Geometric analysis with applications to general relativity

Supervisor: Oliver Petersen

Einstein's theory of general relativity models the universe as a curved spacetime. My research mainly concerns wave equations on curved spacetimes. These describe for example the propagation of electromagnetic fields, gravitational waves and in fact the evolution of the universe itself.

There are many interesting mathematical questions in this field, including the following:

- *Does mathematics tell us that there was a Big Bang at the beginning of the universe?* This corresponds to showing that certain non-linear wave equations have a blow-up to the past, i.e. that the energy becomes infinite.
- *Is a black hole stable to gravitational perturbations?* Here one wants to show that the energy of non-linear wave equations disappear into the black hole or escapes to infinity.
- *Could there be other types of black holes in the universe than the ones we already know of?* This problem was solved by Stephen Hawking in 1972, assuming that the gravitational field is real analytic. Attempts to remove the analyticity assumption are usually based on unique continuation methods for linear wave equations.

These classical questions need to be attacked with modern methods of differential geometry and partial differential equations. Progress on these topics usually comes when we understand exactly how the geometry and analysis interact. I often use microlocal analysis in my research approach, in particular propagation of singularities. For wave equations, this is the theorem that regularity of a solution propagates along lightlike geodesics, i.e. the paths in the spacetime along which light travels.

Our research group at Stockholm University works closely together with the research group on Differential Geometry and General Relativity in the mathematics department at KTH, which is just a 20 minutes walk from our department. Together we provide an active environment for mathematical research in general relativity with many possible collaborators.

You find more information about my research here:

Oliver Petersen at Stockholm University.

There are many potential research topics suitable for PhD studies in this field. Please do not hesitate to contact me at oliver.petersen@math.su.se if you have any questions or want to know about concrete research questions for a PhD project.

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