor plays a crucial role when fixing the cosmic mass density within the EC gravity [14][15]. The chirality of the vorticity of the Universe appears to be closely related to the chirality of the weak interactions [16]. The absence of singularity in the EC gravity, because of the presence of spin densities [17][14], matches the scale of the weak interactions [13].

Evidently, the roles of conformal and discrete symmetries in the relativistic theories of gravity and intrinsic local gauge theories are important, but their manifestations are different according to the substantially diverse nature of the force of gravity compared to the electroweak and strong forces.

7 Indirect evidence of gravity waves or just local conservation of energy-momentum

We know that in many binary systems the kinetic energy loss is calculated and observed to very high precision.

For example, very precise measurements of the binary pulsar B1913+16 with an overdetermined set of measurables give [15]

$$\dot{P}_b(\text{gen. rel.}) = f(P_b, e, m_p, m_e) = (-2.40247 \pm 0.00002) \times 10^{-12},$$

$$\dot{P}_b(\text{measured}) = (-2.4086 \pm 0.0052) \times 10^{-12}.$$
The kinetic energy loss, which is due to the nonvanishing orbital period change rate, is compensated by the potential energy gains hidden in $h_{ij}$ according to the Landau-Lifshitz local conservation equation:

$$\Delta E(\text{kin. en.}, \dot{P}_b \neq 0) + \Delta E(\text{pot. en. change in } h_{ij}) = 0.$$ 

If one neglects the inevitable change of the potential energy, the kinetic energy loss in $\dot{P}_b$ can be compensated by the introduction of the energy of the hypothetical emission of the tensor field (gravity waves):

$$\Delta E(\text{kin. en.}, \dot{P}_b \neq 0) + \Delta E(\text{en. deposited in grav. waves}) = 0.$$ 

However, it is possible to search for the change rate of the quadrupole potentials of binary systems by gravitational lensing, by measuring the change of the polarization of photons passing nearby [19].

We showed recently that the pulsar timing array data can be interpreted as a vortical motions of pulsar’s photons within rotating and expanding Universe without any reference to the stochastic gravitational wave background [20].

8 LIGO detections: gravity waves or geophysical phenomenon

Starting from 2016 the LIGO collaboration reported a great number of events accepted and described as gravity waves from the binary systems with merging black holes, neutron stars, etc. [21]. However, to our knowledge, only one LIGO event GW 170817 is correlated to some GRB event, namely, GRB 170817A. It is not clear which event is reported first, GRB of the Fermi satellite or GW of the LIGO. After establishing the optical, radio, infrared, X-ray, gamma ray and neutrino follow up network, no correlations of LIGO GW events are found with any kind of astrophysical sources. Some LIGO GW events fitted with black hole binary system collapse demand the theoretically forbidden mass of the black hole.

One month after the announcement of the first GW event, the alternative interpretation of the LIGO events was formulated [22], communicated to the LIGO scientists and later cited in the book of H. Collins [23].

We repeat the key argument of ref. [22] that the ocean tidal bulges are responsible for the GW events at LIGO. The order of the magnitude estimate of the ocean bulge height can be done assuming the work per unit volume of the static fluid before and after the action of the conservative force of gravity:

$$\rho (g_{\text{Earth}} - g_{\text{Moon}}) (h + \Delta h) = \rho g_{\text{Earth}} h,$$

where $\rho$ is the mass density of the fluid, $g_{\text{Earth}} = 9.81 \text{ms}^{-2}$, $g_{\text{Moon}} = G_N M_{\text{Moon}}/d^2$, where $d$ is the Moon to Earth distance, $h$ is the average depth of the ocean. It follows:
$$\Delta h = h \frac{g_{\text{Moon}}}{g_{\text{Earth}} - g_{\text{Moon}}}.$$ 

The average depth of the Indian ocean is $h \simeq 4\text{km}$. However, the Indian ocean trenches have up to $h \simeq 7\text{km}$ depth ($\Delta h = O(10\text{cm})$). Hence, the moving tidal bulges formed with the maximal Moon’s and Sun’s gravity forces when crossing the ocean trenches are producing the maximal force on the LIGO detectors.

Precisely this effect is observed in the data analysis of few LIGO GW events by the astrophysical group at the Niels Bohr Institute in Copenhagen [24]. Namely, they found the correlations between the GW events and background time lags.

Sapiens sat.

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