FINE TUNING PROBLEM IN FIVE-DIMENSIONAL BRANE WORLD MODELS

S.H.Fakhr[1], M.Eingorn[2], A.Zhuk[3]

[1,2,3]Astronomical Observatory, Odessa National University
[2]Department of Theoretical and Experimental Nuclear Physics,
Odessa National Polytechnic University
Odessa, Ukraine
[1]seyed.hossein.fakhr@gmail.com, [2]maxim.eingorn@gmail.com, [3]ai.zhuk2@gmail.com

ABSTRACT. Fine tuning can be called a main disadvantage of the Randall-Sundrum model, representing the most popular brane world model, constructed quite artificially in the five-dimensional space-time. It needs a bare multidimensional cosmological constant, which is related strictly to four-dimensional tension (the brane physical property).

Here we try to avoid this problem of naturalness, introducing a perfect fluid with arbitrary equations of state in both three-dimensional external and one-dimensional internal spaces parallel with the cosmological constant. It enables to preserve randomness of parameters of the considered model, which represents the direct generalization of the Randall-Sundrum one. We derive equations for background metric coefficients, determining a wide class of new exact solutions, and discuss uselessness of subsequent development of brane world models in view of their unjustified plurality.

Key words: brane world models, extra dimensions.

Extra spatial dimensions represent one of the approaches to solving such challenges of modern cosmology, astrophysics and elementary-particle physics as dark energy, dark matter and the hierarchy problem. In particular, they are introduced in extremely popular supersymmetric theories [1], pretending to being "theories of everything". Obviously, they should be examined experimentally for compatibility with the observations. In the recent paper [2] it was explicitly shown that Kaluza-Klein models with toroidal compactification of extra dimensions contradict such famous relativistic gravitational tests as the perihelion shift, the deflection of light and the time delay of radar echoes (see [3-6]). Therefore, these models seem very doubtful, and one should look for their viable multidimensional alternatives. They are the brane world models (see the reviews [7, 8]), in which it is assumed that the Standard Model fields are localized on a three-dimensional subspace (a brane), embedded into the multidimensional space (the bulk), while gravity may propagate everywhere. In this very interesting scenario extra dimensions may be either compact or infinite, and a single brane or even several branes are admissible.

The most popular brane world model is the five-dimensional Randall-Sundrum model with one or two branes [7-10]. In this model the bulk is assumed to be empty (not counting dark energy, represented by the five-dimensional cosmological term), while the branes possess tensions (looking like the four-dimensional cosmological terms). Clearly, this scenario is very simple and unlikely well-grounded. Therefore, a natural question arises whether it can be generalized to the case of perfect fluids with arbitrary linear equations of state, filling the bulk as well as the branes.

We produced this important natural generalization and came to the following two main conclusions.

In the case of the empty bulk we found six different static background solutions, generalizing the Randall-Sundrum metrics, and established fine-tuning conditions, imposed on the cosmological constant as well as energy densities and pressures of the three-dimensional perfect fluids, situated on the branes. Consequently, the fine-tuning problem, consisting in dubious reality of such conditions, remains here unsolved.

At the same time in the case of the nonempty bulk we arrived at the situation, when there are a lot of static solutions, and the unlikely solvable problem of the physically sensible choice of the background metrics arises immediately. This unsatisfactory situation is a serious drawback of brane world models.

References

1. J.Polchinski, String Theory, Volume 2: Superstring Theory and Beyond, Cambridge University Press, Cambridge, 1998.
2. M.Eingorn and A.Zhuk: 2010, *Class. Quant. Grav.* 27, 205014.
3. C.M.Will, Was Einstein Right? Testing Relativity at the Century, in 100 Years of Relativity: Spacetime Structure – Einstein and Beyond, ed. Abhay Ashtekar, World Scientific, Singapore, 2005.
4. N.Straumann, General Relativity and Relativistic Astrophysics, Springer-Verlag, Berlin, Heidelberg, 1984.
5. L.D.Landau and E.M.Lifshitz, The Classical Theory of Fields, Fourth Edition, Volume 2 (Course of Theoretical Physics Series), Pergamon Press, Oxford, 2000.
6. C.M.Will, Theory and Experiment in Gravitational Physics, Cambridge University Press, Cambridge, 2000.
7. V.A.Rubakov: 2001, *Phys. Usp.*, **44**, 871.
8. A.O.Barvinsky: 2005, *Phys. Usp.*, **48**, 545.
9. L.Randall and R.Sundrum: 1999, *Phys. Rev. Lett.*, **83**, 4690.
10. J. Garriga and T. Tanaka: 2000, *Phys. Rev. Lett.*, **84**, 2778.