

## MITP Program Final Report

**Title:** Quantum Vacuum and Gravitation

**External organizers:** Manuel Asorey, Emil Mottola, Ilya Shapiro, Andreas Wipf

**List of participants:**

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Prof. Ruth Durrer, Department of Theoretical Physics, Geneva University

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Dr. Alessandro Fabbri, Centro Studi e Ricerche Enrico Fermi

Prof. Valeri Frolov, Dept. of Physics, University of Alberta

Mr. Drazen Glavan, Utrecht University

Prof. Daniel Grumiller, TU Wien, Institute for Theoretical Physics

Prof. Claus Kiefer, Institute for Theoretical Physics, University of Cologne

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Prof. Ralf Schuetzhold, Faculty of Physics, University Duisburg-Essen

Dr. Julien Serreau, APC, University Paris Diderot

Prof. Ilya Shapiro, Universidade Federal de Juiz de Fora

Prof. Alexei Starobinsky, Landau Institute for Theoretical Physics

Prof. Osman Teoman Turgut, Dept. of Physics, Bogazici University

Prof. William Unruh, UBC,

Prof. Matt Visser, Victoria University of Wellington

Prof. Christof Wetterich, Universität Heidelberg - Institute for Theoretical Physics

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## **1. General purposes and scope of the event**

The workshop was especially focused on the field-theoretical methods like the functional renormalization group and conformal anomalies. The issues related to the implications in Astrophysics and Cosmology were also included, with special focus on Cosmology, Black Hole physics and the study of Analogue Models in Condensed Matter and Quantum Optics. In the cosmological part we had some review talks which included the latest experimental and observational data and their understanding in the framework of existing theoretical constructions. Due to the difficulties in experimental verification of the quantum phenomena such as Hawking radiation, we were interested and included an account of the analog models, which are supposed to mimic the same physical behavior and might serve as testing grounds for the interplay between quantum field theory and gravity.

## **2. General overview of the event**

In our evaluation the event was very successful. The talks were always given at the very high scientific level and attracted a lot of attention of the participants and also from the side of local group of theoretical physics, which is well-known by research works in the areas of the workshop. All the talks had some students attending them. The program of the event was very dense, since organizers did not deny to any participants the right to present his/her work in the oral form. A few review talks had 60 minutes for presentation and most of them had 40 minutes. By the end of each day of the event there was a special discussion section, devoted to the talks of the day and related subjects. These discussions were very intensive and fruitful for better understanding of the problems which are in the focus of attention of the nowadays high-energy and gravitational physics.

The brief contents of the review talks was as follows:

Prof. Christof Wetterich from Heidelberg University told us about the general status and role of the quantum vacuum in cosmology. In particular, he addressed the following questions: What is the vacuum in cosmology? Does inflation allow us to observe vacuum properties? Can we compute the vacuum for Gravity? How well justified are "natural guesses" for the value of the cosmological constant? What is the role of scale symmetry and its spontaneous breaking? The quantum part of the talk was based on the functional renormalization group (Wetterich equation) which enables one, in principle, to evaluate the non-perturbative quantum effects for vacuum. This first talk attracted a lot of attention and we had long and interesting discussion about its contents.



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Prof. William Unruh from University of British Columbia gave a review talk about the analog models for black holes in hydrodynamics and explained how the thermal spectrum can be observed in the acoustic waves, such that it can be interpreted as a version of the Hawking evaporation of black holes. Other examples and views of analog models were discussed in the talks by Prof. Ralf Schuetzhold from University Duisburg-Essen and by Dr. Alessandro Fabbri Centro Studi e Ricerche Enrico Fermi.

Prof. Alexei Starobinsky gave a detailed review talk about present status of inflation, and perspectives of future discoveries. Present knowledge about physical properties of an inflationary stage in the early Universe, including curvature and its rate of change, inflaton mass, etc, which follows from the latest observational data. Different possibilities to make new fundamental discoveries were discussed. There are strong arguments to show that the measured value of the slope of the primordial spectrum of scalar (density) perturbations, under some natural additional assumptions, implies small, but not too small amount of quantum primordial gravitational waves generated during inflation,  $r > 0.001$ , similar to that in the original  $R+R^2$  inflationary model (1980). Thus, perspectives of their discovery seem promising. Features in the CMB temperature anisotropy power spectrum in the multipole range  $l=20-40$  are of interest in this respect, too, and may point to some new physics during inflation including the existence of new elementary particles more massive than the inflaton.

Prof. Ruth Durrer from Geneva University presented an interesting review on the Cosmic Microwave Background (CMB) and its relation for Quantum Physics. The development of CMB measurements, from the era of COBE to Planck, marks an impressive progress in the knowledge of the Universe. Hence it was very important for our theoretical meeting, to learn how the results of these enormous amount of data can be seen from the theoretical and especially quantum perspective.

Prof. Valeri Frolov from University of Alberta told about recent works about the singularity problem in the black holes with non-local and local form factors in the higher derivative terms. The singularities are traditionally considered to be the most important indications to the modifies gravity, which is supposed to erase singularity and hopefully provide some detectable consequences at the larger-distance scale. In the case of Newtonian singularities we know that, in general, higher derivatives and quantum corrections remove the singularity. However, in the non-linear case of black hole, the situation is much more subtle and interesting. Very interesting and promising theoretical results were obtained recently and were reviewed in this talk.

Prof. Martin Reuter from University of Mainz gave a general review of Functional Renormalization Group approach and, in particular, on the application to the asymptotic safety program in Quantum Gravity. Functional Renormalization Group enables one to go beyond the conventional perturbative approach and this is especially relevant for the



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quantization of gravity which meets well-known difficulties at the perturbative level. The works on the asymptotic safety in Quantum Gravity attracted a great deal of attention in the last decades and it was instructive for the participants to have a review on this issue from the main developer of this idea. Other talks on the same subject were delivered by Prof. Julien Serreau from University Paris Diderot and by Prof. Daniel Litim from Sussex University.

A more complete account of the contents of the talks can be seen from the list of Abstracts which goes in the Attachment of the present report. Furthermore, the slides of all presentations are available at the homepage of the meeting.