Programme on

"Modern Theory of Wave Equations"

July 6 - September 30, 2015

organized by

Colin Guillarmou (ENS Paris), Werner Müller (U Bonn), Alexander Strohmaier (Loughborough U), András Vasy (Stanford U)

Workshop II on

"Hyperbolic Equations on Spacetimes: Stability, microlocal Analysis and Quantum Field Theory"

September 7 - 11, 2015

- **Monday, September 7, 2015**

  09:00 – 09:30 **Opening & Registration**

  09:30 – 10:30 **Robert Wald**
  Introduction to Quantum Field Theory in Curved Spacetime

  10:30 – 11:00 *coffee / tea break*

  11:00 – 12:00 **Chris Fewster**
  On preferred states for QFT in curved spacetimes

  12:00 – 14:30 *lunch break*

  14:30 – 15:30 **Peter Hintz**
  Quasilinear waves on Kerr-de Sitter spacetimes

  15:30 – 16:00 *break*

  16:00 – 17:00 **Lars Andersson**
  Symmetries and conservation laws

- **Tuesday, September 8, 2015**

  09:30 – 10:30 **Mihalis Dafermos**
  The inside story of black hole stability

  10:30 – 11:00 *coffee / tea break*

  11:00 – 12:00 **Dietrich Häfner**
  Scattering theory for Dirac and Klein-Gordon fields on the (De Sitter) Kerr metric and the Hawking effect

  12:00 – 14:30 *lunch break*

  14:30 – 15:30 **Yakov Shlapentokh-Rothman**
  Scattering for the wave equation on Kerr black hole exterior spacetimes

  15:30 – 16:00 *break*

  16:00 – 17:00 **Rainer Verch**
  KMS-like properties of local thermal equilibrium states in quantum field theory

- **Wednesday, September 9, 2015**

  09:30 – 10:30 **Gunther Uhlmann**
  Seeing Through Space Time

  10:30 – 11:00 *coffee / tea break*

  11:00 – 12:00 **Christian Gerard**
  Hadamard states on spacetimes of bounded geometry

  12:00 – 14:30 *lunch break*

  14:30 – 15:30 **Igor Khavkine**
  Graviton propagator on Schwarzschild spacetime

  15:30 – 16:00 *break*

  16:00 – 17:00 **Michal Wrochna**
  From global propagators to quantum fields: the case of asymptotically Minkowski and extended de Sitter space

  from 19:00 **HEURIGER**

- **Thursday, September 10, 2015**

  10:00 – 11:00 **Klaus Fredenhagen**
  From quantum field theory on Lorentzian manifolds to perturbative quantum gravity I

  11:00 – 11:15 *coffee / tea break*

  11:15 – 12:15 **Kasia Rejszner**
  From quantum field theory on Lorentzian manifolds to perturbative quantum gravity II

  12:15 – 14:00 *lunch break*

  14:00 -15:00 **Claudio Dappiaggi**
  Constructing Isometry Invariant Hadamard States via a Novel Deformation Argument

  Free remaining Afternoon

- **Friday, September 11, 2015**

  09:30 – 10:30 **Dang Nguyen-Viet**
  Equidistribution of the conormal cycle of random nodal sets

  10:30 – 11:00 *coffee / tea break*

  11:00 – 12:00 **Stefan Hollands**
  Entanglement entropy in quantum field theory

  12:00 – 14:30 *lunch break*

  14:30 – 15:30 **Jan Sbierski**
  A dezornification of the proof of the existence of a maximal Cauchy development for the Einstein equations

  15:30 – 16:30 **Piotr Chrusciel**
  Singularities in General Relativity

All talks take place at the ESI, Boltzmann Lecture Hall!

Abstracts:

Lars Andersson: Symmetries and conservation laws

Abstract: In this talk I will discuss some recent work on conservation laws for field equations on spacetimes admitting Killing spinors and related higher order symmetries. Important examples are provided by test fields on the Kerr family of spacetimes.

Piotr Chrusciel: Singularities in General Relativity

Abstract: I will review old and new results about singularity formation in general relativity.

Claudio Dappiaggi: Constructing Isometry Invariant Hadamard States via a Novel Deformation Argument

Abstract: Existence of Hadamard states for a free field theory on a globally hyperbolic spacetime has been proven via a metric deformation argument, proposed by Fulling, Narkowich and Wald in the eighties.The main deficiency of this scheme is the complete loss of any control on the invariance of the state under the action of the background isometries. In order to account for them, one needs to resort to specific construction schemes which are often valid for a given free field with a fixed value of the mass and, if present, of the coupling to scalar curvature. Via an extended version of the Mller operator, we show that, these isometry invariant Hadamard states can be deformed to Hadamard states for any value of the mass and of the coupling to scalar curvature. Furthermore the invariance under any spacelike isometry is preserved, while, for the timelike ones, a kind of adiabatic procedure is necessary. (Joint work with Nicol Drago (U. of Genoa) - arXiv:1506.09122 [math-ph])

Christian Gerard: Hadamard states on spacetimes of bounded geometry

Abstract: I will describe work in progress with Michal Wrochna and Omar Oulghazi on a new construction of Hadamard states on Lorentzian spacetimes of bounded geometry, like for example the exterior region in Kerr-de Sitter spacetime or the Kerr-Kruskal extension. As an application a proof of the Hadamard property of the in/out vacuum states in a rather general scattering framework will be given.

Chris Fewster: On preferred states for QFT in curved spacetimes.

The vacuum state of Minkowski space quantum field theory is distinguished as a state of maximal symmetry. General curved spacetimes have no nontrivial symmetry and therefore lack an obvious candidate vacuum state. Nonetheless, one might wonder whether there is still a way of selecting a preferred state. I will discuss various aspects of this issue, describing a general no-go theorem that excludes the existence of a local and covariant choice of preferred state and also results due to Verch and myself, and Brum and Fredenhagen, concerning a recent class of states originally introduced by Afshordi, Aslanbeigi and Sorkin under the name SSJ state", including an extension to Dirac fields in a recent joint paper with Lang.

Stefan Hollands: Entanglement entropy in quantum field theory

The talk starts with general definitions and properties of entanglement entropy in quantum field theory. Then I will present various bounds for entanglement entropy in various classes of models such as chiral CFTs, 1+1 dimensional integrable models or free fields. (Joint work with K. Sanders)

Igor Khavkine: Graviton propagator on Schwarzschild spacetime

Abstract: The study of graviton Hawking radiation, renormalized interactions of dynamical gravitons with other matter fields, and quantum back reaction of Hawking radiation on the black hole horizon all require the knowledge of the graviton propagator on a black hole spacetime. I will describe an explicit mode-decomposed construction of the de Donder gauge graviton propagator for the Unruh state on the eternal Schwarzschild spacetime. De Donder gauge is chosen for its covariance and locality properties. This is joint work with F. Bussola (Trento).

Jan Sbierski: A dezornification of the proof of the existence of a maximal Cauchy development for the Einstein equations

Abstract: In 1969, Choquet-Bruhat and Geroch showed that there exists a unique maximal Cauchy development of given initial data for the Einstein equations. Their proof, however, has the unsatisfactory feature that it relies crucially on the axiom of choice in the form of Zorn's lemma. In particular, their proof ensures the existence of the maximal development without actually constructing it.

In this talk, we present a proof of the existence of a maximal Cauchy development which avoids the use of Zorn's lemma and, moreover, provides an explicit construction of the maximal development.

Gunther Uhlmann: Seeing Through Space Time

Abstract: We consider inverse problems for the Einstein equation with a time-depending metric on a 4-dimensional globally hyperbolic Lorentzian manifold. We formulate the concept of active measurements for relativistic models. We do this by coupling Einstein equations with equations for scalar fields.

The inverse problem we study is the question of whether the observations of the solutions of the coupled system in an open subset of the space-time with the sources supported in this set determine the properties of the metric in a larger domain? To study this problem we define the concept of light observation sets and show that knowledge of these sets determine the conformal class of the metric. This corresponds to passive observations from a distant area of space which is filled by light sources.

We will start by considering inverse problems for scalar non-linear hyperbolic equations to explain our method.

This is joint work with Y. Kurylev and M. Lassas.

Rainer Verch: KMS-like properties of local thermal equilibrium states in quantum field theory

Abstract: to follow shortly

Robert Wald: Introduction to Quantum Field Theory in Curved Spacetime

Abstract: The formulation of quantum field theory in curved spacetime is reviewed. Since quantum fields are distributional in nature, expressions involving products of fields are intrinsically ill defined. The role of microlocal analysis in characterizing the properties of physically acceptable states and in formulating well defined renormalization prescriptions to define products and time-ordered-products of fields is explained.