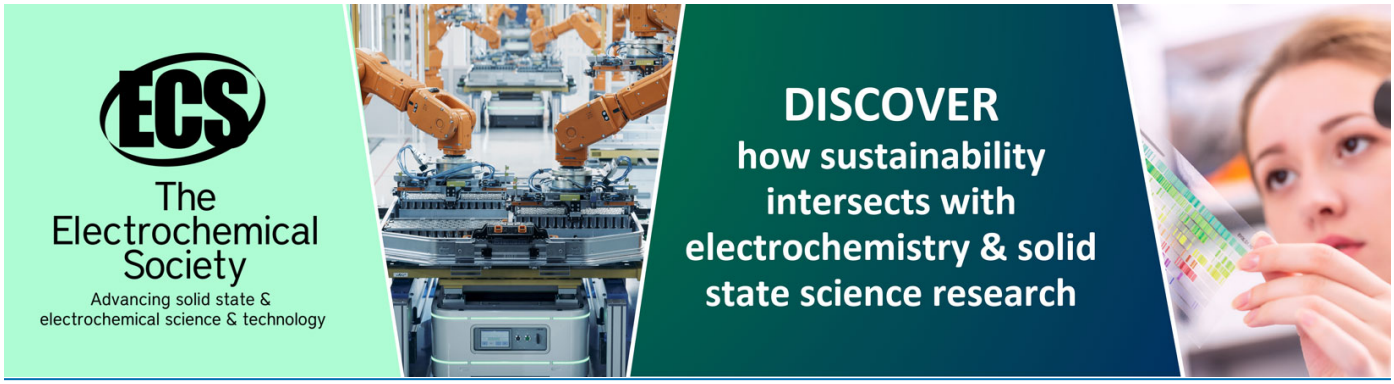
# Non-Regular Spacetime Geometry





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# Preface

Until recently, mathematical studies of Lorentzian causality theory assumed, explicitly or implicitly, smoothness of the metric. This changed a few years ago, after independent work by Fathi and Siconolfi, and by Chruściel and Grant. Since then many papers began to explore causality under weaker conditions such as $C^{1,1}$ metrics, Lipschitz metrics, continuous metrics (and cone structures), or even topological settings. Indeed, new insights are needed when the metric is not twice-differentiable. Hence, manifolds for which the metric is not $C^2$ might be called non-regular, though closer inspection reveals that there are not so many differences between the $C^2$ and the $C^{1,1}$ theories, so one can also refer to the non-regular theories as those whose metric has regularity below $C^{1,1}$.

In Riemannian signature geometers studied non-regular manifolds using comparison geometry and other approaches. Many of these techniques have yet to be exported to the Lorentzian signature since, of course, a number of difficulties have to be addressed. In spite of this, mathematical physicists study non-regular spaces with a strong motivation that stems from the desire of understanding the ultimate nature of spacetime. The idea is that at the quantum level and hence whenever the physical conditions become extreme (say gravitational collapse, or origin of the universe) the spacetime manifold should perhaps not be approximated by a smooth manifold. If this expectation is correct then an understanding of the role of differentiability conditions in general relativity might give hints to the very nature of gravity and spacetime at the quantum scale.

The Florence meeting provided an opportunity for the mathematical relativists interested in non-regular spacetime geometry to get together with mathematical and theoretical physicists interested in non-commutative geometry, in particular in Connes' program for the unification of the fundamental forces. The meeting was also open to related contributions which could help shed light on the geometry of spacetime at the deepest (non-regular) level.

The talks were roughly divided into five interrelated subjects:

(i) Lorentzian geometry and field theory under low differentiability assumptions, (Galloway, Graf, Harris, Khavkine, Klinger, Sbierski, Steinbauer, Vickers);

(ii) Cone structures and time functions under low differentiability assumptions (Bernard, Minguzzi, Siconolfi, Suhr);

(iii) Measures and optimal transport over Lorentzian manifolds (Finster, Martinetti, Miller);

(iv) Length spaces and Alexandrov geometry (Sämann, Alexander);

(v) Non-commutative geometry and other algebraic or quantum related approaches to spacetime (Besnard, Finster, Franco, Minguzzi).

The meeting confirmed that interest in the non-regular aspects of spacetime geometry is gaining momentum. Recent publications, often by young researchers, are improving our understanding of this topic, and much is expected and hoped for in the future.

It was a pleasure to organize the first dedicated meeting on non-regular spacetime geometry, and we are thankful to the many researchers who have contributed to make it a successful event. We are happy that many of the participants contributed to this proceedings volume.

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We cannot end this preface without thanking the Rector of the University of Florence, Luigi Dei, the director of the Department of Mathematics and Informatics "U. Dini" in Florence, Giorgio Ottaviani, and Professor Patrizia Pera for contributing to the financing of the meeting. Several participants benefitted from the financial support from the Department of Mathematics of Vienna University and the Austrian Science Fund FWF.

The meeting took place from June 20 to June 22, 2017, at Centro Didattico Capponi, via Gino Capponi 9, right in the city center of Florence. We thank the President of the School of Educational Sciences Gianfranco Bandini for letting us use the classrooms in such a central and wonderful location.

Piotr T. Chruściel
James Grant
Michael Kunzinger
Ettore Minguzzi

*Editors/Scientific Committee*
Piotr T. Chruściel
James Grant
Michael Kunzinger
Ettore Minguzzi

*Local Organizing Committee*
Daniel Canarutto
Ettore Minguzzi (Chair)
Omar Morandi

*Participants*
Stephanie Alexander, Patrick Bernard, Fabien Besnard, Piotr T. Chruściel, Felix Finster, Nicolas Franco, Greg Galloway, Melanie Graf, James Grant, Stacey Harris, Igor Khavkine, Paul Klinger, Michael Kunzinger, Pierre Martinetti, Tomasz Miller, Ettore Minguzzi, Valter Moretti, Clemens Sämann, Jan Sbierski, Antonio Siconolfi, Roland Steinbauer, Stefan Suhr, James Vickers.

A picture of the last day of the meeting. From left to right. Sämann, Harris, Minguzzi, Vickers (behind), Siconolfi, Bernard, Martinetti, Klinger (behind), Alexander, Galloway, Moretti, Finster, Besnard, Suhr, Khavkine, Miller, Sbierski, Franco, Graf, Steinbauer, Kunzinger, Grant.

Unfortunately, Piotr T. Chrusciel is missing since he had to leave on the day before.