Commun. math. Phys. 44, 245—264 (1975)


# Vacuum Polarization and the Spontaneous Loss of Charge by Black Holes

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Received June 16, 1974

**Abstract.** The spontaneous loss of charge by black holes due to particle emission is discussed. For large black holes (more massive than $10^{17}g$) the process is shown to be governed by a Schwinger type formula. For smaller black holes the method of calculating the process is described and asymptotic forms for scattering and superradiant coefficients given.

## Introduction

The purpose of this paper is to investigate under what circumstances a black hole immersed in a vacuum may possess charge and the mechanism whereby it loses by the spontaneous production of pairs of oppositely charged particles. The motivation for the work is both conceptual – to understand particle production processes in strong gravitational fields- and astrophysical. The astrophysical interest is not so much in black holes of solar mass or above which may have formed from the gravitational collapse of stars, star clusters or galaxies as in black holes of small mass which Hawking [1] has suggested may have formed in the early universe. If these are to be easily detectable than it will be by any charge that they possess, since then they would show up in bubble chamber tracks and possibly using etched track techniques etc.

It is clear that whether or not they may possess charge is crucial to any consideration of searching for such objects. We shall not discuss the astrophysics of small black holes further in this paper but merely note that the question of large black holes is somewhat simpler to answer. One would not normally expect large excesses of charge to occur in the universe and indeed an object of mass $M$ and charge $Q$ will not gravitationally accrete particles of mass $m$, charge $e$, if the inequality

$$eQ > Mm \tag{1.1}$$

holds unless the particles are projected at the object with some initial velocity. (Here we are using, as we shall throughout this paper unless the contrary is stated "natural units", n.u. in which $\hbar = c = G = k = 1$. The electrical units are unrationalized. Since $m/e \approx 10^{-21}$ for electrons we see that a large black hole will naturally acquire hardly any charge and will probably lose it by accreting particles of opposite sign rather quickly. It will turn out that this implies that the amount of activity due to pair formation will be quite negligible.