J. Nig. Ass. Math. Phys.
Vol. 2 (1998)

IS THE GENERAL THEORY OF RELATIVITY A PHYSICAL THEORY?

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It has often been stated that the two great revolutions in physical thought during this century derive from the almost simultaneous creation of the quantum theory and the (classical) general theory of relativity (GTR). In contrast to the quantum theory which has grown and flowered in abundance, the general theory of relativity has remained static. A few examples which justify a recent claim that the general theory of relativity is not a physical theory in the usual sense are discussed.

1. INTRODUCTION

The need for a generalized theory of relativity was recognised by Albert Einstein soon after the creation of his special theory of relativity. He realized that all the natural laws except the law of gravity could be discussed within the framework of the special theory of relativity. The distinction was clearly elucidated by the observation that although the relationship between inertia and energy was explicitly given by the special theory of relativity that relationship does not apply to gravity because in this case the relationship is between inertia and weight (or energy in the gravitational field).

As a way out of this quandary, Einstein decided to construct a theory which satisfied his general principle of relativity[1]: the laws of physics must be of such a nature that they apply to systems of reference in any kind of motion. On the basis of this principle Einstein arrived at his celebrated equation,

$$G_{ab} = 8\pi T_{ab} \qquad (1.1)$$

which he assumed should apply to all the interactions of nature (G is the Einstein tensor and T the energy momentum tensor). Being a space-time theory, (1.1) qualifies as a manifest fundamental physical theory. Experience has shown over the years, as we shall see hereunder, that the classification is misleading and indeed wrong.

2 THE BASIC CHARACTEERISTICS OF THE CLASS OF PHYSICAL THEORIES

In a lecture entitled "The Excellence of General Relativity"[2] that P.AM. Dirac gave on the occasion of Einstein's centennial, he stated inter alia "I have enumerated the successes of the Einstein theory of gravitation. It is a long list, quite impressive. In every case the Einstein theory is confirmed with greater or less accuracy depending on the precision with which the observations can be made and the uncertainties that they involve". In actual fact, however, the successes of Einstein theory as a physical theory are neither long nor impressive! It is quite true that his prediction regarding the precession of the perihelion of Mercury, his prediction of the deflection of light when transversing a gravitational field and resulting time delay, and his prediction of the different rates of clocks in locations of differing gravity have been confirmed quantitatively. But all these relate to the departures from the Newtonian theory by a few parts in a million and of no more than three or four parameters in a post -Newtonian expansion of Einstein's equations. So far, however, no predictions of general relativity in the limit of strong gravitational fields, including its prediction of gravitational radiation, have received any confirmation 82 years after the theory was created, nor are they likely in the foreseeable future .

We should expect that a theory which generalizes a theory as well established in its domain as the Newtonian theory of gravity should refer to predictions which relate to the major aspects of the theory rather than to small first – order departures from the theory it replaces . Would the status of Dirac's theory of the electron, for example, be what it is today if its only success consisted in accounting for Paschen's 1916 measurements of the fine structure of ionized helium? The real confirmation of Dirac's theory was provided by the exact departures provided by the Klein – Nishina formula replacing Thomson's formula for electron scattering; and more particularly in the confirmation of the predictions of the theory relating to the creation of electron-positron pairs in cosmic –

ray showers, and of antimatter. Or, would one's faith in Maxwell's equations of the electromagnetic field be as universal as it is without Hertz's detection of electromagnetic waves propagating with the velocity of light, and without Poincare's proof of their invariance under Lorentz transformations? In the same way a real confirmation of the general theory of relativity will be forthcoming only if a prediction characteristic of that theory and only of that theory is confirmed? Thus, despite the encomiums poured on Einstein, the general theory of relativity is in a very peculiar position today with reference to its confirmation by observations and experiments, and the reasons for its inspiring confidence.

The problem we have had with the general theory of relativity may not be unconnected with our interpretation of it as a physical theory in the same class as the great physical theories of classical mechanics, quantum mechanics, and special relativity. We now show by way of some examples that the general theory of relativity is in a class of its own, being distinct in every respect, apart from the fact that it is a space-time theory, and therein lies the problem.

It has been established since the time of the early Greek philosophers that progress in physics depends critically on a symbiosis of theory and experimentation. Indeed, every respected physical theory is based on experiments that have been checked very carefully. This symbiosis has resulted in endless escalation of knowledge more or less in a cyclic fashion: new experimental facts lead to existing theory being rebuilt, new theoretical predictions leading to new experiments, etc. In fact all the great physical theories of Newtonioan mechanics, quantum mechanics, and special relativity have followed this path . Thus, for example, the works of Tycho Brahe, Johannes Kepler, Nicholas Corpernicus, Galileo Galilei, etc. gave birth to the Newtonian theory; the collapse of Newtonian universe in the realm of high velocities, gave birth to special relativity; the failure of the classical Maxwell theory to explain the stability of atoms and blackbody radiation, gave birth to the quantum theory, and the failure of the classical Maxwell theory to explain the interaction of light with matter, gave birth to quantum electrodynamics. All these, without exception, were dictated by observations and experiments.

The power and strength of this age old procedure is underlined by H. Minkowski "the views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength.

General theory of relativity however is a non-conformist in this regard because the replacement of Newton's theory of gravitation by Einstein's relativistic theory is not known to have been dictated by any experiments or observations. In fact According to Dirac. "When Einstein was working on building up his theory of gravitation he was not trying to account for some new results of observation..." On the contrary, Einstein was guided solely by three principles, the principle of equivalence, and the principle of general covariance (beauty, you may say). Of these three, only the principle of equivalence relates to actual observation, and it is one of the cornerstones of the Newtonian theory as well.

Secondly, every valid physical theory has well established boundaries outside which the theory is not expected to yield correct results. Thus, a non relativistic treatment is adequate whenever relevant velocities are small compared to the velocity of light , otherwise the problem must be treated relativistically. Also if the associated fundamental quantum of action is large compared to Planck's constant h, then the system is macroscopic and must be treated classically, otherwise the system is microscopic and quantum mechanics must apply . This way the various domains of physical theories are delimited neatly according to whether the theory belongs to nonrelativistic classical (or quantum) domain in which case the relevant velocity must not exceed one-tenth of the velocity of light and the dimension must exceed a few microns (not exceed a few angstroms), or relativistic classical (or quantum) domain in which case the relevant velocity must exceed one -tenth of the velocity of light and the dimension must exceed a few microns (not exceed a few angstroms) . All the respected physical theories of Newton, Maxwell, Schrodinger, Heisenberg', Dirac, etc. fall under this general classification.

General relativity expectedly maintains its independence by being the only exception to the above rule. General relativity is limited by the requirement that the intervals of time and of distance are large compared to the Planck scales – $(hG/2c^5)^{1/2} = 5\times10^{-44}$sec, and $(hG/2c^3) = 2\times10^{-33}$cm respectively. This means that the theory is valid for distances of the order of a few parts of 10^{-33} cm and greater, and the energy positive, but small compared to the incredible Planck energy (10^{16}Tev). The implication of the energy constraint is that all physical velocities are admissible!

3 THE NEED FOR A NEW INTERPRETATION OF THE GENERAL THEORY OF RELATIVILTY

The implications of the above observations on the nature of the general theory of relativity are strange indeed. We are forced to conclude that what is small (microscopic) in the usual sense is large (macroscopic) in the GTR sense, and that the energy of every known system in the universe is positive. Consequently the theory is applicable to all systems of any size from a few parts of 10^{-33} cm and greater. In other words the theory is applicable to all known systems in the universe including molecules, atoms, nuclei, electrons and quarks land makes no distinction whatsoever between Bosons and Fermions!

The ultimate test of any theoretical prediction is its experimental verification. As we have seen, only three predictions of the Einsteinian theory have been experimentally confirmed. In every other aspect the theory has been a dismal failure. It must therefore be concluded that the GTR is not a physical theory in the usual sense. This conclusion immediately raises a fundamental question. If Einstein's theory is not a physical theory, what is it? This matter was addressed in a recent paper and the "conflicts" between GTR and the great physical theories have been satisfactorily resolved.

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