Particles and gravity – lecture program

1. Brief introduction to classical field theory:
   - Special relativity [1]
   - The variational principle and the Lagrange formulation of a classical field theory
   - Electrodynamics and gauge invariance (gauge fixing) [1]
   - The Klein-Gordon field
   - The Dirac field
   - Yang-Mills theories
   - The Noether's theorem for internal symmetries and space-time translations
   - The energy-momentum tensor for the electromagnetic, the Klein-Gordon and the Dirac field
2. Basics of quantum field theory:
   - Path integrals: from quantum mechanics to fields and particles, propagator for massive scalar and vector fields [2]
   - Attraction v.s. repulsion [2]:
     - classical potential for scalar-, vector-mediated interactions
     - propagator for massive spin 2 particle a la Veltman [2, 7] and the classical potential for an exchange of spin 2 quanta
3. Gravity as a field theory:
   - Gravity as a theory of spin 2 gravitons described by a symmetric second rank tensor, construction of the kinetic part of the Lagrangian [3]
   - Field equations for massless gravitons, gauge invariance [3] and the path quantization in the harmonic gauge
   - Propagator for massless gravitons [2]
   - The Lagrangian and the propagator for massive gravitons (the Fierz-Pauli model)
   - The deflection of light by massless and massive gravitons and the van Dam–Veltman–Zakharov discontinuity

4. The General Relativity
    - The principle of equivalence [1]
    - The principle of general covariance [1]
    - Curvilinear coordinates and the tensor analysis [1], [4]
    - The general covariance v.s. local gauge invariance [1]
    - The curvature [1], [4]
    - The Einstein's field equations [1] and the Lagrangian formulation of the General Relativity [1], [4] and [9]
    - Conformal transformations and invariance of the Klein-Gordon and Maxwell equations [9]
5. Experimental tests of the General Relativity
    - The Newtonian gravity as a limit of the General Relativity [1], [4], [10]
    - Deflection of light [1]
    - Short distance tests of the Newtonian gravity [6]
6. Particles in a curved spacetime:
    - Effects of gravitation for a material particle and the electromagnetic field [1]
    - The "minimal substitution rule", the Klein-Gordon field and the electromagnetic field in the General Relativity [9], [3]
    - Fermions in a gravitational field
7. Perturbation expansion and Feynman rules
    - Expansion of the gravitational action around a background gravitational field and the gauge invariance of gravitation [11], [1], [2]
    - Quantization and graviton interaction vertices [7], [8], [2]
    - Graviton polarization tensors and the angular momentum content of massless and massive graviton [3], [12]
8. Extra dimensions and Kaluza–Klein theories:
    - 5D gravity, compactification and the classical Kaluza-Klein picture [10]

- Large extra dimensions (ADD)
- Warped extra dimensions: the Randall-Sundrum model
- Stability of extra dimensions: the radion

9. Gravity at high-energy accelerators:
   - Experimental consequences of large extra dimensions: multiple graviton production at colliders
   - Collider tests of the Randall-Sundrum model
10. The cosmological constant problem and its possible solutions
11. Tunneling in the presence of gravity
12. Quantum mechanics of inflation

Literatura

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