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Gravitational waves versus cosmic strings

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Abstract. The equation which governs the temporal evolution of a gravitational wave (GW) in curved space-time can be treated as the Schrödinger equation for a particle moving in the presence of an *effective potential*. When GWs propagate in an expanding Universe with *constant* effective potential, there is a *critical value* (k_c) of the comoving wave-number which discriminates the metric perturbations into *oscillating* ($k > k_c$) and *non-oscillating* ($k < k_c$) modes. The effective potential is reduced to a non-vanishing constant in a cosmological model which is driven by a *two-component fluid*, consisting of *radiation* (dominant) and *cosmic strings* (subdominant). However, the cosmological evolution (gradually) results in the *scaling* of any long-cosmic-string network and, therefore, after some time ($\Delta\tau$) the Universe enters in the *pure-radiation* epoch. The evolution of the non-oscillatory GW modes during $\Delta\tau$, results in the *distortion* of the *low-frequency part* of the *stochastic GW power-spectrum*, which, therefore, departs from *scale invariance* (anticipated in the pure-radiation case). As regards the corresponding *high-frequency part* (which is determined by the evolution of the oscillating modes), we find that the presence of cosmic strings gives rise to the quantum-gravitational creation of *gravitons*, leading to the *amplification* of the GW signal by (almost) two orders of magnitude.

1. Introduction

The so-called *cosmological gravitational waves* (CGWs) represent small-scale perturbations to the Universe metric tensor [1]. Since gravity is the weakest of the four known forces, these metric corrections decouple from the rest of the Universe at very early times, presumably at the Planck epoch [2]. Their subsequent propagation is governed by the space-time curvature, encapsulating in the field equations the inherent coupling between relic GWs and the Universe matter-content; the latter being responsible for the background gravitational field [3].

In this context, we consider the interaction between CGWs and *cosmic strings*. They are one-dimensional objects that can be formed as linear defects at a symmetry-breaking phase transition [4], [5]. If they exist, they may help us to explain some of the large-scale structures seen in the Universe today, such as gravitational lenses [6]. They may also serve as *seeds* for density perturbations [7], [8], as well as potential sources of relic gravitational radiation [9], [10].

In this article we present some recent results concerning another possibility: The presence of cosmic strings in a radiation-dominated Universe being responsible for the constancy of the *effective potential* which drives the temporal evolution of a CGW in curved space-time.

In particular, we shall demonstrate that, a (non-vanishing) constant effective potential is associated to a *critical value* (k_c) of the comoving GW wave-number, which discriminates the metric perturbations into *oscillating* ($k > k_c$) and *non-oscillating* ($k < k_c$) modes, something

