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THE DIRAC "HOLE" THEORY AND NEGATIVE MASS

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Any attempt to discover an "insulator, absorber, or reflector of gravity" in the domain of either experimental or theoretical research, leads inevitably to the question, "is there any reality to the concept of negative mass, and if so, how can we detect it?"

This reduction of the problem to the existence of negative mass can be shown from a number of variant methods of analysis.

Suppose we assume that in a given section of space there exists a gravitational field. The source of this field is the existence of particles of ordinary mass. The considerations that follow are independent of whether we look at the field as a physically real thing in the classically linear space, or a curvature of geodesic lines in the relativistic view point, since both views assume the source to be ordinary mass. Both will produce the same effect if negative mass enters the equations. This is due to the fact that the radius of curvature of space in the relativistic sense, will be the negative of that due to the positive mass if we introduce negative mass.

If we desire an "insulator, absorber, or reflector of gravity", we must be able to surround our portion of space with such a material and have the external gravitational field terminate on it. The enclosed space is then field free. This situation is strongly analagous to the case in electrostatics. Electrostatic fields due to negatively charged particles terminate on positively charged particles. That is, the positive charges act as a "sink" for the field due to negative charges. In order to maintain the analogy we must postulate the existence of a negative mass to act as a sink for the gravitational field of positive masses. Furthermore, we have the requirement on the material used for insulators, that in addition to consisting of positive and negative masses, it must be polarizable; i.e., the positive and negative masses must be able to be separated.

Already in our analysis contradictions are apparent. For any object consisting of positive and negative masses must, in its unpolarized state, be inertially neutral; that is, have a zero mass. Later on it will be seen that this has some significance for us in terms of the Dirac Theory in quantum mechanics.

A second method of analysis which does not require dependence upon analogy is the following:

We start out with a portion of space that is infinitely far from any ordinary masses. We define the potential of the gravitational field at this point as the zero point potential. This then, is our "floor". A test mass placed in this space will not be acted upon by any forces. If we move masses towards this portion of space, the forces on a test mass (attractive forces) increase as the inverse square of the distance from the test mass to the source mass. The potential then increases from the zero point inversely as the first power of the distance. Our problem then requires that the attractive force on the test mass decrease as we move the source mass closer, or as we increase the number of source masses. There are two means of doing this. We may bring a source mass up from the other direction so that the two opposing attractive forces balance to produce no net force on the test mass. This, however, has no relation to our problem and we will ignore this possibility. The second method is to introduce a negative mass into our considerations so that it will produce a repulsive effect on the test mass. The result of the attractive force of the ordinary (positive) mass and the repulsive force of the negative mass, may again balance to produce no net force on the test mass.

Thus we see again, that the nature of the problem of finding "insulators or absorbers of gravity" requires the hypostatization of a negative mass.

To further our arguments, let us assume for the moment the existence of matter in a continuous field structure. This might be approached from the atomic point of view by the close packed density of mass in the liquid or solid phase. A discontinuity, or hole, in in this continuous structure would then have properties that set it apart from the continuum. In the case of a liquid it would be a bubble of insoluble gas, less dense than the liquid, that moves in a direction contrary to the direction gravitational forces would move that portion of the field if there were no discontinuity. For the solid it might be a Frenkel type defect in an ordered crystal, which moves in an applied field in a direction counter to that of the ion or electron that originally filled the space of the discontinuity.

If any general type of detecting system were immersed in this continuum it would read zero, its floor level, throughout the continuous portions of space. But it would give a non-zero reading upon reaching a hole in the continuum.

All this has been necessary as preliminary to understanding the impact of the Dirac theory of the electron on our problem.

With the Dirac theory of the electron, quantum mechanics achieved its most satisfying success. It was brought into complete accord with physical fact by the simple and socially judicious practice of giving certain integrals in the solution of his equation acceptable status and casting the divergent (or infinite) integrals to the other side of the tracks. Of course with new evidence (Lamb-Rethorford shift), we have had to cajole some of these cast off integrals back into the fold.

However, it remains an outstanding, though highly desireable, peculiarity of the theory that in order to solve the problem of a single electron it was necessary to assume an infinite host of electrons. Doncerning these, Dirac made two assumptions. The first, was that all negative energy states possible for an electron from $-m_0c^2$ to $-\infty$ are filled in the absence of external fields. This was done to prevent an electron in a positive energy state from jumping into one of these negative states and disappearing, charge and all. The second assumption was that the electrons filling these negative energy states do not produce any external field, nor contribute to the total energy or momentum of the system. That is, the zero point in our measurements correspond to a filled negative energy state and an empty positive energy. It is additionally necessary to assume that an external field can act upon the electrons in these states.

An underlying basis of physical reality in this concept must be assumed from the following evidence:

It provides a consistent theory of the Compton particle-light scattering, utilizing these negative energy states as the intermediate states in the process. The Klein-Nishina formula derived on this basis for such scattering, has been experimentally verified for energies up to $10 mc^2$ It predicted the existence of positrons, (positively charged electrons) which Anderson discovered in 1932; and permitted the description of a mechanism for pair production (the creation or annihilation of positrons and electrons in pairs with the consequent absorption or emission of a high frequency light quanta).

According to the theory we must assume an all pervading substratum of negative energy electrons with an infinite density. This however, is nothing other than the content of the recently interred Ether, garbed in a far more sophisticated form.

We may freely speculate upon the properties of electrons in such a negative energy state. We find, that such an electron would repel an electron in a positive energy state, and yet constantly be accelerated towards it--an unceasing, rejected suitor.

If an electron is removed from the negative energy state by application of a suitable external field, we have created an electron with a positive energy and momentum and a negative charge. What remains is a "hole" in the negative energy level. This hole would also have discernable properties. For it would have a positive energy, a positive charge, and a momentum opposite to that in its corresponding negative state. Its mass would, therefore, be that of an ordinary electron in a positive state. This "hole" constitutes a positron.

Enough of the Dirac theory has been laid to illustrate some major points. We have seen that the assumption of a continuity in nature is not an unnatural one. If we have such a continuity, then under certain conditions we may have a vacancy in the continuity. This vacancy or "hole" will have definable properties, whereas the original occupant in the site will have no discernible properties. The properties of the vacancy will be the negative of the particle released from the vacancy.

A pertinent result of the Dirac theory is the so called "polarization of the vacuum". It is a well established feature that for electrons bound in a coulomb field, the positive and negative energy levels become mixed. Thus, if we introduce a coulomb field adiabatically in a vacuum, a certain finite number of electrons in the negative energy state would be in a positive energy state with respect to the binding field. This means that there will be a separation of charges of the positive energy electrons and holes in the negative energy states (positrons). This constitutes the polarization of the vacumm. In the solution of the problem of the electron, the infinite energy contributed by this effect is subtracted out of the equations.

The significance of the Dirac theory for our problem lies in this; the negative energy states from $-m_0c^2$ to $-\infty$ correspond exactly to the condition of the existence of electrons with negative mass filling the universe.

A quantum of energy of $2mc^2$ provides the equivilent mass necessary to raise an electron with negative mass to the corresponding positive mass. The hole remaining in the negative energy continuum will, as we have shown before, exhibit properties counter to that of the medium. Or, it will have a positive mass (a hole in a continuum of negative mass), and a positive charge (a hole in the continuum of negative charge). This hole is the positron as shown above.

We can see now why it has never been possible to detect directly, the existence of a negative mass. The continuum of negative mass exists through all space. All our detectors are immersed in this continuum and therefore always read zero in the absence of positive masses. If a hole exists in this continuum then it will register on our detector. But this hole corresponds to a positive mass.

There does exist a possibility of indirectly detecting a negative mass. This utilizes the phenomena of polarization of the vacuum. It required an electrostatic coulomb field of fairly strong intensity (on the order of the field strength 10^{-8} centimeters away from a positively charged nucleus) to produce polarization. Since gravitational forces are far weaker than electrostatic forces, it would require an intense gravitational field to polarize the vacuum. It would also have to be done in the absence of electric forces in order not to mask the effect.

These conditions are precisely those which hold in the vicinity of a large celestial body such as the sun, which has no permanent electric moment.

If light passes through a medium that is inhomogeniously polarized, there must occur a bending of the optical path. The bending of the path of light that passes close to the sun has been predicted by the Theory of Relativity, measured and corroborated. This is, a possible phenomenological explanation of the mechanism whereby the bending occurs.

It would be necessary to put the polarization of the vacuum on a much more quantitative basis than at present, in order to be able to compute the amount of bending and compare it with measured data. There is no reason to expect that this could not be done; if so, it would advance our understanding of gravity considerably and bring the possibility of finding insulators, absorbers, or reflectors of gravity closer to actuality.

ABSTRACT

THE DIRAC "HOLE" THEORY AND NEGATIVE MASS

It is shown that the problem of finding insulators, absorbers, or reflectors of gravity reduces to the fundamental question of the existence of negative mass. The properties of "holes" in continuous fields are analyzed. The Dirac theory of the electron postulates an all pervading substratum of electrons in the negative energy states. It is shown that these states may correspond to electrons with nggative masses. This provides an explanation as to why negative mass cannot be detected directly by physical apparatus. An indirect way of detecting negative mass is proposed, utilizing the quantum phenomena of polarization of the vacuum.