Electrogravitational Coupling: Empirical and Theoretical Arguments

Toivo Jaakkola
Tuorla Observatory
University of Turku
Turku, Finland

In a cosmological approach to a unified physical theory, it is first shown that certain general global-scale arguments suggest a coupling of the electromagnetic and gravitational interactions. Three historically important and still actual issues further motivate the study. Several more recent and still unexplained observations are introduced as evidence that neither electromagnetic nor gravitational phenomena can be interpreted consistently by the current standard theories, and as indicators of the important role of the EGC in the physics of all scales of nature.

The universal redshift effect, containing the cosmological redshift, intrinsic redshifts in QSOs and intermediate strengths of *z* depending on the density of a system, is interpreted as a quantized loss of energy from the photon to a vacuum composed of gravitational quanta. The model covers consistently all the observed features of redshift, including its quantized fine-structure, observed both in distant-dependent and distance independent redshifts.

Gravitation thus appears as a pressure effect of cosmic gravitational quanta. The apparent two-body attraction results from mutual screening of the gravitational pressure of the background vacuum. Denoting the distance from the centre as r, the density as r, the strength of gravitation as G and the strength of redshift as a, we find that the functions $A = G(r)\,\mathrm{a}\,(r)$ and $a_c = G(r)\mathrm{r}(r)/\mathrm{a}(r)$ are universal constants. Here A is the electrogravitational coupling constant, and a_c is the gravitational pressure constant which determines not only the global mass-to-radius structure of galaxies and systems of galaxies, but also intrinsic structure and dynamics, and also affects density evolution. The non-Newtonian dynamics deduced for the galaxies explains the flat rotation curves without non-luminous matter. On smaller scales, anomalous accelerations found for planets and satellites in the inner solar system, tidal anomalies during the solar eclipses as well as data usually presented in terms of a “fifth force”, fit into the new picture of gravitation. On both the small and the large scale, the EGC seems to make sense of the data.

In the discussion, rather than examine the implications of the theory in more detail, I point out similarities between this approach and others presented in the workshop.

1. Introduction

In this paper I shall discuss a number of phenomena that lack an explanation within the framework of conventional theory. I try to show that the hypothesis of an intimate interconnection of the gravitational and electromagnetic interactions brings a certain degree of order to the apparent disorder prevailing in observation and theory. The author’s original aim was to find the real physical mechanism of the redshift effect, which has been shown incompatible with the Doppler interpretation (Jaakkola 1978, 1983, Jaakkola et. al. 1979). It soon became obvious that even in the most general data from cosmological observations, there are features that systematically point to a crucial role for coupling of the two main long-range physical forces. This kind of coupling is obviously of significance for the advance of fundamental physics, which seeks to build a unified, consistent world view.

In the quest for a unified field theory, the most eminent champion of which was Einstein in his later years, two broad strategic orientations can be discerned. One is favoured mainly by physicists who either work in laboratories or use laboratory results as their point of departure. Their strategy is to proceed from the non-unified to the unified, *i.e.,* to try to unify the four known physical forces. Their essential technique is simply to crank up experimental energies. In order to join gravity together with the rest of the family of forces, they must invoke energies they believe to have been available only during the first moments of the hypothetical big bang event.

The other strategy starts out from the idea that what is termed a unified theory must be related to something unique in physical reality. Now what in nature is unique? Nature itself, obviously—the Universe. Thus, a unified theory is a theory that explains the Universe. To explain the array of “forces”, we must begin by explaining the oneness of Nature, the Universe, and then proceed to elucidate specific processes that arise under special conditions.

The Universe has many faces: it comprises innumerable phenomena and a seemingly inexhaustible variety of structures of matter, a vast range of motions and evolutionary processes. It also poses a host of fundamental, yet still unsolved, problems: the cosmological paradoxes, including the Olbers-de Cheseaux paradox, and its gravitational counterpart, are just two examples. We might regard a theory as a “unified theory” if it could solve a good many of the major problems and also managed to embrace the more mundane data.

This latter approach to cosmology is perhaps more complicated, but it is also much more realistic and fruitful than the former, which has a somewhat mechanistic flavour, and might, ironically, be seen as a product of an era dominated by energy politics. Rather than work in terms of (quasi-)infinite energies, it refers to infinite distances and infinite time, which are certainly present in the Universe we know, as well as to the accompanying multitude of physical processes.

In the next Section I shall attempt to identify the main problems, *i.e.,* those of a global scale, which a unified cosmological theory should deal with. These problems fall into two separate domains—one concerns electromagnetic radiation, and the other gravitation. The hypothesis of electrogravitational coupling (EGC) should at best be able to solve the principal problems in both branches of cosmology simultaneously. The next two sections deal with historical (Section 3) and more recent (Section 4) problems with a common basis in both domains. Altogether, Sections 2 to 4 are intended to show that on all scales of cosmic nature, there are phenomena which more or less directly hint at the existence of a fundamental connection between the two long-range forces. Furthermore, the many anomalies discussed underscore the urgency of a deeper understanding of the very foundations of the two interactions. This is the aim of the theoretical treatments in Sections 5 and 6, the former focussing mainly on the redshift of electromagnetic radiation as an EGC effect, the latter looking at the fundamentals of gravitation and briefly targeting unsolved riddles identified in the empirical part.

2. Global-Scale Problems

A. Radiation Cosmology

Cosmological Redshift is not a Doppler phenomenon due to an "expansion of the Universe", as astronomers commonly believe. There is abundant evidence of this, derived from four broad groups of tests, each one embracing tens of separate tests. One group deals with properties of *z* in various physical conditions in systems of various scales (Jaakkola 1978). Another systematizes the results of the classical and local cosmological tests for expanding and static models: all test results fit the latter model, but are highly contradictory with one another in the former (Jaakkola *et al.* 1979). The third group tests for the existence of cosmological evolutionary effects: after weeding out a number of trivial selection effects and instances of circular reasoning, we find that no such effects exist (Jaakkola 1982, 1983, Laurikainen & Jaakkola 1985). The fourth group is the powerful Hubble-Tolman test: all the data considered so far consistently supports the static model (Jaakkola 1986).

The question that arises is: what kind of interaction causes cosmological redshift? The proposition I wish to advance is that the answer to this question might best be sought within a framework that should also solve other major problems, including those in gravitation.

Olbers' Paradox. One sign of the incompleteness of present-day knowledge of the fundamentals of physical nature is the fact that even the simplest cosmological observation, which every layman can notice without any technical device (*i.e.,* the fact that the night sky is dark), has yet to be properly explained. The common answer to this problem, known as Olbers' paradox, is that the finite background brightness is due to expansion and a finite cosmic time. In view of the above, this answer cannot be valid. Redshift as an absorption of light energy by gravitation solves the question at a superficial level. The complete solution is hinted at in the text of Section 2c.

The Cosmic Background Radiation (CBR). Much attention has been paid to the discovery of isotropic background radiation, which is found to have a blackbody spectrum at 2.7°K. The attention is indeed justified: the energy density of this radiation is everywhere of the same magnitude as stellar radiation energy density within galaxies.

The CBR is often heralded as the proof of the big bang hypothesis, in spite of the fact that such a spectacular metaphysical state could have produced anything one might imagine: if not centaurs or animals with two noses, or without noses at all, at least any blackbody temperature and otherwise a Universe completely different from the one we observe. By contrast, a non-expanding universe in an equilibrium state and containing stars implies this property *a priori*. It has been shown (Jaakkola 1983) that the predicted background, without any *ad hoc* hypotheses, must have all the properties we have in fact observed: intensity, temperature, possible deviation from the Planck spectrum, global-local equivalence, photon-baryon number ratio and dipole anisotropy of a correct order of magnitude. To achieve the same results, the usual interpretation appeals to *ad hoc* notions, yet the well-known problems of isotropy and the absense of any signature of early galaxy formation persist.

In this study I shall only look in passing at how to situate the CBR within the EGC process..

B. Gravitational Cosmology

Gravity Paradox. Gravitation exhibits a paradox that is analogous to the Olbers' (radiation) paradox: in an infinite static Universe, Newton's gravitational potential is indeterminate, and attraction from all directions is infinite. We will look into this matter further in Section 3A.

Local Structure. A prominent feature of gravitational cosmology is the contrast between discrete local structure and the homogeneous global distribution of matter. How does gravitation contrive to arrange matter hierarchically up to a certain order, into stars and planetary systems, groups and clusters of stars, systems the size of galaxies, groups and clusters of galaxies, second order clusters—at which point hierarchical organization seems to stop abruptly, giving way to an infinite, by and large uniform lattice network? I have suggested (Jaakkola 1983, 1987, 1989) that the EGC plays a significant role here.

Homogeneity and Isotropy of the observed Metagalaxy is the crucial empirical property of the Universe, without which a genuine cosmology would not be possible. As Hubble stated (1934), commenting on galaxy counts made in 1926: "There are as yet no indications of a super-system of nebulae analogous to the system of stars. Hence for the first time, the region now observable with existing telescopes may possibly be a fair sample of the universe as a whole". Indeed, for cosmology, this finding was perhaps even more epoch-making than the discovery of the redshift law.

Any true "unified physical theory" must almost by definition contain an interpretation of this essential feature of cosmic nature, structurelessness in the large scale. As in the case of the problem of local structure, a plausible solution to this problem seems to be offered by the EGC hypothesis.

The Density Problem. The problem of the mean density, and of whether there exists a considerable amount of non-luminous matter, is a quite natural component of gravitational cosmology. This question will be discussed in Sections 4 and 6. The mere fact that the question is usually discussed in terms of mass-to-light (M/L) ratios offers a hint that these observations are important for our topic.

C. The Equilibrium Principle

Everything evolves—the whole does not evolve. This is the third major paradox with which an infinite cosmological frame confronts science. The problems arising from this paradox may form the most important field of physical science in the coming century. Clearly, these problems cannot be solved in the limited context of electrogravitational interaction alone. Proofs that this problem is empirically relevant were referred to at the start of Section 2A.

I hope this brief discussion of eight global-scale problems has succeeded in illustrating the magnitude of the problem. It will be quite evident that if the physics of the EGC can be established, the advances in our understanding of the Universe will be immense. Gravitation would solve the problems in radiation cosmology, and vice versa. Bringing these two forces, plus the nuclear forces, into play, may solve the equilibrium problem, which underlies all the others. Taken as a whole, this would constitute the cosmological chapter of the long-awaited “unified theory” of physical reality.

3. Three Historical Deductions

A. Seeliger, Neumann and Zwicky

The Gravity Paradox. A historical perspective is essential for a deeper insight into the problem. One approach involves combining two theoretical developments in the two domains of cosmology. Difficulties with an infinite Newtonian universe were noted at the end of the last century. In 1895, H. Seeliger, and independently, C. Neumann (see North 1965 for references) pointed out that when the volume filled by a finite matter density tends to infinity, the gravitational potential and the force of gravity become indefinite. To avoid this difficulty, they added an exponential factor to the Newtonian potential, yielding:

$$\boldsymbol{\Phi}\left(r\right)=\int\frac{\mathbf{r}}{r}e^{-a\,r}\,\mathrm{d}V \qquad (1)$$

Here a is so small that the extra term only has an effect over very large distances. Physically, the exponential factor was thought to be due to a long-range repulsion force that would weaken the pull of gravity. In essence, Einstein's Λ-term, the "cosmological constant", had the same physical meaning as the Seeliger-Neumann exponential.

Both of these solutions of the global gravity problem have been correctly criticized for their *ad hoc* character, *i.e.,* for introducing a new interaction in order to solve the logical difficulties in the workings of the original interaction. However, the exponential modification may itself be correct. It may result from a wider physical context in which gravitation is present, *i.e.,* the totality of physical processes in the Universe, including electromagnetic radiation and the two nuclear forces.

The exponential factor must be interpreted not as an additional *ad hoc* force, but as a necessary consequence of a close relation between the two long-range interactions, a relation that must be present *a priori* in the Universe viewed as a unified whole. It should be emphasized here that physics is the science of interactions. Now an interaction entails absorption of energy from a body or substance into the interacting agent, and we know that all absorption effects obey exponential distance laws. This point argues in favour of the EGC interpretation of the Seeliger-Neumann solution to the gravity paradox, an approach which also solves the other problems of gravitational cosmology.

The paradox of the finite within the infinite, which was so clear and challenging in the minds of Seeliger, Neumann and Einstein, and before them in the minds of those who grasped the paradox of the dark night sky, has been swamped under speculations concerning an expanding, temporary universe. But as we now know, this solution was mistaken, and the paradox still confronts science today.

Redshift as a Gravitational Effect. In the same year, 1929, that Hubble announced his redshift-distance law, Zwicky published a theoretical interpretation which is one of the most correct presented as yet. He made the reasonable assumption that the gravitational action has a finite velocity of transmission, possibly equal to the velocity of light. The gravitational signal of a photon passing mass points around its path from the source to the observer reaches the mass points after the photon has passed the nearest point to the masses, and the photon therefore feels the action of the masses as a gravitational "drag", or loss of momentum in the direction opposite to its motion. This would be the redshift effect. There is also a change of momentum in the transverse direction. At the same time there are changes in the momentum of the masses passed by the photon in the opposite directions. While not discussed by Zwicky, this might affect the force law of gravitation, giving rise to the exponential factor, and thus resolving the gravity paradox.

Therefore, if we bring together the theoretical contributions of Seeliger and Neumann, on the one hand, and Zwicky, on the other, we see that even as early as the first decades of this century, sound, but not necessarily final theoretical ingredients for a grand unification of physics were already present. Though at first sight apparently quite distinct from one another, the combination of these two proposals provides a historical foundation for our examination of the role of EGC in the mechanism of cosmic nature.

B. Experiments on Electrogravitational Induction

There is another historical clue, this time with a more experimental accent, that originated in the first half of the 19th century and achieved its first positive results just a few years ago. This story is described by Woodward's article "Early Attempts at a Unitary Understanding of Nature" (1983, further references therein).

In an 1836 memoir, O. Mossotti, who had been influenced both by the doctrine of the unity of nature and Cartesian-Leibnizian metaphysics, suggested that gravitation results from a slight difference in the strengths of electrical attraction and repulsion.

Mossotti's force law governs both intermolecular distances and Newtonian attraction which, with increasing distance, again approaches a null attraction in accordance with an exponential distance law.

More significant for our purposes, however, is work which dates back to Faraday's pioneering experiments. Faraday undertook several series of experiments to show that the gravitational and electromagnetic fields are inductively coupled. His attitude is illuminated in his 19th series of "Experimental Research in Electricity" (1845):

> *I have long held an opinion, almost amounting to conviction in common with many other lovers of natural knowledge, that the various forms under which the forces of matter are made manifest have a common origin, or, in other words, are so directly related and mutually dependent that they are convertible, as it were, one into another, and possess equivalents of power in their action.*

Faraday evidently had in mind an analogy: just as moving electric charges induce a magnetic field, moving gravitational fields should induce electrical fields. He thought that the massive bodies are coupled by gravitational lines of force whose tension changes with the motion of the body, and induces an electrical field around the lines of force.

Faraday's persistent experiments, in which he used as an exciting mass either a rotating ring or a cylindrical core vibrating back and forth, gave null results. However, his motivation lives on:

> *All this is a dream. Still, examine it by a few experiments. Nothing is too wonderful to be true, if it is consistent with the laws of nature and in such things as these, experiment is the best test of such consistency." It was almost with a*

> *feeling of awe that I went to work, for if the hope should prove well founded, how great and mighty and sublime in its hitherto unchangeable character is the force I am trying to deal with, and how large may be the new domain of knowledge that may be opened up to the mind of man...*

More experiments were done later, during the 1890s. Lorentz's attempt to construct a field theory of gravitation at the turn of the century was influenced by Mossotti's hypothesis. Observation of the solar magnetic dipole field during a total eclipse inspired Schuster, Kelvin, Wilson and Swann, and in the 1940s, Blackett, to consider the possibility that stellar and planetary magnetic fields might be induced by rotation of these bodies. Laboratory experiments designed to probe this question again gave negative results.

Even so, it is my feeling that specialists in planetary, stellar and galactic magnetism should take seriously the possibility that the magnetic fields they deal with are not just relic fields that are conserved and continue to operate according to the dynamo mechanism, but actually a direct consequence of gravitational excitation. In the case of a universal effect, we cannot resort to initial conditions; rather, we must seek a mechanism that acts in Nature at all times.

The experimental breakthrough in the field of electrogravity occurred in the 1980s through the work of Woodward (1982, 1983), who achieved orders of magnitude higher accuracy than before in his tests. He obtained a positive result when impacting a mass on the ground, where the coupling constant of electrogravitational induction had a value of $\boldsymbol{b} = 3.3 \times 10^{-11}$ stat coulomb/dyne in the equation

$$Q = \boldsymbol{b}\, ma \tag{2}$$

where Q is the induced charge, m the accelerated mass, and a is the acceleration. The result of the rotating cylinder experiment fit the prediction in which charge is proportional to the square of the spin, and *b* has a value obtained in the impact test. According to Woodward, the various tests probably rule out conventional charging mechanisms.

What could the observed electrogravitational induction mean in the cosmological context? Perhaps its significance is as follows: non-gravitational acceleration is necessary to induce an electrical field by gravitation. The gravitational redshift effect in the scheme suggested below simultaneously changes the momentum of the gravitons, which brings about the requisite accelerations, inducing electric fields. The field is homogeneous on the cosmological scale and is a function of mass density and the strength of redshift on other scales. On the cosmic scale this would be observed as the CBR; on smaller scales, related and possibly variable effects are to be expected. Furthermore, as noted above, the positive test results by Woodward might point to a direct origin for magnetic fields in different scales through the EGC mechanism.

C. The Classical Tests of General Relativity

One set of observations has had a tremendous influence on physics in the present century: the solar tests of general relativity. A review of these tests, including also further data which are obviously connected to these tests, is necessary for a re-examination of the status of relativity theory. At the same time, this data adds to the empirical basis for a new insight into the nature of the gravitational and electromagnetic forces.

Solar Redshift Effects. Three aspects of the redshift data relating to the Sun invalidate the argument in favour of Einstein's theory and support the present approach. 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 prediction following from a direct interaction between photons and electrons in the atoms of the solar chromosphere, as proposed by Marmet in this volume and probably also the kind of gravitational interaction suggested here. In both 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.

Light Deflection. The relativistic wave in physics, which has been in vogue for over a century, received a publicity boost from Eddington's famous measurement of light deflection in the 1919 solar eclipse. A deflection is also predicted by Newton's theory, calculated by Soldner as early as 1803; in 1911, Einstein obtained a similar value from the principle of equivalence. Observations seemed 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 does 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 opposite direction to the relativistic effect.

Hence, we might say, in a skeptical vein, that the fit is fine for both Newton and Einstein, but it could be better in some other theoretical framework.

Precession of the Perihelion of Mercury. It has been known for one and a half centuries, since Lavoisier, that the advance of Mercury's perihelion exceeds what would be caused by the other planets and other known causes by 43 arcsec a century. This fits the GR prediction 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 is involved in the fit.

Interestingly, the other domain that is accessible to tests of GR predictions, cosmological observation, offers the theory no support whatsoever. Local density is not enough to "close" the world model, and, moreover, contradicts the models based on Hubble diagrams, counts of extragalactic sources at different wavebands, surface brightness tests and angular diameter tests, which, in turn, contradict one another in the relativistic framework. There is no sign of an expected relativistic minimum at $z \approx 1$ in the angular diameter-redshift diagrams. All this data fits the non-relativistic predictions. The Universe, unlike the GR model, is stable. Therefore, the discrepancies in the solar tests are no surprise. What is strange about all this is the scientific folklore about good fits with the data!

4. Further Observations Suggesting EGC

The preceding arguments have involved either an infinite range or dimensions of the order of the Sun or the laboratory. For a full empirical treatment to establish the existence of a universal EGC, other scales much also be considered. Attention should be paid to all anomalies in redshift or gravitation, while we should be alert to any systematic trends appearing over the whole observed scale.

Non-Cosmological Redshifts. Halton Arp has provided sufficient evidence to prove that many quasars are physically connected to nearby galaxies (*cf.* Arp 1988). In fact, the observed quasars, as a class, are closer to us than the observed galaxies, despite the oft repeated claim that “quasars are the most distant objects man has observed”. In addition to Arp’s direct proofs, there are convincing statistical arguments in favour of quasar-galaxy associations, most notably those given by *G*. Burbidge. There are probably also quasars at true cosmological distances, mainly those with steep spectrum extended radio-sources and Type I Seyfert-like objects, while the rest, *i.e.,* the majority, especially those with the largest redshifts, are nearby (Jaakkola *et al.* 1975, Jaakkola 1984). While cosmological redshift (z_c) takes us deep into infinite space, intrinsic redshift (z_i) leads us deep into the extreme conditions of matter. Between z_i and z_c, we see intermediate effects in systems of all scales. One aspect of the data on z_c, z_i and intermediate effects is that these appear in preferred periodic values (Tifft 1976, Arp *et al.* 1990). This feature needs to be integrated into the general picture. There is no reason to doubt that z_c, z_i in QSOs, intermediate effects and the periodicity can be traced to one and the same physical mechanism.

Strength of Redshift-Density Relation. Customarily, a fixed rate of change over distance is ascribed to the redshift effect, as expressed by the Hubble constant, H, about 60 kms^{-1} Mpc^{-1}. However, a careful study of the properties of the redshift effect in systems of different scales—the Metagalaxy, supergalaxies, clusters, groups and pairs of galaxies, single external galaxies and our own Milky Way, the nuclear regions of galaxies, QSOs, external stars and our own Sun (Jaakkola 1978)—indicates that the redshift phenomenon is much more complicated. The steepness of the redshift-distance relation, h, varies over a broad range by a factor on the order of 10^{11}. In the homogeneous Metagalaxy, h is by definition equal to H. In the disk of the Galaxy and other galaxies, the effect is magnified by a factor of ten, in nuclei by a factor of $10^3 - 10^5$, increasing toward the centre. At the solar surface the value is 8×10^{12} kms^{-1}Mpc^{-1} (velocity units are used merely for convenience). Within the hierarchical structure of matter we find between h and density r (in cgs units)

$$h(r) = H\left(1 + 2.5 \cdot 10^{12}\sqrt{r}\right) \tag{3}$$

if the standard mass values for normal astrophysical systems are used. It is not readily apparent from this relation that gravitation is the redshifting mechanism; other tired light redshifting agents might produce a similar curve. However, a gravitational hypothesis is perhaps the one with the best chance of passing the Occam razor, and I feel that the proportionality indicated above is a strong argument in favour of the EGC hypothesis.

Mass Discrepancy in Galaxies and Clusters of Galaxies. Perhaps the most hotly debated issue in astronomy and cosmology in the past few decades is the disproportion between the observed luminous mass and the mass calculated with classical dynamics from the observed apparent motions. The problem was noted by Zwicky in clusters of galaxies in the 1930s. If we use as the measure of mass discrepancy the parameter $D = (M_{dyn} - M_{obs})/M_{obs}$ we find typical values of D ranging from 0.2 to 5 for galaxies overall, and up to 100 on their fringes. For groups and clusters, D ranges from 5 to 100, and for a hypothetical closed big bang universe, D would be on the order of 100.

In principle, we can imagine five kinds of solutions to the mass problem. First, there might exist non-luminous matter to bind the systems; as such, this is a reasonable possibility, but over the years the data has shown that much exotic matter to be increasingly improbable. Second, dynamics may be non-Newtonian; this idea is adopted here. Third, the line-shifts may be non-Doppler, *i.e.,* they may furnish no basis for a dynamical analysis. Fourth, the systems might not be bound; this does not explain the (more or less) symmetric galactic rotation curves, while galaxy distributions and time scales advise against this solution in most systems of galaxies. Fifth, various combinations of the above four solutions may occur in different contexts.

My view is as follows: there is no cosmological missing mass paradox based on dynamical considerations in a non-expanding Universe. In the case of systems of galaxies, the paradox can be solved in terms of non-Doppler intergalactic and intragalactic redshifts. Most difficult, and most interesting in the present context, is the mass discrepancy problem posed by the flat outer rotation curves of spiral galaxies.

The following empirical features are worthy of note. In the inner regions, rotation velocities rise linearly, indicating rigid rotation. Maximum velocities are reached within the optically bright regions. The outer rotation curves, usually based on the 21 cm data, remain characteristically flat out to the farthest measured point, with a trend toward a slight decline of V for galaxies with high luminosity, surface brightness and V, and a slight increase in galaxies with low values of these parameters. Luminosity L and $V(r)$ are correlated by the Tully-Fisher relation $L \approx V^4$. The dynamical problem in galaxies can be expressed as follows (Sanders 1990): if one proceeds without assuming considerable non-luminous mass, then below a critical acceleration $a_0 \approx V^2/r_0 \approx 10^8$ cms^{-2}, *i.e.,* for $r > r_0$, the dynamics turns from an inverse square law to a $(1/r)$-type force law.

These empirical features of galaxies, if not presented in the *ad hoc* terms of missing mass (which is inescapable in Newtonian dynamics), require an attempt at explanation in the framework of a more general dynamics.

Mass Outflows from Galactic Nuclei. The physical mechanism of the high-energy phenomena observed in the nuclei of galaxies has been extensively discussed in the literature. It is common to hypothesize a massive black hole in the nucleus to power the highly energetic radiation observed and its variation. Massive outflows of matter from nuclei, and, even more, expulsions from galaxies in the form of coherent bodies, set even higher energy requirements. This, together with prejudices about the nature of redshift, is the basic reason why Ambartsumian's (1971) and Arp's cosmogonic schema for extragalactic objects has not received general acceptance. However, Arp has given compelling direct evidence for expulsion processes, and there are also statistical arguments that most of the quasars originate in this way. We may therefore conclude—and this must be emphasized—that there is a real disagreement between the observations and Newtonian dynamics on the scale of the nuclei of galaxies, as there is all over the galaxies.

The problem becomes more tractable if the EGC hypothesis is correct. The "missing energy" problem and its obverse, the "missing mass" problem, would both be solved in a coherent manner. If the strength of gravitation behaves as suggested in Section 6, the energy required for expulsion becomes lower by orders of magnitude.

Anomalies Accelerations of the Satellites. The riddle posed by tidal acceleration of the Moon's orbital velocity, with no geological evidence of an actual close orbit of the Moon about 1300 million years ago, belongs to the same category as Mercury's perihelion motion. So does the secular acceleration of Phobos, which cannot be explained by tidal friction from Mars. The Martian and terrestrial satellites belong to the opposite extremes in the solar system in terms of the dynamics outlined in Section 6.

Gravity Anomalies during Solar Eclipses. That gravitation is still, 300 years after the *Principia*, far from being fully understood, is strikingly demonstrated by the gravity anomalies during solar eclipses. Saxl and Allen (1971) reported that the period of a torsion pendulum, and hence local surface gravity, increased during the eclipse of March 7, 1970 by a factor 10^5 times larger than expected from Newtonian theory. Comparable results have been obtained at Harvard experiments over a period of 17 years. An earlier qualitatively similar effect involving a Foucault pendulum has also been noted. A high precision measurement with a 177-meter long water balance situated in a mine was performed in Finland during the perfect solar eclipse of July 22, 1990. A preliminary analysis indicated a $(12 \pm 3) \times 10^{-5}$ arcsec change of the plumb-line direction, which is 0.24 percent of the maximum lunisolar tides. This reinforces earlier doubts as to the validity of classical theory. Do these data point to an effect of radiation in gravitational action, along the lines of other effects mentioned above, or to an even more radically new mode of gravitational action?

Fifth Force. Gravitation does not follow the $1/r^2$ law in either the cosmological or the galactic scale. Analogous observations also exist on the terrestrial scale. Currently, they travel under the name “fifth force”, which is assumed to be a repulsion force with a strength about 1 percent of gravity and a range of a few hundred meters. Measurements have been made in mine shafts, in deep holes bored into glaciers, and on towers. A recent view is given by Schwarzschild (1986).

Attempts have also been made to explain the effect as the difference of two additional forces, one attractive and the other repulsive, with a different strengths, but both on the order of Newtonian gravitation, and both following Yukawa-type exponential laws with short ranges of about 450 km. It should be pointed out that this interpretation, like the fifth force itself, is highly *ad hoc.* It would be preferable if this data could be interpreted in terms of a fundamental theory of gravitation.

Composition Dependent Gravitation. As the evidence in favour of a non-trivial gravitation anomaly grows, it becomes imperative that checks on possible dependences on parameters like distance, velocity, direction, temperature, rotation and composition be made. The latter kind of test was done early in the century by Eotvos, who showed that the inertial and gravitational masses are equal to one part in 10^9. However, this data, as reviewed by Fischbach *et al.* (see Schwarzschild 1986), turns out to indicate a composition dependence: $\Delta a/g$, the fractional difference in acceleration between two materials depends on $\Delta(B/m)$, the difference in baryon number per unit mass. The effect has been connected to the “fifth force”, and is thought to be coupled to hypercharge. There is considerable uncertainty about the role of this data: it may possibly be of relevance for an understanding of one aspect of how gravitation works.

Discussion of Empirical Data. It is my impression that the global-scale empirical facts point to an interpretation valid for both radiation and gravitation. Redshift is obviously related to the presence of matter, suggesting it may be due to gravitation. This mechanism would also provide a solution to the paradoxes of the finite and gravitation backgrounds. The CBR behaves as if it were due to reprocessing of the original radiation by some other long-range force—*i.e.,* gravitation. The extreme smoothness of the CBR and the uneven distribution of baryonic matter set up a fundamental contradiction which is impossible to explain on the basis of prevailing theories.

Rapid rotation of the invisible outer parts of spiral galaxies, proving strong gravitation in spite of little (luminous) mass, and weak gravitation in the nuclear regions, which is apparent in outward motions, in spite of much (luminous) mass, indicates that the effect of gravitation is currently not understood at all on the galactic scale. These features suggest a coupling between the inward action of gravitation and the outward directed radiation, weakening gravitation in the presence of intense light, and *vice versa*.

The solar redshift appears in a differential manner as a centre-to-limb effect, and actually represents a redshift-distance gradient. As such, it is directly related to the cosmological redshift effect. The grazing redshifts of Taurus A and Pioneer 6 prove that redshift is indeed caused by matter along or surrounding the photon path. These effects, plus light deflection and the precession of Mercury's orbit, which are, in part, commonly thought to be evidence of Einstein's gravitational theory, seem to be telling us that a new insights are badly needed for both gravitation and the electromagnetic interaction.

At the same time, they indicate that the two interactions are intimately inter-connected.

Terrestrial observations of the tidal force during the solar eclipses, of the “fifth force” representing an anomalous weakening of gravitation at the surface of the Earth, and an apparent dependence of gravitation on composition in Eotvos’ data, all justify the inference that the very foundations of gravitation should be thoroughly reconsidered. The recent news about the production of electric charge by gravitational induction culminates a century and a half of history, and extends the topic into laboratory work.

The redshift (*i.e.,* electromagnetic interaction) and gravitation at all scales in nature behave in a manner that belies claims of a full or nearly full understanding of the two interactions. On the positive side, the same data seem to support systematically the view that the two long-range forces are in a fundamental way interconnected at all scales.

5. Theoretical Treatment: Redshift

Cosmological Redshift. We do know with some certainty that gravitation weakens, *i.e.,* redshifts, radiation. Consider the gravitational effect on a photon emitted from a source at distance r from an observer. The gravitational action of masses along the path is mediated by gravitons, quanta forming a gravitational bath whose average density is r. The particular form of the interaction between the gravitons and the photons, or other gravitons, will not be specified here. The quantum description of gravitation ensures the logic of the discussion. The dichotomy between “action-at-a-distance” and local interaction vanishes: through the gravitons already present everywhere, the masses surrounding the photon path and the whole

Universe affect the advance of the photon right from the moment it is emitted.

Accordingly, the gravitational effect on the photon is a linear function of distance:

$$\frac{\mathrm{d}Jx}{Jx} = \frac{\mathrm{d}E}{E} = \frac{\mathrm{d}n}{n} = -a\,\mathrm{d}r \tag{4}$$

i.e., the photon loses part of its forward momentum J and energy $E = hn$ in the graviton bath through which it moves.

Integrating from the source, where $E_0 = hn_0$, to the observer at distance r, and using $z = E_0/(E - 1)$:

$$\int_{E_0}^{E} \frac{\mathrm{d}E}{E} = \int_{n_0}^{n} \frac{\mathrm{d}n}{n} = -a \int_{0}^{r} \mathrm{d}r \tag{5}$$

$$E = E_0\, e^{-a\,r} \tag{6}$$

$$\ln\left(1+z\right) = a\,r \tag{7}$$

Eq. 6 is the derivation of the Seeliger-Neumann factor in the potential, Eq. 1. Eq. 7 gives the redshift-distance relation in the EGC model (or in other tired light models, for that matter). Before deriving the coefficient a, we will present the redshift law in the observable terms of magnitude m,

$$m = 2.5f = -2.5f_0/[r^2(1+z)]$$

where f_0 and f are the emitted and redshifted fluxes at distance r. Then we have

$$m = 5\log\ln\left(1+z\right) + 2.5\log\left(1+z\right) + K\left(z\right) + C \tag{8}$$

where $K(z)$ is the K-correction (effect of z on m through the form of the spectrum and broadening of the rest-frame), and constant C

contains the absolute magnitude and the distance scale a. The first term on the right comes from the geometrical $1/r^2$ effect of distance via Eq. 7, and the second term is the energy effect of redshift diminishing the flux by a factor $1/(1+z)$.

Now equation (8) is a very close approximation to the original Hubble relation

$$m = 5\log z + K\left(z\right) + C \tag{9}$$

At $z = 0.1$ the difference between Eqs. 9 and 8 is $\Delta m = 0.0008$ mag, at $z = 1$ $\Delta m = 0.043$ mag, and at as high as $z = 10$, $\Delta m = 0.50$ mag. Hubble's linear (m, $\log z$) relation is commonly adopted intuitively without any theoretical justification. However, it has been observed repeatedly in the (m,$\log z$) diagrams of galaxies from the 1930s to the present day (Jaakkola *et al.* 1979). The embarrassing dilemma that the data actually fit the linear (m, $\log z$) relation deduced through erroneous steps from an erroneous linear redshift-distance law ($z = ar$, instead of Eq. 7), is lifted by the practical identity of Eqs. 8 and 9. At the same time, the fact that the observations fit the unique prediction of Eq. 8 (Jaakkola *et al.* 1979) is a strong positive test result for the EGC theory, although it does not distinguish it from other tired-light models.

Clearly, the constant a is, in more familiar terms:

$$a = \frac{H}{c} \tag{10}$$

For a full theoretical derivation of the Hubble law, and in order to banish the Doppler notions implicit in the units of H and c, we must derive a from independent parameters. Noting that $pD^2 r\,\mathrm{d}r$ is the mass within an effective radius D around the photon path along the interval $\mathrm{d}r$, the potential energy of this mass on a photon having a mass hn/c^2 is

$$\mathrm{d}\Phi = \frac{-p\,D^2 G\,r\,h n\,e^{-a\,D}\,\mathrm{d}r}{Dc^2} \tag{11}$$

Equating this differential with the energy loss dE/E of the photon, we obtain

$$\frac{\mathrm{d}E}{E} = -\frac{p\,DG\,r}{c^2}\,e^{-a\,D}\,\mathrm{d}r \tag{12}$$

Hence the constant a in the above equations is

$$a = \frac{p\,DG\,r}{c^2}\,e^{-a\,D} \tag{13}$$

The “effective gravitational radius of the Universe” D can reasonably be defined by $z = 1$ (see discussion after Eq. 20). Then $D = \ln 2/a$, and we obtain

$$a = \frac{\left(p\,\ln 2\,G\,r\,e^{-\ln 2}\right)^{1/2}}{c} = 1.04\,\frac{\sqrt{G\,r}}{c}. \tag{14}$$

Adopting $r = 10^{-30}$ g cm^{-3} for the homogeneous cosmological distribution of matter, and inserting the usual values for G and c, we obtain $a = 0.90 \times 10^{-29}$ cm^{-1}. This should be compared with the value of H/c (for $H = 60$ kms^{-1} Mpc^{-1}, deduced from observations) of 6.33×10^{-29} cm^{-1}, *i.e.,* ~ 7 times higher than the theoretical value. However, the actual value of H may be slightly lower than the one adopted, and it will be shown in Section 6 that the cosmological value of the strength of gravitation, G_c, must be higher than the locally measured value G_0. With $G_c \approx 10\,G_0$, the theoretical and the observed values of a are in rough agreement.

The fine structure in the universal redshift effect should be incorporated into the general picture. Quantization of z is not unexpected in view of the quantum character of photons and the gravitons with which they interact. This generates the quantization that has been found in the redshift distribution of QSOs and even in the cosmological redshift. Quantization actually proves that redshift is an interaction effect, not a Doppler effect, since the latter would imply geocentric configurations. It conforms to the very basic idea of quantum physics, that energy losses and gains occur in quantized steps. If the universal and unique character of the quantization can be established (*i.e.,* quantizations in z_c and z_i unified), this may be seen as an argument also favouring the EGC theory among all tired light theories, since in this case a really universal agent, such as gravitation, is needed, and the special conditions that may be present only, say, in QSO nuclei, would not suffice.

A quantization within the linear redshift means that energy is being lost in constant fractions ΔE over constant distance intervals Δr, *i.e.,* $\Delta E/E = -a\Delta r$. From Eqs. 4 to 7 we obtain

$$\Delta \ln\left(1+z\right) = a\Delta r = C_1 = \text{const.} \tag{15}$$

Hence, the quantum description of photon interactions leads to a prediction of a periodicity not exactly in z, but in the logarithm of the corresponding energy factor $(1+z)$. For small redshifts, $z < 0.05$, $\ln(1+z) \approx z$, and a periodicity is expected in the direct z-values.

The redshift is a universal, not just a cosmological effect, and affects, in different conditions with varying strengths, $a = h/c$. Owing to this universality, Eq. 15 must also be universal, independent of a. Now if we define Δr as a non-constant distance interval between subsequent energy losses, *i.e.,* as the mean free path (L) in different conditions, we have $L = C_1/a$. The dimensionless constant C_1, or in more general terms, the metastructure defined by a set of constants C_i, characterizes the universal redshift effect. $C_1 = 2.4\times10^{-4}$, corresponding to the 72 km/s interval discovered by Tifft and confirmed by Napier (this volume), characterizes the cosmological redshift. Its sub-quanta are expected to be found in the galactic redshift fields. $C_2 = 0.206$ discovered by Karlsson (1971) and confirmed by Arp et al (1990) in QSO redshifts, probably characterizes the quantized evolution of intrinsic z. The velocity effects and steep z-gradients at each scale, and the increasing total z, smooth out successively larger details in the z structure, so that for large z_c no quantization is either predicted or observed.

Without going into a detailed empirical discussion, it can be concluded that the gross features of what is known as the redshift as a cosmological, universal and quantized effect, and embracing both the distance-dependent and the distance-independent redshifts as a single physical effect, can be understood and deduced theoretically from the EGC hypothesis. What remains to be clarified is the fundamental nature of the interactions at the level of the smallest quanta. This question is still quite open for all physical interactions, *i.e.,* the whole of physics.

6. Theoretical Treatment: Gravitation

The theoretical treatment of the redshift has led the author to a thorough rethinking of the notion of gravitation, which now enters upon the scene not as an attractive “force”, but rather as a repulsive pressure in the dynamic interconnection between a local system and the Universe. Consequently, my earlier conception of the “Machian force” (Jaakkola 1983, 1987, 1989) has been turned upside down. However, this does not change its implications for local structure, which still depends on the requirement of local-global equilibrium.

Gravitation as the Pressure of the Cosmic Vacuum. Consider a mass system in interaction with the other masses in the Universe. Gravitational interaction is mediated by material carriers, gravitons, which are energy quanta with finite velocities in space. The gravitons and photons emitted and absorbed by the masses of the Universe, and in large-scale equilibrium with those masses, generate the cosmological background substance, often called the ether or the vacuum. The vacuum, which is homogeneous on the large scale and has density *r*, forms the rest frame with respect to which the gravitons and photons travel at characteristic (though not necessarily constant) velocity *c* and massive bodies move with velocities *v*.

The logical choice of considering the physical interaction as actually "physical", and not an "action-at-a-distance" effect—since the latter involves an unavoidable metaphysical "past of physics" essence—leads us to the conclusion that gravitation toward the centre of a mass system is a pressure effect by gravitons transmitted from the cosmic vacuum.

Local gravitation is not only a passive response to the action of the vacuum. How can the mass factor in the familiar gravitational force law be understood without resorting to the notion of action-at-a-distance? Implicit in the mass factor, there is a directed flow of quanta from the vacuum. This results from the processes between the quanta from the vacuum, and those from the body, and from multiple interactions between the quanta and the particles in the body's atmosphere and the body itself. Through these interactions, something which can be called a "gravitational field" is set up around the body.

The Two-Body Problem. It is a logical consequence of a model of gravitation based on the pressure of a directed inflow of vacuum quanta that the apparent mutual attraction between two bodies must be understood as a screening effect. The inflow of cosmic gravitons into the first body, B_1, is blocked by the second body, B_2, which covers a fraction $A_2/4Gp = p R_2^2/4p r^2 = R_2^2/4r^2$ of the sky, where r, R_2 and A_2 are the distance, radius and solid angle of B_2. This brings about a net force in B_1, *i.e.,* a change of momentum $S_1 = k_1 m_1 R_2^2 / 4\mathrm{r}^2$ towards B_2. Moreover, B_1 shields the inflow to B_2, causing a further change of momentum toward B_2 of $S_2 = k_2 m_2 R_1^2 / 4r^2$, κ_1 and κ_2 are coefficients which define the pressure of the vacuum, specific and possibly different at B_1 and B_2. The screening effects on B_1 and B_2, which are of equal size, are not actually direct mutual "forces" between B_1 and B_2. S_1 results from interaction not between the two bodies, but between B_1 and the vacuum, and its geometrical screening by B_2. The relation between B_2 and B_1 is thus physical in the same sense that the relationship between a shade and a shadowed wall is physical. In S_2 the role of B_2 is more active, representing a kind of "roundabout attraction" which, however, comes about through the repulsive force of the vacuum. Getting rid of the illusory concept of "forces" between different bodies, of an "attraction" involving a kind of "draught without a harness", clearly represents an advance in our picture of the physical world. We have also managed to get rid of the dichotomy between local and non-local action.

The familiar $1/r^2$ factor results here from the geometrical contraction of the solid angle subtended by the screening body, and the decrease of the surface density of the graviton inflow toward that body. The screening effects are rigorously as S_1 and S_2 if the flux density of the gravitational fields follow inverse square laws over the distance r.

Of course there is also direct physical interaction between the two bodies, e.g. radiation from a star and its dynamical effect as radiation pressure. Likewise, massive bodies not only absorb gravitons from the vacuum; they also emit gravitons. This causes a pressure effect of B_2 on B_1 of $S_3 = -b_2 m_2 R_1{}^2/4r^2$. This direct mutual "gravitational" interaction must be repulsive, not attractive, in order to have closed celestial orbits, and much weaker than the cosmic pressure.

The total gravitational action toward B_2 is

$$F = S_1 + S_2 + S_3 = \frac{\left(k_1 m_1 R_2^2 + k_2 m_2 R_1^2 - b_2 m_2 R_1^2\right)}{4r^2} \tag{16}$$

Considering the system B_1=Earth, B_2=Sun, assuming that $\kappa_1/4 = \kappa_2/4 = \kappa$, setting $B_2/4 = B$, taking into account that $R_i^2 = 3m_i/(4p\, r_i R_i)$, and then approximating, it is possible to compare the law in Eq. 16 with Newton's law F_N. We obtain.

$$\begin{aligned} F_{12} &= \frac{Gm_1 m_2}{r^2}\left[\frac{k}{G\frac{4}{3}p}\left(\frac{1}{R_2 r_2} + \frac{(1-b)}{R_1 r_1}\right)\right] \\ &\approx F_N \frac{k}{\left(G\,{}^4\!/_3\, p\, R_1 r_1\right)} = \frac{F_N k R_1^2}{Gm_1} = F_N \end{aligned} \tag{17}$$

if $\kappa = Gm_1/R^2 = 9.8\ /\mathrm{s}^2$ = Earth's surface gravity.

Therefore, in the limit, using simplifying assumptions and approximations, we obtain the Newton law, as expected. This does not mean that the solar system's celestial mechanics follows Newtonian dynamics. Usually, we know only the product *Gm*, not *G* and *m* separately, and if *G* depends on the properties of the body, the familiar values of *m* and density may not remain true.

Cosmic gravitational dynamics can be divided into four broad classes. Three are determined by which of the values the ratio S_1/S_2 in Eq. 16 takes on: < 1, ≈ 1 or > 1. The fourth is defined by $S_3 >> x(S_1 + S_2)$, where x is a parameter proper to the topic of study, accuracy of measurement, *etc.* In the first case, the mass, and in the third case, the solid angle of the central object dominate the dynamics. In the second case, both are important. Case 1 could be called a quasi-

Newtonian dynamics: denoting $\kappa_2 R_1^2/4 = Gm_1$, $F = S_2 = Gm_1m_2/r^2$. In the orbital anomalies in the inner solar system both S_2 and S_1, and in some cases a third body, attend the effect. In the "fifth force" data (and partly perhaps in Mercury's perihelion motion), the situation may be case 4 (with $x \approx 0.01$ for the fifth force). We meet the third case in the galactic dynamics described below.

In principle, the theory of pressure induced gravitation would appear very amenable to empirical testing. It may well be that existing data on the solar system, the tides, exceptional natural screening effects (such as eclipses) and data obtained in laboratory work are sufficient to settle the issue.

Machian interaction. The preceding discussion has ranged quite far from the main topic, but the digression was necessary in order to put gravitation in its proper place within the framework of EGC.

We now consider the gravitational (pressure) effect of a graviton emitted from a distant body on an observer at distance *r*. As it passes through the vacuum, the graviton loses energy in exactly the same way photons do:

$$E = \frac{E_0}{(1+z)} = E_0 e^{-ar} \tag{18}$$

with the same value of $a = H/c$ as for the redshift effect. This provides the theoretical justification for the Seeliger-Neumann-type potential function. (For the sake of historical consistency, I will not use the expression "Yukawa term" which was suggested at a later date, for electrical interactions, and for much smaller-scale phenomena.)

As shown previously (Jaakkola 1983, 1987, 1989), the gravitational acceleration induced by the masses within radius *r* and the corresponding *z*, say, per steradian, can be calculated by integrating:

$$a(r,z)=\int_0^r G r e^{-ar}\,\mathrm{d}r=\frac{Gr}{a}\frac{z}{1+z}=\frac{Gr}{a}\left(1-e^{-ar}\right) \tag{19}$$

When r and z go to infinity, this approaches a finite value

$$a_c=\frac{Gr}{a} \tag{20}$$

The parameter a_c, a fundamental cosmological parameter, determines the pressure force of the cosmological vacuum, *i.e.,* the cosmic background gravitation (CBG). On historical grounds, we might refer to this as the Machian force. Through a variety of transformations, this force can be said to be present in all everyday phenomena, as in the 2-body problem discussed above. A graph illustrating $a_z/a_c = z/(1+z)$ and $a_z/a_c = \Delta z_i/[(1+z)(1+z-\Delta z_i)]$, which gives the fraction of CBG coming from within z and from different Δz wide z-intervals, has been shown in earlier papers (Jaakkola 1983, 1987). The same figure is also valid for I_z/I_c and I_i/I_c, the fractions of the cosmic background radiation (CBR) coming from within z and Δz_i. That figure characterizes the Machian force, specifying the physical effect of the Universe in extent and strength. One half of the CBR comes from within $z = 1$, where $a_z/a_c = I_z/I_c = z/(1+z) = 1/2$.

This scale may be referred to as an “effective radius of the Universe”. For $H = 60$ kms^{-1} Mpc^{-1}, $r_{eff} = 3465.7$ Mpc. This is the rigorous scale parameter which can be attached to an infinite universe. The value of $a^{-1} = c/H = 5000$ Mpc, which is often used, occupies no special position in z ($z = 1.718$, and $z/1+z = 0.632$.).

The cosmological matter distribution, which is homogeneous on the large scale and constant in time, is the only physical circumstance where the parameters of a_c, *i.e.,* G, r and a, are strictly constant (“by definition”, see Jaakkola 1989). If we assume that we already know from observations what the values of r_c and a_c are ($r_c = 10^{-30}$ g cm^{-3}

and $H = \mathbf{a}_c c = 60\,\mathrm{kms^{-1}\ Mpc^{-1}}$), then we are still faced with the problem of determining G_c. The only thing we know about the strength of gravitation, quantitatively, is the value $G_0 = 6.67 \times 10^{-8}\,\mathrm{cm^3 s^{-2} g^{-1}}$, measured locally on the Earth, and the corresponding surface gravity $981\,\mathrm{cms^{-2}}$. It is unwarranted to assume that the strength of gravity should be the same everywhere when conditions vary over such a wide range. The value of G_c must be determined by extrapolating from G_0 via the galactic gravitational field.

Local Dynamics. Implicit in the EGC model is a relation $G = G(\mathbf{a})$. Since the 1970s, it has been known that $\mathbf{a} = \mathbf{a}(r)$: $\mathbf{a} = \mathbf{a}_c + ar\text{-}p$ over the cosmic scale from the Metagalaxy to the surface of the Sun $p \approx 0.8$ (Jaakkola 1978a); for the disk and nucleus of the Galaxy, $p \approx 1.25$ has been found (Jaakkola 1978b). Tentatively, we can set $p = 1$, *i.e.,* $\mathbf{a}(r) = \mathbf{a}_c + d/r$, where $\mathbf{a}_c = H/c$ and d is another constant. The object is to find $G(r)$ using $G[\mathbf{a}(r)]$.

In the EGC theory, in a quasi-stationary system, and neglecting the two nuclear forces, $G(\mathbf{a})$ must be in the form

$$G(r) \propto (r) = A = \text{constant} \tag{21}$$

With local values of G and $\mathbf{a}$, *i.e.,* $G_0 = 6.67 \times 10^{-8}\ \mathrm{cm^3 g^{-1} s^{-2}}$ and $\mathbf{a}_0 \approx 10\ H/c = 6.33 \times 10^{-28}\mathrm{cm^{-1}}$, $A = 4.22 \times 10^{-35}\ \mathrm{cm^2 g^{-1} s^{-2}}$. Instead of restricting ourselves to a local value G_0 and a cosmological value $\mathbf{a}_c{=}H/c$, we should consider the universal behaviour of the variables $G(r)$ and $a(r)$, the product of which, the electrogravitational coupling constant A, is a more fundamental constant than the special values G_0 and $\mathbf{a}_c$. With the above values of $\mathbf{a}_c$,$\mathbf{a}_0$ and G_0, we obtain from Eq. 21 $G_c \approx 10G_0 = 6.67 \times 10^{-7}\,\mathrm{cm^3 g^{-1} s^{-2}}$. The strength of gravitation is indeed greater in the cosmological medium than in the systems: there exists no opposite force balancing the Machian gravitational pressure

a_c. Further, a_c in Eq. 20 becomes $a_c = G_c r_c / a_c = 1.05 \times 10^{-8}$ cm s^{-2}. Actually, a_c is uncertain by a factor of a few integers.

Taking into account that $a(r)$ is proportional to r^{-1} and $G(r) = A \approx (r)^{-1}$, the gravitational force law in a system like a galaxy obtains the form

$$F = \frac{mMG(r)}{r^2} e^{-a(r)r} = \frac{G^* mM}{r} + \text{constant} \tag{22}$$

where $G^* = Ad^{-1}e^{-d.}$ Therefore, the EGC theory implies a galactic dynamics with $F \approx r^{-1}$, which has been suggested by detailed studies of galactic data (Sanders 1990, see also discussion in Section 4). The empirical ingredient in the above derivation is the relation $a(r) \approx r^{-1}$, which is independent of the rotation curves. For the latter, $V(r)$, since $F = ma(r) = mV^2(r)/r$, we obtain from Eq. 22:

$$V(r) = (G^* m)^{1/2} = \text{constant} \tag{23}$$

This solves the dilemma of the flat rotation curves of galaxies, and hence the most difficult case of the missing mass problem.

Also, the screening approach to gravitation yields a $(1/r)$ dynamics. Let B_1 be a star, B_2 the bulge of the galaxy, and let B_2 have a substantial fraction of the galactic mass, say $m_2 = 10^{10}\mathrm{m}_1$. Then

$$S_1/S_2 = \kappa_1 R_2^{\,2}/\kappa_2\, 10^{10} R_1^{\,2}$$

and for any reasonable value of R_2, say $R_2 = 5\text{kpc} \approx 10^{11} R_1$, $S_1/S_2 >> 1$. Consequently, in galaxies and their systems, we are dealing with the third class of dynamics in the above classification, with the distinctly non-Newtonian force law:

$$F = S_1 = \kappa_1 m_1 R_2^{\,2}/4r^2.$$

Noting that $k_1 = k_1(r)\boldsymbol{a}G(r)$, a $(1/r)$ force law is obtained, and with suitable changes in notation a formula identical to Eq. 22 can be found.

It has been found (Jaakkola 1983, 1987) that the Machian force a_c (or actually $4\boldsymbol{p}$ times the a_c given here) is of the same magnitude as the local gravitational acceleration $a_l = GM/R^2$ over a wide range of scales, from single galaxies to supergalaxies. This was taken as an indication that the background gravitation determines the local mass-to-radius structure. All this is still valid, although the picture of gravitation has changed from one of an attraction to a pressure effect, and parameter G, in both a_c and a_l, has a different value $G(R) \approx G_c \approx 10G_0$.

Inserting the above formulae $[\boldsymbol{a}(r) \approx dr^{-1}$ and $G(r) \approx Ar/d]$ into the function $a(r) = G(r)\boldsymbol{r}(r)/\boldsymbol{a}(r)$, and making the reasonable assumption that the density distribution follows that in the Emden gravitational thermal gas sphere, *i.e.*, $\boldsymbol{r}(r) = Kr^{-2}$, Zwicky (1957) has applied this model successfully to clusters of stars and galaxies. We thus obtain the remarkable result that the gravitational pressure force

$$a\left(r\right) = \frac{G(r)\,\boldsymbol{r}\,(r)}{\boldsymbol{a}\,(r)}\,\mathrm{d}\,\frac{AK}{a^2} = \text{constant} \tag{24}$$

Evidently this constant is equal to a_c in Eq. 20: $a(r) = 10^{-8}\,\text{cm s}^{-2}$. The constant a_c is therefore a fundamental universal constant which determines the macroscopic structure in the Universe: global mass-to-radius structure over the mentioned range of scales, transition from hierarchic structure to the uniform cosmological distribution and homogeneity, and intrinsic structure $\boldsymbol{r}(r)$ of galaxies and their systems. Moreover, a_c also controls the (smooth) evolution of these systems. Eq. 24, the equation of state for quasi-stationary stellar systems, is a plausible result: any gradient in $a(r)$ would mean an imbalance between inward and outward pressures, causing either a contraction or an expansion of the system.

Once consequence of Eq. 24 and the requirement $a_l > a(r) = a_c$ is that the Oort cloud of comets cannot be either primordial or even of very ancient origin: with $R \approx 10^5$ a.u., $a_l = G_0 M_{Sun}/R^2 = 6 \times 10^{-11}$ cm $s^{-2} = 0.006\ a_c$, which indicates a serious instability of that source of the comets.

To be realistic, it should be pointed out that $a(r)$, $G(r)$ and $r(r)$ vary from system to system and are more complicated than the power laws $a(r) \approx r^{-p}$, $G(r) \approx r^p$ and $r(r) \approx r^{-2p}$. Of course, the statistical value of power p need not be exactly equal to one. But in stationary systems the field equations 22 and 24 should be taken literally. Observations of $a(r)$, $V(r)$ and luminosity distributions $L(r)$ of galaxies and systems of galaxies provide easily accessible material for testing the theory proposed here.

7. Discussion

To give a consistent discussion of the theoretical implications of what has been said above and make empirical comparisons would require more space than we are allotted here: every topic introduced in the first part of the paper deserves a separate investigation. Rather, I shall look at possible connections with other approaches presented by participants in this workshop.

For the implications in the field of gravitational cosmology, I refer the reader to an earlier paper in *APEIRON* (Jaakkola 1987). The general features of the local hierarchical structure, the transition to a cosmological distribution, the homogeneity, isotropy and stability of matter on the cosmic scale, were derived from an equilibrium between local gravitation a_l and the Machian background gravitation a_c. Implications for the missing mass problem in galaxies and systems in galaxies, as well as the phenomena in galactic nuclei, are obvious from the discussion here, but will require a more detailed treatment. Implications for the problem of the origin, evolution and fate of galaxies are currently under study.

An obvious phenomenological connection with the work of Halton Arp can be pointed out: ejections from galactic nuclei, and "variable mass" theoretical interpretations, put forward by Arp, and in a different context, by Victor Clube, may now be seen in a broader context.

It may or may not be premature to link the view of gravitation presented here, namely that gravity is the result of the background pressure of the Machian force, with David Roscoe's elegant mathematical deduction of gravitation inertia as action-at-a-distance mediated by disturbances travelling through a relativistic ether.

In the present theoretical framework, a perfect solar eclipse would essentially "turn off" lunar gravitation. Effects along these lines have been observed repeatedly. Other dynamical phenomena in the solar system, such as the acceleration anomalies of the Moon and the Martian satellites, the advance of the perihelion of the inner planets, and the angular momentum distribution in the solar system, might now be looked at afresh via a screening effect dynamics. The whole solar system furnishes a rich field of research in this connection. Amitabha Ghosh has addressed some of these problems, and his success is impressive. His notion of "velocity-dependent inertial induction" might now be understood in a straighforward manner with the picture of gravitation as an external pressure effect: any motion toward the background field will increase the pressure force.

As for the "fifth force" gravitational anomaly measured in the Earth's surface gravity, something like this may be predicted from the definitive requirement of a large-scale equilibrium of absorption and emission of gravitational quanta. Emission of gravitons from all massive bodies—a gravitational analogue of the photoelectric effect—is expected, but only at a rate low enough not to cancel gravitation. Equilibrium on the large scale is maintained by radiation, non-stationary phenomena in stars and galactic nuclei and processes in the vacuum.

This example shows the power of certain general "principles" or logical assertions in science, leading to explanations or even predictions, not only at the level of generality of the principle, but in specific cases as well. The equilibrium principle, which is another expression for the "perfect cosmological principle" discussed in detail by Konrad Rudnicki and myself in Number 4 of *APEIRON*, is one such framework for producing an adequate cosmological theory. In the present proceedings, Peter Kropotkin points out the deep relation between this principle and the fundamental effect in cosmology, the redshift effect. Incorrect mechanical inferences for a universal applicability of some parameters that are measured in certain physical circumstances, such as H and G_0, offer valuable lessons in how not to apply such general "principles".

Moving on to the domain of radiation cosmology, a unified theoretical framework was proposed in Section 5 to explain z_c arising in the most dispersed conditions in the cosmological vacuum, z_i arising in the most concentrated matter in QSOs, and density dependent redshift z_r in intermediate conditions. This process required a closer look at the quantum basis of EGC, leading on the one hand to the model of gravitation just discussed, and on the other hand to a global notion of redshift encompassing z_c, z_i and z_r, as well as the fine structure of these redshift phenomena. This may provide a plausible context to envision the redshift periodicities both in distance-dependent z, the existence of which has been claimed by Tifft and others, and confirmed in these proceedings by Bill Napier, and the larger period found in the QSO intrinsic redshifts, z_i, as shown by Burbidge, Karlsson, Arp, Pecker's and Vigier's group and others.

A tired-light mechanism as an alternative to or possibly interconvertible with the gravitational redshift is advocated by Paul Marmet. The implicit assumption of the existence of some amount of unobservable matter is rational, and as such even probable, but this approach can hardly solve the full range of problems discussed here. If we adopt a skeptical standpoint, perhaps the fractional mass in missing physical theory will be greater than the fraction of the still unobserved physical mass.

Another quantum picture of physical nature that bears a resemblance to the ideas presented here has been developed by Henrik Broberg. Broberg constructs a whole series of particles from an elementary energy quantum hypothesis introduced to interpret the cosmological redshift phenomenon. If these results, on the one hand, and the results we have deduced here from the $a_1 = a_c$ requirement, on the other hand, are confirmed by independent investigation, we would have a rough idea of the laws that govern the structure of matter in the Universe from the largest scale down to the smallest. This would be the realization of cosmology in the original meaning of the Greek word *kosmos*, the great order of the world.

As I wrote this paper, I felt that my grasp of physics became a little bit stronger. Being a poor theorist, my grip has always been unsure and trembling. But having worked in cooperation with Jean-Pierre Vigier on numerous occasions over almost two decades, I have been encouraged by the vigorous spirit of physics which seems to be a permanent feature of the atmosphere he creates around him. Four features of this atmosphere can be delineated quite readily. First, there is a firm sense of historical continuity. Vigier has, in his own right and through his links with de Broglie, played an important role in what might be called the critical tradition—a tradition sadly broken at the establishment level within the physical sciences, but kept alive by eminent astrophysicists like Hubble, Zwicky, Mayall, Humason, Finlay-Frendlich, Holmberg, Kipper, Kropotkin, Pecker and Arp, and physicists like Einstein, de Broglie, Born—and Vigier. Second, this tradition has always included some degree of materialist philosophical viewpoint on questions of science, and this is particularly clear in the case of Jean-Pierre. Third, throughout his activity, there has always been a strong tone of internationalism, as it must be in all true science and other human activities in the modern world. And fourth, Vigier's scientific life has been one of battles. True science is often a fighting science.

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