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Manuscript

Radial monopoles and dipole dark energy for Hubble expansion with acceleration

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Abstract

Extended carriers of mass-energy with r^{-4} radial densities correspond to observable particles obeying Newtonian attractions in weak fields but repulsions in strong ones. Space interference of such overlapping radial monopoles maintains unobservable $r^{-2} \times r^{-2}$ dipole formations of dark mass-energy which conserves the metric energy integral of the material space continuum. The Newton fall attraction followed by strong field gravitational repulsion in such a continuum can quantitatively explain the Hubble expansion rate rH_o, with calculated acceleration $r(H_o)^2$, and qualitatively comply with Penrose's cyclic cosmology. Laboratory tests with precise clocks may justify in principle the non-empty, material space paradigm for nonlocal physical reality of everywhere overlapping continuous bodies.

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1. Metric theorem from GR energy definition

Einstein's metric theory of gravitational fields is to be revised in a self-contained form in order to avoid the conceptual shortage of the Newton attraction of spatially separated point masses. A self-contained theory would unlikely reiterate infinite negative potentials at vanishing interaction distances as one

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might infer for a moment from Newtonian gravitation. While Newton employed the formal model of point masses in empty space, material sources in the Einstein Equation are stress-energy tensor densities but not scalar mass invariants. Energy density type of source is more suitable for a continuous distribution of the extended elementary mass rather than for a point mass singularity. In other words, Newtonian empty-space references cannot be accepted in principle (or by default) by Einstein's metric gravitation of overlapping mass-energy distributions or for extended energy-charges.

Again, it is essential to employ metric references for General Relativity (GR) not on the basis of the Newton empty space theory, but on a self-contained basis like the Special Relativity (SR) limit for GR energy of a probe body. In favor of coherent self-references, Einstein's metric formalism uniquely relates the forth component [1],

$$P_o \equiv mcg_{o\mu}\frac{dx^\mu}{ds} \equiv mc(g_{oo}V^o + g_{oi}V^i) \equiv \frac{mc\sqrt{g_{oo}}}{\sqrt{1-v^2c^{-2}}} \equiv \frac{(K+U)}{c}, \qquad (1)$$

of the covariant four-momentum $P_\mu \equiv mcg_{\mu\nu}dx^\nu/ds$ of the probe scalar mass m to its full relativistic energy $E = K + U$ containing positive kinetic energy $K = mc^2/\sqrt{1-v^2c^{-2}}$ and negative potential energy U associated with gravitational interactions. One can use the GR energy definition $E \equiv cP_o > 0$ in order to rewrite the metric component g_{oo} in terms of the negative gravitational potential U/cP_o for GR energy-charge E, which is the only measure of inertia (and gravity) of the probe mass m:

$$\sqrt{g_{oo}} \equiv (K+U)\frac{\sqrt{1-v^2c^{-2}}}{mc^2} \equiv 1 + \frac{U\sqrt{g_{oo}}}{E} \equiv \frac{1}{[1-(U/E)]}. \qquad (2)$$

Basing on identical algebra operations in (2), one can formulate the following g_{oo}-theorem: "Time-time component of the pseudo-Riemann metric tensor in Einstein's GR is defined by a gravitational field potential $\varphi = U/E$ exactly as $g_{oo} = (1-\varphi)^{-2}$, which has no peculiarities for $-\infty < \varphi \leq 0$". It is following from (2) that Schwarzschild [2] and Droste [3] empty-space metrics (where $g_{oo} = [1-(2GM/c^2r)]$ was extrapolated for strong fields from the Newton weak-field reference) do not match the $g_{oo}-$theorem and, consequently, the Einstein energy definition in General Relativity. An ultimate reason for this strong-field misconduct is the conceptual fact that Newton's point mass gravitation is not a true limit for weak-field gravitation of overlapping energy-charges, which are continuously distributed over spatial structures of their own fields contrary to unstructured point charges.

2. Metric energy conservation for united non-empty space of observable monopoles and dark dipoles

In 1939 Einstein characterized Schwarzschild's metric with singularities as 'not relevant to physical reality' [4]. GR metric solutions without singularities correspond to non-empty space relativistic physics of continuous particles, for example [5, 6], rather than to point matter in empty space. New physics of geometrized, field-like continuous particles describes [7] main relativistic tests and observations much more self-consistently than the point particle physics which is enable to interpret the scalar Ricci curvature as the scalar mass density. Below we demonstrate further advantages of non-empty (material) space by its application to the many-body system. Exact compensations of Newtonian potential energy by interference energy of dark dipole formations in joint and united material space will be derived. The non-empty space paradigm for gravitation assumes overlapping continuous masses with local energy exchanges (applied to correlated electrons' densities in condensed matter physics) or interference (applied to wave densities in optics and quantum mechanics). Principally new, inertial kind of interference energy (called dipole dark energy) can be justified only in the non-empty space paradigm. Indeed, spatial material overlaps cannot be introduced and satisfactorily described in the Newton scheme, where absolute empty space is considered as an arena for spatially separated masses.

The many-body metric solution for static non-empty space of overlapping mass-energies has been already found [6], while empty space has not provided yet an exact metric solution for the many-body gravitating system. Mechanical (inertial or passive, $\mu_p c^2$) and gravitational (potential or active, $\mu_a c^2$) energy densities of such a continuous material space comply with the Einstein Principle of Equivalence for scalar mass densities,

$$\mu_p(\mathbf{x}) \equiv \frac{[\nabla W(\mathbf{x})]^2}{4\pi G c^2} = \frac{\nabla^2 W(\mathbf{x})}{4\pi G} \equiv \mu_a(\mathbf{x}), \tag{3}$$

which depend in static systems on the same metric potential or the metric stress,

$$W(\mathbf{x}) \equiv -c^2 ln \frac{1}{\sqrt{g_{oo}(\mathbf{x})}} = -c^2 ln \left(1 + \frac{r_1}{|\mathbf{x}-\mathbf{a}_1|} + \frac{r_2}{|\mathbf{x}-\mathbf{a}_2|} + ... + \frac{r_n}{|\mathbf{x}-\mathbf{a}_n|}\right). \tag{4}$$

Here $r_i \equiv GE_i/c^4 = Gm_i/c^2$ is Schwarzschild-type coordinate scale of the elementary energy-charge E_i (distributed everywhere but mainly in the vicinity of $\mathbf{a}_i$). The non-empty space metric g_{oo} in (4) corresponds to the equality (2) and the aforementioned g_{oo}-theorem.

The inhomogeneous local stress (4) fits to strict conservations of active (potential) and passive (inertial) metric space energies, $\int d^3x \mu_p c^2 = \int d^3x \mu_a c^2 = E_{metric}$, of the united material continuum of n overlapping energy-charges:

$$E_{metric} \equiv \frac{c^4}{4\pi G} \int d^3x \left(\frac{\frac{(\mathbf{x}-\mathbf{a}_1)r_1}{|\mathbf{x}-\mathbf{a}_1|^3} + \frac{(\mathbf{x}-\mathbf{a}_2)r_2}{|\mathbf{x}-\mathbf{a}_2|^3} + ... + \frac{(\mathbf{x}-\mathbf{a}_n)r_n}{|\mathbf{x}-\mathbf{a}_n|^3}}{1 + \frac{r_1}{|\mathbf{x}-\mathbf{a}_1|} + \frac{r_2}{|\mathbf{x}-\mathbf{a}_2|} + ... + \frac{r_n}{|\mathbf{x}-\mathbf{a}_n|}} \right)^2 \tag{5}$$
$$= (m_1 + m_2 + ... + m_n)c^2 = const.$$

It can be tested by numerical computations that the system mass $E_{metric}/c^2 = M_{metric}$, originated from the consolidated metric stress (4) of continuous mass-energies $m_i c^2$, is independent from spatial positions $\mathbf{a}_i$ in (5). Such a universal mass-energy conservation for a system of overlapping particles under negative gravitational potentials can take place due to hidden (from direct observations) energy contributions into paired, dipole formations of material densities in (5), where $E_{metric} \equiv E_{monopoles} + E_{dipoles}$.

If all elementary energies are centered at one point, $\mathbf{a}_1 = \mathbf{a}_2 = ... = \mathbf{a}_n$, than the metric mass-energy integral (5) can be taken analytically. Spatial displacements of initially centered mass-energies $m_i c^2$ and $m_k c^2$ split their densities in (5) into radial monopole, $\propto r_i^2 |\mathbf{x} - \mathbf{a}_i|^{-4}$, and interference dipole, $\propto 2r_i r_k |\mathbf{x}-\mathbf{a}_i|^{-2} |\mathbf{x}-\mathbf{a}_k|^{-2}$, fractions of gravitating matter. Again, despite negative potential energy shifts take place for observable radial elements in (5), metric mass of the many-body system stays steady, $\sum m_i = const$, due to compensating deposits from dipole positive energies. This keeps scalar masses of many-particle bodies in spite of mutual internal interactions of material elements. If centers of overlapping elementary masses are separated into infinite distances than both positive interference contributions and negative potential shifts vanish. Analytical integration in (5) yields $c^2 \sum m_i$ for remote radial particles, which can be observed separately due to the existence of radial waves in practice. When radial centers are separated into finite distances, than n-body metric energy $c^2 \sum m_i$ contains both directly observable (radial) and non-observable (dipole, dark) fractions of gravitational/inertial mass-energy. The minimal part of directly observable energy in the n-body system is $\sum m_i^2/(\sum m_i)^2$, while the maximum part of dark energy is $[(\sum m_i)^2 - \sum m_i^2]/(\sum m_i)^2$.

3. Dark energy deposits into dipole formations

Now we derive from (5) GR energies of observable probe monopoles in external gravitational potentials. For the most of weak-field applications one can use $|\mathbf{a}_k - \mathbf{a}_i| \equiv R_{ik} >> r_i + r_k = G(m_i + m_k)/c^2$ for distances between centers of radial particles in (5),

$$E_{monopoles} \approx \frac{c^4}{4\pi G}\int d^3x \frac{r_1^2}{|\mathbf{x}|^4(1+\frac{r_1}{|\mathbf{x}|}+\frac{r_2}{|\mathbf{a}_1-\mathbf{a}_2|}+...+\frac{r_n}{|\mathbf{a}_1-\mathbf{a}_n|})^2}$$
$$+\frac{c^4}{4\pi G}\int d^3x \frac{r_2^2}{|\mathbf{x}|^4(1+\frac{r_1}{|\mathbf{a}_2-\mathbf{a}_1|}+\frac{r_2}{|\mathbf{x}|}+...+\frac{r_n}{|\mathbf{a}_2-\mathbf{a}_n|})^2}$$
$$+...+\frac{c^4}{4\pi G}\int d^3x \frac{r_n^2}{|\mathbf{x}|^4(1+\frac{r_1}{|\mathbf{a}_n-\mathbf{a}_1|}+\frac{r_2}{|\mathbf{a}_n-\mathbf{a}_2|}+...+\frac{r_n}{|\mathbf{x}|})^2} =$$
$$c^2\sum_{i=1}^{n} m_i\sqrt{g_{oo}^{\neq i}(\mathbf{a}_i)} \approx \sum_{i=1}^{n} m_i\left(c^2 - \sum_{k\neq i}^{n}\frac{Gm_k}{R_{ik}}\right) > 0 \quad (6)$$

Here items for static monopole mass-energies, like $E_2 \equiv c^2 m_2\sqrt{g_{oo}^{\neq 2}(\mathbf{a}_2)} \equiv c^2 m_2/\left(1+\frac{r_1}{|\mathbf{a}_2-\mathbf{a}_1|}+\frac{r_3}{|\mathbf{a}_2-\mathbf{a}_3|}+...+\frac{r_n}{|\mathbf{a}_2-\mathbf{a}_n|}\right)$, for example, contain negative shifts, associated with paired Newtonian interactions within the united material space. Negative Newtonian potentials for energy of monopoles (6) do not mean decrease of the system metric energy (5), because paired gravitational interactions are always accompanied by interference, dark deposits in a form of dipole energy formations,

$$E_{dipoles} = \frac{c^4}{4\pi G} \sum_{i=1}^{n} \sum_{k \neq i}^{n} \int_0^{2\pi} d\varphi \int_0^{\infty} r^2 dr \int_0^{\pi} \frac{r_i r_k \left(r^2 - R_{ik} r cos\theta\right) sin\theta d\theta}{r^3 (R_{ik}^2 + r^2 - 2R_{ik} r cos\theta)^{3/2}}$$
$$\approx \sum_{i=1}^{n} \sum_{k \neq i}^{n} \frac{G m_i m_k}{R_{ik}} > 0. \qquad (7)$$

It is worth to recall that only non-empty space paradigm for GR may reveal the positive interference energy (7), while GR metric gravitation for point particles (without spatial overlaps of gravitating matter) is free from local material overlaps or energy interference. One may say from (6) and (7) that paired attractions of radial mass-energy monopoles generate dipole fields with positive energy borrowed from the very interaction partners. In this way, there are no negative energy gravitational fields at all. Gravitational attractions of positive energy bodies are always accompanied by positive energy of interference (dipole) fields. In fact, gravitation is not a formal decrease of negative potential energy of Newtonian field (which without host radial particles does not exist in (6) as a self-maintained field), but the universal tendency of a free mechanical system toward distribution of its total energy between all physical degrees of freedom. Equipartition distributions of mechanical energy between observable monopoles and dark dipoles may be expected, in principle, for an equilibrium gravitational system. But how might gravitational equilibrium of extended particles take place instead of the gravitational collapse in the theory of point particles?

4. Radial fall toward gravitational repulsion

The concept of extended radial particles and positive mass-energy fields in united material continuum [5, 6] not only confirms all known GR tests [7], but also predicts that the empty-space paradigm can be verified by precise clocks.

Indeed, fine measurements of the gravitational time dilation in the Earth-Sun-Moon system with the time varying Newton potential φ can directly distinguish the empty space paradigm with the Schwarzschild dilation [2] $(d\tau - dt)/dt \equiv \sqrt{g_{oo}} - 1 \approx \varphi(1 - \varphi/2c^2)/c^2$ from the non-empty space paradigm with $\sqrt{g_{oo}} - 1 \approx \varphi(1 + \varphi/2c^2)/c^2$ from (4).

Material space continuum in Einstein's GR metric formalism always keeps Euclidean 3D section of curved 4D space-time due to inherent symmetries [5] of the real world geometry. GR geodesic equations of motions in pseudo-Riemann space-time with $0 \le g_{oo} \le 1$ and flat 3D intervals, $g_{oi}g_{oj}g_{oo}^{-1} - g_{ij} = \delta_{ij}$, have been derived [7] for strong static fields,

$$\begin{cases} g_{oo}dt/dp = 1, dp/ds = g_{oo}dt/ds = E_m/m = const \\ r^2 d\varphi/dp = J_\varphi = const, r^2 d\varphi/ds = J_\varphi E_m/m \equiv L = const \\ (dr/dp)^2 + (J_\varphi/r)^2 - g_{oo}^{-1} = const \ (= -m^2/E_m^2) \\ (dr/ds)^2 + (r d\varphi/ds)^2 - E_m^2/m^2 g_{oo} = -1, \end{cases} \quad (8)$$

where $m = const$ is the probe scalar mass, while energy $E_m = const$ and angular momentum $J_\varphi = const$ are the first integrals of relativistic motion. For the pure radial fall from infinity, when $E_m/m \equiv c^2\sqrt{g_{oo}}/\sqrt{1 - v^2c^{-2}} = const \Rightarrow 1$ and $d\varphi/ds = 0$, $ds = \sqrt{g_{oo}}cdt\sqrt{1 - v^2c^{-2}}, v^2 = (dr/\sqrt{g_{oo}}dt)^2$, the last equation in (8) results in

$$dr/dt = \pm c\sqrt{g_{oo}(1 - g_{oo})} \quad (9)$$

for the free radial motion with respect to the world (coordinate) time t of a distant observer. Static metric field (4) with one gravitating center, $g_{oo} = 1/[1 + (r_o/r)]^2$, leads in (9) to (unstable) motionless states, $dr/dt = 0$, of small probe masses at final stages of their radial falls. And probe mass reaches maximum radial speed $dr/dt = c/2$ of the central field fall at $r = r_o(1 + \sqrt{2})$ because below this transition distance decelerating part of the fall takes place due to gravitational repulsion of strong fields.

Coordinate acceleration d^2r/dt^2 can be derived from (9) by taking its time derivative,

$$d^2\mathbf{r}/dt^2 = -c^2 r_o \mathbf{r}(r^2 - 2r_o r - r_o^2)/(r + r_o)^5, \quad (10)$$

which universally describes the Newton attraction $-r_o c^2 \mathbf{r}/r^3$ for $r_o \ll r$ and the strong-field GR repulsion $+\mathbf{r}c^2/r_o^2$ for $r \ll r_o \equiv GM/c^2$. Attraction acceleration in (10) takes its extreme value $9.2 \times 10^{-3} c^2/r_o$ at $4.48 r_o$, while repulsion acceleration takes its maximum $0.12 c^2/r_o$ at $0.35 r_o$. According to the metric stress presentation (4), both repulsion and attraction of free probe masses correspond to their motion in always negative gravitational potentials.

5. Conclusions

Centers of massive objects in the Earth laboratory are always separated by huge distances compared to gravitational scales and, therefore, dark interference or dipole energy deposits of laboratory bodies are very small compared to their relativistic energies. Nonetheless, mechanical laboratory experiments could verify, in principle, the constancy (5) of the system integral mass-energy $E_{metric} = const$ independently from mutual positions of interacting material elements.

Massive galaxies have detectable gravitational scales and contemporary observations of matter near a galaxy center can provide relevant data to elicit dipole (dark) mass-energy deposits. Observed central area of dense matter in our galaxy is larger than its gravitational scale. And diameters of neutron stars are always above their gravitational scales as is known. Gravitational equilibrium can be assumed for these massive systems and the GR gravitational repulsion in (10) may shed extra light on stability of extreme dense matter.

Nowadays the radial dimension of the Metagalaxy is less than its gravitational scale $R_o = GM_{Meta}/c^2$. According to (10), the dense Metagalaxy should repeal its material elements behind $R_o(1 + \sqrt{2})$. The strong-field limit of (9), when $r \ll r_o$ and $dr/dt = cr/R_o \Rightarrow rH_o$, corresponds to the Hubble law of expanding galaxies at $R_o \Rightarrow c/H_o = 1,3 \times 10^{26} m$ or at $M_{Meta} =$

$R_o c^2/G = 1.8 \times 10^{53} kg$. The Universe expansion acceleration in this limit, $d^2r/dt^2 = c^2 r/R_o^2 \Rightarrow rH_o^2$, is proportional to the distance r like the Hubble expantion rate.

A mega system with gravitational repulsion of monopoles in common negative potential keeps due to (5) an exact metric energy conservation for all visible matter and its dark dipole deposits. The Big Bang fragmentation of one radial monopole into the system of expanding (with acceleration) radial monopoles and dark dipoles corresponds to (9)-(10) and to the aforementioned tendency to equipartition distribution of energy between monopole and dipole degrees of freedom. In this way, all Metagalaxy's matter in whole is provisionally in the phase of strong-field expansion with acceleration. One day a mature Universe with constant metric mass-energy (5) of its continuous material space will enter into the contraction phase toward its configuration equilibrium next to equipartition distribution of dark and observable energy contents within the united material space. Numerical simulations may provide more details regarding the global Universe pendulum with 80 billions of galaxies.

Simulations of nonempty space pulsations around its equilibrium material densities would be useful to compare with similar oscillating models of the empty space Universe, including the recent Penrose's construction for conformal cycling cosmology [8]. In general, dynamics of the pulsating metric space should count kinetic energy of mechanical translations and spins. Equipartition distribution of energy between kinetic degrees of freedom of monopole and dipole fractions of matter may also be important for computations. Non-empty space with local rotations of continuous material densities is the next challenge for nonlocal world cosmology.

6. References

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