TORSION AND THE COSMOLOGICAL CONSTANT PROBLEM

VENZO DE SABBATA and C. SIVARAM

World Laboratory, Lausanne, Switzerland; Dipartimento di Fisica, Università di Ferrara, Italy, and Indian Institute of Astrophysics, Bangalore, India

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Abstract. It is shown that the recently suggested energy-dependent torsion coupling constant can make the spin contributions of matter sources large enough to cancel the cosmological constant term at all stages in the early universe from the Planck epoch.

The so-called problem of the cosmological constant has been receiving considerable attention in recent years. A good current review of the situation concerning the problem is due to Weinberg (1989). Basically the problem is to explain why the effective cosmological constant is so small if not zero at the present epoch vastly less than the values one would expect from elementary particle physics theories. Anything that contributes to the energy density of the vacuum acts just like a cosmological constant the effective vacuum energy density being of the form

\[ \rho_v = \frac{\Lambda_{\text{eff}} c^4}{8\pi G} \]

There would have been large changes in the vacuum energy in the early universe as a result of phase transitions due to the breaking of some symmetry group as the expanding universe cooled. If the symmetry breaking takes place at some energy \( M \), then the induced vacuum energy density is \( \sim M^4 \). For instance at the Planck epoch, \( t \approx 10^{-43} \) s, \( M \approx 10^{19} \) GeV, one would expect a large vacuum energy density term \( \sim 10^{14} \) ergs cm\(^{-3} \), corresponding to an effective cosmological constant \( \Lambda_{\text{Pl}} \approx 10^{66} \) cm\(^{-2} \). This could arise as a result of scale invariance breaking and quantum gravitational contributions to the vacuum energy (Sivaram, 1986a, b, c, 1985) in the very early universe at the Planck epoch. Again the GUTS phase transition at energies \( \approx 10^{15} \) GeV, would similarly induce another large \( \Lambda \) of \( \Lambda_{\text{GUTS}} \approx 10^{50} \) cm\(^{-2} \). There would also be other large contributions from other symmetry breaking phase transitions at the electroweak scale for instance at somewhat later epochs in the early universe.

The question is what has happened to all these large contributions to the \( \Lambda \)-term. Why is the present value of \( \Lambda^{50} \) vanishingly small?

Weinberg summarizes five different approaches undertaken in recent years to understand this question. He consider supersymmetry (exact global supersymmetry would indeed make the vacuum energy and, hence, \( \Lambda \) vanish). But we know that supersymmetry must be broken quite strongly and this would give a large contribution to \( \Lambda \) which would not vanish. There is no symmetry principle known (like gauge invariance in electromagnetism implying zero-photon mass) which would make \( \Lambda \) vanish exactly and Weinberg states that it is very hard to see how any property of...
supergravity or superstring theory could make the effective cosmological constant sufficiently small. He also resorts to the anthropic principle to explain why $\Lambda$ is so small but this is a rather weak argument (see also de Sabbata, 1983, 1984). Again most attempts have involved some sort of adjustment mechanism (e.g., Dolgov, 1982; Wilczek, 1985) which requires some extra scalar field, which evolves and acts as a counterterm to cancel the cosmological term. However, it turns out that in all such attempts the scalar field must have some very special ad hoc properties and involves a lot of ‘fine-tuning’ at all stages, apart from there being no evidence of such extra fields. Other attempts have dealt with changing the structure of Einstein’s equations but this also leads to several consistency problems. Recently there has been a lot of excitement about a new mechanism suggested by Coleman (1988) which follows up an earlier work of Hawking which described how in quantum cosmology there could arise a distribution of values for the effective cosmological constant with an enormous peak at $\Lambda_{\text{eff}} = 0$. Coleman considers the effect of topological fixtures known as wormholes, consisting of two asymptotically flat spaces joined together at a 3-surface, and shows that the probability distribution or expectation values has an infinite peak at $\Lambda_{\text{eff}} \to 0$. However, several objections have been raised, including the reality of wormhole existence, the use of Euclidean quantum cosmology (it is essential that the path integral be given by a stationary point of the Euclideanized action) which may have nothing to do with the real world. Moreover, if the path integral has a phase, that might eliminate the peak in the probability distribution at zero cosmological constant. In short there are too many controversies with Coleman’s very speculative proposal.

One promising possibility which has not been considered so far in understanding the cosmological constant problem is the use of torsion in a framework such as the Einstein–Cartan (E–C) theory which is natural in considering the gravitational contributions of particles with spin which is indeed a universal property of elementary particles. In fact at sufficiently early epochs the energy content of the Universe can indeed be spin dominated and the temporal evolution of the spin-density tensor is important in describing the cosmological dynamics (Trautman, 1973; de Sabbata 1988a, b).

In the Einstein–Cartan theory, the Lagrangian is the usual scalar curvature (de Sabbata, 1985)

$$L_{\text{E-C}} = (-g)^{1/2} R(\Gamma),$$

where $\Gamma$ is non-symmetric affine connection

$$\Gamma_{\alpha\beta}{}^\mu = \left\{ \begin{array}{c} \mu \\ \alpha \beta \end{array} \right\} - K_{\alpha\beta}{}^\mu$$

and $K_{\alpha\beta}{}^\mu$ is the contorsion tensor which is related to the torsion tensor $\mathcal{Q}_{\alpha\beta}{}^\mu \equiv \Gamma_{[\alpha\beta\mu]}$ by

$$K_{\alpha\beta}{}^\mu = - \mathcal{Q}_{\alpha\beta}{}^\mu - Q^{\mu}_{\alpha\beta} + Q^{\mu}_{\beta\alpha}.$$