Astrophys Space Sci (2012) 339:25–30
DOI 10.1007/s10509-012-0978-9

REVIEW

Towards a quantum universe

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Received: 18 November 2011 / Accepted: 5 January 2012 / Published online: 19 January 2012

Abstract In this short review we study the state of the art of the great problems in cosmology and their interrelationships. The reconciliation of these problems passes undoubtedly through the idea of a quantum universe.

Keywords Cosmology · Gravitation theory · Quantum mechanics · General relativity · Large numbers · Cosmological constant

1 Introduction

The great challenge of contemporary physics is to reconcile quantum mechanics, applied at micro cosmos, and general relativity applied, in general, at macro cosmos. General relativity and classical electrodynamics equations are invariant under a scale transformation of time intervals and distances, provided we scale too the correspondent coupling factors. In particular, the scale invariance of general relativity was applied to the strong gravity Salam and Strathdee (1977, 1978), Caldirola et al. (1978), Sivaram and Sinha (1979) that tries to derive the hadron properties from a scaling down of gravitational theory, treating particle as black-hole type solutions. Last years, in several works, it was suggested that also quantum mechanics must be invariant under discrete scale transformations, see Carneiro (1998). All suggest that these two irreconcilable theories, the gravity defined by the General relativity and the quantum mechanics, can be applied to any scale. Should therefore be complementary theories that explain the same physical reality.

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However, the introduction of the Planck's constant h in the quantum mechanics defines a very particular scale, at which the quantum effects must be considered. The quantum equations, as Schrödinger and Dirac ones, are not scale invariants, due to the presence of h. The question that naturally arises is whether it is really a physical constant at any scale.

The invariance under discrete scale transformations appear from one of the curious features between particles physics and cosmology. These features are the possibility of obtaining cosmological large numbers, as mass M_U radius R_U and age T of the universe, scaling up the typical values of mass m, size r and life time t appearing in particle physics, by the scale factor 10^{38-40}. The scale relations are $T/t \sim R_U/r \sim (M_U/m)^{1/2} \sim \lambda = 10^{38-40}$. From here we can scale h in order to obtain the new constant $\mathcal{H}$ of the new scale invariance of quantum mechanics. From a simple dimensional analysis we have $\mathcal{H} \sim \lambda^3 h$. The possible meaning of this new constant $\mathcal{H}$ is that $\mathcal{H}/(2\pi)$ is the angular momentum of a rotating universe and this explanation is close to the Gödel's spin, with the Kerr limit for the spin, and with the Muradian's Regge-like relation for galaxies and clusters, see Carneiro (1998) and references therein. In fact this new constant is $\mathcal{H} \sim 10^{120} h$ and is what is call in Alfonso-Faus (2008) the *cosmological Planck's constant*. With this new Planck's constant no large numbers appear at the cosmological level. In Carneiro (1998) it is also described an intermediate scale invariance of quantization related to the angular momenta of stars and close to the Kerr limit for a rotating black hole with mass around 10^{30} kg. All these ideas suggest treating the universe as a single particle, as we shall see later. In fact as a cosmological quantum black hole. In the following sections we will see that several scaling laws can explain some of the present cosmological problems.