Particles and Gravity I

Academic year 2006/2007,
lecture: Friday, 10:15–12:00, SDT, class: Tuesday, 14:30 SDT

Gravitational interactions are often considered to be extremely feeble at energies accessible in contemporary particle accelerators, hence they are usually neglected in quantitative discussions of particle physics near the electroweak scale. However, there are good reasons to go beyond this standard approach. Firstly, cosmological applications of particle physics become increasingly relevant, and their better theoretical understanding turns out to be a pressing and demanding challenge. Secondly, theories unifying elementary interactions, like the string theory and local supersymmetry, necessarily include gravity and electroweak and strong interactions at equal footing. Incorporation of gravity into unified picture of fundamental interactions always leads to modifications of 4-dimensional Einstein gravity. Often the electroweak interactions are also influenced by modifications of gravity and mixing between electroweak and gravitational degrees of freedom emerges. It opens up a fascinating new perspective for going beyond the Standard Model of electroweak interactions. This course is intended to provide a basic link between the high-energy physics thought of as a quantum field theory and gravity understood as a theory of fluctuations of a graviton field around certain background. We shall try to introduce at elementary level tools allowing consistent description of Standard Model degrees of freedom interacting with gravity within the framework of field theory, and at the same time to discuss most interesting phenomena in the realm of particle physics that are sensitive to gravitational interactions.

The course will be held in English. It requires some knowledge of quantum mechanics and basics of special relativity. The language of a classical field theory will be adopted, so its knowledge will also be helpful, though not necessary. The lectures should be accessible already to 3rd year students, and fully understandable to 4th and 5th year students. The course can serve as an introduction to the Cosmology course by Prof. Marek Olechowski.

The outline of the course:

1. Brief introduction to classical field theory:
2. Basics of quantum field theory:
   - Path integrals: from fields to particles
   - Forces: attraction v.s. repulsion
3. Gravity as a non-renormalizable field theory:
   - Gravity mediated by gravitons, spin of gravitons,
   - Gravity as a theory of spin 2 gravitons described by a symmetric second rank tensor
   - Graviton field equations
   - Curvilinear coordinates and the tensor analysis
   - The general covariance v.s. local gauge invariance
   - The Einstein's field equations and the Lagrangian formulation of the General Relativity
4. Experimental tests of the General Relativity
   - The Newtonian gravity as a limit of the General Relativity
   - Deflection of light
   - The van Dam–Veltman–Zakharov discontinuity
   - Short distance tests of the Newtonian gravity

Bibliography:
1. S. Weinberg, "Gravitation and cosmology : principles and applications of the general theory of relativity",
2. A. Zee, "Quantum field theory in a nutshell",
3. R. Feynman, F. Moringo and W. Wagner, "Feynman Lectures on Gravitation",

Bohdan Grządkowski