PHOTOPRODUCTION OF GRAVITONS ON SPINOR PARTICLES

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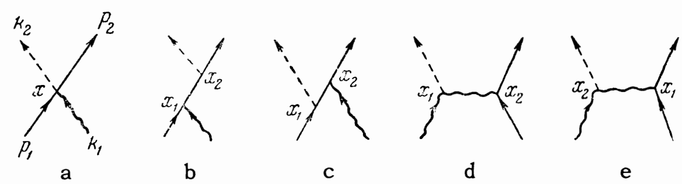
The differential effective cross section for the photoproduction of gravitons on spinor particles is calculated. An estimate is made of the gravitational luminosity of stars associated with this process.

IN this note we give the results of our investigation of the process of the conversion of a photon into a graviton when the photon is scattered by a spinor particle.[1)] In order to calculate the differential effective cross section for this process we utilize the Lagrangian density for the interaction between the spinor, the gravitational and the electromagnetic fields given in the paper of Vladimirov[1] [formula (27)]. The contributions of the terms of the S-matrix to the matrix element are shown graphically by means of Feynman diagrams a – e (cf., diagram) with the contributions of the last two diagrams mutually cancelling each other.

Carrying out standard calculations we obtain the expression for the differential effective cross section in the laboratory coordinate system (l.s.) in the form

$$d\sigma = \frac{e^2\varkappa}{(16\pi)^2}\frac{k_2^2}{m^2k_1}\Big[k_1\sin^2\theta - 2k_1\sin^4\theta - 2k_2\sin^2\theta\cos\theta + 2k_2\sin^2\theta + \frac{2m}{k_1}(k_1-k_2)(1+\cos^2\theta) + \frac{\sin^2\theta}{m}(k_1^2\sin^2\theta - k_1k_2(1-\cos\theta))\Big]d\Omega, \qquad (1)$$

where k_1 is the photon momentum, k_2 is the graviton momentum, e, m are the charge and the mass of the spinor particle, $\varkappa$ is the gravitational constant. Here we have averaged over the polarizations of the incident photons and summed over the polarizations of the gravitons created.



Graphical representation of the contributions made by the terms of the S-matrix to the matrix element: dotted line is the gravitation line, wavy line is the photon line, and the straight line is the fermion line.

For very hard photons ($k_1 \gg m$) we have

$$d\sigma = \frac{e^2\varkappa}{(16\pi)^2}\frac{k_1k_2^2}{m^3}\sin^4\theta\, d\Omega, \qquad (2)$$

$$\sigma = 6.6\cdot10^{-2}e^2\varkappa k_1/m. \qquad (3)$$

For soft photons ($k_1 \ll m$, $k_2 \approx k_1 = k$) we have

$$d\sigma = \frac{e^2\varkappa}{(16\pi)^2}\frac{k^2}{m^2}[3\sin^2\theta - 2\sin^4\theta - \sin^2\theta\cos\theta + 2(1-\cos\theta)(1+\cos^2\theta)]\,d\Omega, \qquad (4)$$

$$\sigma = 1.8\cdot10^{-2}e^2\varkappa(k/m)^2. \qquad (5)$$

Formulas (2), (4) show that in the direction of motion of the photons ($\theta = 0$) there will be no gravitational radiation and maximum radiation will be observed for $\theta = \pi/2$. It should also be noted that the effect is necessarily connected with the recoil of the scatterer, since for $m = \infty$ the effect disappears. The probabilities of gravitational transformations are extremely small. However, the possibility of their existence is significant as a matter of principle for the elucidation of the nature of the gravitational field, of the role played by gravitation in the relativistic theory of elementary particles and for the solution of a number of cosmological problems[1-3].

Having the latter problems in mind we have made an estimate of the gravitational luminosity of a star. Assuming that the thermal radiation within a star is distributed in accordance with

1)This process was considered in the paper by Vladimirov[1] in which, however, the value obtained for the cross section reduces identically to zero on transformation to the laboratory system of coordinates. According to a private communication from the author that article gives an incorrect indication of the region of validity of his formula. It has been derived for the case $|\mathbf{p}_1| \gg |\mathbf{k}_1|$, $|\mathbf{p}_1| \gg |\mathbf{k}_2|$, which permits passage neither to the laboratory nor to the center of mass systems of coordinates. Because of this it is impossible to draw any conclusions regarding experimentally observable effects.

Planck's formula and that the medium is fully ionized we have obtained with the aid of formula (5) the value of the gravitational energy w radiated per cm^3 of the medium per second:

$$w = 1.5 \cdot 10^{-49}\ nT^6\ \text{erg/cm}^3\ \text{sec}.$$

Here n is the electron density, T is the temperature in keV. The gravitational luminosity of a star of the type of the sun (using the standard homogeneous hydrogen-helium model) turns out to be of the order of 10 W. The principal role is played by gravitational radiation accompanying Coulomb scattering of electrons.[4] Under the same conditions the ordinary luminosity amounts to several hundred thousand kw. The gravitational luminosity is smaller than the photon luminosity by 18 orders of magnitude and, therefore, cannot play any role in the process of stellar evolution.

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[3] D. Ivanenko, Abstracts of the First Soviet Gravitational Conference, Published by the Moscow State University, 1961, p. 98.

[4] G. Gandel'man and V. Pinaev, JETP **37**, 1072 (1959), Soviet Phys. JETP **10**, 764 (1960).

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