Quantum Field Theory III

Frederik Denef

Transcribed by Ron Wu

This is a graduate course. Offered in Spring 2015 at Columbia University.

Contents

1 GFT in Curved Space **3**

1.1 Free Scalar Field in a Box 3
1.2 Entanglement & Entropy 4
1.3 QFT in Expanding Universe 4
1.4 QFT in dS Space 4
1.5 Unruh Effect 4

Course Outlines

Lecture 1 (1/27/15)

1. QFT in curved space. Ordinary fix curves in gravitational background field, or free QFT in non-inertial space.
   Reference: Mukhanov, Winitzki, *Introduction to Quantum Effects in Gravity.*

2. Quantum gravity

   a) Canonical quantization. treat gravity as ordinary quantum field, not known at the time, this treatment ran into several problem. The technique later gave EFT, but unlikely it will be a complete theory.
      Reference: DeWitt(1967) "Quantum Theory of Gravity".

   b) Semiclassical approximation to quantum gravity. 1970-1980 Worked by Hawkins. The idea is

      $$\text{Gravity} = \text{Thermodynamics}$$

      For example, for black hole

      $$\text{entropy} \rightarrow \text{area}$$

      $$\text{temperature} \rightarrow \text{surface gravity}$$

      For cosmological horizon, there is similar thermodynamical interpretation.

   c) Cosmological constant problem (big open problem) It is measured to be 10^6 times smaller than expected. We will discuss landscape-Weinberg solution.

3. Supersymmetry. The idea is to invent another problem, so that

   $$\text{(problem)+(-problem)=no problem}$$

   so far it has no observable consequence, maybe for extreme high energy we will see Supersymmetry.

4. String theory. This produces massive particles. However there are 10^{500} different string theories. We have no idea which theory is the right one for any specific universe. One success of string theory is that it turns out to be a complete theory (i.e. non perturbatively) for anti-deSitter space (i.e. with negative cosmological constant, looks like gravitational potential well).

5. Holographic theory (Hooft, Thorn) It looks increasingly likely quantum gravity is holographic. String theory is able to quantize degree of freedom of gravity that live at the boundary of the spacetime after we diffeomorphic our universe to antidesitter (Susskind), but we need more, we need to quantize degree of freedom of gravity that live at every point of spacetime. Thus we think maybe our universe is holographic, not string theory. But certainly string theory and supersymmetry provide us good toy model for testing new theory and discovery interesting new mathematics.

1 GFT in Curved Space

The idea is very simple. For free QFT in flat space we think them as decoupled harmonic oscillators

$$w_{\vec{k}} = \sqrt{k^2 + m^2}$$

and $a_{\vec{k}} a_{\vec{k}}^{+}$ count the number of particles. Now apply time-dependent force to the SHO, so Hamiltonian becomes time dependent, so energy is not conserved, so number of particles is not conserved.

Later we will discuss Unruh effect, which claims that for an accelerated observer in Minkowski vacuum will detect particles. And by equivalence principle so does gravitational field produce particles.

1.1 Free Scalar Field in a Box

Lecture 2 (1/28/15)

1.2 Entanglement & Entropy

1.3 QFT in Expanding Universe

1.4 QFT in dS Space

1.5 Unruh Effect

Lecture 3
(2/2/15)