EFT for thermal systems

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Effective theories have been intuitively used in many-body systems for a very long time: centuries ago, it was already understood that water flows can be understood without having to track all particles in them, A coarse-grained description, hydrodynamics, is both more practical and insightful.

When hydrodynamics is applied to systems that are not that large (heavy ion collisions being one example), it becomes important to quantify and control the errors from such coarse-graining. A systematic effective theory approach accomplishes this task; for gas-like thermal systems, effective theories also allow to connect hydrodynamic to the underlying microscopical dynamics.

These lectures will present a sequence of effective theories which have been developed to describe weakly coupled relativistic plasmas at various length scales, ending with the most macroscopic description, relativistic hydrodynamics.

In four lectures I aim to cover the following three main topics:

- Statics: perturbative computations of thermodynamic quantities in scalar and gauge theories; dimensional reduction.
- Dynamics of weakly coupled (gauge) theories: Kinetic theory& Boltzmann equation, screening of long-range interactions and hard thermal loops.
- Relativistic hydrodynamics: gradient expansion; anomaly matching; fluctuation-dissipation theorem and recent developments concerning fluctuations.

Suggested readings

[1] J. I. Kapusta and C. Gale, "Finite-temperature field theory: Principles and applications."

[2] M. Laine and A. Vuorinen, "Basics of Thermal Field Theory," Lect. Notes Phys. **925** (2016) pp.1 [arXiv:1701.01554 [hep-ph]].

[3] P. B. Arnold, G. D. Moore and L. G. Yaffe, "Effective kinetic theory for high temperature gauge theories," JHEP **0301** (2003) 030 [hep-ph/0209353].

[4] P. Romatschke, "New Developments in Relativistic Viscous Hydrodynamics," Int. J. Mod. Phys. E **19** (2010) 1 [arXiv:0902.3663 [hep-ph]].