Cluster of Excellence Precision Physics, Fundamental Interactions and Structure of Matter
PRISMA

Mainz Institute for Theoretical Physics

Quantum Fields – from Fundamental Concepts to Phenomenological Questions

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Understanding the structure of quantum field theories and their observational consequences beyond the realm of perturbation theory constitutes one of the central challenges in theoretical physics. Progress along this research frontier may be the key for answering fundamental questions related to the structure of space, time, and matter. In this spirit, the workshop surveyed both fundamental aspects of quantum spacetime and potential quantum gravity signatures observable in particle physics, black holes, and cosmology. The goal was to develop new roadmaps for obtaining a description of our world valid on all scales and identify new connections between the fundamental descriptions and phenomenological consequences within the various approaches.

The topical workshop was held to the honor Professor Martin Reuter's 60th birthday. The broad scope of the scientific program, comprising 17 short scientific presentations, 3 highlight lectures and many discussion sessions, reflected the wide scientific interest of the laureate. All presentations were on an extremely high level, focusing on recent breakthrough results in the field. The discussion of many recent research highlights revealed how the research field started by Martin Reuter two decades ago has matured into a very active and dynamic area of research. In particular, the broad and diverse research interests of the laureate were reflected in a topical workshop which led to many discussions of potential new connections to neighboring fields. The attitudes of the speakers are well-captured by the following quote by one of the participants "I always wanted to give this talk with Martin in the audience. I always wanted to discuss these developments with him."

The highlight lectures, all given by renowned physicists from the United States, constituted a particularly successful element of the workshop, serving as springboards for ensuing discussions. Two of them focused on "Dynamical dimensional reduction as a universal feature in quantum gravity" (Steve Carlip) and "Prospectives for learning about quantum gravity from cosmological observations" (Abhay Ashtekar) surveying some of the current trends in the field. On the technical side, the very pedagogical lecture presented by Prof. Gerald Dunne outlined the method of "resurgence" as a novel and extremely powerful technique for carrying out non-perturbative computations in quantum mechanics and quantum field theory.

While each of the shorter talks definitely warrant a detailed summary, we just mention three key results presented at the topical workshop. On the fundamental side, the talk by

Benjamin Knorr highlighted that contrary to widespread belief, the theory space of Lorentz-invariant quantum field theories in general does not act as a low-energy attractor for renormalization group flows. Clearly, this insight will have a significant impact on any quantum gravity program including Lorentz-violating effects at the Planck scale. Moreover, the coordinated talks by Gian Paolo Vacca and Alessandro Codello gave a detailed summary of the status and application perspective for determining conformal field theory data from functional approaches. Prospectives for obtaining a predictive quantum field theory comprising gravity and the matter content of the Standard Model have been summarized by Astrid Eichhorn.

A major outcome of the workshop was the suggestion to honor Martin Reuter's outstanding contributions to the development of asymptotic safety by referring to the non-trivial renormalization group fixed points that appear on the theory spaces of pure gravity and gravity-matter systems as "Reuter fixed points".

Concerning future developments, the construction of the quantum effective action for gravity and gravity matter-systems was flagged as one of the main targets. First steps in this direction were outlined in the presentations by Omar Zanusso, Basim El-Menoufi and Frank Saueressig. Perspectives of using this object to connect various approaches to quantum gravity and quantum gravity phenomenology were discussed. Finding the vacuum state associated with asymptotic safety and the transition from Euclidean to Lorentzian signature, computations were identified as important conceptual questions which should be addressed in the near future. Throughout the presentations and discussion it became apparent that many approaches to quantum gravity and, in particular the asymptotic safety program, have reached a maturity where key physics related to cosmology, blackholes, and the Standard Model of particle physics can be addressed from a fundamental perspective.

The organizers are also very happy that they were able to award two "Universe Presentation Prices" for young scientists (400 SFR each) to Alessia Platania and Basem El-Menoufi for their outstanding presentations on "Cosmological bounds on the field content of asymptotically safe gravity-matter models" and "Infrared quantum gravity: status report". Moreover, proceedings of the topical workshop will be published in a special issue "Quantum Fields – from fundamental concepts to phenomenological questions" within "Universe".