Pair creation induced by electric and gravitational fields

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We study the pair production phenomena from spatially homogeneous strong electric fields in two-dimensional expanding spacetimes. Using the adiabatic subtractions for renormalization we determine the form of the most relevant physical observables. The backreaction effects of the created pairs can be naturally incorporated into the semiclassical Maxwell equations.

Keywords: Pair creation, backreaction, adiabatic renormalization, semiclassical Maxwell equations.

One of the most interesting problems in the study of particle production phenomena caused by time-dependent background fields is to incorpore the backreaction effect of the created particles in a self-consistent way. This is a very important step to further analyze the quantum phenomena induced by gravity in the early universe [1, 2]. This is the basic motivation underlying the introduction of a modified set of equations, referred as the semiclassical Einstein equations $G_{\mu\nu} = -8\pi G\langle T_{\mu\nu}\rangle$. The right hand side represents the expectation value of the stress-energy tensor operator, which acts as the source of the gravitational field. It is well-known that the formal expression for $\langle T_{\mu\nu}\rangle$ is divergent and one needs a renormalization prescription to obtain a finite an well-defined result to be plugged into the semiclassical equations.

For homogeneous, time-dependent spacetimes a generic expression for $\langle T_{\mu\nu}\rangle$ was obtained for scalar fields by means of the so-called adiabatic regularizacion/renormalization scheme. The adiabatic method is naturally suggested by the definition of single-particle states in an expanding Friedmann-Lemaitre-Robertson-Walker (FLRW) universe, required to establish the particle creation phenomena in gravitation [3]. The method is widely used in cosmology and it turns out to be very efficient to implement numerical computations. More recently, it has been extended to spin-1/2 fields [4, 5]. In this context one has all the ingredients to write down the semiclassical Einstein equations.

Time-varying electric fields coupled to charged quantized fields can also create particles. In the limit of a constant electric field in Minkowski space one recovers the Schwinger effect [6]. This effect can may be at the verge of being experimentally detected in upcoming ultrashort lasers of unprecedented intensities. In these scenarios, the expectation value of the electric current operator $\langle j^\mu\rangle$ acts as the source of semiclassical Maxwell equations $\nabla_\mu F^{\mu\nu} = \langle j^\nu\rangle$. For homogeneous, time-dependent spacetimes and spatially homogeneous electric fields one can systematically extend the adiabatic method to determine the renormalized expectation value of the current $\langle j^\nu\rangle$, and also the stress-energy tensor $\langle T^{\mu\nu}\rangle$.

The aim of this work is to extend is to extend the adiabatic regularization method for scalar and Dirac fields living in a cosmological background by adding the interaction with an external homogeneous electric field [7]. In particular, we analyze the semiclassical equations in the simplified setting of a two-dimensional spacetime of the form $ds^2 = dt^2 - a^2(t)dx^2$ and a homogeneous gauge field $A_\mu = (0, -A(t))$. We also explain and clarify the ambiguities of the method (already stressed in [8]). Finally, we give some physical results to prove the consistency of the method.

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