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Recent PhDs
Recently two students of the RTG obtained their PhD:
- Marvin Pinkwart-Walker, Bremen (20.03.20)
- Eugenia Boffo, Bremen (23.04.20)

New PhD student
Giuseppe Gentile works with Boris Vertman in Oldenburg and joined the RTG in February.

New equal opportunities officers
Audrey Trova (chair) and Sarah Kahlen (substitute) are equal opportunities officers since January.

Upcoming events
The following events will take place online due to Covid-19.
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RTG Colloquia
28.10.20 (Uni Hannover)
25.11.20 (Uni Bremen)

RTG Workshop
06.-08.10.20 (Bielefeld)

Graded and generalized geometry methods for gravity

Eugenia Boffo

Going beyond Einstein’s gravity, from the theoretical viewpoint, is one of the research paradigms of the latest years. Might they try to overcome General Relativity from the IR or the UV, many different strategies have been suggested, often offering new interesting perspectives and solutions to some observations that could not be explained in the classical theory, but also exposing some other problems.

In the course of my PhD under the supervision of professor Schupp we opted for a generalization of Riemannian geometry, Generalized Geometry, conceived as the study of the Whitney sum bundle of a vector space with its dual. It encodes naturally elements of complex and symplectic geometry too. The concept of an algebra on the sections of such bundle was soon noticed to appear in 2-dimensional variational problems of string theory. Hence it is fair to claim that Generalized Geometry provides a more geometrical and algebraic setting to the characterization of the graviton (and the other particles in its multiplet) as done in the theory of closed strings. There is also another rich setup equivalent to Generalized Geometry, that we deployed in our work: graded symplectic geometry with a given (graded) Hamiltonian function.

Combining aspects of both these settings, we could reformulate some gravitational theories, first of all the Supergravity action (for just some of the fields) which is the most natural one in this setting, and afterwards GR and Einstein-Cartan theory too, though the method slightly changed for these. Among the achievements of such reformulation we surely count that it can be applied to gravitational theories with different regimes of validity, thus bringing them together, and that quantization is more straightforward (anyway I have not dealt with this aspect within my PhD studies).

The technique is roughly the following: we started with a graded Poisson algebra of degree 2, where the Poisson bracket on the degree-1 functions has the properties of a metric tensor, and we locally shuffled the velocities, with point-dependent “rotation coefficients”. By doing so, a metric connection arises in the graded Poisson algebra. A Hamiltonian function of degree 3 is constructed: when it does not commute with itself, then the dynamics of a classical probe particle in Einstein’s gravity (and in Einstein-Cartan theory) is found from Hamiltonian mechanics (where the degree 2 function measuring the failure of the degree 3 Hamiltonian to commute is used for that). If instead the degree 3 function is forced to be Hamiltonian, then the symplectic picture is equivalent to an algebroid over $T \mathcal{M} \oplus T^* \mathcal{M}$. The bracket of the algebroid, derived from the Poisson brackets and non-antisymmetric, together with another type of bracket which is antisymmetric, defines a connection on the sections. Choosing a projection to tangent space, the (almost) Hilbert-Einstein action functional of the connection can correspond to the Supergravity action in 10 dimensions, for the NS-NS bosonic sector, due to our specific choices we made. If the geometrical data (the metric, the connection, the projector etc.) were different, other action functionals would be open to studies.
Quantum aspects of cosmology

Marvin Pinkwart-Walker

In the present work we examine the cosmological horizon problem from a quantum mechanical to effectively quantum gravitational perspective. We first note that spacetime coarse graining is a basic property of many quantum gravitational theories. In this spirit, noncommutative and nonassociative models yield spacetime uncertainties. A small time uncertainty is enough to solve the horizon problem without adding a cosmological inflationary process, because this small time uncertainty induces an infinite spatial uncertainty on the initial hyperplane. We interpret this as maximal quantum entanglement of the cosmological quantum state. Then, we analyze noncommutative models that can be used to shed more light on these thoughts. Eventually, we analyze a non-local deformation of quantum field theory; the canonical equal time commutation relations of a scalar quantum field with its canonical momentum allow for an isotropic and homogeneous deformation which incorporates violation of microcausality. The physical core of this consideration can be traced back to a deformed dispersion relation in the Hamiltonian, which allows quantum correlations across the classical light cone. This explicitly Lorentz-violating model furthermore allows to calculate the deformation in the quantum fluctuation spectrum.

In order to measure the initial entanglement (via the principal of deferred measurement) it is necessary to consider a particle probe which propagates on the quantum spacetime and later also on the classical spacetime. The correct quantization of this probe including spin, interactions and gravity, needs a common mathematical framework for the classical theory. For this purpose, we consider graded Poisson brackets which are deformed via gauge interactions and gravity. We show that the bosonic string with Background B-field lifts to a Courant σ-model in which the interaction can be described via a deformed graded Poisson structure. Furthermore, we show that in a sufficiently general framework, interaction can always be described by a shift in the momentum coordinate. Finally, the spinning particle, its coupling to electromagnetism and gravity, as well as the local supersymmetry allow for a formulation in terms of graded Poisson structures, as well.

Ultimately, models have to be compatible with physical observations. In this work we describe two methods which are used to investigate the temperature fluctuations of the Cosmic Microwave Background on the celestial sphere. They allow for the detection of deviations from the standard assumptions of statistical isotropy and non-Gaussianity. Multipole vectors and pseudo entropies are closely related methods (we present this relation) but with distinct focus. We show that the fluctuations are consistent with statistical isotropy on large angular scales with the exception of an (anti-)correlation with the kinetic dipole. Furthermore, the entropy methods allow for the investigation down to small angular scales. There, one can identify ranges which are incompatible with the standard assumptions at approximately $3\sigma$. 

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