

Quantum treatment and equation of state of a Friedmann-Robertson-Walker brane embedded in a five dimensional fluid bulk

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Abstract In the present paper, we deal with the five dimensional warped $k = 0$ -FRW Universe, with a perfect fluid in the bulk. By solving the Einstein's Equations, we get the corresponding scale function, a , and the warp factor. Particular attention is given to the effective potential $V(a)$, which is used in solving both the Wheeler-DeWitt equation and the stationary Schrödinger equation. Inspired by similar considerations carried out in a series of recent papers, we assume that the brane matter is made of two interacting perfect fluids. We compute the corresponding densities and pressures and write down the Equation of State, whose dynamic parameter is taking all the intermediate values, from $w = 1$, at $t = 0$, to $w = -1$, in the far future.

Keywords FRW universe · 5D branes · WDW equation · Two-fluid scenario

1 Introduction

The pioneering work of Randall and Sundrum (RS) (Randall and Sundrum 1999) opened the way to a whole range of theories of branes embedded in an ambient higher dimensional space. At least one of these branes contains the particles of the Standard Model and this one corresponds to our Universe.

When working with spatially homogeneous and isotropic Friedmann-Robertson-Walker (FRW) slices, one can not employ the first-order formalism based on a kind of superpotential, as in supergravity, to generate solutions (Bazeia et al.

2006; DeWolfe et al. 2000) and has to solve the Einstein's Equations in the bulk, with suitable matter content.

As recent data from type Ia supernovae (SN Ia) (Perlmutter et al. 1997, 1998, 1999; Riess et al. 1998, 2004) and cosmic microwave background radiation (Caldwell and Doran 2004; Huang et al. 2006) are encouraging the idea that our universe had an earlier deceleration era, followed by the present accelerated expansion, it has been suggested that the transition between the two phases has been driven by the so-called *dark energy* (Bamba et al. 2012). For explaining the cosmological stages, a matter source made of two ideal fluids with a suitable coupling between them has been considered as reliable candidate (Amirhashchi et al. 2011; Saha et al. 2011).

The present work is following some previous investigations on a five dimensional warped ($k = 0$)-FRW Universe (Dariescu and Dariescu 2010). By assuming that the observed large-scale structure can exist on the brane embedded in a dS_5 bulk filled with a perfect fluid, we deal with the frozen Wheeler-DeWitt (WDW) equation (Wheeler 1968; De Witt 1967), as well as with its time-evolving version. Coming from the bulk into the visible brane with two interacting fluids, we compute the corresponding energy densities and pressures and the Equation of State (EOS).

2 Warped FRW universe with a perfect fluid

Inspired by the original RS model (Randall and Sundrum 1999), where the four-dimensional metric is multiplied by a warp factor $e^{-2kr_c\Phi}$, with the scale factor k of order of the Planck scale, Φ the fifth coordinate and r_c fixing the compactification scale, by $\mu = 1/r_c$, we consider the 5-dimensional metric written as

$$ds_5^2 = e^{2F(\tau,\xi)} \eta_{ik} dx^i dx^k + (d\xi)^2, \quad i, k = \overline{1, 4}. \quad (1)$$

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