From black holes to wormholes in higher spin gravity (TIFX04-17-29)

Background
Conformal transformations change the scale but preserve angles, properties well-known from analytic transformations of complex functions. Theories possessing conformal symmetries currently attract a lot of interest in research and arise in many different contexts: they are a fundamental ingredient in string/M theory (M for membrane) and play a crucial for our understanding of phase transitions in condensed matter systems, and appear in recent approaches to high Tc superconductivity, the fractional quantum Hall effect and many other strongly coupled systems. Such systems are also analyzed today using AdS/CFT where higher spin generalizations of gravity are a very hot subject. Most of the above physical systems are three-dimensional where Chern-Simons topological theory often plays a key role.

Problem Description
The aim of this project is to give the students a first glimpse of group theory and Lie algebras, with emphasis on the realization of the latter in terms of Poisson brackets, a basic tool in mechanics, and commutators familiar from QM. By “gauging a Lie algebra” we can obtain most of the important theories used in the standard model, gravity, string theory and modern condensed matter theory. Here we derive the equations of conformal and ordinary gravity in three dimensions from Chern-Simons theory. The goal is to find solutions describing the big bang and black holes and how their singularities can be resolved in higher spin theories. The big bang case was done in a BSc thesis in 2015 and in the present project we analyze black holes in a similar way. When resolved they turn into wormholes which are very important in current research in string and M-theory. This incorporation of higher spin fields thus leads to a generalized notion of “geometry” which is not yet fully understood.

Methodology
The project will require a mixture of literature, ranging from textbooks to research and review articles. In order to master the mathematical techniques the students will be encouraged to perform many explicit calculations on their own, mainly by hand. Basic knowledge of special relativity and quantum mechanics is required.

Group size: 3-4 students

Target audience: F, TM, GU Physics

Handledare
Bengt E.W. Nilsson
email tfebn@chalmers.se
office Origo 6104C, phone 031-772 3160
Institutionen för fysik, Chalmers