

Applied Newton-Cartan Geometry

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The field of applied Newton-Cartan geometry is currently a rapidly developing field which attracts researchers from different directions. Recent studies of non-AdS holography involving Lifshitz spacetimes have led to field theories with non-relativistic scaling coupled to an extension of Newton-Cartan geometry that includes so-called twistless torsion. Parallel to this development, effective field theories in a Newton-Cartan background have been studied in condensed matter physics and are used to describe a variety of non-relativistic systems such as the fractional quantum Hall effect, chiral superfluids, and simple fluids. Besides the holographic and effective field theory applications, there have been many other recent applications of Newton-Cartan geometry in different fields ranging from hydrodynamics to modified gravity, and even connections to string theory. For instance, it has been shown that Horava-Lifshitz gravity and novel extensions can be described using dynamical Newton-Cartan geometry. Furthermore, Newton-Cartan geometry obeys a duality with its ultra-relativistic cousin, Carroll geometry. Carroll symmetries have been shown to occur as symmetries of strongly coupled gravity and, more recently, of plane gravitational waves while a conformal extension of it is related to the so-called BMS symmetry of flat-space holography. Finally, studying supersymmetric non-relativistic field theories on curved Newton-Cartan backgrounds makes it possible to apply powerful localization techniques to extract exact non-perturbative results for these field theories such as the partition function and the vacuum expectation value of Wilson lines.

The aim of this interdisciplinary topical workshop was to advance the recent exciting applications of Newton-Cartan geometry in different directions and to enable participants from different backgrounds (condensed matter physics, mathematics, statistical physics, gravity and string theory) to interact and exchange new ideas. The first topical workshop of this kind was organized at the Simons Center for Geometry and Physics in Stony Brook (USA) in March 2017. The Simons workshop was a huge success and led to many contacts across different disciplines which otherwise would never have been established. The aim of the Mainz workshop was to repeat the success of the Simons workshop and keep the momentum in this growing research field by organizing a similar topical workshop in Europe.

The schedule of the workshop consisted of a number of 60 minute overview talks, which were given at the beginning of each day, plus a number of 45 minute and 30 minute presentations. Between and after the talks there was ample time for informal discussions.

The week started with an overview of Newton-Cartan Geometry by Matthew Roberts (Imperial College). On the same day there were interesting talks from the mathematical point of view about a twistor formulation of Newton-Cartan spacetimes (Maciej Dunajski, Cambridge) and from the physics point of view about higher-spin extensions (Daniel Gruemiller, Vienna). The day was closed with an informal welcome reception. Tuesday started with an overview talk by Peter Horava (Berkeley) about non-relativistic naturalness thereby putting the issue of non-relativistic physics in a somewhat wider perspective. Other interesting talks that day were presented by Dieter van den Bleeken (Istanbul) who pointed out that the conventional post-Newtonian approximation allows a natural extension to include so-called twistless torsion and by Marios Petropoulos (Paris) about Carrollian hydrodynamics. On Wednesday Jelle Hartong (Edinburgh) gave an interesting overview talk on non-relativistic holographic dualities and the role of non-relativistic strings. Other particularly stimulating talks were the one by Kevin Grosvenor (Copenhagen) about recent coset constructions of non-relativistic geometries and the one by Sergej Moroz (Munich) on a specific application of Newton-Cartan geometry to effective field theory in a condensed matter setting. Thursday opened with an inspiring overview talk by Marika Taylor (Southampton) about BMS symmetries for AdS spacetimes which led to many interesting discussions. Noteworthy talks of the same day were the one by Francisco Pena-Benitez on non-relativistic scaling in semimetals and the one by Giagreco Puletti on Entanglement entropy in generalized Quantum Lifshitz theories. The day was closed with a social conference dinner at a local restaurant in town. The last day of the workshop started with an overview talk by Jan Rosseel on non-relativistic supergravity which gave rise to the hope that non-relativistic supersymmetry may play a crucial role in calculating the exact partition function of a non-relativistic supersymmetric field theory. That same day both Jose Figueroa-O'Farrill (Edinburgh) as well as Stefan Prohazka (Bruxelles) gave talks about specific features of (non-relativistic) kinematical Lie algebras.

Overall, the topical workshop featured a highly communicative atmosphere along with an active participation of all participants. It strengthened already existing networks of collaboration and widened the field of interested researchers. Moreover, the topical workshop led to new collaborations and exchanges. It is also deserves to be mentioned that there was a healthy age distribution, ranging from senior professors to junior faculty and postdocs all the way to younger PhDs, which shows that this field also attracts and stimulates the next generation of researchers. Finally, a proactive effort was undertaken to make sure that there was not only diversity in age, but also in gender, which lead to a (relatively) high fraction of female participants and speakers. The MITP topical workshop revealed that the field of applied Newton-Cartan geometry is currently a rapidly developing field which attracts researchers from different directions, that are inspired to uncover the many possible interconnections and applications. New directions where set in motion at the topical workshop like novel applications of massive gravity in the fractional quantum Hall effect, the role of hydrodynamics without boost invariance

and new applications of torsion in holography and condensed matter physics. Moreover, in the directions that were already under investigation (such as non-relativistic gravity theories, including supersymmetry, relations to non-AdS holography and string theory, connections to novel algebras and symmetry structures, effective field theories) further progress was made thanks to the lively interaction at the topical workshop. There is no doubt that the Mainz workshop has given a significant boost to this emerging field and its cross-disciplinary opportunities.