Emergent properties of space-time

Report of Contributions

https://indico.cern.ch/e/469723

Contribution ID: **1** Type: **not specified**

On the metric theory of gravity

Monday, 20 June 2016 14:00 (1 hour)

I plan to use the introduction to review some past work on emergent symmetries. But then in the spirit of the workshop I will describe some ongoing work on a pathway to describe why general relativity appears as a metric theory, without initially making that assumption.

Presenter: DONOGHUE, John (Unknown)

Contribution ID: **2** Type: **not specified**

Causal Dynamical Triangulations: The emergence of spacetime

Monday, 20 June 2016 15:30 (1 hour)

Causal Dynamical Triangulations (CDT) is a candidate theory for quantum gravity, formulated nonperturbatively as scaling limit of a lattice theory in terms of triangulated spacetimes. I will describe briefly the rationale behind this approach and its ingredients, and will then summarize the status quo of what we have learned so far about its phase structure and dynamical behaviour, focusing mostly on the physical case of four spacetime dimensions.

Presenter: LOLL , Renata

Contribution ID: **3** Type: **not specified**

Emergent stable (2+1)d conformal field theory at the boundary of a class of (3+1)d symmetry protected topological phases

Tuesday, 21 June 2016 10:00 (1 hour)

By definition, a d-dimensional symmetry protected topological (SPT) phase must have nontrivial d-1 dimensional boundary states. The boundary of a large class of (3+1)d SPT phases can be described by a (2+1)d nonlinear sigma model (NLSM) with a topological Wess-Zumino-Witten (WZW) term. We will demonstrate that a stable strongly interacting (2+1)d conformal field theory (CFT) could emerge in the quantum disordered phase in this boundary system, due to the existence of the WZW term. This CFT is stable in the sense that any symmetry allowed perturbation will be irrelevant. In order to perform a controlled calculation, we choose to study the NLSM whose target manifold is the Grassmannian U(N)/[U(n) x U(N-n)], which permits a WZW term in (2+1)d for any N and fixed n, and hence permits a large-N generalization. Through a large-N, large-k, and epsilon generalization of this model, we indeed identify a stable CFT fixed point in the quantum disordered phase through a (quasi) controlled renormalization group calculation.

Presenter: XU, Cenke

Contribution ID: **4** Type: **not specified**

A Higher-Spin Theory of the Magneto-Rotons

Tuesday, 21 June 2016 11:30 (1 hour)

Fractional quantum Hall liquids exhibit a rich set of excitations, the lowest-energy of which are the magneto-rotons with dispersion minima at finite momentum. We propose a theory of the magneto-rotons on the quantum Hall plateaux near half filling, namely, at filling fractions $\nu = N/(2N+1)$ at large N. The theory involves an infinite number of bosonic fields arising from bosonizing the fluctuations of the shape of the composite Fermi surface. At zero momentum there are $O(N)$ neutral excitations, each carrying a well-defined spin that runs integer values 2, 3,... The mixing of modes at nonzero momentum q leads to the characteristic bending down of the lowest excitation and the appearance of the magneto-roton minima. A purely algebraic argument show that the magneto-roton minima are located at $q\ell_B = z_i/(2N+1)$, where ℓ_B is the magnetic length and z_i are the zeros of the Bessel function J_1, independent of the microscopic details.

Presenter: SON, Dam Than

Contribution ID: **5** Type: **not specified**

Relaxation and the emergence of thermalization in an isolated many body quantum systems

Monday, 27 June 2016 14:00 (1 hour)

Presenter: SCHMIEDMAYER , Jörg

Contribution ID: **6** Type: **not specified**

Overview: from qubits to space-time

Wednesday, 22 June 2016 10:00 (1 hour)

In this talk I will make an overview of how space-time properties emerge from the entanglement structure of many-body wavefunctions. I will mainly focus on the connection between Entanglement Renormalization and AdS/CFT, but I will mention briefly other topics such as the appearance of spin networks in symmetric tensor networks, and the definition of "entanglement Hamiltonians" through a bulk-boundary correspondence for Projected Entangled Pair States. I will also discuss several open questions along these directions.

Presenter: ORÚS, Román

Contribution ID: **7** Type: **not specified**

Emergence of bulk locality in the gauge/gravity duality

Wednesday, 22 June 2016 11:30 (1 hour)

Presenter: FREIVOGEL, Ben (University of California at Berkeley)

Contribution ID: **8** Type: **not specified**

Emergence of Symmetries from Entanglement

Wednesday, 22 June 2016 14:00 (1 hour)

Maximal Entanglement appears to be a key ingredient for the emergence of symmetries. We first illustrate this phenomenon using two examples: the emergence of conformal symmetry in condensed matter systems and the relation of tensor networks to holography. We further present a Principle of Maximal Entanglement that seems to dictate to a large extend the structure of gauge symmetry.

Presenter: LATORRE, José Ignacio (Universitat Barcelona)

Contribution ID: **9** Type: **not specified**

Quantum Quenches and Black Hole Formation at large c

Thursday, 23 June 2016 10:00 (1 hour)

Holography allows us to formulate questions about quantum gravity in terms of more ordinary quantum field theories without gravity. A natural and long-standing goal has been to understand the physics of black holes using holographic duality. I will report on some recent progress on this question formulating the spherical collapse of an in-falling shell of null matter in three dimensions in terms of a first-principles CFT calculation. I will argue that the apparent loss of information in the CFT can be traced back to late-time non-perturbative effects in an expansion in large central charge.

Presenter: SONNER, Julian (Universite de Geneve (CH))

Contribution ID: **10** Type: **not specified**

On Information Loss in Two-Dimensional CFT

Thursday, 23 June 2016 11:30 (1 hour)

We discuss information loss from black hole physics in AdS_3, focusing on two sharp signatures infecting CFT_2 correlators at large central charge c: 'forbidden singularities' arising from Euclidean-time periodicity due to the effective Hawking temperature, and late-time exponential decay in the Lorentzian region. We study an infinite class of examples where forbidden singularities can be resolved by non-perturbative effects at finite c, and we show that the resolution has certain universal features that also apply in the general case. Analytically continuing to the Lorentzian regime, we find that the non-perturbative effects that resolve forbidden singularities qualitatively change the behavior of correlators at times t˜S_BH, the black hole entropy. This may resolve the exponential decay of correlators at late times in black hole backgrounds. By Borel resumming the 1/c expansion of exact examples, we explicitly identify 'information-restoring' effects from heavy states that should correspond to classical solutions in AdS_3. Our results suggest a line of inquiry towards a more precise formulation of the gravitational path integral in AdS_3.

Presenter: KAPLAN, Jared (SLAC)

Contribution ID: **11** Type: **not specified**

S-matrix from the Conformal Bootstrap

Friday, 24 June 2016 10:00 (1 hour)

We consider QFT in hyperbolic space and study correlation functions of operators inserted at the conformal boundary. By construction, these observables transform like correlation functions of a lower dimensional Conformal Field Theory. We then apply conformal bootstrap techniques to find universal bounds on the mass spectrum and scattering amplitudes of the QFT. The AdS/CFT correspondence extends this holographic description of QFT to quantum gravity. We comment on how the conformal bootstrap can been used to derive universal properties of quantum gravity.

Presenter: PENEDONES , Joao Miguel (Universidade do Porto (PT))

Contribution ID: **12** Type: **not specified**

Horizon as critical phenomenon

Friday, 24 June 2016 11:30 (1 hour)

We show that renormalization group flow can be viewed as a gradual wave function collapse, where an initial state associated with the action of field theory evolves toward a final state that describes an IR fixed point. The process of collapse is described by the radial evolution in the dual holographic theory. If the theory is in the same phase as the assumed IR fixed point, the initial state is smoothly projected to the final state. On the other hand, the initial state can not be smoothly projected to the final state, if the system is in a different phase. Obstructions to smooth projection appear as dynamical phase transitions, which in turn give rise to horizons in the bulk geometry. We demonstrate the connection between critical behavior and horizon in an example, by deriving the bulk metrics that emerge in various phases of the U(N) vector model in the large N limit based on the holographic dual constructed from quantum renormalization group.

Presenter: LEE, Sunk-Sik

Contribution ID: **13** Type: **not specified**

Entanglement Renormalization and Two Dimensional String Theory

Monday, 27 June 2016 10:00 (1 hour)

Recently, new tools coming from quantum information theory have been used to understand the way spacetime could emerge from underlying microscopic building blocks. These tools allow to systematically analyze the structure of the quantum correlations in the quantum states of quantum many body systems in condensed matter and quantum field theories. Remarkably, it has been hypothesized that they could provide relevant insights into the physics of black holes, horizons and emergent spacetimes.
In this talk, I will first briefly review on one of these tools known as Entanglement Renormalization Tensor Networks, in both its discrete and continuous versions. Then I will present some recent results in which the entanglement renormalization flow of a (1+1) free boson is formulated as a path integral over some auxiliary scalar fields. It will be shown how the resulting effective theory for these fields amounts to the dilaton term of non-critical string theory in two spacetime dimensions. A connection between the scalar fields in these two theories will be provided. The results might help to understand how spacetimes may emerge from distributions of quantum states, or more concretely, from the structure of the quantum entanglement concomitant to those distributions, allowing to acquire novel insights into how a theory of gravity emerges from the entanglement structure of another one without gravity.
I will conclude mentioning a list of relevant challenges in the field.

Presenter: MOLINA-VILAPLANA , Javier

Contribution ID: **14** Type: **not specified**

Classical and Quantum Computing near Conformality

Monday, 27 June 2016 11:30 (1 hour)

We reformulate the O(2) model with a chemical potential and the Abelian Higgs model using the Tensor Renormalization Group method (both on a 1+1 space-time lattice).
The reformulation allows exact blocking, is manifestly gauge invariant and connects smoothly the classical Lagrangian formulation
used by lattice gauge theorists to the quantum Hamiltonian method commonly used in condensed matter.
We calculate the entanglement entropy in the superfluid phase of the O(2) model and show that it obeys the Cardy scaling (c/3)*Ln(L).
We calculate the Polyakov loop in the Abelian Higgs model and discuss the possibility of a deconfinement transition at finite volume.
We propose to use Bose-Hubbard (BH) Hamiltonians with two species as quantum simulators for these models.
Using degenerate perturbation theory, we obtain effective Hamiltonians resembling those relevant for the two models discussed above.
We propose optical lattice implementations of these BH Hamiltonians.

Summary

Presenter: MEURICE, Yannick (University of Iowa)

Contribution ID: **15** Type: **not specified**

Emergent symmetries and lack thereof at quantum critical points in semimetals

Tuesday, 28 June 2016 10:00 (1 hour)

I will review recent work on quantum criticality in three-dimensional gapless semiconductors, which feature quadratic band crossing at the fermi level. These rather ubiquitous systems, such as gray tin and mercury telluride, feature only a Galilean (z=2) invariance at low energies, and should exhibit interesting new phases and transitions as a result of electron-electron and electron-phonon interactions. I will discuss how the phenomenon of fixed point collision replaces the putative Abrikosov's scale-invariant phase with a nematic insulator at low energies, with the former phase leaving a trace in the characteristic separation of scales that ensues. A sufficiently strong electron-phonon interaction, on the other hand, leads to a quantum critical point with emergent particle-hole and rotational symmetries, but also with a non-integer dynamical critical exponent, at which the system develops s-wave superconducting order.

Presenter: HERBUT, Igor (Simon Fraser University)

Contribution ID: **16** Type: **not specified**

A unification of information and matter and a solution of chiral fermion problem

Tuesday, 28 June 2016 11:30 (1 hour)

Presenter: WEN, Xiao-Gang

Contribution ID: **17** Type: **not specified**

Nonrelativistic Naturalness and the Higgs

Thursday, 23 June 2016 14:00 (1 hour)

Presenter: HORAVA, Petr (University of California, Berkeley)

Contribution ID: **18** Type: **not specified**

Quantum error correction and the information structure of holography

Wednesday, 29 June 2016 10:00 (1 hour)

In this talk I will take a quantum information perspective of static holography motivated by AdS/CFT yet agnostic of the underlying theory.
This approach follows the recent trend of deriving the geometry of space from the entanglement structure of a critical boundary theory.
I will provide explicit examples of how these properties may be realized by QECCs obtained from tensor network constructions.
A particular driving principle for these constructions will be the subregion-subregion duality and the entanglement wedge hypothesis.

Presenter: PASTAWSKI, Fernando

Contribution ID: **19** Type: **not specified**

Proof of central charge bounds

Wednesday, 29 June 2016 11:30 (1 hour)

I will discuss a proof of bounds for central charges in unitary CFTs using crossing symmetry and its implication for the average null energy condition.

Presenter: HOFMAN, Diego (Princeton University)

Contribution ID: **20** Type: **not specified**

Emergent conformal symmetry in quantum mechanics and black holes

Wednesday, 29 June 2016 14:00 (1 hour)

Presenter: MALDACENA, Juan (Unknown)

Contribution ID: **21** Type: **not specified**

Non-perturbative definition of the energy-momentum tensor on the lattice

Thursday, 30 June 2016 10:00 (1 hour)

By enforcing suitable relations associated to the Poincar\'e invariance of the continuum theory, it is possible to define an energy-momentum tensor on the lattice which satisfies the appropriate Ward Identites and has the right trace anomaly in the continuum limit. The renormalization conditions come forth when the length of the box in the temporal direction is finite, and they take a particularly simple form if the coordinate and the periodicity axes of the lattice are not aligned. I show an implementation of these ideas for the SU(3) Yang–Mills theory discretized with the standard Wilson action in the presence of shifted boundary conditions in the (short) temporal direction. By carrying out extensive numerical simulations, the renormalization constants of the traceless components of the tensor are determined with a precision of roughly half a percent for values of the bare coupling constant in the useful range 0<g<1.

Presenter: GIUSTI, Leonardo (Universita & INFN, Milano-Bicocca (IT))

Contribution ID: **22** Type: **not specified**

Conformal field theory and energy-momentum tensor on the lattice

Thursday, 30 June 2016 11:30 (1 hour)

Some non-abelian gauge theories coupled with many massless fermions show the conformal behavior in the low energy limit.
The range of the number of fermions, where the theory has the nontrivial infrared fixed point, is called "conformal window".
Recent lattice studies confirm the existence of the conformal window from the first-principle calculation, and clarify those conformal properties, e.g. the scaling behavior, the values of the anomalous dimension and the other critical exponents.
In this talk, I briefly review of these recent lattice works.
Next, one of the important tasks is to determine the central charge of the conformal field theory nonperturbatively.
An approach to this aim is give by the calculation of the multi-point function of the energy-momentum tensor.
However, to calculate EMT using the lattice simulations is a nontrivial task due to the explicit breaking of the Poincaré invariance on the lattice.
I also introduce the recent challenges to calculate the energy-momentum tensor using the lattice gauge theory on the basis of the Yang-Mills gradient flow is proposed.
Furthermore, I may show alternative trial to determine the central charge, namely the measurement of the entanglement within the lattice simulations, if I have a time.

Presenter: ITOU, Etsuko (Kyoto University, YITP)

Contribution ID: **23** Type: **not specified**

The Effective Bootstrap

Friday, 1 July 2016 10:00 (1 hour)

We study the numerical bounds obtained using a conformal-bootstrap method where different points in the plane of conformal cross ratios are sampled. In contrast to previous methods, we can consistently integrate out" higher-dimensional operators and get a reduced simpler, and faster to solve, set of bootstrap equations. We test theeffective" bootstrap by studying the 3D Ising and O(n) vector models and bounds on generic 4D CFTs,
for which extensive results are available in the literature.

Presenter: SERONE, Marco (SISSA)

Contribution ID: **24** Type: **not specified**

Emergent gravity: From Condensed matter analogues to Phenomenology

Friday, 1 July 2016 11:30 (1 hour)

Analogue models of gravity have proved in the past formidable tool for testing quantum field theory in curved spacetime and the robustness of its phenomenology against UV physics.
However, they can be also used as toy models for emergent gravity scenarios. In this talk I will discuss a few lessons which can be learned from these models and consider some of their phenomenological implications amenable to observational or experimental tests in the near future.

Presenter: LIBERATI, Stefano (SISSA)