Living on a brane*

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ABSTRACT

We briefly review the distinctive signals of brane world models with low tension. We pay special attention to the brane fluctuations (branons), whose phenomenological consequences could be important both in high energy particle physics experiments and in astrophysical and cosmological observations.

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1 Introduction

All the present experimental evidence is compatible with the existence of only three spatial and one time dimensions. However, some of the modern theories of the fundamental interactions predict the existence of additional spatial dimensions. Such theories include Kaluza-Klein models, supergravity, string theory and the more recent M-theory.

In particular, in the last years, it has been found that certain fundamental extended object, similar to multidimensional membranes embedded in a higher dimensional bulk space, and known as branes, play a fundamental role in the dynamics of string and M theory. Recently, it has been suggested that all the Standard Model (SM) fields could be confined in one of those (world) branes with three spatial dimensions whereas gravitation would have access to the whole bulk space [1]. In this scenario, the fundamental scale of gravity is not the Planck scale, but another scale $M_F$ which could be as low as the electroweak scale. In such a model, known as ADD model, the enormous difference between the Planck scale ($10^{16}$ TeV) and the electroweak one (1 TeV) could be explained due to the existence of two or more compactified large extra dimensions (with sizes ranging from 0.1 mm to 1 fm for two and seven extra dimensions respectively).

2 New phenomenology: KK gravitons, brane fluctuations and topological states

Probably the main phenomenological consequences of this scenario are, on one hand, the modification of the gravitational interaction at short distances [1]. Thus, whereas at large distances the inverse square law is respected, it is expected to be modified at distances close to the size of the extra dimensions. On the other hand, the existence of extra dimensions implies that new fields will appear on the brane, corresponding to the tower of light Kaluza Klein (KK) modes of the bulk gravitons.

In addition to these features, the fact that a relativistic brane cannot be a rigid object, requires the existence of some other new particles describing its fluctuations with respect to the equilibrium position [2]. These excitations, known as branons, couple to the energy-momentum tensor of the SM fields with a strength suppressed by the brane tension scale ($f$) [3]. Another
interesting consequence of the brane flexibility is the suppression [4] of the couplings of the KK modes to the SM particles when the tension scale is much smaller than $M_F$. In this case, for flexible enough branes, the only relevant degrees of freedom at low energies would be the branons and the SM fields. Finally, in addition to the branons, the brane can support also a new set of topological states. These states are defects that appear due to the non-trivial homotopies of the vacuum manifold. In fact, string, monopole, skyrmion and wrapped brane configurations have been studied in different works [5, 6]. However, the existence of this kind of states depends very much on the topology of the extra space, unlike the brane fluctuations, whose low-energy dynamics is universal, depending only on the number of branons and the brane tension. The geometry of the bulk space determines only the branon masses [6].

3 The branon field

Since the mechanism responsible for the creation of the brane is in principle unknown, we will assume that the brane dynamics can be described by an effective action. In this sense, the branons could be interpreted as the mass eigenstates of the brane fluctuations in the extra-space directions. Thus, branons are a kind of new scalar fields, which are massless only in ideal cases in which the extra space isometries are not explicitly broken, but only spontaneously broken by the presence of the brane. In such a case they could be identified with the Goldstone bosons of this ideal symmetry breaking pattern [2, 3].

4 Brane dark matter

Branons interact typically by pairs. Therefore they are expected to be stable, massive and difficult to detect since their interactions are suppressed by the tension scale ($f$). Thus the massive oscillations of the brane are natural candidates to dark matter [7] in the brane-world scenario where $f < M_F$ (see FIG. 1).
Figure 1: Relic abundance in the $f - M$ plane for a model with one branon of mass: $M$. The line on the left is the $\Omega_{Br}h^2 = 0.129 - 0.095$ curve for hot-warm relics, whereas the right line corresponds to cold relics. The lower striped area is excluded by single-photon processes at LEP-II [9] and the upper area is also excluded by branon overproduction.

5 Future prospects

Brane fluctuations could be, not only natural cosmological dark matter candidates, but they could also make up the galactic halo and explain the local dynamics. In such case, they could be detected in direct search experiments through their interactions with nucleons, or in indirect ones, due to annihilations in the galactic halo which give rise to pairs of photons, positron-electron or neutrinos. This kind of experimental analysis is complementary to the searches in colliders [8, 9] whose present bounds are also plotted in FIG. 1.

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