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GRAVITATION, FORCE, AND TIME

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Abstract

Gravitation is described as a uniquely geometric phenomenon, incompatible with the concept of force, and only analogically comparable with force by means of mathematical formalisms. Two thought experiments are employed to demonstrate that the association of gravitation with force is irreconcilable with the geometric interpretation, and without theoretical foundation or empirical support. Motion in time is identified as the dynamic source of what has been attributed as the energetic component of gravitational phenomena.

Keywords: Gravitation, Force, Time, General Relativity

Introduction

The mathematics of relativistic gravitation theory is remarkable both for its expansibility and physical ambiguity. To a large extent it can apply equally well to an interpretation of gravitation as a geometric deformation of spacetime and as a force of some kind. But given the persistent pre-relativistic association of gravitation with force, that ambiguity, fomented by the consolidation and predominance of mathematics in the interpretation of physical phenomena, has resulted in an overextension of the mathematics and consequently in theoretical misdirection.

Conceptualization of the general theory

Two principal mathematical analogies can be identified in the early development of relativistic gravitation theory and implicated in its diversion. One derives from Einstein’s heuristic insight associating gravitation with geometry, apparently due to an idea suggested by his friend Paul Ehrenfest (1909), who was himself inspired by Max Born’s investigation of relativistic rigidity (1909). Ehrenfest noted that the ratio of circumference to diameter of a rotating disk would have to deviate from *pi* with relativistic accelerations at the radius. In Einstein’s subsequent pursuit of a generalization of relativity the similarity between the inertial effect produced at the radius of the rotating disk and the gravitational pressure we experience at the earth’s surface suggested that gravitation might be explicable as a fundamentally geometric principle. Experimentation has confirmed the validity of that seminal geometric insight and the service of the mathematical analogy. But in the kinematical similarity between objects on a rotating disk and in gravitational orbit there is a distinct empirical difference: A test body in a box that is fixed at the edge of a rotating disk presses against the radial wall of the box, manifesting a centrifugal “force”, derivative of the actual force that is rotating the disk; in contrast, a test body in a box orbiting an astronomical body floats freely, following its geodesic in spacetime in parallel with the box, and gives no indication of the presence of a force or acceleration. There is thus a mathematical analogy due to the similar kinetics of the rotating disk and the orbiting body, but not a physical equivalence.

The development of the field equations of General Relativity was based on another mathematical analogy, formalizing the behavior of bodies being accelerated or pressured toward an attractive or determinant vortex as in a field of force, and a collapsing, concentrating sphere. The analogy holds in this case because gravity, like a field of force, produces a typically concentric form to the motion of affected bodies. But again, the mathematical analogy is not a physical equivalence. A neutral test body inside a charged box that is accelerating toward the vortex of a field of force presses against the wall of the box opposite the direction of force, and a charged body of different mass than the box accelerates at a different rate than the box, moving consequently toward one wall or its opposite. In contrast, a test body in a box falling or spiraling in a gravitational field floats freely, following its geodesic in spacetime in parallel with the box, and gives no indication of the presence of a force or acceleration.[1]

In both cases -- in the similarities between the rotating disk or orbiting body and between the attractive or determinant field -- there is a discernible difference in the *empirical* behavior of test bodies being acted upon by a force and those moving in a gravitational field. In these pivotal models grounding relativistic gravitation theory, the mathematical analogies between gravitation and force are limited to descriptions of idealized curvilinear trajectories of idealized, dimensionless particles.

Physics and Mathematics

The special and general theories of relativity were conceptual in origin and mathematical only in their corroboration and utilization. The general theory has represented gravitation as a product of the “curvature” or deformation of spacetime in the vicinity of mass, and both the evidence and the supportive mathematics have been entirely adequate to justify its acceptance. But the field equations of general relativity are indifferent to the dynamic basis of gravitation, and geometry is distinctly non-dynamic. Theorists who have sought to associate gravitation with force have consequently been compelled to develop non-geometric extensions of the field equations, usually based on electromagnetic analogy. Gravitation has been described in terms of the mathematics of quantum theory as a *force* and associated with a hypothetical particle, without either an explanation of the relationship between geometry and force or an explicit dissension from the geometric interpretation, and without empirical evidence of a particle. In terms of the stated and accepted principles of science, this represents a radical theoretical discontinuity.

Conceptual physics -- which can be considered roughly coextensive with pre-quantum physics -- involved the initial development of coherent hypotheses, then *secondarily* the employment of mathematics (and/or experiments) to support their plausibility. A mathematical formalism without conceptual coherence would have been regarded as irremediably provisional, if not unsatisfactory, in the former methodology. With respect to the former physics, two thought-experiments will be employed below, without resort to mathematics, to demonstrate that the association of gravitation with force is conceptually flawed and without empirical support.

Two Thought Experiments

The first experiment would be unnecessary except that the pre-relativistic association of gravitation with inertia, and of inertia with universal mass, is still maintained on occasion, if only tacitly, and may be the ultimate basis of the continued misidentification of gravitation with force. The misidentification may also be a residue of one of our most familiar and persistent experiences on the earth's surface: The pressure we feel between ourselves and the surface (weight) is fundamental to our original concept of gravitation; we tend to regard the pressure as a force (“the force of gravity”) and our relatively static surface frame of reference as being at rest. The following experiment may therefore be helpful in more clearly dispelling the identification of gravitation with force and inertia, and also in prefacing the second experiment, which will illustrate the continuity between force-free astronomical gravitation and gravitation at the surface of a massive body.

Imagine a spacecraft coasting on a uniform path relative to the "fixed stars" which comes under the influence of a stellar object nearby and begins to deviate toward it, while continuing in uniform motion by the evidence of free-floating objects inside. In order to maintain the original course a thruster is fired, and inertial effects are experienced onboard as the craft accelerates just enough to counter the influence of the local gravitational field in order to maintain the intended course.

In this experiment inertial effects are associated not with gravitation, but with the *counteraction* of a gravitational acceleration, and with supposedly *uniform* motion relative to the distant stars, contrary to the pre-relativistic expectation. Aside from the discrimination of inertia from any influence of the overall mass of the universe (an association that is seldom explicitly defended now anyway), the experiment demonstrates what I hold to be most significant, that at least in the situation just described, force becomes evident in conjunction with gravitation only when gravitation is being *resisted*.

Now consider an experiment that comprehends the transition from astronomical gravitation to an involvement with force and inertia at the surface of a massive body:

Imagine two test bodies gravitating toward the earth from some considerable distance. For the sake of simplicity, consider the earth to be at rest with the test bodies gravitating toward its center of mass. (They appear to be simply “falling” from a perspective on the earth’s surface.) One body is an immense hollow sphere of negligible mass, the other is relatively small in size -- an extra-vehicular scientist, let's say -- and also of negligible mass. Notice that while the test bodies are falling toward the earth (or more accurately, while the three bodies are converging) there is among them a purely relative transformation of potential energy to kinetic energy as each moves uniformly in its own frame of reference -- there would be, at least as yet, no occasion for an exchange of mass-energy in the form of the supposed *gravitational* energy.

Let the sphere and the scientist be placed initially close together so that as they approach the earth their geodesics converge enough to bring their surfaces in contact some time before the larger impact. (It is the fantastic size of the hollow sphere that allows the surfaces of the two bodies to meet somewhere above the earth's surface). From the moment the sphere and the scientist come in contact until they reach the surface of the earth, a static inertial acceleration between them will intensify as each tries to conform to its own geodesic at an ever greater angle from the normal. The situation will, if viewed in isolation, come to resemble the gravitation of a small body pressing against a planetary surface (although the gravitation between them is actually insignificant due to their negligible masses) and the scientist will even be able to stand upon the sphere. This development of an increasing inertial acceleration between the test bodies is the only aspect of the situation that changes from the moment they meet; the earthward component of their motion continues as before, a relative gravitation.

In a manner that is similar to the first experiment, force has developed in the *resistance* to what is in this case a convergent gravitation of two bodies toward a third. And once the two reach the earth the situation remains essentially the same: Each of them, now in conjunction with the entire conglomerate of the earth, presses toward the center of mass with the same sort of conflict of geodesics as was observed between the two when they were gravitating from a distance. Along with the other components of the earth at and below the surface, they are resisted, and thereby induced with a static acceleration by those further below, due to the coincidence of the common inclination toward the center of mass and all the subterranean obstructions.

This second experiment demonstrates that it is only in the inertial conflict of geodesics (or as in the first experiment, in a singular inertial acceleration) that force can be observed in association with gravitational phenomena. The intersection of geodesics and the consequent inertial effects constitute the *interruption* of gravitation, and what is commonly conceived as “the force of gravity” at a surface can be more accurately described as *anti-gravitation*.

The Principle of Equivalence

Einstein’s original conception of an “equivalence” between gravitation and inertial acceleration pre-dated his recognition of gravitation as a product of spacetime geometry. In the beginning he expected a generalization of relativity to demonstrate that gravitational and inertial accelerations can be equated as aspects of a single principle, just as uniform motion and non-motion (i.e. rest) had been resolved in the Special Theory.

Using a thought experiment with an elevator, Einstein sought to illustrate the equivalence "of a gravitational field and the corresponding [inertial] acceleration of [a] reference frame" (1907) by comparing the experience within the elevator in a familiar gravitational situation with its being accelerated by a cable attached to a spacecraft somewhere beyond gravitational influence. Although he evidently never revisited the experiment after developing his geometric interpretation of gravity, it should be clear by now that the only reason for the similarity of the two situations is that in the one there is an inertial acceleration due to mechanical force and in the other there is an inertial acceleration due to the *resistance* to gravitation. Inertial acceleration is the only principle common to both situations, and the only correspondence.

The notion of equivalence remains a foundational principle in gravitation theory, although its ongoing theoretical relevance and practical application is questionable. The principle has more recently been interpreted with greater circumscription, sometimes as an axiom that gravitational and inertial masses are equivalent, but more often, as in Dicke's "weak principle of equivalence" (1970), as a dispensation that gravitational effects in most laboratory experiments can be transformed away by regarding the lab as falling freely.

In any case, the subsequent variations on "equivalence" share with the original an implicit identification of gravitation with inertia. The idea of *gravitational mass* presumes a distinct gravitational force; otherwise gravitational mass is just another name for inertial mass, and there can be no question that the two might be exactly equivalent.

The "weak principle” in its common interpretation is actually recommending the transformation of inertial (not gravitational) effects at the earth's surface so that experiments can be more clearly and easily interpreted; the gravitational effects are actually the uniform motion (the “free-fall”) being assumed.

But even if "equivalence" is formulated in acceptable geometric terms, if it is only claimed that in a sufficiently small region of spacetime gravitational distortions can be ignored for practical purposes, "equivalence" is thereby reduced from a physical principle to a prescription or license for experimental expedience. If it is claimed that the spacetime restriction rescues the principle from the objection that geodesics converge in a gravitational field but not in an inertial acceleration, the expedient becomes a theoretical sleight of hand. It would, after all, be a curious principle that could only be invoked if we agreed to limit the scope of our observations and the precision of our instruments just enough to render its actual falsification undetectable. We might as well claim that red and blue are equivalent if a laboratory is sufficiently dark.

Implicit in the Equivalence Principle (we should say "principles") is the more pertinent antithesis, which may be formulated as follows: First, drawing from the considerations and experiments discussed earlier, there is no relationship, and certainly no equivalence, between gravitational and inertial acceleration; the one can be definitely distinguished from the other. Second, however similar the trajectories of a gravitational and an inertial acceleration may appear, it is always possible in principle to distinguish curvilinear motion due to gravitation from that due to a forceful influence; an electrically neutral test body in a container will, for example, distinctly express a situation as either gravitational or inertial by either floating freely or tending toward one side of the container. Third, to affirm what the idea of "equivalence" is often used to suppress, there is, in principle, no place in the universe, however small, that is truly "flat", and no two coordinate systems, however proximate, that share exactly the same spacetime metric; the fact remains that geodesics converge in a gravitational field, while bodies acted on by a mechanical force respond in parallel. Although there are limits to our ability to discern local geometric deformations, and although in many cases we are justified in treating the differences as insignificant, if there is to be a principle in gravitation theory pertaining to inertial acceleration, it should be a principle of *non*-equivalence.

Relativity, Absolutes, and Energy

When gravitation is isolated from circumstances where it is being resisted there is only geodesic motion, curvilinear or straight depending on the coordinate system. In the relative accelerations and decelerations of orbital dynamics, and in the perturbations of orbits due to external gravitational influences, there is no indication of force or gravitational energy, there is only the *appearance* of acceleration from other reference frames.[2]

The original goal of the generalization of relativity was to establish that inertial and gravitational accelerations, like the special case of uniform motion, are relative. It may be that there is now a more-or-less unconscious aversion to abandoning that aspiration to grand simplicity. But from the perspective of a purely empirical and conceptual physics, given a clear experimental discrimination between gravitation and inertia, a generalization of relativity to include force and inertial accelerations is manifestly untenable. It bears repeating: A simple experiment with a test body in a container can confirm that an inertial acceleration is absolute, whereas an unobstructed gravitation is not.

Gravity has to be considered absolute in the aspect that a geometric vortex exists at a center of a sufficiently large mass that cannot be transformed -- either conceptually or mathematically -- but unless the geodesic of a body becomes obstructed, as at the surface of a planetary body, gravitation involves *uniform* motion with only *relative* accelerations. No force or energy can be attributed.

The problematic reliance on mathematics for conceptualization and inference discussed earlier is nowhere more striking than in the conventional treatment of the problem where the Field Equations presume gravitational energy but don’t allow it to be identified or mathematically expressed in local circumstances. It isn’t questioned, in consequence of the meta-mathematical approach, whether such an elusive sort of energy actually exists, it is simply said that it cannot be “localized” (Misner, Thorne & Wheeler 1973). Thus a problem of non-conformity between the theoretical and physical is considered nothing more than a mathematical oddity, and thereby rendered satisfactorily unproblematic. Mathematics trumps physics, and formulas trump observation.

The Dynamic of Time

There remains a most significant aspect of the distinction between gravitation and force to be comprehended, although its full implications must be left outside the scope of this discussion. The energy expressed in the continuous static acceleration of bodies at and below a massive surface is rendered inexplicable in purely geometric terms when gravitation is finally distinguished from force. If gravitation is a deformation of spacetime due to the influence of mass, if there is no “force of gravity”, what accounts for the persistent energy pressing against a massive surface after a body has come to a relative state of rest? Recall that in the initial appearance of force in the second experiment described above, only a conflict of geodesics is present and resistant against the otherwise uniform motion of the test bodies. No extrinsic source of energy can be identified, yet there is a static acceleration between the two, even while their gravitation with the earth remains force-free.

I believe the answer lies in a curiously under-explored, if not *un*explored implication of Minkowski’s (1908) interpretation of special relativity, which described space and time as a four-dimensional continuum. His graphic representation of relativistic effects (the Minkowski diagram) as expressed by the Lorentz transformations shows uniform motion to be motion in time, perpendicular to space (while of course remaining *in* space), and relative motion to be less in time the more rapid it is in space. It follows from this evident covariance of the spatial and the temporal that if time is a form of motion which is normally unapparent as-such in our world of experience, where bodies move in time with infinitesimal deviations from the parallel, then time must be dynamic, and possessing an incessant energy, imponderable except when a body is persistently resisted, as at a gravitational surface.

Motion in time, the motion of matter in general, must be regarded in this view as absolute, although relative in the incidental spacetime orientations and velocities between individual bodies. The source of the energy usually identified as gravitational energy can thus be attributed to an intrinsic and ceaseless dynamic of mass-energy moving in time, independent of gravitation, and obscured by the conflation of gravitation and inertial acceleration in circumstances when they happen to coincide (as at a gravitational surface) but revealed by a clear recognition of their fundamental distinction.

Conclusion

Having briefly acknowledged the implications of a consistent geometric theory of gravitation, that gravitation and motion in general are each in their own way both relative and absolute, and that time is intrinsically dynamic and the source of the energy disclosed by the opposition to gravitation in its occasional resistance, I will consolidate the findings with regard to quantum theory and other force-based theories in the following summation:

By all evidence, gravitation is a deformation of spacetime due to presence of mass, its effect being a geometric concentration of spacetime toward centers of mass. Bodies moving under the influence of gravitation move uniformly in their own reference frame unless obstructed by a body massive enough to form a spacetime vortex, when their incessant motion in time causes them to continue to press toward the surface. Being a strictly geometric phenomenon, gravitation cannot be a force, it cannot therefore be mediated by a particle, and cannot radiate as mass-energy. The assimilation of gravitation by quantum theory and its derivatives as a field of force, and the positing of a gravitational quantum of action where none is apparent, theoretically necessary, or conceptually coherent, is entirely without justification.[3]

This is an admittedly unsettling proposition, but in consolation, its acceptance makes one of the principle objectives of quantum theory much less complicated, as gravitation with all its peculiarities can be disregarded in the pursuit of a unified field theory. And the concept of time as being spatially dynamic, and a primary determinant in gravitation theory, suggests an intriguing new area for investigation. I hope it might also signal the need to rely more upon conceptualization, and not so heavily on mathematical formalisms, in the development of physical hypotheses.

End Notes

[1] There may be an appearance of force if the gradient of a gravitational field is extreme enough relative to a body's extension in the direction of the field to produce tidal stresses on the body's molecular binding energies. (The earth's ocean tides are a dramatic instance.) But this too is entirely geometric in its origin, and only manifests local variations in the intensity of the distortion of spacetime. A tidal effect can be identified when a free-floating liquid test body manifests a distinctive elongation along the axis of gravitational influence.

[2] The most prominent case of hypothetical gravitational energy and its radiation is the inspiraling binary star system, where there is evidently a loss of net relative (kinetic/potential) energy between the companions due to their deteriorating orbital dynamics. In terms of gravitation as a geometric principle, the idea of a transformation of relative accelerations to force-like radiation is incongruous; the extrinsic energy corresponding to the decrease within the binary system should be interpreted instead as a purely relative increase of (kinetic/potential) energy between a binary system and the rest of the universe.

[3] Like energy-bearing gravitational waves, other hypotheticals -- gravitomagnetism, dark matter, and dark energy -- can be expected to continue eluding detection, as all are based on the presumed association of gravitation with force.

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