MP 9: Geometry, Black Holes, Universality

Time: Thursday 11:00–12:30 Location: KH 02.013

Invited Talk MP 9.1 Thu 11:00 KH 02.013

Light Cone Structure of Quantum Spacetime Geometry — •Wolfgang Wieland — Lehrstuhl für Theoretische Physik III, Friedrich-Alexander-Universität Erlangen-Nürnberg

In Einstein's theory of general relativity, the causal structure of spacetime is itself dynamical. Causality is encoded into the geometry of light cones that bend under the influence of gravity. Quantum theory, on the other hand, tells us that nature is intrinsically probabilistic. A sharply defined causal structure, as it appears in classical general relativity, contradicts quantum theory. A more general framework is needed. This talk outlines a research programme in quantum gravity to develop a mathematical understanding of the causal structure at the quantum level. This is, in fact, a problem common to different approaches from local quantum field theory, to the perturbative S-matrix approach and loop quantum gravity. After a brief introduction into the conceptual aspects of the problem, we will report on several new results on this frontier. First, we explain how to construct physical observables using the light cone geometry. Then, building upon earlier results in loop quantum gravity, we take the description to the quantum level. Finally, we explain how a fundamental quantum discreteness of geometry can alter the spectrum of highly luminous gravitational wave events. The talk is based on arXiv:2504.10802, 2402.12578, 2401.17491, 2104.05803.

MP 9.2 Thu 11:30 KH 02.013

Finite Projective Physics: the world as a process of events — •Klaus Mecke — Universität Erlangen-Nürnberg, Germany

Modern physics is based on the assumption that natural phenomena are the result of force fields and elementary particles moving in a continuous space-time, whereby the dynamics can be described mathematically using differential equations. An alternative to this substance ontology is the assumption that phenomena are processes of elementary events that are causally linked to each other, so that space, time, and matter properties emerge from fundamental process relations. This process ontology - proposed by Alfred North Whitehead - can be formulated mathematically as a finite projective geometry of event points, whereby the dynamics is simply given by local quadratic forms, i.e., by a finite metric field. The task remains to derive from this geometric structure the dynamical laws that are known to be empirically adequate. To this end, finite projective analogues of classical mechanics (time dependence), electrodynamics (spatial gauge fields), and quantum mechanics (random particle events) are formulated and their equivalence to standard analytical theories is demonstrated in the continuum limit. The origin of important concepts such as Legendre transformation, gauge symmetry, and commutator relations can be explained by fundamental features of finite projective geometry, which characterizes any event process. Finally, the possibility of a unified theory of general relativity and quantum field theory of elementary particles is outlined, in which finite projective geometry is the basic structure instead of a differentiable Riemannian manifold.

MP 9.3 Thu 11:45 KH 02.013

Rényi second laws for Charged AdS Black Hole — Alice Bernamonti[1], Federico Galli[1], and •Emiliano Rizza[2] — [1]Università degli Studi di Firenze, Florence, Italy — [2]Jagiellonian University, Krakow, Poland

Hawking's black hole area theorem offers a geometric interpretation of the second law of thermodynamics, imposing fundamental constraints on gravitational dynamics. By examining entropic inequalities following from the monotonicity of Rényi entropies, it is shown that these constraints often set stricter bounds than those imposed by the area theorem in asymptotically AdS space.

This work aims to explore in detail the case of charged AdS black holes, which exhibit rich thermodynamic phase structures in the canonical ensemble. In particular, we study the coalescence of charged black holes in AdS, establishing a lower bound on the mass of the final state and an efficiency bound on the amount of gravitational radiation.

MP 9.4 Thu 12:00 KH 02.013

A New Universality Emerging in the Generic Approach to Stochastic Quantum Scattering — •Simon Köhnes and Thomas Guhr — Universität Duisburg-Essen, Duisburg, Deutschland

Scattering theory is indispensable to understand a variety of systems ranging from nuclei and atoms to systems in mesoscopic and condensed matter physics, but also to wireless communication. These systems often exhibit chaotic dynamics in a broad sense which prompted generic stochastic approaches. Recently we succeeded in deriving the distributions for off-diagonal scattering matrix elements and cross sections by using Random Matrix Theory and Supersymmetry. We arrive at integrals over Goldstone modes, more precisely over a coset supermanifold. These results now facilitate to prove a 60 year old conjecture: Ericson argued that the mentioned distributions become Gaussian or exponential, respectively, in the regime of strongly overlapping resonances. Our proof is based on an asymptotic expansion which we carry out after a proper reparameterization of the multidimensional integration manifold.

MP 9.5 Thu 12:15 KH 02.013

Work versus force: Simultaneous processes for describing interactions — •Grit Kalies[1], Duong D. Do[2], and Cornelia Breitkopf[3] — [1]HTW University of Applied Sciences, Dresden, Germany — [2]The University of Queensland, Brisbane, Australia — [3]Technical University of Dresden, Dresden, Germany

A consistent description of nature is an essential goal that has not been achieved by current theoretical physics, which uses four different fundamental forces to describe interactions. This could change when interactions are described by processes (work is actio) rather than by forces, not only at the macroscopic level but also at the quantum level. We discuss and contrast the two distinct concepts of interaction and interpret the idea of an acting force (force is actio) as a helpful geometric substitute, obscuring the simultaneous processes that actually take place. Using examples such as the lifting, acceleration or displacement of a body as well as of quantum objects, we demonstrate the advantages of applying process equations, including those that describe a change in the momentum of a particle or body. The results indicate that simultaneous processes allow for a more detailed energetic analysis of quantum objects and pave a path for reconciling classical thermodynamics and quantum physics towards a deterministic description of quantum objects.