Reports

Nonexistence of Gravity Shields

Electric forces exhibit sign reversals that can be associated with plus and minus signs for elementary charges. In considering gravitational effects upon antimatter, it is essential to know whether a similar sign change occurs for gravitational forces. This note gives an elementary argument for a negative conclusion—namely, the dominant gravitational force between matter and antimatter is attractive, just as between matter and matter. This conclusion may be of significance for cosmological speculation involving antimatter (*1*).

The following discussion involves two approximations: the gravitational field is considered as weak, so that distortion of space-time can be neglected; and relative velocities are supposed to be small, so that only the static interaction terms need be included. Both approximations are appropriate to most practical applications of gravitation. Under these approximations, the electromagnetic and gravitational interactions between two systems assume identical forms:

$$V = -\iint d^3r_1\rho_1(r_1)\,\varphi(|r_1 - r_2|)\,\rho_2(r_2)\,d^3r_2 \quad (1)$$

Here φ is a function exclusively determined by the properties of the gravitational or electromagnetic field transmitting the interaction from r_1 to r_2, and ρ_j is an appropriate density junction for system j. In the static approximation $\varphi(x) = x^{-1}$ for both gravitational and electromagnetic fields, since both are massless. The quantities ρ_j are different for the two cases, however: the charge density is the fourth component of a 4-vector, while the matter density is the double-fourth component of a second-order tensor.

In the weak-field approximation, the interaction between gross aggregates of matter is the sum of the interactions between their constituent elementary particles (nucleons and electrons). Thus the behavior of V for gross matter is determined by its behavior for elementary particles. In quantum mechanics, the essential step in transforming from a particle to an antiparticle is the operation of complex conjugation, where the associated conventional coordinate system is (x, y, z, ict). Thus complex conjugation is also associated with reversal of the sign of t and of all 4-components; the charge density ρ_j will hence change sign upon substitution of antimatter for matter, while the matter density will not, having the signature $(-1)^2 = +1$.

Another statement of this conclusion is that "gravitational charge" has only one sign. This immediately negates the possibility of a shield for gravitational forces: the action of an electric shield depends on the separability of two types of charge with opposite sign. This result may be limited by the approximations stated but should certainly be valid for all terrestrial applications.

This argument obviously extends to fields of any intrinsic multipolarity: if two particles interact through the mediation of an nth order tensor field (*2*), the associated static potential will or will not suffer sign changes for antiparticles, according as n is odd or even. Association of the imaginary factor i with the time coordinate characterizes a second alternation of sign between even and odd n. For like charges, $(\rho_1\,\rho_2)$ has a factor $(i)^{2n} = (-1)^n$; with the additional minus sign in Eq. 1, like charges are repulsive for odd n, attractive for even n. Hence attractive static potentials are possible for any n, but repulsive potentials occur only for odd n.

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References and Notes

1. For example, M. Goldhaber, *Science* **124**, 218 (1956).
2. Pseudotensor fields are excluded from consideration, for they yield a vanishing interaction in the static approximation.

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Sulfhydryl Groups and Cell Division

The idea has long been held that sulfhydryl groups are particularly important in cell division. Support for this idea has come from three lines of evidence, all established by early investigators (*1, 2*): the strong nitroprusside reaction of a number of proliferating tissues; the inhibition of division by thiol poisons and its reversal by cysteine, glutathione, or thioglycollate; and the fall and rise in concentration of soluble thiols prior to first cleavage in the fertilized sea-urchin egg.

On the basis of these observations, Rapkine (*1*) proposed a theory of division in which a reversible denaturation of protein and a reduction of oxidized glutathione were the key mechanisms. In Rapkine's scheme, protein denaturation was the primary event that had to precede division since it was by the resultant exposure of the —SH radicals that the intracellular store of oxidized glutathione was reduced. The glutathione thus formed altered the oxidation-reduction level of the cell so as to effect a fermentative metabolism leading to division.

Later, Brachet (*3*) pointed out that the oxidation of protein —SH to the disulfide could be given in addition a structural function by relating the disulfide linkage to the formation of the mitotic spindle. Recently, Mazia (*4*) dismissed the idea that the changes in soluble sulfhydryl concentration were related to metabolic shifts in the dividing cell. Instead, he interpreted the fall and rise in soluble sulfhydryl concentration as resulting from the formation and dissolution of the spindle elements. To support this interpretation, he presented preliminary data showing that at the time of spindle formation in the fertilized sea-urchin egg, protein —SH was at its lowest and soluble thiol at its highest concentration, and that throughout the cycle from fertilization to first cleavage, protein —SH and soluble —SH were in reciprocal concentrations.

It is the purpose of this communication (*5, 6*) to report briefly some analytic results that have a bearing on these speculations. Developing anthers of a lily (*Lilium longiflorum* var. Croft) were analyzed for their content of soluble and protein sulfhydryl during an 11-day interval surrounding the mitosis of the microspores. It is possible to determine the interval easily because of Erickson's demonstration that the length of a flower bud is correlated with the synchronous divisions of the germinal cells in the anther (*7*). At 41 mm, these cells are all present as young microspores; at 62 to 63 mm, the mid-point of the interval studied, they undergo mitosis to yield binucleate pollen cells, the only quick and marked change between 41 and 180 mm, the time of anthesis.

During this interval, the microspores and pollen are the principal components of the anthers. They differ from the much studied sea-urchin egg in at least two important respects: (i) they do not have the extraordinarily low nucleo-cytoplasmic ratio of the newly fertilized egg in which cytoplasmic changes (the growth and disappearance of the spermaster, for example) could well obscure changes directly related to nuclear division and (ii) they do not undergo cytoplasmic cleavage. Since such cleavage is