ON THE QUESTION OF ANTIGRAVITATION

Iu. A. ALEKSANDROV, V. N. ANDREEV, and I. I. BONDARENKO

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In connection with the discovery of heavy antiparticles (antiprotons and antineutrons) there have been several papers discussing the possibility that antiparticles have negative gravitational mass.[1,2,3] The attractiveness of such a hypothesis lies in the fact that it enables us to understand the absence of antiparticles in our stellar system and its vicinity,[4] since the gravitational repulsion of matter and antimatter would be a mechanism assuring their spatial separation.

It is of interest to discuss the degree of agreement between the hypothesis of antigravitation and present physical theories and experimental facts.

1. Experiments on the deflection of positrons and antiprotons in magnetic fields provide evidence that the inertial masses of antiparticles are positive (if we regard it as established by the fact of annihilation that the electric charge of the positron is positive and that of the antiproton is negative).

2. According to present ideas, physical phenomena in a set of antiparticles must go on in just the same way as in a set of ordinary particles (invariance of the laws of motion with respect to combined inversion). This leads to the result that the inertial masses of particles and antiparticles must be of the same sign, i.e., positive. In the opposite case, two antiparticles interacting gravitationally would fly apart (independently of the sign of the gravitational mass), in contrast with the behavior of ordinary particles. These same considerations require us to suppose that the gravitational masses of antiparticles are proportional in magnitude to their inertial masses, as is true for ordinary particles.

The considerations presented in these two points indicate that the inertial masses of antiparticles must be positive. If this is so, the hypothesis of negative gravitational mass for the antiparticles is in obvious contradiction with the general theory of relativity (the principle of equivalence).

3. Acceptance of the hypothesis of the negative gravitational mass of antiparticles also leads to a number of additional difficulties, connected with the existence of bosons (particles with integer spin). According to the present quantum theory there is for bosons no difference between particles and antiparticles. Remaining within the framework of this theory, we may suppose that all bosons have gravitational masses of the same sign. We then have two possibilities: either the gravitational masses of bosons are different from zero, or they are equal to zero. In the former case it is not hard to show that by using the phenomena of interconversion of bosons and fermions (creation and annihilation) in a gravitational field we can arrive at a violation of the law of conservation of energy. The second assumption contradicts the usual interpretation of the observations on the deflection of light in the gravitational field of the Sun, and the observations of the gravitational shifts of spectral lines in light coming from white dwarfs and other stars. The hypothesis that bosons are divided into particles and antiparticles with different signs of their gravitational masses does not agree with the observed angular distribution of the photons in three-photon annihilation of an electron and positron.

4. From what has been said it can be seen that acceptance of the hypothesis of negative gravitational mass of antiparticles would require radical changes in our present physical ideas. Owing to this, a direct experimental determination of the sign of the gravitational mass of antiparticles seems extremely desirable, despite the enormous difficulty of the experiments in question. One such experiment could be the observation of the "fall" of positrons in the gravitational field of the earth.

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[1] H. Bondi, Revs. Modern Phys. **29**, 423 (1957).

[2] F. A. Kaempffer, Canad. J. Phys. **36**, 151 (1958).

[3] G. Burbidge and F. Hoyle, Sci. Amer., April 1958, p. 34.

[4] G. Burbidge and F. Hoyle, Nuovo cimento **4**, 558 (1956).

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279