Adam Mickiewicz University in Poznań

Doctoral School of Exact Sciences AMU

Quantum Field Theory in Curved Spacetimes

dr Ko Sanders

Scientific lectures, workshops

Field of science	Mathematics
Teaching method	Lectures
Language	English
Numbers of hours	20
Aims of the course	This course aims to provide an up-to-date introduction to the mathematical structure of Lagrangian Quantum Field Theories in curved spacetimes. A particular topic of interest are the Energy Conditions of General Relativity and the corresponding Quantum Energy Inequalities for quantum fields. We will discuss their range of validity and their consequences for the mathematical structure and for the physical predictions of the framework (e.g. the celebrated Singularity Theorems of Hawking and Penrose).
Course contents	Classical field theory: • Lagrangian densities, equations of motion including Einstein's Equations in General Relativity • locality, covariance and initial value formulations • Energy Conditions in General Relativity (interpretation and consequences, e.g. singularity theorems) Quantum Field Theory (QFT): • Algebraic/locally covariant QFTs, C*-algebras, states and GNS-representations, Lagrangian QFTs • free scalar QFTs as a toy model (canonical commutation relations, operator algebraic description, Hadamard states) Quantum Energy Inequalities (QEIs): • renormalized quantum stress tensors for free scalar QFTs • violation of pointwise Energy Conditions • stress tensor bounds on free scalar quantum fields.
Prerequisites and co-requisites	The course requires a good working knowledge of linear algebra and functional analysis (Banach and Hilbert spaces). It also assumes some previous exposure to differential geometry, partial differential equations and, ideally, some distribution theory. A general interest in physics is expected and some basic knowledge of quantum physics and relativity theory would be beneficial.

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<tr><th colspan="2">Learning outcomes</th></tr>
<tr><th>On completion of the course PhD candidates will be able to:</th><th>Assessment mode</th></tr>
<tr><td>demonstrate an understanding of the mathematical structures arising in the description of quantum field theories in curved spacetimes
confidently work with basic models, such as free scalar quantum fields
discuss the definition of the stress tensor for classical and quantum fields
discuss the role of energy conditions in classical and quantum field theory with a view to their validity and applications.</td><td>E_W01
E_W02
E_U01
E_U02
E_U05</td></tr>
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<tr><td>Literature</td><td>Lecture notes will be provided.
Additional literature:
Quantum Field Theory on Curved Spacetimes, eds. C. Bär and K. Fredenhagen, Springer, Heidelberg, Lecture Notes in Physics Vol. 786 (2009)
Quantum field theory in curved spacetimes and black hole thermodynamics, R.M. Wald, University of Chiacgo Press, Chicago (1994)</td></tr>
<tr><td>Additional information</td><td></td></tr>
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