INTERNATIONAL SOLVAY INSTITUTES BRUSSELS

Abstract Book

Solvay Workshop on

"The asymptotic structure of spacetime"

23 - 24 November 2020

CONTENTS

INVITED TALKS

INVITED TALKS

Supertranslations in higher dimensions

Ankit Aggarwal
ULB, Brussels, Belgium & UvA, The Netherlands

Soft graviton theorems are known to exist in all dimensions. However, BMS symmetries have been claimed to be absent in higher (d>4) dimensions. How to associate the soft graviton theorem with the asymptotic symmetries in higher dimensions? We address this conundrum by computing, from first principles, the asymptotic charges associated with supertranslation symmetry in higher even dimensions and showing that (i) these charges are nontrivial and finite and (ii) the corresponding Ward identities are indeed the soft graviton theorems.

Modular Invariance in Casimir effect

Francesco Alessio
INFN, Napoli, Italy

I will consider the partition function of a free massless scalar living on $T^2 \times R^{d-1}$, where two dimensions, including Euclidean time, are wrapped around two circles and the remaining d-1 are extended. By turning on a chemical potential for the momentum in the compact direction, the partition function of the theory turns out to be a modular form of weight d-1 and can be expressed in terms of the real analytic Eisenstein series, which is one of the most relevant examples of modular forms.

I will discuss the applicability of this result in the context of finite temperature Casimir effect, in order to highlight the modular properties of the partition function and its related high-temperature/low-temperature dualities.

Gravitons in a Casimir box

Martin Bonte
ULB, Brussels, Belgium

I will present how to reformulate the physical degrees of freedom of the linearized gravitational field (spin-2 field) inside a box with Casimir-like boundary conditions, in terms of two massless scalar fields. This allows to compute exactly the partition function, and to find the right observable to add to the partition function to make it modular covariant.

Higher Spin Extensions of the BMS group

Andrea Campoleoni
UMONS, Belgium

We present boundary conditions for higher-spin fields in Minkowski spacetimes of dimension greater or equal to four giving an infinite-dimensional asymptotic symmetry algebra. The latter contains suitable generalisations of both BMS supertranslations and superrotations. We also show that Weinberg's factorisation theorem for amplitudes involving soft particles of any spin can be derived from supertranslation Ward identities.

TMG with Compere-Song-Strominger boundary conditions

Luca Ciambelli
ULB, Brussels, Belgium

Compere-Song-Strominger boundary conditions give a semidirect product of Virasoro and u(1) Kac-Moody asymptotic symmetries. After showing so, I will compute the black holes entropy using thermodynamics in the bulk and prove that it is equal to the degeneracy of states in a warped CFT. I will then demonstrate that at special values of the Chern-Simons coupling the symmetries reduce to either Virasoro or u(1). Studying linear perturbations, we will find a graviton, a photon and a massive mode. These modes have non-negative energy at the special values of the Chern-Simons coupling, indicating that these points are stable. This implies that there exists a stable and consistent gravity theory dual to a theory with u(1) affine symmetry.

Asymptotic symmetries and celestial CFT

Laura Donnay
TUWien, Vienna, Austria

Universal relationships between asymptotic symmetries, QFT soft theorems, and low energy observables have reinvigorated attempts at flat space holography. In this talk, I will review recent advances in the celestial holography proposal, where the 4d S-matrix is reconsidered as a 2d correlator on the celestial sphere at null infinity. In this framework, asymptotic particle states are characterized by the point at which they enter or exit the celestial sphere as well as their SL(2,C) Lorentz quantum numbers: namely their conformal scaling dimension and spin instead of the energy and momentum. I will present a unified treatment of conformally soft Goldstone modes which arise when spin-one or spin-two conformal primary wavefunctions become pure gauge for certain integer values of the conformal dimension.

The Λ-BMS algebroid

Adrien Fiorucci
ULB, Brussels, Belgium

The aim of my talk is to summarize brand-new results obtained in the context of the asymptotically locally (A)dS phase space in arbitrary dimensions. I will explain how to renormalize the Einstein-Hilbert symplectic structure in order to get finite surface charges, without assuming any further boundary condition than the minimal falloffs allowing for conformal compactification. Then I will introduce the Λ-BMS algebroid arising from some boundary gauge fixing which amounts to set a foliation and a measure as universal structure at infinity. The fluctuation of the transverse metric leads to leaky configurations for which the symplectic flux is non-zero at infinity. Finally, I will introduce the flat limit of the Λ-BMS phase space in four dimensions, which reduces to the Generalized BMS_4 phase space including smooth Diff(S^2) super-Lorentz transformations as asymptotic symmetries.

Reference:

- A. FIORUCCI, R. RUZZICONI, *Charge Algebra in Al(A)dS$_n$ spacetimes* (Nov 2020). e-Print: 2011.02002 [hep-th]
- G. COMPÈRE, A. FIORUCCI, R. RUZZICONI, *The Λ-BMS$_4$ Charge Algebra* (Apr 2020). e-Print: 2004.10769 [hep-th]
- G. COMPÈRE, A. FIORUCCI, R. RUZZICONI, *The Λ-BMS$_4$ group of dS$_4$ and new boundary conditions for AdS$_4$* (Sep 2019). e-Print: 1905.00971 [hep-th]

Celestial CFT and extended super-BMS algebra

Angelos Fotopoulos
Northeastern U., Boston, USA

I will discuss celestial amplitudes in Yang-Mills and gravity. A Mellin transform of 4D amplitudes recasts them in the form of conformal correlators in 2D. The proposed holographic correspondence between the 4D theory and its 2D Celestial CFT dual is explored using field theoretical methods. I will show how to use soft and collinear theorems of the Einstein-Yang-Mills theory to derive the OPEs of the operators associated to massless particles. The symmetry underlying the CCFT is expected to be the extended BMS symmetry of (asymptotically) flat space time. I will discuss the realization of the extended BMS symmetry in the CCFT picture for both the purely bosonic and its N=1 supersymmetric extension. The algebra of the supersymmetric BMS generators agrees with expectations based on earlier work on the asymptotic symmetry group of supergravity.

Asymptotic structure of the Rarita-Schwinger theory in 4D at spatial infinity

Oscar Fuentealba
ULB, Brussels, Belgium

In this talk, we investigate the asymptotic structure of the free Rarita-Schwinger theory in four spacetime dimensions at spatial infinity in the Hamiltonian formalism. We impose boundary conditions for the spin-3/2 field that are invariant under an infinite-dimensional (abelian) algebra of non-trivial asymptotic fermionic symmetries. It is shown that the compatibility of this set of boundary conditions with Lorentz invariance requires the introduction of boundary degrees of freedom, along the lines of electromagnetism. We also show that Poincaré transformations have well-defined (integrable, finite) canonical generators. Moreover, improper fermionic gauge symmetries–which are also well-defined canonical transformations–are shown to be parametrized by three independent angle-dependent spinor functions at infinity, which lead to an infinite-dimensional fermionic algebra endowed with a central charge. Finally, we extend the analysis to the supersymmetric spin-(1,3/2) and spin-(2,3/2) multiplets, showing the compatibility of this set of improper fermionic gauge symmetries with super-Poincaré (enhanced by abelian bosonic gauge symmetries) and super-BMS, respectively.

Edge modes and corner symmetries

Marc Geiller
ENS, Lyon, France

The physical relevance of asymptotic symmetries and their charges has been acknowledged for a long time. In this talk we change slightly perspective and focus instead on quasi-local charges for arbitrary subregions, with the aim of presenting a framework for quantum gravity based on the quantization of a so-called corner algebra. After presenting this corner algebra for various formulations of general relativity, we will illustrate its physical content in the case of 3d gravity and 4d tetrad gravity. This will in particular enable us to introduce also a notion of dual charges. Finally, we will end by presenting the formalism of edge modes, whose role is to restore gauge-invariance at boundaries while preserving non-trivial charges.

The asymptotic structure of lower-dimensional spacetimes

Daniel Grumiller
TUWien, Vienna, Austria

I review the asymptotic structure of two- and three-dimensional spacetimes, with emphasis on some recent developments.

Super-geometry of null-infinity and Super-Twistors

Yannick Herfray
ULB, Brussels, Belgium

We will discuss a road-map for investigating the Super-Geometry of Null-Infinity in a systematic way through the use of Super-Twistors. This new strategy is based on some recent non-sypersymmetric results that I recently established: Making use of (local) twistors one can show that the geometry of Null-Infinity is equivalent to an intrinsic Poincaré-valued connection (in particular, the curvature invariantly encodes the presence of gravitational radiations). What is more, this connection can be explicitly related to the bulk Poincaré-connection through a SO(4,2)-valued connection (in the bulk) which encompasses both. I will review these results and explain why they appear to be a perfect starting point for a systematic investigation of the super-geometry of null-infinity in the super space formalism. This is essentially because super-local-twistors have been well-studied and are known to be the correct framework to develop super-conformal gravity in super-space.

Asymptotic symmetries of linearized gravity

Sucheta Majumdar
ULB, Brussels, Belgium

The infinite-dimensional BMS group that arises as the symmetry group of Einstein's theory at asymptotic infinity can also be studied from the perspective of the linearized theory of gravity. The Pauli-Fierz theory, involving free massless spin-2 fields, offers a deeper insight into the nature of these asymptotic symmetries. In this talk, I will discuss the key similarities and differences between the asymptotic symmetry analysis in the full Einstein's theory and the linearized case. For the massless spin-2 fields, invariance under Lorentz boosts leads us to identify the "pure" supertranslations with improper gauge transformations, which are inherently different from the ordinary Poincarè translations. In the last part of the talk, I will briefly discuss another example of BMS analysis in the linearized theory, namely, gravity in the light-cone gauge. I will highlight the main features of the light-cone realization of the BMS algebra and some of its implications.

Asymptotic symmetries at spatial infinity

Javier Matulich
ULB, Brussels, Belgium

The BMS (Bondi-Metzner-Sachs) group was shown long ago to be the group of asymptotic symmetries of gravity in asymptotically flat spacetime. This group naturally emerges at null infinity, however, analyses at spatial infinity did not exhibit any sign of the BMS group. This discrepancy was recently resolved by considering appropriate "parity-twisted boundary conditions" at spatial infinity leading to a full agreement with the result at null infinity. The purpose of this talk will be to briefly describe how the infinite-dimensional BMS group appears at spatial infinity in the case of Electromagnetism and General Relativity and it will provide the context for the subsequence talks on recent efforts on asymptotic symmetries at spatial infinity for the Fiery-Pauli, Rarita-Schwinger and supergravity theories.

Asymptotic realization of the super-BMS algebra at spatial infinity

Turmoli Neogi
ULB, Brussels, Belgium

Explicit boundary conditions are given at spatial infinity for four-dimensional supergravity, which provide a realization of the super-BMS algebra of Awada, Gibbons and Shaw.
The results are then generalized to the N- extended super-BMS algebras.

Celestial CFT

Andrea Puhm
CPHT, Palaiseau, France

I will discuss recent progress on "celestial CFT" proposed to be holographically dual to a bulk theory living on asymptotically flat spacetime.

Coadjoint representation of the BMS group in four dimensions

Romain Ruzziconi
TUWien, Vienna, Austria

The coadjoint representation of a group is the dual of its adjoint representation. At the classical level of a theory, the coadjoint representation of the symmetry group plays a fundamental role through the momentum map. At the quantum level, unitary representations of the symmetry group are related to the coadjoint orbits. In this talk, I will discuss recent advances on the coadjoint representation of the BMS group in four dimensions. The representation will be described in terms of conformal fields, weighted scalars and derivative operators on a two-dimensional surface. The sub-sector of asymptotically flat gravitational solutions at null infinity captured by this representation will be identified.

Flux-balance laws at null infinity

Ali Seraj
ULB, Brussels, Belgium

After an overview of the asymptotic structure of gravity in four dimensional flat spacetime, I will discuss the generalized BMS symmetries and their balance equations derived from the equations of motion.

Finally, I will briefly discuss various applications of the balance equations for radiating systems.

Asymptotic symmetries of YM at spatial infinity

Roberto Tanzi
University of Bremen, Germany

In this talk, I will discuss the asymptotic structure of the free SU(N)-Yang-Mills theory using the Hamiltonian formalism, which allows one to derive the asymptotic-symmetry group from clear-cut first principles. These principles include the minimal assumptions that are necessary to ensure the existence of Hamiltonian structures (phase space, symplectic form, differentiable Hamiltonian) and, in case of Poincaré invariant theories, a canonical action of the Poincaré group. Specifically, I will show that, differently from the electromagnetic case (first studied by Henneaux and Troessaert), the above principles lead to trivial asymptotic symmetries and charges in the Yang-Mills case. This seems to hint at a kind of colour-confinement built into the classical Hamiltonian formulation of non-abelian gauge theories.

Boundary degrees of freedom and asymptotic symmetries

Cédric Troessaert
HERS, Libramont, Belgium

As was shown in the case of electromagnetism, extra boundary degrees of freedom are sometimes needed in order to define the hamiltonian generators associated to asymptotic symmetries. I will show how extra boundary degrees of freedom can also be used to promote leading and subleading boundary conserved quantities to hamiltonian generators.

Charges in three dimensional Bondi gauge

Céline Zwikel
TUWien, Vienna, Austria

In this talk I will discuss the renormalization and the integrability of the charges for generic asymptotically locally AdS and asymptotically locally flat spacetimes written in three dimensional Bondi gauge, without assuming further boundary conditions than the standard falloffs for conformal compactification.