Sujet de stage de Master 1

Service de *Physique de l'Univers, Champs et Gravitation*

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All possible symmetries of S-matrix (E. Skvortsov)

S-matrix is the ultimate observable in quantum field theory. Therefore, it is important to understand as much as possible about its general properties, without having to appeal to any concrete QFT, Lagrangian and perturbation theory. One of the most important properties of any theory is in the global symmetry it has. This symmetry manifests itself in the S-matrix. One symmetry always present 'by default' is the Poincare symmetry. It is important to know what the options are to have a bigger symmetry: is it always a product of Poincare group with some internal (having nothing to do with space-time) symmetries or not?

This question was settled in an important paper by Coleman and Mandula. The goal of the project is to understand the proof as well as the weak points of the theorem they proved.

As different from many other important QFT-papers, the paper by Coleman and Mandula is short, written in a playful style, is easy to read and does not require a lot of QFT-material to understand it

The most important reference is

[1] All Possible Symmetries of the S Matrix, Sidney R. Coleman, J. Mandula (1967) Published in: Phys.Rev. 159 (1967) 1251-1256

[2] Weinberg, Quantum Field theory 2

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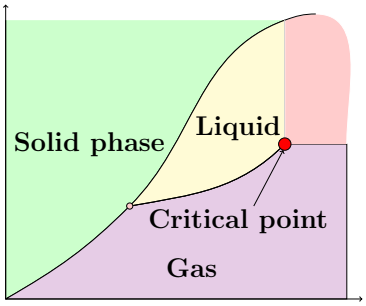
Conformal field theories and universality of second order phase transitions (E. Skvortsov)



Let's have a look at the phase diagram of virtually any substance. It is hard to say anything about any generic point on this diagram as the properties will heavily depend on the material we took. However, there is one point where it is not the case – the critical point where the coexistence curve of gas and liquid ends. This is the point of the second order phase transition.

One remarkable property of second order phase transitions is *universality*, i.e. properties of completely different systems in the critical point and its neighborhood turn out to be the same. For example, these properties are the same for water (basically, any other liquid) and, surprisingly, magnet at the Curie point.

One more remarkable property of second order phase transitions is that any system at the critical point exhibits an enhanced symmetry: the symmetry group jumps from the usual translation+rotatons to a much bigger conformal symmetry. At the same time, the behavior of the system is described by a special class of quantum field theories that are called conformal field theories.

The goal of the project is to understand the phenomenon of universality and the basic properties of conformal field theories.

The most important references are:

[1] Scaling and Renormalization in Statistical Physics Series: Cambridge Lecture Notes in Physics, John Cardy, University of Oxford

[2] TASI Lectures on the Conformal Bootstrap, David Simmons-Duffin, https://arxiv.org/abs/1602.07982