Action-at-a-Distance and Local Action in Gravitation: Discussion and Possible Solution of the Dilemma

Toivo Jaakkola
Tuorla Observatory
University of Turku
FIN-21500 Piikkiö, Finland

The problem of the character of gravitation is approached by discussing three main possible modes of action from the historical, theoretical and empirical standpoints. The "Newtonian" mode of action-at-a-distance (AAAD)—in which Newton himself did not believe—is followed through three centuries, though the aim is not historical accuracy. This approach includes several Weber-type theories of velocity-dependent action; these are found to be compatible with or transformable to the mode of the "material field local action" (MFLA). The historical roots of the mode of relativistic local action (RLA) are sketched, and it is criticized on both conceptual and empirical grounds. For the MFLA mode, a new theoretical framework is presented by giving a summary of equilibrium cosmology (EC) recently developed by the author. In EC, gravitation is an equilibrium process providing energy balance in systems of baryonic matter, while electromagnetic radiation is the contrary effect. Gravitation on a body is a pressure effect of gravitational quanta (gravitons) conducted from the background field by the gravitation field of the body. The formation of the field is outlined. Gravitons and photons interact via electrogravitational coupling (EGC), which causes the redshift effect and an analogous weakening of gravity, as well as the cosmic background radiation which is a re-emission equilibrium effect. From pressure-induced gravitation and EGC, a dynamical theory (EGD) can be constructed which unifies the gravitation effects in systems on different scales; until now, numerous ***ad hoc*** *hypotheses had been necessary to explain the effects.*

When EGD is applied to the two-body problem, Newton's law is obtained directly. In it the force is a sum of two equal terms which are due to the two fields of graviton flow into the bodies, which are mutually screened by the second body. While gravitation is basically not an attractive but rather a repulsive pressure force, the two-body attraction results from the screening effect. The dilemma of a distant action versus a local action character of gravitation receives a simple but unexpected solution: both are true. While the momentum due to the pressure of gravitons flowing towards the second body has a distinctly local character, the momentum obtained due to the screening of the body's own field by the second body is an action at the distance of that body. Both are expressions of a single interaction between the mass systems and the background field.

1. Introduction

The mechanism of gravitation is one of the unsolved fundamental questions of physics. Newton, who gave a mathematical law according to which gravitation works in his *Principia*, was fully aware of the need for a physical explanation of the effect. He was not in favour of the mode of action-at-a-distance and searched for a material transmitter of gravitation. In this he was followed by many of the great physicists in the next two centuries. The currently prevailing theory, Einstein's general relativity (GR), belongs to the same tradition of the local action approach, but here the metrical properties of space, instead of some material medium, are the agent. Criticisms of GR have been made throughout this century, and in last few years international symposia have been devoted to the topic. In quantum mechanics, a non-local mode is nowadays favored due to apparent faster-than-light velocities implied in the experiments testing the Bell inequality (see *e.g.* Bertlmann, 1990). For gravitation, the action-at-a-distance mode still finds supporters (*e.g.* Hoyle and Narlikar, 1974; Phipps, 1990).

Therefore, the problem of the nature of physical interactions remains quite open, obscure and even poorly identified. A solution is a prerequisite for a consistent conceptual basis of physics and the removal of the disturbing dichotomy in theories of the world at the macroscopic and quantum levels. Moreover, a solution to the riddle would open the way for advances in concrete problems of gravitation, which appears to be, in both observations and theory, a more multifaceted phenomenon than usually conceived.

I shall discuss three alternative concepts of gravitation in a historical perspective and in the light of recent empirical and theoretical results. These are: action-at-a-distance (AAAD; Section 2), relativistic local action (RLA, Section 3) and material field local action (MFLA, Sections 4 and 5). AAAD means conventionally that gravitational (or similarly, electromagnetic) action between two masses (charges) depends only on the mutual distance, and in some theories on its time-derivatives, with no reference to an external frame, medium or observer. Transmission of the action is usually thought of as instantaneous, but it may also propagate with the velocity of light (c, constant or not), or in the ballistic theories additively by $c+v$ where v is radial velocity of the source; gravity may also have its own characteristic transmission velocity v_g. Identification of a particular theory with the AAAD mode or the MFLA mode appears to be a delicate question. More essence to AAAD will be given in 5.*ii*.

In RLA, action is mediated through a metric field, *i.e.* it is determined by the geometrical properties of the space-time which itself depends on the distribution of matter. In MFLA, action is transmitted by a material medium. The composition of the medium and propagation of the action vary in from one theory to another. A stationary, all-pervading and space-filling æther is the classical form presented for the medium, which is thought also to be required for the propagation of light waves as well the conception represented in Sections 4 and 5, *i.e.* that the medium is composed of gravitational and electromagnetic quanta (gravitons and photons). The "field"-term is adopted, with the meaning of structuring of the medium due to position-dependent variation of density, velocity and energy of the transmitters.

The present paper will be in a sense, a report of personal research: it is based on a reading of previous historical reviews and original papers, on my own writings and reflections, as well as on concrete scientific work. The main historical sources are Cohen (1980), Hawking and Isræl (*eds*., 1987), North (1965), Pais (1982) and Roseveare (1982).

During writing the paper, the historical problem treated here has grown in the author's mind to one comparable to a thriller or detective story; occasionally this will appear in the style of presentation. The solution to be given to the riddle of gravitation will appear a surprising one. It was such also to the writer.

2. Action-at-a-Distance: Historical and Recent Discussion

i. Newton's Position

Contrary to what is often believed, Newton did not think gravitation to be an AAAD effect. He frequently expressed his objection to viewing it as an inherent property of mass systems. He sympathized the æther viewpoint and attempted, though unsuccesfully, to formulate such a theory. His attitude is clearly expressed in a letter to Bentley in 1693 (Newton 1958, pp. 302*sq*; Cohen 1980, p. 117): "that one body may act upon another at a distance through a vacuum without a mediation of any thing else by or through which their action of force may be conveyed from one to another is to me so great an absurdity that I believe no man who has in philosophical matters any competent faculty of thinking can ever fall into it". *Principia* was a mathematical treatise of mechanics, and not, as Newton carefully pointed out, a physical treatise (Cohen 1980, Section 3). His physical ideas were published posthumously as *A Treatise of the System of the World* (1728) and were presented more openly in his letters. His physical viewpoint remained much less known in the scientific community than the mathematical treatise of *Principia*.

In referring to gravitation Newton used general and neutral terms like "centripetal", "circumterrestrial", "circumsolar", *etc.* force, which do not refer to its fundamental nature. He used the word "attraction" very carefully: of 108 instances of the word in *Principia*, 90 were in the mathematical books 1 and 2, of the rest, nine referred to electric or magnetic effects and nine appeared in contexts not referring to a fundamental character of gravitation (Cohen 1980, p. 83). When speaking about attraction, Newton stressed that "we are here concerned with mathematics; and therefore, putting aside any debates concerning physics, we are using familiar language so as to be more easily understood by mathematical readers" (Sect. 11, bk 1).

In the latter connection, Newton reveals something about his physical viewpoints: "... considering attractions, although perhaps—if we speak in the language of physics—they might more truly be called impulses". He used the term "impulses" frequently. This will be quite relevant when we consider the concept of gravitation given in Sections 4 and 5. Interestingly enough, perhaps anticipating the double solution I will give in Section 5, Newton writes (bk. 1, prop. 45, corol. 2) that in addition to the centripetal force a body revolving in an elliptical orbit is affected by another "extraneous force" that is "added to or taken away from this centripetal force".

As mentioned, Newton thought gravitation to be caused by ætheral particles, or as he wrote, by "the æther or of air or any medium whatsover—whether corporeal or incorporeal—in any way impelling toward one another the bodies floating therein". The strength of his conviction in the æther interpretation varied, as did its forms. In 1675 he wrote to Oldenburg: "Thus perhaps all things be originated from æther". In the early 1660's Newton speculated about a shower or stream of æther particles, which later came to have a varying density. His emphasis on the third law of equal action and reaction and the question of a resisting effect of the æther made him suspicious, though he still thought that "some exceedingly subtle matter... seem to fill the heavens". To such an explanation, "if someone would make it", he was "far from objecting", as he wrote to Leibniz in 1693. In 1702 Newton wrote that there is no fluid medium in space, and he turned his attention to a possible electrical cause of gravitation. However, in his last views on the topic, as in the *Optics* (1717/1718) Newton returned to the æther, the density of which was to be variable.

Referring to Newton as the founder of the action-at-a-distance conception of gravitation is thus a serious misconception which may have affected the later development of physics. This began with the second edition of *Principia*; in its preface Cotes discussed Newtonian gravity as an essential property of matter. Newton's case is an example of a scientist who was fully aware of the fundamental importance of the problem of gravitation, and who through his active life intensively and without compromise sought an answer to the challenge. The three different æther approaches of Newton mentioned above have preserved all their interest. All three are contained in the theory of gravitation to be presented in Sections 4 and 5. The latter approach was founded on modern empirical and theoretical results in cosmology, and its resemblance to Newton's attempts became apparent only afterwards.

ii. Other Early Discussions

According to Leibniz, the rival of Newton for the honour of being the inventor of infinitesimal calculus, an AAAD attraction, "properly so called, is a miraculous thing", it is "inexplicable, unintelligible, precarious, groundless and unexampled" (North 1965, p. 25). British empirists Locke and Berkeley held the view that for physical action one must choose between the alternatives AAAD on one hand and elasticity, cohesion, contact pressure and impact on the other hand. To Hume causality required spatial contiguity of the links in a causal chain (North 1965, p. 42). The dialectician Hegel and his materialist followers looked for a unity of attractive and repulsive forces. Mach (1872-1911) comments on the history and the status of the problem: "The Newtonian theory of gravitation, on its appearance, disturbed almost all investigators of nature because it was founded on an uncommon unintelligibility. People tried to reduce gravitation to pressure and impact. At the present day gravitation no longer disturbs anybody: it has become common unintelligibility." Of the major philosophers of the time one finds Kant defending the plausibility of AAAD.

During the 18th and 19th centuries, intense work in search of a mechanism of gravitation continued, but the triumphs of Newton's mathematical theory in astronomy, including the discoveries of Uranus and Neptune, Ceres and other minor planets, and Halley, Encke and other comets were more conspicuous in the public mind. The general spirit in fundamental research was against the AAAD mode, and various theories which can be included in the MFLA category were worked out by several more notable physicists of the time. Such names as Bernoulli, Euler, Le Sage, Laplace, Cauchy, Faraday, Riemann, Maxwell, Thomson, Seeliger and Lorenz can be mentioned here (North, Chapter 3). One group of theorists supposed a velocity-dependent action; this important school, usually considered under the AAAD label, is discussed below separately. In Section 3 we discuss the emerging RLA theory. Nevertheless, according to North (p. 41)," by the end of the 19th century the general view was almost surely that the most conspicuous clue to the mystery [of gravitation] was the discovery of the electromagnetic æther", of whose "reality the nineteenth century was never in doubt". However, AAAD retained an important role in the subject, as it still does today.

iii. Velocity-Dependent Theories of Gravitation

Since the first half of the 19th century there has been an influential group of theories of electrodynamics, which also affect studies of gravitation, where it is assumed that physical action depends on velocity and acceleration between the charges or masses. These theories are usually thought to belong to the AAAD mode, but as it will be shown, the basic character of the velocity-dependent(VD) action is a delicate question.

The school of VD theories started principally with Weber (1846), though in 1835 Gauss had already suggested a VD force law. Others who developed VD theories were Riemann (1861), Clausius (1877), Ritz (1908-1911) and Gerber (1898); for later theories see below. A review of these theories is given in Roseveare (1982, most refs. of the above there). All the various electromagnetic force laws presented in these theories have been applied to gravitation. The gravitational analogue of Weber's law has the form

$$F = \frac{Gm_1m_2}{r^2}\left\{1 - \frac{1}{h^2}\left(\frac{\mathrm{d}r}{\mathrm{d}t}\right)^2 + \frac{2r}{h^2}\frac{\mathrm{d}^2r}{\mathrm{d}t^2}\right\} \qquad (1)$$

If $h = \sqrt{2}c$, the form of Eq. 1 becomes equivalent to Weber's generalization of Coulomb's law for moving charges.

The most advanced of the classical VD theories was due to Ritz (1908-1911). His aim was to contruct a unified theory of electromagnetic and gravitational phenomena, but his death at the age of 31 broke off the attempt. He thought gravitation to be basically an electromagnetic effect, wherein Newton's law corresponded to the fourth-order term in the force law and Mercury's perihelion motion was contained in the sixth order term. In this ballistic VD theory, action transmitted by fictitious particles propagates with velocity $v + c$, in disagreement with special relativity. De Sitter (1913) put forth the binary star argument in support of the latter theory, and it is indeed a strong empirical argument in favour of the SR postulate of constancy of velocity of light. However, Freundlich (1913) answered that a variable velocity of light would cause an apparent preferred orientation of the line of apsides such that periastron would point away from the Earth, and such an effect had already been observed by Barr in 1908 (see Roseveare, p. 135).

Today, a great number of light curves of eclipsing binaries are available, many of them catalogued. Although I have not yet made a systematic study, it is my impresion that the slopes before and after the light minima are systematically asymmetric in the sense supporting $c + v$ instead of Einstein's c. Of course, the velocity differences must be smoothed out in the stellar neighborhood in order to have any regularity in the light curves. Smoothing, due to the electrogravitational coupling (Section 4), is an expected effect. And it must be added that there are certainly enough light curves with strongly irregular forms.

iv. Recent VD-Theories

Surdin (1962) based a Weber-type theory on the æther approach of Prokhovnik. He obtained $\frac{2}{3}$ of Mercury's perihelion motion and the same solar redshift and light deflection as GR.

Assis has used Mach's principle and a Weber-type potential as the basis of his studies (1989, 1992a,b). He has succesfully treated perihelion motions of the planets, Hubble's law, Olbers' paradox, CBR, and gravitational absorption in his theory. In many respects, the results of this AAAD theory coincide with those of the MFLA theory of the present author (Jaakkola, 1983, 1989, 1991, 1993).

Like Ritz, Assis considers gravitation to be fundamentally an electromagnetic effect appearing as higher-order terms in the force law. As mentioned above, Newton had attempted an electric approach. In 1836 Massotti suggested that gravitation results from a slight difference in the strengths of electrical attraction and repulsion, a hypothesis which has influenced many later experiments, including Faraday's classical work (see Woodward, 1983; Jaakkola 1991).

The comparative and reductive approaches in applications of electrodynamical force laws to gravitation are reasonable. However, unification in nature and in theory probably may not be found in one basic force (or one basic quantum) from which the other forces (particles) can be derived. Rather, unification might be sought more successfully in physical interactions and interconnections between the different elements of physical reality. Ultimately a unity can be found in the Universe only.

Ghosh (1984, 1991) started from Mach's principle and, noticing Sciama's (1961) concept of inertial induction (an acceleration-dependent term in the force law), added a further term with second power of velocity. Unlike in the other VD-theories, the additional terms add to, rather than subtract from, the force in Ghosh's "velocity-dependent inertial induction" theory. Moreover, gravity is assumed to be transported by material particles. Through this theory Ghosh has given interpretations of the secular retardation of the Earth's spin without a catastrophically close Moon orbit in the past, as is required by from the usual tidal theory. (Another possibility is a tidal deceleretion of the spin plus æther drag on the Moon, quite in agreement with Ghosh's VD-term; see below.) Further, the anomalous acceleration of Phobos, solar center-to-limb redshift and grazing redshifts, as well as the cosmological redshift, are all explained by Ghosh's theory.

v. VD: AAAD or MFLA

Velocity-dependent theories of gravitation (and electrodynamics) have been treated by Roseveare (1982) and obviously by most of the theorists themselves as belonging to the AAAD mode. I would like to call this classification into question. In this mode there cannot be any rationale for the higher-order terms of the force law. Furthermore, if gravitation is regarded as pure AAAD "without a mediatiation by anything else", the zeroth-order (Newtonian) term also remains without rationale: in place of $F \propto 1/r^2$ any other distance law could apply. The basic fact is that—as Newton himself stressed—Newton's law is not a theory but a mathematical expression (see also the quotation from Mach above). In Section 5 an AAAD-like meaning will be found which participates in Newton's law, but the general mode of action is through the field of gravitational quanta; *i.e.* MFLA.

The meaning of the velocity-dependent terms in the MFLA gravitodynamics is likewise problematic and cannot be covered in detail here. In electrodynamics some of the Weber-like theories have been succesful in reproducing Coulomb's law, Ampere's force and Faraday's law of induction (Phipps, Jr. 1990). In gravitation the main realm of application is planetary and satellite orbits, where the radial velocities dr/dt are minimal, and if velocity-dependence is considered, tangential orbital velocities must also be considered. In the two-body problem, this is implied by the Newtonian term in the MFLA theory suggested in Sections 4 and 5, and any additional VD term is in regard to the gravitational æther connected to a third body or a large-scale system. It might be interpreted as the resistive effect of the æther; note that v^2 is proportional to the kinetic energy of the collisions. We encounter here the known complexities of the three-body problem, as well as the drag problem, often used as an objection to the æther theories, which was known also to Newton. With reference to Ghosh's results, which I interpret just as the resistive drag, I leave the question here.

vi. A Recent Defence of the AAAD

In electrodynamics, there is an extensive recent literature on a local (versus distant) character of the action, mainly centred around the Bell theorem and respective laboratory results pointing to instantaneous action. To keep the scope of this already wide ranging essay limited, I shall not go into this discussion.

Phipps, Jr. (1990) has made an important contribution, mainly pertaining to electricity, but relevant here for its ciriticism of GR (*i.e.* RLA) and all field theories (MFLA of Sections 4 and 5 is a "field" theory). He points out that GR and all field theories violate Newton's third law, which is firmly established in laboratory, and that recent laboratory results by Graneau, Phipps, Jr. and others indicate the existence of Ampère longitudinal forces, which counterindicates universal covariance, causal retardation and spacetime symmetry. Further, Phipps argues that absence of gravitational aberration is suggestive that gravity is instantaneous, and that Mach's principle, if that "much vexed and behexed principle" is adopted, involves distant simultaneity. The concept of "relativity of simultaneity" is bitterly criticized. A modified Weber potential is adopted, which fits the experimental and theoretical requirements given by Phipps.

Without becoming involved in experimental questions of electrodynamics, I only point out that (1) Newton's third law is strictly valid in the MFLA derivation of Newton's law in Section 5*.i*. (2) There is an "instantaneous" component in the action connected to the screening effect; otherwise the velocity of gravitational action v_g is not specified. If Wesley's (1988) relation $n_g^2 v_g = n_g^2 c$ holds good, and graviton frequency $n_g = H$ as Broberg (1982) and Shlenov (1991a,b) assume, Laplace's limit $v_g > 10^8 c$ is met very well. Another, more likely possibility is that when there is no exchange of gravitons g in two-body gravity, though gravitation is mediated by the gs (see Sections 4 and 5), there is no apparent gravitational aberration either, and v_g may be of the order of c, which itself is a variable $c = c(r)$. (3) In the "Machian" global-local interaction the question, on the new view, concerns the mediation of the action from the cosmological background field CBG through the hierarchy of local fields to a particular, *e.g.* terrestrial, gravitation field. As there is no cosmic time, the question of instantaneous *vs.* retarted Machian action loses its significance.

Leaving aside the AAAD for a while, the mode remains buried with the epitaphs given to it by men of physics and philosophy, like Newton, Leibniz and Mach: it is an absurd, miraculous, inexplicable, precarious, groundless and unexampled common unintelligibility. In Section 5, AAAD will rise up from this grave and reincarnate with fresh flesh and blood in its new embodiment.

3. Relativistic Local Action

i. Historical Background

A brief historical account of relativistic ideas, which are viewed here from a critical standpoint for reasons given below, seems to be in place. Of course, a proper history of the topic cannot be given here.

One element of the story is the mathematization of physics. The eminence and practical success of Newton's mathematical theory of mechanics played an important role in this process. Newton's mathematics was often, in particular in the French literature, conceived in the sense of "géométrie" (Cohen 1980, pp. 120-127). The physical incomprehensibility of gravitation as an attractive AAAD force facilitated this trend, forcing purely mathematical treatments of the problems encountered. At the same time Newton's own actual distaste for AAAD and the idea of an attractive force was not well known, since this was not made explicit in the *Principia*.

The second element is the physicalization of mathematics (its one part, geometry). That this trend continued and was linked to the opposite trend without a break is, though ironic, not surprising. In a theoretical climate impregnated by mathematics, the non-Euclidean geometry developed in the 19th century by Lobachevsky, Bolyai, Gauss and Riemann could well be absolutized such that the space concept achieved a status comparable to that of matter. Geometry, a branch of pure mathematics, became an empirical science. Gauss is known to have measured angles between three mountain tops (North 1965, p. 75). Today the same programme is being carried on with the most up-to-date technology, measuring the curvature of space (q_0) using distant galaxies and radio sources as standard candles and meters. Since 1876, non-Euclidean space gas been treated in the context of the force law, matter-space relation, and structure of the Universe by Clifford, Killing, Neumann, Fitzgerald and Schwarzschild (see Roseveare 1982, pp. 163—165).

As found in Section 2.*iii*, there was a strong school of Weber-type velocity-dependent AAAD theories of electrodynamics in physics, applied also to gravitation, and Maxwell's field theory presented an alternative to these. The field concept rested originally upon the conception of the æther. The non-Euclidean space concept which, by about 1870, was popular among mathematicians and adopted by some notable physicists, replaced the ætheral field with a metric field. This did not happened overnight, but it was greately facilitated by the Michelson-

Morley experiment, which was all too hastily interpreted as disproving the æther.

As for the long-term vein of the story, the metric field means, in effect, dematerializing the field concept, since a geometrical continuum is clearly less "material" than the æther, while the concept of a curved physical space itself involved an almost vulgar materialization of the space concept.

The geometrization of the world was sometimes accompanied by theories which assumed that gravitation was caused by a connection between our world and the Universe having higher dimensions. Such ideas were presented by Riemann (1853) and Pearson (1891) (see Roseveare 1982, pp. 106-108). The notions like matter pouring into our world from other universes as suggested by Jeans, continual creation, superstrings or 11-dimensional universes are not as novel ideas as they may seem.

In keeping with the AAAD vein of thought, the relativity of mass as dependent on velocity was considered by Lorenz, Wien, Darwin and others (Roseveare, pp. 159-160).

The scientific arena where this happened itself was highly theoretical and abstract, and full of parallel, contrary, interlacing, permanently changing, new and old ideas. This was just as it should be for a major scientific enterprise. All the time the target was the problem of the mechanism of gravitation, parallel with the electromagnetic interaction.

The setting for this lively scientific scene was a social milieu that was equally lively and full of new and old, changing and often opposite ideas, and these ideas crossed and influenced—deliberately or not—the scientific scene. The great ideologies of the nineteenth century society were materialism, appearing in the rising Marxist movement and the Darwinist evolutionary doctrine, and its opposite based on the idealist philosophical tradition, religion and bourgeous society. Science, as always, tended to remain neutral with respect to the ideological battle, and Mach's positivist philosophy was the most notable expression of this aim. It emphasizes the act of perception and observation over the questions of real nature of the measured objects; ontological problems were branded as metaphysics.

When developing his two relativity theories, Einstein was, as he admitted (Einstein 1949), deeply influenced by Machian positivism. The connection is clear in the GR gravitation theory: when the path of light rays curves in the solar neighborhood it is said that space is there curved, and if it slows, time is said to go slower. In his later years Einstein (1949), in particular in the debate with the Copenhagen school on quantum mechanics, Einstein withdrew from the positivist standpoint.

From the historical viewpoint, the positivist philosophical doctrine on one hand provided a foundation for a genuine theory of gravitation (GR), and on the other, permits representation of gravity purely mathematically according to Newton's (or some other) mechanics, without a need for a physical understanding. In the latter dimension, positivism argues that the centuries-long efforts of scientists to understand gravitation, which can be seen as central theme of the development of physics, was in vain. In this sense positivism "canonizes ignorance".

In the light of these long-term processes in science, philosophy and society, Einstein's relativity theory is historically understandable. In the half-century preceding 1915, about a hundred papers had been published on non-Euclidean statics, dynamics and kinematics, attraction and potential, Laplace's equation, *etc.* GR binds togehter non-Euclidean geometry and Machian epistemology. Behind it were some empirical arguments drawn from experimental work. GR gave the first well-formulated solution to the problem of the mechanism of gravitation, which had been a focus of attention since the days of Newton. Whether the solution is satisfactory conceptually and empirically will be discussed below.

There is still one more historical element, which carries the story to the present day situation in physics and related sciences, cosmology and astrophysics. This is the cosmological redshift effect, whose discovery (1929) directly followed GR (1915) and the unstable relativistic world models of Friedmann (1922-1924) and Lemaitre (1927). It seems to me that the mere temporal coincidence of the two important developments strongly influenced the interpretation of the redshift as a Doppler effect due to expansion of the Universe. The expanding cosmological models, reciprocally, supported the GR by emphasizing its importance as a tool in physical sciences. Both (GR and the big bang postulate) have grown together to form today a monolith which pervades physics, cosmology and astrophysics. In the author's view the historical coincidence was unhappy: a twisted theory in one branch of science twists another branch of science, and in this the order between the sciences, cosmology and gravitation research, can be read in either direction.

It is not necessary here to discuss the phases of construction of the two relativity theories; this has been more properly documented by others. The most important factor was, of course, Einstein's own role. After his early succesful theories he strove for almost four decades, until the days of his death, to construct a unified field theory synthetizing gravity and electromagnetism, and with the aim to obtain known particles as special solutions. This was an extremely ambitious goal, if not an improbable one; Einstein was aware of this but held to his path tenaciouslyly and without compromise. In March 1955, a month before his death, he quoted in a text to Lessing: "The aspiration to truth is more precious than its assumed possession". His way of making science carried him into a controversy with the main-stream physics, in particular with the "Copenhagen school" in quantum mechanics. It was a solitary position. Einstein felt it, but he had also a good sense of humor: "I am generally regarded as a sort of petrified object, rendered blind and deaf by the years. I find this role not too distasteful..." (see Pais, 1982, p. 462).

Einstein was a genuine enough a scientist that he rejected attempts to build a "unified theory" by binding together his success, GR, and the other success of the century, QM, which he did not believe in as a fundamental theory. "Our problem is that of finding the field equations of the total field" (1949, Pais p. 465). While he was quite obstinate in regarding GR as the necessary basis for unification for a long time, he may also have sought new alternatives. "One must note, however, that the wave-particle duality demands something unheard of" (1942). Doubts must arise in every sound individual working in the field of theory. Einstein seems to have doubted the big-bang cosmology using GR as the fundamental theory: "To admit such cases seems senseless to me". And (Einstein, 1955, p. 129): "One may... not assume the validity of the equations for very high density of field and matter, and one may not conclude that the 'beginning of expansion' must mean a singularity in the mathematical sense". Einstein (1949) also makes a provision: "... provided that the Hubble effect is interpreted as a Doppler effect". In a letter to Born in 1949 Einstein writes: "Even I cannot adhere to [my "respective hobby-horse"] with absolute confidence". In a letter to his friend Besso he wrote in 1954: "I consider it quite possible that physics cannot be based on the field concept, *i.e.* on continuous structures. In that case, nothing remains of my entire castle in the air, gravitation theory included, [and of] the rest of modern physics" (see Pais, p. 467).

Those who comment that these are the ramblings of a sick old man, evidently think that science is an enterprise for energetic young males (actually novices with no sense of history, general problems of the field, and other branches of science and life).

Today many active scientists are critical of relativity theory and at the same time the great goal of the older Einstein. For them, as for the others, Einstein's personality as a scientist, intellectual and a man deeply involved in the affairs of humankind may serve as personal goals. While we make below conceptual and empirical criticisms of relativity theory, this is not intented (and not able) to finish Einstein's greatness.

I wonder whether the "unheard of", the alternative approach of which the older Einstein had a feeling, might be the redshift as a tired-light effect, from which follows that the Universe is in equilibrium, which really unifies the Universe. And the unified Universe may be the only realistic starting point for construction of a unified physical theory.

ii. Conceptual Remarks

The relativistic conception of gravitation necessicates an analysis of the space concept. A body in a spatial position has a gravitational field around it, or in terms of GR, space is curved there. The field moves out with the body, but that particular volume of space, as definable through the outer Universe, remains. Rather than a property of space, gravitation is an attribute of matter.

Much of what is written about space comes from the ideological "idealist"/"materialist" standpoints. The former point of view has been expressed, *e.g.*, by Leibniz who considered space as an "order of coexistences"; "being neither a substance, nor an accident, it must be a mere ideal thing". To Ernst Mach (1893), "space and time are well-organized systems of series of perception". The extreme materialist point of view, well suitable also to GR, is space (like time) is a "form of existence of matter". The classics of Marxism clearly defended the Newtonian concepts of space and time.

For GR, curved space is not a mere mathematical trick for dealing with physical problems, but it is conceived ontologically, as physics itself. For Einstein, the field is the only reality to which the matter concept should be reduced. The relativistic ideal is crystallized poetically in Jeans' picture of galaxies as "mere straws in the stream of space".

This amounts to a re-absolutization of space, which is a result of absolutizing one kind of physical motion, that of electromagnetic radiation. When light from distant stars is deflected in the field of the Sun, GR says that space is curved, if it is delayed, time (not light!) runs slower. Basing the space and time concepts on a single physical effect exposes these concepts and the whole physics to the perturbations affecting this effect. As a valid parallel example, if the time concept were based on terrestrial rotation, numerous observable processes of distant galaxies would have accelerated in a measurable amount during historical time, and a major earthquake would shake the whole Universe. Such a shadow world is also inbuilt in relativity theory, where everything may shrink or stretch like chewing gum: nice if there is no bang. And indeed, in the Beginning, there was the Big Bang.

Einstein may have been embarrassingly conscious of this problem, but he defended the status of the absolute motion of light in his physics as follows (1951, transl. English-Finnish-English): "In order to give physical significance to the concept of time, processes of some kind are required which enable relations to be established between different places. It is immaterial what kind of processes one chooses for such a definition of time. It is advantageous, however, for the theory, to choose only those processes concerning which we know something certain. This holds for the propagation of light *in vacuo* in a higher degree than for any other process which could be considered, thanks to the investigations of Maxwell and H.A. Lorentz." The same argument applies to Einsteins space concept. Here Einstein adopts the positivist point of view of reality; on the other hand, he rejected this viewpoint in his later years, in particular in the debate surrounding quantum mechanics.

In addition to its epistemological contents, Einstein's statement on the status of electrodynamics can also be criticized for its physical concepts. Such pioneers of theory and observation as de Broglie, Hubble and Zwicky probably would not have subscribed to the cited viewpoint which is fundamental to the relativistic notions of time, space and gravitation. Subsection *v*. gives modern arguments on the point.

iii. Empirical Criticism of the Relativistic Mode of Action: Solar Tests

Three aspects of the redshift data relating to the Sun invalidate the argument in favour of Einstein's theory and support the approach in Section 4. First, the centre-to-limb variation of redshift is not at all predicted by relativity theory, which predicts a constant value of $z = 2.12\times 10^{-8}$ independent of the position on the solar disk. Nor does the exact form of the variation fit models of radial mass motions or effects of granules. It does, however, fit the predictions following from velocity-dependent inertial induction (Ghosh, 1991), direct interaction between photons and electrons in the atoms of the solar chromosphere, as proposed by Marmet (1991), and probably also predictions from the kind of gravitational interaction suggested below.

In these models, the size of redshift corresponds to the length of the path of the photons through the redshift field, the length depending on the position in the disk. Hence, the solar redshift appears as a redshift-distance relation. This actually connects the solar redshift directly to the cosmological redshift effect.

Second, at the limb, observed z values are larger than the relativistic prediction. Forgetting for a moment the differential character of the solar redshift, it is improbable that the observed value (at the limb) would be a combination of a relativistic gravitational effect plus something else. Occam's razor would rule that we are actually dealing with one and the same physical effect that influences both gravitation and, through this, radiation (in the form of redshift).

Third, redshifts have been observed to occur symmetrically before and after occultation by the Sun. This kind of effect has been noted in the 21 cm absorption line of Taurus A (Sadeh *et al.* 1968). An indication that there are chances of testing the various redshift theories experimentally is the fact that the 2292 MHz signal from Pioneer-6 was redshifted systematically and symmetrically when the spacecraft passed behind the Sun (Goldstein 1969). At the projected distance of 3 solar radii, the redshift was approximately 5×10^{-8} (Merat *et al.* 1974a). There is no doubt that what we are seeing is in fact a redshift-distance effect, the strength per unit distance being a function of distance from the Sun. Likewise, there is good reason to infer that this electromagnetic effect is physically the same one that causes the limb redshift normally interpreted as an Einstein gravitational effect.

Deflection of light in the solar field is also predicted in Newton's theory; this was first calculated by Soldner as early as 1803. In 1911, Einstein obtained a similar value from the principle of equivalence. Observations seem to fit the full relativistic prediction (1915) of 1.75 arcsec at the solar limb, which is twice the Newtonian value. Actually, the data possesses only 30% accuracy, and in general the optical deflections are greater than the GR prediction (see Will 1987). The situation can be summarized as follows: at distances greater than 5 solar radii, both optical and radio data roughly fit the GR prediction, as do the closer radio data. But data from some 200 closer optical deflections show a 10% excess, which is significant at the 4σ level (Merat *et al.* 1974b). The optical-radio difference is explained as a higher radiowave refraction in the electron plasma; interestingly, refraction works in the direction opposite to the relativistic effect.

The advance of Mercury's perihelion exceeds what would be caused by the other planets and other known causes by 43 arcsec a century. The effect has been known since Le Verrier's work one and a half centuries ago. GR predicts the observed value very well. Actually, it is doubtful whether the exact fit between data and theory here supports or, rather, disproves the theory: a very special configuration of the Sun, perfect sphericity, is involved in the fit.

iv. Empirical Criticism: Cosmological Tests

In Fig. 1 empirical results on various global and local tests of the relativistic world models by various authors are given as a function of year of publication. The survey (Jaakkola *et al.*, 1979) is systematic up till 1978; one later result of a careful analysis of the largest sample of double radio sources until now (Nilsson *et al*. 1993) is added. According to a nonsystematic follow-up of the data, nothing since 1979 has changed the situation implied by Fig. 1.

It is evident from Fig. 1 that there is a serious internal contradiction in the cosmological data when considered within the relativistic theoretical frame. This is of a systematic and permanent character, independent of the number and state of development of observations. The Hubble diagrams give a closed universe ($q_0 = +0.93\pm 0.19$), and various local estimates of the near density give an open universe ($q_0 = +0.03\pm 0.08$). Optical angular diameter tests (q, z) give either an open model, or even require the repulsive factor involved in the cosmological constant (q_0 = -0.9 ± 0.2). Radio (q, z)-relations fall out of the whole range of relativistic predictions (symbolically "$q_0 < -1$"). No trace of a minimum q at $z \approx 1$ predicted in the relativistic models can be seen in any data. The empirical inconsistency of the standard cosmology is thus as bad as it could be: it is actually difficult to draw all the different results in a single diagram.

Attempts have been made to get around the difficulty by constructing numerous *ad hoc* models of cosmic evolution. The processes suggested often appear implausible, and the total picture becomes extremely complicated, with number of "epicycles" exceeding that of the Ptolemaic picture before its collapse. The empirically most plausible evolution effect (in the standard frame), an increase of luminosity of the brightest cluster galaxies due to mergers, only increases the empirical contradictions in the standard model.

The cosmological test results summarized in Fig. 1 give no support whatsoever to GR and its theory of gravitation. At the same time, these show a good fit with the static Euclidean world model, and provide a significant argument in favour of the new picture of the Universe as an entity in the state of equilibrium. Further evidence of that, also of crucial importance for the problem of the mode of gravitation, is given below.

v. Relativistic Space Concept and the Redshift Effect

Empirical analyses during the last decades, *e.g.* by the present author (1978, 1983, 1988, 1989, 1991, 1993a; Jaakkola *et al.* 1979), have shown definitely that the universal redshift effect is not a Doppler effect but an effect of an interaction of light with matter (actually with a gravitational substance, see 4.*i*); accordingly, the Universe does not expand. In general, the strength of redshift is proportional to the square root of density. The redshift of most quasars originates within the objects (Arp 1987). Both cosmological and intrinsic redshifts are quantized (Tifft 1988, Napier 1991, Arp *et al.* 1991).

In view of the role played by the motion of light signals as the foundation of relativity theory, as pointed out by Einstein in the citation in 3.*ii*., redshift as an interaction effect is, in itself, enough to disprove the relativity theory. The motion of light signals appears to be intimately connected with the presence of matter, and it has nothing to do with the supposed properties of space. This demolishes not only the empirical arguments of GR based on the solar and cosmological redshifts, but also the chain of reasoning at the core of relativity theory.

Therefore, the only well-developed theory of gravitation must be rejected. In this regard, science finds itself in a similar situation as it was in Newton's time. It may be helpful here to describe a recent approach to the riddle of gravitation starting from a novel cosmological theoretical framework.

4. Material Field Local Action

The third mode of action of gravitation, MFLA, is based on a material bombardment from space. The theory to be outlined below has its origin in cosmological considerations. It would seem that the idea has a long history: such names as Huygens, Newton, Le Sage, Maxwell, Compton, Seeliger, Lorenz and Nernst, among many others, belong to this tradition. Among its present proponents, I mention Broberg (1982, 1991) and Shlenov (1991a,b). Weber-type velocity-dependent theories may also be seen in this context (see 2.*iii*). A more detailed historical account cannot be included here.

i. A Cosmological Frame to Approach the Problem of Gravitation

There are four broad groups of tests of the cosmological expansion hypothesis, each containing tens of separate tests. The results of the tests indicate convincingly that the Universe does not expand. First, analysis of the redshift effect in systems of different scales (Jaakkola 1978) proves that it is not a Doppler but an interaction effect. Second, data represented in Fig. 1, systematizing the cosmological test results, are mutually inconsistent in the expanding theoretical frame, but they are consistent in the static model (Jaakkola *et al.* 1979). Third, the powerful Hubble-Tolman test indicates nonexpansion in all four samples analyzed, the critical remarks presented in Jaakkola (1986) apply also to the later contrary conclusion by Sandage and Perelmuter (1989). Fourth, cosmic evolution, necessary for an expanding model, does not exist. The two most strongly argued effects, number evolution of QSOs and colour evolution of galaxies, are artifacts of selection and of the K-effect (Jaakkola 1982; Laurikainen and Jaakkola 1984a,b).

The Universe is not only non-expanding, but it is even in a state of equilibrium. This is indicated by the fourth argument, by proper inferences from the isotropy of the Universe, in a very straightforward manner by the blackbody spectrum of the cosmic background radiation (CBR)—precisely an equilibrium spectrum—and by equality of the CBR energy density with various local energy densities.

The theory of the Universe in equilibrium, equilibrium cosmology (EC), is based theoretically on the (already empirically suggested) strong cosmological principle (CP), which also contains the temporal aspect, and second (actually as a consequence of CP) on electrogravitational coupling (EGC; see below). EC can be divided into three sections. In radiation cosmology, the existence and properties of the redshift and the CBR are derived and Olbers paradox is solved, all directly from fundamental principles. In gravitation cosmology, an explicit expression for the Machian interaction of distant masses, a solution of the gravity paradox, isotropy and stability on the large scale, and smaller-scale structure (galaxies, groups, clusters and supergalaxies) are derived. The third part of EC concerns the equilibrium processes postulated by CP. This branch of EC is at its beginnings; it may become the central part of science in the coming century.

Within the EC framework, gravitation is an equilibrium process, an absorption effect which provides energy in systems of baryonic matter unchanged on the cosmological scale, while electromagnetic radiation is the contrary effect. Redshift and CBR are equilibrium effects between gravitation and radiation. In such contexts, one can speak of a unique effect of electrogravity.

A mode of gravitational action must be sought, which is suitable for consideration of various equilibrium processes where gravitation is a counterpart. The following mode was obtained during the search for a gravitational mechanism of the redshift effect; gravitation as a general reason for the redshift is implied by several empirical arguments. The same mode may be valid for gravitation in general, as it should be if valid for the redshift effect.

ii. A Modern Æther Concept

Gravitation works *via* gravitational quanta, gravitons (g). This is the only possibility after finding that for classical AAAD its attributes as given by Leibniz are still valid, and a continuous structure of the gravitating agent, *i.e.* GR and RLA, was found empirically and conceptually invalid. Quantized gravitation is also required by the redshift and other equilibrium effects (Jaakkola, 1993a). Gravitons are gravitational equivalent to electromagnetic quanta, photons (g), both those of the cosmic background radiation CBR (g_b) and incident photons from galaxies (g_g). Gravitons, g and baryonic matter (b) interact and are in equilibrium on the cosmological scale. The g–g interaction is the redshift effect, and the CBR is re-emission of energy gained by the cosmological gs (g_b) in the redshift effect. Gravitation, as usually understood, is a g-b interaction; this is the equilibrium process which maintains energy balance in systems of baryonic matter, while radiation g_g is the contrary effect.

A few words about the gravitational æther, and the æther concept in general may be in place here. The æther hypothesis was thought to be buried by the Michelson-Morley experiment, but today it is more alive than ever, in the form of the CBR: experiments capable of finding the æther were not possible in the 1880s, but were possible in 1960s. In a sense, the electromagnetic æther has always been observed—as the heat of the Sun (since as pointed out, CBR is reprocessed g_g.

The gravitational æther must be structured much like its electromagnetic counterpart. Local fields would cause the ordinary gravitational processes. Corresponding to CBR, there must be a cosmic background gravitation, CBG, probably with its specific gravitational spectrum. How to observe CBG? It has been already observed, as the cosmological redshift effect, z_c. This z_c should be conceived as a gravitation effect in the same sense as is terrestrial surface gravity. The observation of the CBG is real, provided that the universal redshift effect (including z_c) is ultimately certified to be due to gravitaton; the amount of evidence is already remarkable; see references in 3ν. The dark night sky, *i.e.* the de Cheseaux-Olbers paradox, is the second observation, with the same reserve as above. The equality of surface gravity within a broad range of scales from galaxies to supergalaxies (Jaakkola 1983, 1987, 1993) may be regarded as the third. Further kinds of empirical and theoretical arguments for—or against—the reality of the CBG should be researched.

Returning to Michelson and Morley, the names momentous in the history of the æther, they indeed killed the classical æther hypothesis that can be traced to Descartes and beyond (a closer historical account is not here possible). The Cartesian æther was homogenous and stationary, and through that the Earth was thought to be making its circles. So much was already known about the actual structures in the heavens, that what the 1881 and 1887 results killed was already an anachronism. These experiments say nothing about the æther causing gravity on the Earth, as will be described below, since that æther belongs to the Earth. Just as the brightness of the Sun moves with the Sun in the Galaxy, the gravitational field of the Earth revolves with it in the solar system. That æther could not be observed by the arrangements of Michelson and Morley, it can be observed by sitting on a stool or climbing a mountainside, or by some more sophisticated experiment.

To summarize the author's view of the æther, it contains electromagnetic and gravitational counterparts, composed by gs and gs, respectively. Both have homogenous cosmological components (CBR and CBG, g_b and g_b), and localized components (g_g and g_g) connected to the hierarchically organized structure of baryonic mass systems. All are in mutual interaction, and in equilibrium on the cosmological scale. All the main cosmological, astrophysical and physical facts: the gravity and Olbers paradoxes, redshift effects and CBR, gravitation and radiation, and the existence of particles can be conceived in the framework of this æther concept.

Though the author recognizes the "æther" term, the term "gravitational field" will be mainly used below, partly for its neutrality, but mainly because it contains in itself a sense of structurality needed in these contexts.

iii. Gravitation as a Pressure Effect of Gravitational Quanta

Gravitation on a body is a pressure effect of gravitons (g) flowing from the background space. As a rule, due to the equilibrium principle, the flow is proportional to the mass of the body. As for all concentric flows (*e.g.* radiation) the surface density of the graviton inflow follows the familiar inverse square distance law. The g–g interaction, which we call electrogravitational coupling (EGC, Jaakkola, 1991, 1993), can be omitted in the first approximation for small-scale bodies like those in the solar system. The energy of the gravitons is proportional to the parameter which we call "strength of gravitation", G. Therefore, we obtain for the surface gravity on a spherical body with mass M and radius R the familiar Newtonian $a = GM/R^2$.

The g-inflow is conducted by the gravitation field of the body. The field is formed and maintained by interactions of the gravitons of the background field with those of the local field and with the radiation field and the particles of the body and its atmosphere. Hypothetically, there may be cases, rare but interesting, where *e.g.* due to rapid explosive displacement of mass the field is not fully developed and M-dependence is not strictly valid.

The background field, which is the source of the graviton inflow, is associated with the higher-order system—for the Earth, the solar system and the Galaxy, which form their own local gravitation fields and hierarchically thereafter, up to the homogenous cosmological background field CBG. The strength of gravitation is a variable, $G(r)$, the locally measured value of which is Newton's constant G_0. The cosmological value corresponding to the g_b's and the CBG is denoted by G_c. I have called the proposed mode of the gravitational action "pressure-induced gravitation" (PIG).

iv. Electrogravitational Dynamics and Unification of Gravitation Effects in Systems of Different Scales

A substantiation of a new hypothesis may be a fair request. The effect of gravitation appears in nature more ramified than usually conceived: without *ad hoc* appendages, each macroscopic scale requires a particular force law in order to explain the phenomena: $1/r^2$ (solar system), $1/r$ (flat rotation curves of galaxies), $e^{-\alpha r}/r^2$ (Seeliger-Neumann cosmological gravity paradox). The dynamics based on the PIG and EGC hypothesis, which shall be called "electrogravitational dynamics", EGD, appears capable of unifying all these different gravitational effects.

The g–g coupling, EGC, means absorption of gravitation, bringing into the force law the familiar exponential absorption factor $e^{-\alpha r}$, and with varying density of light *e.g.* in a galaxy, the absorption coefficient α is a variable, $\alpha(r)$. Due to conservation of energy and momentum in EGC, $\alpha(r)$ is identical to absorption of photon energy, *i.e.* to redshift. The unit of $\alpha(r)$ is cm^{-1}, and its cosmological value is $\alpha_c = H/c$, where H is Hubble's constant. Due to EGC, the strength of gravitation is variable, $G(r)$, which, due to the conservation principle, is related to $\alpha(r)$ as

$$G(r)\alpha(r) = A \tag{2}$$

where the constant $A \approx 4.22 \times 10^{-35}$ cm^2 g^{-1} s^{-2} (Jaakkola, 1991, 1993). Eq. 2 may be regarded as the electrogravitational field equation.

Together with arguments given in the preceding subsection, a "generalized Newtonian force law" follows

$$a(r) = \frac{G(r)M(r)e^{-\alpha(r)r}}{r^2} \tag{3}$$

On the cosmological scale $\alpha(r) = \alpha_c = H/c$, $G(r) = G_c \approx 10\, G_0$ (from Eq. 2 and observations of the redshift effects, see above refs.), and $M(r) = \rho_c r^2\, dr$ per steradian (ρ_c the mean density). One then obtains the "Machian" gravitational interaction of the masses within r or z:

$$a(r,Z) = \int_0^r G_c \rho_c e^{-\alpha_c r} dr = \frac{G_c \rho_c}{\alpha_c}\left(1 - e^{-\alpha_c r}\right) = \frac{G_c \rho_c}{\alpha_c}\frac{Z}{1+Z} \tag{4}$$

When r and Z go to infinity, we have the cosmic force

$$a_c = \frac{G_c \rho_c}{\alpha_c} \tag{5}$$

which, for $\rho_c = 10^{-30}$ g cm^3, is $a_c = 1.1 \times 10^{-8}$ cm s^{-2}. Equations (4) and (5) are an explicit formulation of Mach's principle. The finite value of a_c resolves the Seeliger-Neumann gravity paradox.

Evidence that a_c is at work in the Universe is given by its similarity with the local acceleration $a_1 = G(R)M(R)/R^2$ at the edges of supergalaxies, clusters and groups of galaxies and single galaxies. Therefore, the Machian force is the factor which designs and controls macroscopic structure in the Universe. It sets the scale at which the transition from local hierarchic structure to the homogenous isotropic cosmological distribution occurs. Its finite value allows global stability.

EGD resolves the mass paradox in galaxies and systems of galaxies without resorting to dark matter, which has showed unobservable in all wavebands and by all indirect methods. In systems of galaxies, the problem is solved (Jaakkola 1994) by EGD and the observational fact that the high redshift dispersion is due to both intragalactic and intergalactic non-Dopplerian redshifts (Jaakkola, 1971, 1978, 1980, Moles and Jaakkola 1976).

$F \propto 1/r$ corresponding to flat rotation in optically invisible outer parts of galaxies (Sanders, 1990) results from $G(r) \propto \alpha(r)^{-1} \propto r$ (Eq. 2 and redshift data within the Galaxy and other galaxies, Jaakkola *et al.* 1975, 1978, 1984; Jaakkola 1991, 1993a, 1994). The factor $e^{-\alpha r} \approx 1$ on that scale. Rigid inner rotation demanding, in Newtonian dynamics, an unnatural constant mass density within galactic bulges—a second galactic paradox—corresponds to $\rho \propto 1/r$ in EGD. The dependencies $D(r) \propto r$ and $D(R) \propto R$ of the mass discrepancy D, Tully-Fisher relation, and transition rotation in the visible outer parts, are derived (Jaakkola 1993b, 1995).

Comment:

In the solar system $M(r) \approx M(\mathrm{Sun})$, $e^{-\alpha(r)r} \approx 1$ and, since the scale is very much smaller than that of the background field (the Galaxy), $G(r) = \text{constant} = G_0$. Therefore, Newton's law is obtained. (In a closer analysis, gravity anomalies found in the solar system, such as those found in orbits of the Moon, Phobos and inner planets, eclipse effects, "fifth force", and Fischbach *et al.* (1986) composition-dependent gravitation (Ghosh, 1991; Jaakkola, 1991) can be accounted for in the present theoretical framework. The former effects are just the drag expected for an æther gravitation by Newton, and have been a theoretical obstacle since then. Therefore, up to the present state of analysis, EGD contains a unified theory of gravitational phenomena in systems of different scales.

5. The 2-Body Problem, Newton's Law, and Solution of the Dilemma

i. Derivation of Newton's Law

For the needs of the general topic of the present paper, let us derive Newton's law in yet another way. Consider two spherical bodies B_1 and B_2 with masses m_1 and m_2, radii R_1 and R_2, separated by a distance r. The inflow of cosmic gravitons onto B_1, which is proportional to m_1, is partially blocked by B_2, which covers a fraction $A_2/2p$ of the sky on B_1; $A_2 = pR_2^2/r^2$ is the solid angle of B_2 seen from B_1. This brings about in B_1 a change of momentum towards B_2, *i.e.* a net force, $S_1 = h_2 m_1 A_2/2p = h_2 m_1 R_2^2/2r^2$. Moreover, B_1 shields the inflow of the gravitons onto B_2, causing a further change of momentum toward B_2, $S_2 = h_1 m_2 A_1/2p = h_1 m_2 R_1^2/2r^2$. Coefficients h_1 and h_2 measure the power with which the bodies B_1 and B_2 absorb gravitons; evidently these are identical with the surface gravity: $h_1 = Gm_1/R_1^2$ and $h_2 = Gm_2/R_2^2$. Altogether, the change of momentum of B_1 towards B_2 is

$$F = S_1 + S_2 = \frac{Gm_1m_2}{2r^2} + \frac{Gm_2m_1}{2r^2} = \frac{Gm_1m_2}{r^2} \qquad (6)$$

This is identical to Newton's law.

The simplicity, almost triviality of the above deduction may hide some points of principle. First, contrary to the common viewpoint, the effect between two bodies is not due to a direct mutual attraction by the bodies, but the link runs *via* the Universe external to the system.

Second, the simple Newtonian formula contains two terms, S_1 and S_2, identified in magnitude, but quite different in character. While the "pushing term" S_2 means the effect of the field of the second body (*e.g.* of the field of the Sun on the Earth), the "shadow term" S_1 is due to the field of the body (the Earth) itself, when affected by the shadow of B_2 (the Sun). Separation of the two terms may prove to be of significance for some mechanical problems in the solar system, as well as for the tides and some other problems. Newton's third law works such that in B_2, vectorially, $S_1(B_2) = -S_2(B_1)$, $S_2(B_2) = -S_1(B_1)$, $F(B_2) = -F(B_1)$.

Third, the inverse square distance factor in the formula, which in the Newtonian picture of an attractive gravitation force has no rationale except experience, here results from the geometrical contraction of the solid angle subtended by the screening body, and the $1/r^2$ dependence of the surface density of the graviton inflow toward that body. The underlying assumption, discussed further in Sections 4 and 5, is that EGC has no significant effect over the scale under consideration.

Therefore, the above derivation of Newton's law is, though simple, a non-trivial and physically conceivable treatment, valid for spherical bodies. Further physical aspects of the theory are discussed below.

ii. Solution of the Dilemma

When gravitation is treated as a general effect, the mode discussed above implies a distinctly "local" action. As Newton anticipated, gravitation is "impulses" from space. This is evident for gravitation directed to single bodies. In two-body systems, the Earth, *e.g.*, moves in the field of the Sun, with its back face permanently bombarded by gravitons belonging to the stream towards the Sun. This is S_2 in Eq. 6. Though undoubtedly local in character, the meaning of the word may have changed from an exchange of particles in local interactions.

What to say about the term S_1, which deals with the Earth's own field? The Sun acts at its distance as a screen for gravitons streaming from the background space in its direction. S_1 is action-at-a-distance in the same sense that S_2 was of a local character. This is analogous to when a mountain hides the scene behind it.

As to the particular gravitons which are screened by the Sun, the effect on the Earth is instantaneous. For objects in circular orbits, the question of instantaneous or retarted action is not significant, because the configuration between the body, the screen and the background field does not change. For eccentric orbits, graviton velocity v_g may also be significant in the S_1-term. Nor is the question of the velocity of the action relevant for the Machian interaction of distant masses. More essential there is the progression of the effect through the hierarchically arranged subsequent local fields. Different v_g-values are probably attached to each level of hierarchy and to the position in each large-scale field.

Hence, if the mode of gravitation outlined in Section 4 and appearing as an attractive effect as explained in 5.1. proves to be correct, the centuries old dilemma of a "local" versus "distant" character of the action of gravitation obtains a surprising solution: both are true. Fundamentally, however, gravitation is an interaction between mass systems and the background field, one of the equilibrium effects maintaining the energy balance between the various substances of the Universe.

iii. Empirical Tests of MFLA and of the Dual Solution

The existence of an æther medium connected to the Earth, identifiable with the MFLA theory as described in preceding sections, is indicated by many experiments reviewed by Hayden (1990a,b); these measure the velocity of light in different directions with respect to terrestrial rotation. In 1913 Sagnac (Sagnac and Boyty, 1913) performed an experiment with light circulating around a table which rotated in the opposite directions. A fringe shift was obtained corresponding to a non-isotropy of velocity attachable to the rotation of the Earth. An enlarged version of the Sagnac experiment was made by Michelson and Gale (1925), where the path of light was a rectangle of 340 by 610 meters. Light traveling counterclockwise around the loop lags behing the clockwise motion, again corresponding to $v_g = c \pm V_r$, where V_r is terrestrial spin velocity (350 meters/s at 40° latitude). There is a curious absence of this notable result in literature concerning the topic of light velocity, in spite of the fact that it is quite essential to relativity theory. The result has since been confirmed several times with larger, more modern devices. A Sagnac-type experiment on a planetary scale using geosynchronous satellites and several ground stations was performed by Allan *et al*. (1985); again east-traveling signals lagged behind west-bound signals. Ironically (exposing the scientific practice and "epistemology" behind various "verifications" of the relativity theory), these results have only attained the status of a "Sagnac correction" necessary to synchronize clocks in satellites at various positions around the Earth.

The Michelson-Morley experiment in 1887, designed to check the orbital velocity of 30 km/s through the æther, observed no anisotropy of light velocity. A modern round-trip experiment of a similar type by Brillet and Hall (1979) claim anisotropy down to 30 m/s, also against an effect of the Earth rotation, in contradiction to the results of the Sagnac-type area-enclosing experiments. However Hayden (1990a,b) has shown that this results from the way data has been dealt with, and points out that anisotropy exists in the original data, not in the sidereal coordinates, but clearly in the diurnally rotating laboratory coordinates.

The famous Hafele-Keating (1972) experiment carried atomic clocks in aircrafts, and is claimed to support the special relativity prediction that moving clocks are slowed. However, the west-bound clock actually moved faster than the clock in the laboratory. In SR, the change of the time-rate cannot be dependent on direction.

I consider the Sagnac effect and the other data referred to here as evidence supporting the PIG and EGC hypothesis: these indicate that the material gravitational field bound to the Earth exists (PIG), and its effect on the light velocity indicates EGC. The crucial results brought to light by Hayden disprove relativity theory, which is already an anachronism like the Cartesian variant of the æther hypothesis was in the epoch of the Michelson-Morley experiment. They also point to a physics based on a new concept of the æther.

Direct gravitational effects relating to the Earth is rotation other than those on the velocity of light should be investigated, *e.g.* gravity on preceding and trailing hillsides *etc.*, but the much lower accuracy of gravitational (compared to electromagnetic) measurements and atmospheric effects may hide such effects. Other parameters worth testing, which may be connected to the PIG and EGC hypotheses, but yet lack quantitative predictions, are: distance ($1/r^2$ law), mass, density, material, temperature, time, velocity, acceleration, rotation, shape, orientation with respect to the Earth, Moon, Sun, plane, center and rotation of the Milky Way, and with respect to the CBR dipole, electric field, magnetic field, occultations of the Moon and Sun, and other intervening matter. Existing "anomalous" observations which may be conceived in the EGC-framework have been discussed (Jaakkola, 1991, 1993). The aspects of the new theory may require new experimental setups. Many of the factors listed have not yet been studied, and surprises may await us in future experimental gravity research.

Also the dual nature of two-body gravitation implied by the "shadow" and "pushing" terms S_1 and S_1 involved in Newton's law (Eq. 4) should be tested properly. The eclipses—both solar and lunar—offer possibilities of testing the S_1-term. There are reports of anomalous effects during both kinds of eclipses. Saxl and Allen (1971), in a torsion pendulum experiment during a solar eclipse of March 7, 1970 a 10^5 times larger effect than expected from Newtonian theory. According to them, comparable results had been obtained at Harvard experiments over a period of 17 years. Anomalies have also been reported after later eclipses; an up-to-date review seems to be lacking and would be highly desirable.

The lunar eclipses naturally do not affect the S_1-term on the Earth but do affect it on the Moon. A century ago Newcomb (1895) found anomalous periodic fluctuations in the moon's longitude, and Bottlinger (1912) suggested absorption of gravitation by the Earth during the eclipses (however, see de Sitter (1913b). The present status of the problem is not clear, but in the analysis of Assis (1992) valuable arguments for the reality of the absorption (screening) effect of the S_1-term are given. What would be a better way to celebrate the centenary of Newcomb's important observation, and at the same time Seeliger's (1895) and Newmann's (1896) important cosmological work, all in mutual connection, than arranging in 1995 a joint international effort to settle the status and make new observations in both eclipse problems. Also, the next flight to the Moon should contain, perhaps as its most important load, instrumentation to measure gravity anomalies during the lunar (there solar) eclipses.

Purely terrestrial laboratory experiments of gravitational absorption, the first and evidently the last performed by Majorana (1920, 1930), with positive results, are also relevant to the duality problem and S_1. Naturally, repeating such experiments is most urgent.

The pushing term S_2 can be tested by measuring the diurnal, monthly and annual variations of terrestrial surface gravity, and by analysis of the new and rich existing data in a relevant manner, with no preconceived opinions or too many *ad hoc* models "to save the appearances". As S_2 has the character of the general pressure-gravitation, the numerous test parameters listed above are of interest in this context as well.

6. Discussion

A historical viewpoint—acquired either before or after the actual work—is one of the author's principles of scientific enquiry. The PIG theory of gravitation presented in Sections 4 and 5 is based on recent results of empirical cosmology and was originally somewhat unhistorical; its counterpart, EGC had some historical substantiation from the start. The PIG theory also involves the AAAD aspect, though basically it is an MFLA effect. Eventually, a historical introduction to all the main hypotheses on the nature of gravitation, the presently prevailing general relativity included, was established as the topic of the present paper. The original aim of presenting the antecedents of the PIG theory in the MFLA tradition is not well fulfilled; rather the phases of its alternatives, RLA and AAAD are to some extent delineated. This contradictory outcome is due to the fact that the history of MFLA theories is such a vast subject—it involves almost the whole history of physics—that it cannot be packed into the present paper; a separate survey is under way. Some historical glimpses or the MFLA mode were necessarily involved in the accounts of the alternative theories given here. In the history of the views of gravity (since Newton) there has prevailed a tension due to the dichotomy of two opposite views, AAAD and MFLA. During the last century the relativistic mode, RLA, has added to the tension by opposing both of its predecessors. With the crosswise solutions presented, the history of the problem has become an exciting and sometimes dramatic story.

I also consider the exacting physical problem of local or distant gravitation a good avenue for understanding the history of physics, and *vice versa*, an historical study offers a good means to understand physics.

The many dimensions of the problem have required considerable thought and also allowed a lot of freedom in the manner of presentation. The method adopted is closer to that of a detective who uses reasoning and follows all possible clues and hints no matter how faint they may be, rather than use the rope's end and revolver. The topic is indeed one which Sherlock Holmes might have called a three-pipe problem.

When I embarked on the problem, I also felt like a spectator at a wrestling match where two ghosts are fighting about which of them is real. The ghosts were the AAAD and RLA. In the course of the investigation, both have gained more flesh and blood. In the solution of the dilemma in Section 5, AAAD is real, appearing as the term S_1 of Eq. 4. AAAD may have many appearances in different physical conditions. I only mention the very important context of the formation of stars and galaxies. The actual mode of S_1, *e.g.* how it depends on the ratio m_1/m_2, is not known. The way ahead will be shown by experiment and observation. While the derivation of Eq. 4 is strictly mathematical, I wish to emphasize the methodological principle of "physicality". In two-body attraction, the question is not only easily calculable solid angles of the bodies: the two fields of graviton inflow may interfere, and everything which follows from this is an open question today.

The other "ghost", RLA(GR), has in the author's mind acquired a lot of reality in the writing of this paper. Historically, it is a completely justified and respectable theory. It is also the best formulated theory yet presented. It has had some empirical successes, but ultimately it fails in this respect. Conceptually it cannot be accepted, except if its notions of space and time are taken only as figurative expressions of the spatial and temporal features of the effects treated and GR is only used as mathematical machinery. Then RLA could be one of the many MFLA theories (which the supporters of GR certainly do not accept).

In spite of the ramification due to the AAAD S_1 term, gravitation as a general effect works according the MFLA mode. It is an interaction between a mass system and the background gravitation field, acting *via* the local field, which itself is a product of interactions. Furthermore the scope of gravitation contains the effects on the other physical interactions, of which we have only been concerned with the electromagnetic interaction (in EGC-contexts). In addition to gravity in mass systems, the redshift, CBR and a part of QSO radiation also fall into the category of gravitational effects. There, the two long-range forces are both so directly present and intermingled that the cause and the effect, electromagnetism and gravity, cannot be separated; rather, a unique interaction is manifest. It might be called "electrogravity". The various gravitational effects found in various physical systems and at various scales can be unified by this concept and the dynamics based on it (Section 4.*v*. and Jaakkola 1994a, 1995b). In the cosmological dimension, gravitation has general validity as one of the processes that maintains the energy balance between the various material substances of the Universe.

As to the original question of this article—the local or distant character of the action of gravity, the plot of the noveller—in the closing scene, both of the suspects were shown to be guilty. This solution was a great surprise to the writer of the story as well. It is pertinent to the matter that hints to this solution have been present since the beginning of the mystery more than three centuries ago. When writing about an extraneous force to be added to the centripetal force, chief inspector Newton had a presentiment of a double solution.

References

Allan, D.W., Weiss, M.A. and Ashby, N., 1985, *Science* 228, 69

Arp, H. 1987, *Quasars, Redshifts and Controversies*, Interstellar Media, Berkeley

Arp, H., Bi, H.G., Chu, Y. and Zhu, X., 1990, *Astron. Astrophys*. 239, 33

Assis, A., 1989, *Found. Phys. Lett*. 2, 301

Assis, A. 1992a, *Apeiron* 12, 10

Assis, A., 1992b, *Apeiron* 13, 3

Bertlmann, R.A., 1990, *Found. Phys*. 20, 1191

Bottlinger, C.F., 1912, *Astron.Nachr*. 191, 147

Brillet, A. and Hall, J.L., 1979, *Phys. Rev. Lett*. 42, 549

Broberg, H. 1982, *ESA Journal* 6, 207

Broberg, H., 1991, *Apeiron* 9-10, 62

Cohen, L.B., 1980, *The Newtonian Revolution*, Cambridge Univ. Press

Cook, A.H., 1987, in S.W. Hawking and W. Isræl (*eds*.), *Three Hundred Years of Gravitation*, Cambridge Univ. Press, p. 51

de Sitter, W., 1913, *Phys. Z*. 14, 429

Einstein, A., 1949, in P. Schilpp (ed.), *Albert Einstein: Philosopher-Scientist*, Tudor, New York, p. 211

Einstein, A., 1951, *The Meaning of Relativity*, Methuen & Co. Ltd., London (5th ed.), p. 27

Fischbach, E.B., Sudarsky, D., Szafer, A., Talmadge, C. and Aaronson, S.H., 1986, *Phys. Rev. Lett*. 56, 3

Freundlich, E., 1913, *Phys. Z*. 14, 835

Ghosh, A., 1984, *Pramana* 23, L671

Ghosh, A., 1991, *Apeiron* 9-10, 35

Goldstein, R.M., 1969, *Science* 166, 598

Hafele, J.C. and Keating, R.E., 1972, *Science* 177, 166

Hawking, S.W. and Isræl, W. (*eds*.), 1987, *Three Hundred Years of Gravitation*, Cambridge Univ. Press.

Hayden, H.C., 1990a, *Galilean Electrodynamics* 1, 10

Hayden, H.C., 1990b, *Galilean Electrodynamics* 1, 71

Hoyle, F. and Narlikar, J.V., 1974, *Action at a Distance in Physics and Cosmology*, W.H. Freeman and Co., San Francisco

Jaakkola, T., 1971, *Nature* 234, 534

Jaakkola, T., 1978, *Acta Cosmologica* 7, 17

Jaakkola, T., 1982, *Astrophys. Space Sci*. 88, 283

Jaakkola, T., 1983a, in A. van der Merve (ed.), *Old and New Questions in Physics, Cosmology, Philosophy and Theoretical Piology, Essays in Honor of Wolfgang Yourgrau*, Plenum Press, New York and London, p. 223

Jaakkola, T., 1983b, *Astron.Nachr*. 304, 103

Jaakkola, T., 1986, in Hïnni and I. Tuominen (*eds*.), *Proc. 6th Soviet-Finnish Astron*. Meeting, p. 190

Jaakkola, T., 1987, *Apeiron* 1, 5

Jaakkola, T., 1988, in F. Bertola, J.W. Sulentic and B.F. Madore (*eds*.), *New Ideas in Astronomy*, Cambridge Univ. Press, p. 333

Jaakkola, T., 1991, *Apeiron* 9-10, 76

Jaakkola, T., 1993a, in H. Arp, C.R. Keys and K. Rudnicki (*eds*.), *Progress in New Cosmologies: Beyond the Big Bang*, Plenum Publ. Co., p. 111

Jaakkola, T., 1993b, *Tuorla Obs. Informo* No. 171

Jaakkola, T., 1994, *Apeiron* 18, 1

Jaakkola, T., 1995, to be published

Jaakkola, T., Donner, K.J. and Teerikorpi, P. 1975a, *Astrophys. Space Sci*, 37, 301

Jaakkola, T., Holsti, N., Laurikainen, E. and Teerikorpi, P. 1984, *Astrophys. Space Sci*. 107, 85

Jaakkola, T., Moles, M. and Vigier, J.P., 1978, *Astrophys. Space Sci*. 58, 99

Jaakkola, T., Moles, M. and Vigier, J.P., 1979, *Astron. Nachr*. 300, 229

Jaakkola, T., Teerikorpi, P. and Donner, K.J., 1975, *Astron. Astrophys*. 58, 99

Laurikainen, E. and Jaakkola, T., 1985a, in J.L. Nieto (ed.) *New Aspects in Galaxy Photometry*, Springer Verlag, Berlin, p. 309

Laurikainen, E. and Jaakkola, T., 1985b, *Astrophys. Space Sci*. 109, 111

Le Sage, G.L., 1784, *Nouveaux Memoires de l'Acad,mie Royale*, Berlin, p. 404

Mach, E., 1872, engl. transl. 1911, *History and Root of the Principle of the Conservation of Energy*, Open Court, Chicago, p. 56

Mach, E., 1883, engl. transl. 1960, *The Science of Mechanics*, La Salle: Open Court

Majorana, Q., 1920, *Phil. Mag*. 39, 488

Majorana, Q., 1930, *J. de Phys*. 1, 314

Marmet, P., 1991, *Apeiron* 9-10, 45

Merat, P., Pecker, J.C., Vigier, J.P., 1974a, *Astron. Astrophys*. 30, 167

Merat, P., Pecker, J.C., Vigier, J.P. and Yourgrau, W., 1974b, *Astron. Astrophys*. 32, 471

Michelson, A.A., 1925, *Astrophys. J*. 61, 137

Michelson, A.A. and Gale, H.G., 1925, *Astrophys. J*. 61, 140

Michelson, A.A. and Morley, E.W., 1887, *Am. J. Sci*. 34, 333

Moles, M. and Jaakkola, T., 1976, *Astron. Astrophys*. 53, 389

Mossotti, O.F., 1936, engl. transl. 1839, *Sci. Memoirs* 1, 448

Newton, J., 1687, engl. transl. 1952, *Mathematical Principles of Natural Philosophy*, Cajori edition, Chicago

Newton, J., 1728, *A treatise of the system of the world*, London Nilsson

K., Valtonen, M.J., Kotilainen, J. and Jaakkola, T., 1993, *Astrophys. J*. 413, 453

North, J.D., 1965, *The Measure of the Universe, A History of Modern Cosmology*, Clarendon Press, Oxford

Pais, A., 1982, "Subtle is the Lord...", *The Science and the Life of Albert Einstein*, Oxford Univ. Press

Phipps, Jr., T.E., 1987, *Heretical Verties: Mathematical Themes in Physical Description*, Urbana, Classic Non-fiction Library

Phipps, Jr., T.E. 1990, *Apeiron* 8, 8

Ritz, W. 1911, *Gesammelte Werke*, Gauthier- Villars, Paris

Roseveare, N.T., 1982, *Mercury's Perihelion from Le Verrier to Einstein*, Clarendon Press, Oxford

Sadeh, D., Knowles, S.H. and Yaplee, B.S., 1968, *Science* 159, 307

Sagnac, M.G. and Boyty, M.E., 1913, *Comptes Rendus* 157, 708 and 1410

Sandage, A. and Perelmuter, J.M., 1991, *Astrophys. J*. 370, 455

Sanders, R.H., 1990, *Astron. Astrophys*. Rev. 2, 1

Saxl, E.J. and Allen, M., 1971, *Phys. Rev*. D3, 283

Seeliger, H., 1895, *Astron. Nachr*. 137, 129

Shlenov, A., 1991a, *Apeiron* 11, 9

Shlenov, A., 1991b, preprint

Surdin, M., 1962, *Proc. Camb. Phil. Soc*. 58, 550

Tifft, W., 1988, in F. Bertola, J.W. Sulentic and B.F. Madore (*eds*.) *New Ideas in Astronomy*, Cambridge Univ. Press, p. 173

Torr, D.G. and Kolen, P., 1984, *Precision Measurements and Fundamental Constants 11*, B.N. Taylor and W.D. Phillips (*eds*.), Natl. Bur. Stand. (U.S.), Spec. Publ. 617

Weber, W., 1846; 1893, *Werke*, Vol. 3, Springer, Berlin, pp. 25-214

Wesley, J.P. 1988, *Physics Essays* 1, 85

Will, C.M., 1987, in S.W. Hawking and W. Isræl (*eds*.) *Three Hundred Years of Gravitation*, Cambridge Univ. Press, p. 80
Woodward, J.F., 1983, in A. van der Merwe (ed.), *Old an New Questions in Physics, Cosmology, Philosophy and Theoretical Biology*, Plenum Press, p. 873