Contribution ID: **64** Type: **Oral Presentation**

A resolution of the cosmological constant problem

Tuesday, 10 July 2012 15:10 (20 minutes)

Abstract content
   (Max 300 words)

In the operator formulation of quantum field theory (QFT) various basic expressions are routinely replaced by normal ordered products to eliminate vacuum contributions. On the other hand, nonzero vacuum expectation values are considered essential in many applications of QFT, leading to a lack of consistency in the treatment of the vacuum. In standard formulations QFT contributes to an absolute vacuum energy, which has serious consequences for the space-time structure of the universe in general relativity. Cosmology puts limits on the magnitude of this vacuum energy and leads to a discrepancy of typically 120 orders of magnitude between theory and observation (the so-called cosmological constant problem).

We suggest a solution to this problem by replacing the normal product by the more fundamental R-product, which mathematically realizes the property that particles and anti-particles have opposite directions (arrays) in interaction diagrams. The product also restores certain symmetries between particles and anti-particles. The imposition of this product must thus be considered as mandatory and must form a –hitherto missing - part of the foundations of QFT. The QFT vacuum energy now vanishes, leading to the resolution of the cosmological constant problem.

However, there are a number of well-known phenomena in physics: zero point energy, vacuum polarization, Lamb shift, the extremely precise measurements of (g-2)_μ , and the condensates in QFT, that are seen as vacuum effects and appear to contradict the R-product. Fortunately, most of these phenomena (in particular those that are predicted accurately) are not affected by the R-product. However, the problem of condensates in QFT requires a reassessment. Broadly speaking universal vacuum condensates must be replaced by fields that are localized near the particle to which they are coupled.

The R-product also plays an essential role in the application of QFT to the localized description of isolated elementary particles, and in fact emerged as a necessary tool from such calculations. Another dramatic consequence of the introduction of this product is that all bosons must be represented as particle-antiparticle configurations, so that the application of the R-product can be implemented for bosons and ensures the vanishing of unacceptable QFT boson vacuum energies.

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Primary author: Dr GREBEN, Jan (CSIR)

Presenter: Dr GREBEN, Jan (CSIR)

Session Classification: Theoretical

Track Classification: Track G - Theoretical and Computational Physics