Advanced Studies in Theoretical Physics
Vol. 18, 2024, no. 4, 195 - 202
HIKARI Ltd, www.m-hikari.com
https://doi.org/10.12988/astp.2024.92137

A Simple Geodesic Equation for Gravity, Electromagnetism and all Sources of Energy

Riadh Al Rabeh

Department of Mech. Eng., University of Basra, Iraq (retired)
Present address: Cheltenham, Gloucester, UK

Abstract

The geodesic and field equations are well known in conjunction with Einstein GR. The geodesic equation describes the motion in a field that contains sources of energy. Mass and energy are said to bend the spacetime as described by the field equations. In the geodesic equation any mass is said to move in a curved spacetime with no acceleration- like a free-falling body but in curved coordinates- the spacetime. We note next, that even though GR doesn't restrict the energy type in its energy momentum tensor to mechanical terms, the customary practice is to stop short of this generality and treat other sources of energy via terms added to the right side of geodesic equation. Add to this the fact that the derivation of the GR equations is quite involved and commonly described as heuristic [**7**]. All this seemed to mask the essence of these equations and encouraged many to put doubts around the completeness of GR equations. The author recently advanced a novel theory to explain gravity in terms of centrifugal motion of mass and energy(radiation) around distant masses [**3,2**] in line with the ideas of Mach. In the present work we derive in scalar 3D+time space, a simplified geodesic equation of motion stating that motion is induced by the negative gradient of 'any' energy. Then show that GR itself embodies the same idea of energy gradient leading also to centrifugal forces that appear as a result of the gradient operation on kinetic energy. This is because the centrifugal force contains velocity squared which is energy, and the division by distance in this formula is equivalent to a spatial gradient. Our method is useful in being immediately applicable to all other sources of energy like electromagnetic, heat, and others. All energy gradients in a field can contribute to the final motion of a particle in a space and this is the only cause of motion. Our work might then help to understand the function of the space-time curvature in GR and could encourage some new simplified methods to implement GR in practical situations. Other questions of whether GR is complete, permit singular solutions, or an expansion of spacetime in astronomy can be understood in a more enlightened fashion. For simplicity and accessibility, we use only single scalar variables and leave a generalization to tensor variables for anyone wishing to take the next step.

Keywords: Geodesic equations, spacetime bending, energy gradient, centrifugal forces, origin of gravity, unified forces singular solutions, expanding universe

1. Introduction

Einstein GR is considered the wonder of modern physics. It gained this fame from the fact that it is accurate in its prediction of physical events and solved the small anomalies experienced using Newton theories for gravity and motion. Despite some considering GR as a heuristic theory [**7**], it was never easy to introduce modifications to GR to suit more recent anomalies. The simple addition of a minute number like the cosmological constant, has created much heated discussions extended till today. All this suggests that there is something fundamental about the GR equations. The derivation of GR is based on two principal ideas. In addition to the constancy of the speed of light, there is the equivalence principle in which a falling body experiences no forces and moves at a constant speed in its frame of reference. Any acceleration that is observed externally in this case must then be due to changes in the spacetime frame and this should apply in general. The step that follows is to find how a spacetime is curved by the presence of masses, momentum, stress, etc. – all collected in the so-called stress-energy-momentum tensor. This tensor is also called the energy tensor by some. In principle, it should then be possible to include any energy source like that from electromagnetism, heat and others. In practice however, additional sources are included via additional terms in the field equations- may be due to the large difference in magnitudes between the energy content in mass (condensed energy) and that of the other ‘flowing’ energies- because of the c^2 factor.

The derivation and usage of GR in solving problems does not clarify the logic behind the bending of space time by its energy content, considering it simply as a fact of life despite its controversial and non-intuitive nature. Furthermore, the universal constant of gravitation of Newton G, need to be inserted in ‘by hand’ for the GR equations to work. So far, no one showed a way for calculating this value from GR alone- especially as this constant is extremely small- by some 40 orders of magnitude compared to the electrical forces for example- which raises obvious questions regarding its origin.

Further, this constant is universally valid which is another mystery. There is also the question why GR needed to be nonlinear, together with a related question of why the gravitational field should interact with itself- another non-intuitive matter. We try to shed light on all these issues by investigating how the gradient origin of energy affects the motion of matter. We also connect the new findings with a previous work of the author [**3**] that explained gravity as resulting of the centrifugal forces due to rotation around distant- masses as was advocated by Ernest Mach- the distant masses effects on local events idea, via an energy gradient.

2. Theory

An early indirect hint of the connection between a centrifugal force and gravity was indirectly given in Bertrand theorem- who showed that particles conserving momentum locked in an orbit should experience either an inverse square force or a space spring type force. The second case was shown to be a special case of the first [**2**]. As is known, the centrifugal force resembled gravity in many ways. It is spherically symmetric and infinitely penetrating- in the sense that any masses in between two gravitating bodies can't shield gravity. The big difference between the two however, is that the centrifugal force is repulsive/explosive whereas gravity is attractive. As argued in [**3**] above- guided by an old suggestion by Earnest Mach, this similarity can be made complete if we consider the forces to be the result of rotation around distant masses and not around the local center of mass. The effect of local masses come from the vector addition of the cumulative effects of all small distant mass effects.

A centrifugal force is not sensitive to velocity direction since the velocity in it occurs as a dot product with itself(squared). But it is sensitive to the direction vector between the interacting masses- the separating distance. It is positive in the case of centrifugal forces and negative in the case of rotation around distant masses. According to Newton's potential theory, the potential inside a mass shell is constant with no forces resulting from it- meaning distant masses have no effect on local masses. However, this changes when a mass moves and the action has to propagate at the finite speed of light. The asymmetry that leads to zero forces is broken due to the directionality of the position vectors in the gradient. Further, this makes gravity fully dependent **only on the energy/mass contents.** Furthermore, all types of energy can be involved as they are all forms of electromagnetic radiation [**1**]. It is expected however that the cumulative effect of mass is much more noticeable than other types of energy- being of highly condensed nature with the factor *c^2* in the conversion equation *E=mc^2*.

In [**3**] the author carried numerical simulations with many particles interacting under the centrifugal force alone- but originating either out of the center of masses to represent normal centrifugal forces, or into the center of masses to take the effect of distant masses. The acceleration due to motion with respect to distant masses as calculated in this way, is weak and constant- due to the huge radius of the universe compared to local radii. The calculated value of G based on this thinking was very close to the experimentally obtained value of Newton's gravity constant- if the known values for the mass and radius of the universe are used. The terminal acceleration of galaxies was also found to agree with the astronomically determined values [**2**]. These simulations produced orbits of the same elliptical structures as those obtained from applying the Newton theory of inverse square gravity alone. In the present work, we connect all these results with a more fundamental way to calculate acceleration of any mass/energy determined by the energy gradient, which can also be found from a fresh interpretation of the GR theory. These calculations also throw a new light on the origin of the various terms in GR- normally masked by the mathematical complexity of the theory.

Our starting point is the well-known relation that a force is the negative gradient of potential distribution, which is the cause any force and motion. This can be seen in Newton's law of gravity for example, since $F = G\ Mm/r^2$, and the acceleration (force/unit mass) is; $a=GM/r^2$. The potential in this case is given by; $\varphi = G\ M/r$. Then the gradient of the potential along r is acceleration; $a=-\nabla\varphi=-\partial\varphi/\partial r= -GM/r^2$. The sign is always negative even when not shown as the acceleration is in a direction opposite to the energy/potential increase. That is; acceleration is always from high energy to lower energy densities. This is rather intuitive since to accelerate means to increase speed and kinetic energy which is extracted from the difference in potential along the path. That is why heat always flows from high to low temperature and electricity flows from high voltage to low voltage/potential and never the other way round. If we take a mass m in orbit around a larger mass M that is kept in position by the centrifugal force; $F=m\ v^2/r$, the acceleration in this case is the centrifugal force; $a= v^2/r$. Since v^2 is kinetic energy- in effect a 'potential' distribution, the acceleration becomes a gradient over the radius distance. That is; the acceleration (force/unit mass) can be obtained from the gradient of v^2. That is; $a=(v^2)/r$. The $(1/r)$ expresses the gradient for the simple case of circular motion for a constant speed- that is constant energy 'potential' and point rotating mass. This is similar to the acceleration (electric field/unit electric charge) being given by the potential V/d across the distance between two parallel plates. Note that the differentiation is not along the path of a rotating mass, but normal to it- which is the 'connection' between the points of high and low energies. Different energy expressions would appear- necessarily of (1/length) dimension, which is what is termed the 'connection' in curved non-circular motion/curved spacetime. Using units alone we have; for unit mass, acceleration is in m/s^2, and energy is (m^2/s^2 as in v^2) and the gradient is 1/length(m) resulting in the similarity of units between acceleration and the gradient of energy.

In general, we can conclude that the resultant/total acceleration comes from the sum of the various potential/energy distributions. That is, we should have for the total acceleration: $a= -\nabla \sum (e_m + e_k + e_e + e_s + ...)$, where e is energy per unit mass and the subscripts; *m, k, e, s,* refer to energy of a static mass, kinetic energy, electromagnetic energy, stress energy (pressure and shear) and any other energy. The direction of each contribution to the acceleration is determined not by the scalar energy but by the sign of the distance/gradient/connection to the various energy distributions. In the case of a flux of energy as in motion, we need to use vector operations to find the relevant distances/connections in a more complex case, to evaluate the gradient- with energy being positive always. Positive acceleration represents explosive/repulsive forces or motion away from the center of mass. This is the case for the normal centrifugal force, pressure forces, and the repulsive electromagnetic forces.

If the connection is to the distant masses in the universe instead, the sign is negative compared to the local coordinates and would represent acceleration and motion *into* the local center of mass, which is how gravity forces work. This is also another way to look at the concept of rotating around distant masses of [**3**]- replacing it by the acceleration induced by the energy gradient caused by the distant masses. The energy gradient due to the mass of the universe- neglecting local masses being small in comparison, gives us the terminal acceleration of galaxies as; $a_0=c^2/R_u = 2e-10\ m/s^2$, and $G = aR_u^2/Mu=(M_u c^2/R_u)*R_u^2/M_u=c^2 R_u/M_u$, where subscript u refers to the universe values. These are the same formulae found in [**2,3**] .

Further, a direct differentiation of the kinetic energy v^2 can show how acceleration can be related to the energy contents. Using scalar variables in one dimension only we get;

$\nabla(e_k) =.5\ (d/dx)\ v^2 = v\ dv/dx= v\ (dv/dt)(dx/dt)=v\ a\ (1/v) = a$. This gives; $\nabla(ek) = a$. In a more general set up, vectors along curved lines need to be taken and the multiplying factor '*a*' would not be constant. This is what the geodesic equation of GR tries to do [**5,6,8,9,10**] since:

$\boldsymbol{F^j = x^{\cdot\cdot j} + \Gamma^j_{lk}\ x^{\cdot l}\ x^{\cdot k} = a^j}$, is the acceleration for a unit mass, with x, Γ standing for the position coordinate and the Christoffel symbol respectively. This way, a geodesic equation can be looked at as simply determining the path of a particle when the curvature of spacetime is known and $a=0$, or a *free fall* situation. When $l=k$ we get the kinetic energy and its gradient via Γ *which has the dimension of (1/length)*, and when not equal we get a centrifugal type acceleration. It can also be looked (in a reverse way) as the curving required in spacetime to reduce a particle acceleration and keep it at its free-fall zero value as is normally done.

3. Conclusions

Since a force/acceleration per unit mass is the negative gradient of a potential/energy, simple units argument shows that; *(energy/unit mass) / distance=m^2/s^2/unit mass =*

m/s^2 is acceleration. We can then write a universal geodesic equation in the form; ***a* = - ∇∑ *(all energy distributions)***, suitable for all energies- regardless of the dimensions of the space in use- that is 3D+time or 4D spacetime. This is what GR geodesic equation do since we can arrange it as; $\mathbf{a}^j = -\Gamma^j_{lk}\ x^{\cdot l}\ x^{\cdot k}$, (no external forces). The two equations play a similar role and can thus be applicable in the wider sense to any type of energy (a scalar) as: kinetic (.5 ***x.x****)*, *mass (mc^2)*, mechanical stress/pressure(*1/*$|A|^2$*)* ***F.A***), heat (mC_p) and electromagnetic energy (*.5* ***E.E),(****.5* ***B.B***) collectively- multiplied by a factor like ***Γ*** to account for the geometry and the distances involved to find the gradient of energy flux (vector). In all cases, the distribution of energy contributes to the acceleration via the gradient and can be positive or negative depending on the geometry and the local connections to the various parts of the domain- especially when dealing with vector energy fluxes. The '*energy flux*' is a vector quantity that can change with space and time. For this general geometry case the tensor Christoffel operator is a necessary tool. This captures the essence of the working of the geodesic equation of GR as an implementation of a negative gradient of (kinetic) energy in a general distribution of energy flux. In flat space and straight-line coordinates, the acceleration is simply that of *F=m a*, as in the Newtonian mechanics, which is the result of a negative potential gradient as shown above.

It is now apparent why GR continues to defy modification attempts- because of its basic structure relying on the basic characteristics of energy/matter distribution and the natural tendency for energy to move/spread from high to low concentrations. This is also what makes GR universal- combining different energy sources in its energy tensor. Since everything in the universe is either flowing energy (radiation) or condensed energy as mass, GR becomes a theory of everything indeed and by the simplest of logic. It must also be pointed out clearly here that; *objects that can't be expressed in energy terms cannot contribute to motion and can't exist or even sensed by any means in the first place*. We also see here that there is nothing special to a gravity force that allows for something to be described as dark- be it matter or energy- that is entities affected by gravity but not by other energy sources like light. This is because; *anything that has energy must affect motion and anything that doesn't have energy can't affect motion, can't exist and can't be sensed in any known way*- agreeing with the well-known fact that the act of measurement itself must introduce a small change in the measurand in order to give any result. We can also conclude that the curved spacetime notion is not an essential part of GR understanding. It might be essential for calculations only and thus can be simplified in some cases. Einstein himself was quoted to have said that the curved spacetime is only a mathematical necessity and not something to be taken as real- see [**4**] and quote.

Our work treats gravity as a force like all other affecting matter- resulting from the variation in the energy distribution in space, then gives a reason for its extremely weak nature as being due to the energy gradient is that to the distant masses of the universe. This makes the gravity laws align with other energy gradient driven fluxes like conduction, convection, mass transfer, electric current (electron flux) and others. We also note that because of the large *c^2* multiplier in converting mass to energy, large masses effects on acceleration of matter become overwhelming and dominant. It is also worth noting that Einstein was quite convinced of the importance of Mach principle and very much wanted to incorporate it in his theory. He said he had to abandon it as being not compatible with what he was doing. As described above, it appears that GR can in fact include the effect of distant masses indeed as shown above- using the energy gradient concept and as a result we can account for the terminal velocity of galaxies which removes the need for dark matter. It also permits the calculation of the value of G, the universal gravity constant of Newton from the forces on a unit mass due to distant masses. Finally, explaining gravity as an energy gradient leaves us with a single fundamental force which is **electromagnetism** from which all forces are derived- gravity together with the strong and weak nuclear forces of particle physics [**3**] as coulomb forced modified by the effects of inertia on crowded particles. But to complete the rules of physics, we must add conservation of momentum and the constancy of the speed of light/radiation in empty space.

Acknowledgements. The author would like to thank his physicist friend Dr J. Hemp for many fruitful discussions throughout many years, all the authors who permitted free access to their hard work, and the search engines and depositories that made this possible. The author also acknowledges fruitful interactions with the newly available GAI which has become a best friends for checking science facts. This is from the AI (Poe) comments when I fed the abstract of this paper: "Your passage provides a solid overview of complex concepts in general relativity (GR) and proposes a novel approach". See the full discussion and comments at:

https://www.quora.com/profile/Riadh-Al-Rabeh

References

[1] Al Rabeh, R.H, On the Radiation origin of matter, *Adv. Studies Theor. Phys.*, **15** 2021, no. 6, 267 – 278. https://doi.org/10.12988/astp.2021.91654
https://www.m-hikari.com/astp/astp2021/astp5-8-2021/p/alrabehASTP5-8-2021.pdf

[2] Al Rabeh, R.H, Simplifying Astronomy via Mach's Principle, Einstein Equivalence Principle, and the Gravity Phase-shift, *Adv. Studies Theor. Phys.*, **17** (2023), no. 3, 121 – 138. https://doi.org/10.12988/astp.2023.92008
https://www.m-hikari.com/astp/astp2023/astp1-4-2023/p/alrabehASTP1-4-2023.pdf

[3] Al Rabeh, R.H, A Novel Distant Masses Centrifugal Origin for Gravity, *Adv. Studies Theor. Phys.*, **18** (2024), no. 1, 17 – 29.
https://doi.org/10.12988/astp.2024.92085
https://www.m-hikari.com/astp/astp2024/astp1-4-2024/p/alrabehASTP1-4-2024.pdf

[4] Lehmkuhl, D., Why Einstein did not believe that general relativity geometrizes gravity, *Studies in History and Philosophy of Science Part B: Studies in History and Philosophy of Modern Physics*, **46** (2014), 316-326.
https://doi.org/10.1016/j.shpsb.2013.08.002

[5] Sochi, T., *Introduction to Differential Geometry of Space Curves and Surfaces*, Createspace, ISBN 10: 1546735895, various publishers.

[6] Spiegel, M.R. et al., *Vector Analysis*, Schaum's Outlines, McGraw Hill (USA), 2009.

[7] Wikipedia, Centripetal Force. https://en.wikipedia.org/wiki/Centripetal_force

[8] Wikipedia, "General relativity", Quote:" General relativity can be understood by examining its similarities with and departures from classical physics. The first step is the realization that classical mechanics and Newton's law of gravity admit a geometric description. The combination of this description with the laws of special relativity results in a *heuristic* derivation of general relativity"
https://en.wikipedia.org/wiki/General_relativity

[9] Wikipedia, "Geodesics in General Relativity",
https://en.wikipedia.org/wiki/Geodesics_in_general_relativity

[10] Wikipedia, "Potential Gradient",
https://en.wikipedia.org/wiki/Potential_gradient

Received: September 12, 2024; Published: October 11, 2024