BLACKBODY RADIATION DRAG
ON A RELATIVISTICALLY MOVING MIRROR

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We compute the drag force on a mirror moving with a relativistic velocity relative to the blackbody radiation background.

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Recently a great deal of attention has been devoted to the problem of frictional force acting on a neutral particle when it moves through blackbody radiation [1–4]. However, despite of all efforts an unambiguous generalization of the results [1,2] in the case of relativistic velocities of the particle at the moment is missing (see [4]) .

In this letter we solve blackbody radiation drag problem exactly in the case of "structureless" moving body, i.e. for a mirror.

Let us consider a mirror moving with a velocity \( v \) through a thermalized photonic gas with a temperature \( T \). In the frame of the mirror the distribution function of photons is given by the expression [5]

\[
n(\mathbf{k}, v) = \frac{1}{e^{\gamma(\omega + \mathbf{k} v)/T} - 1},
\]

where \( \gamma = 1/\sqrt{1 - \beta^2} \), \( \beta = v/c \).

By using distribution function (1) we find the momentum density \( p \) of the electromagnetic field:

\[
p = \frac{2d\mathbf{k}}{(2\pi)^3} \mathbf{k} n(\mathbf{k}, v) = -v \frac{16}{3c^2} \sigma T^4 \frac{1}{1 - \beta^2},
\]

where \( \sigma \) is the Stefan-Boltzmann constant

\[
\sigma = \frac{\pi^2 k_B^4}{60\hbar^2 c^2}.
\]

Then, for a plane mirror moving perpendicularly to its surface we get for the drag force \( f \) per unite area of surface the following expression:

\[
f = \frac{32}{3c} \sigma T^4 \frac{\beta}{1 - \beta^2}.
\]

This is the main result of this communication and it is correct for arbitrary large velocities of the mirror. As seen, the drag force (3) is proportional to \( T^4 \) as in case of a nonrelativistically
moving metallic particle [1].

It is useful to compare the drag force pressure (3) with the of blackbody radiation pressure \( P \) [6]

\[
P = \frac{4\sigma}{3c} T^4. \tag{4}
\]

From expressions (3) and (4) we find the ratio

\[
f / P = \frac{8\beta}{1 - \beta^2}. \tag{5}
\]

Thus, in the nonrelativistic limit of velocities \((\beta \ll 1)\) the drag force is proportional to the velocity of mirror:

\[
f / P \propto \beta \tag{6}
\]

and is very small.

For the velocities \( v; 0.1c \) the drag pressure becomes comparable with the blackbody radiation pressure:

\[
f / P \propto 1. \tag{7}
\]

In the limit of relativistic velocities \((\beta \rightarrow 1)\) of the mirror the drag force density \( f \) becomes infinitely large:

\[
f / P \propto (1 - \beta)^{-1}. \tag{8}
\]

References