Aspects of Gravity, Mathematics and Physics

1 Schedule

Monday, March 21st

- 9h45 : Welcoming coffee
- 10h-10h50 : Guillaume Bossard, Polytechnique
- 10h50-11h05 : Coffee break
- 11h05-11h55 : Zoe Wyatt, University of Cambridge
- 12h-12h50 : Harvey Reall, University of Cambridge
- 12h50-14h15 : Lunch Break at the Magnan
- 14h15-15h05 : Eleonora di Nezza, Polytechnique
- 15h05-15h20 : Coffee break
- 15h20-16h10 : Jose Luis Jaramillo, Université de Bourgogne Franche-Comté
- 16h15-17h05 : Martin Taylor, Imperial College London

Conference dinner at La Contre-Allée

Tuesday, March 22sd

- 9h45 : Welcoming coffee
- 10h-10h50 : Nicolas Besset, Université Paris Saclay
- 10h50-11h05 : Coffee break
- 11h05-11h55 : Danièle Steer, Université de Paris
- 12h-12h50 : Michal Wrochna, Université de Cergy
- 12h50-14h15 : Lunch Break at the Magnan

- 14h15-15h05 : Leonhard Kehrberger, University of Cambridge
- 15h05-15h20 : Coffee break
- 15h20-16h10 : Blagoje Oblak, Sorbonne/Polytechnique
- 16h15-17h05 : Grigorios Fournodavlos, Princeton/University of Crete

2 Abstracts

Guillaume Bossard *Unravel hidden symmetries in gravity*

Einstein's equations with commuting isometries are known to exhibit hidden symmetries from Ehlers and Geroch. Many attempts have been done in trying to extend these symmetries to the full untruncated equations. The same question arises naturally in Cremmer-Julia-Scherk supergravity, with important implications in string theory. Some advances have been done in this direction following ideas of West, Samtleben and Hohm that have allowed Kleinschmidt, Sezgin and myself to define a formulation of eleven-dimensional supergravity with an extended Kac-Moody covariance. In this talk I will explain this formulation for the vacuum Einstein's equations in four dimensions.

Zoe Wyatt *Global Stability of Spacetimes with Supersymmetric Compactifications*

Spacetimes with compact directions which have special holonomy, such as Calabi-Yau spaces, play an important role in supergravity and string theory. In this talk I will discuss a recent work with Lars Andersson, Pieter Blue and Shing-Tung Yau, where we show the global, nonlinear stability a spacetime which is a cartesian product of a high dimensional Minkowski space with a compact Ricci flat internal space with special holonomy. This stability result is related to a conjecture of Penrose concerning the validity of string theory. Our proof uses the intersection of methods for quasilinear wave and Klein-Gordon equations, and so towards the end of the talk I will also comment more generally on coupled wave–Klein-Gordon equations.

Harvey Reall *Well-posedness and causality in gravitational effective field theories*

Fundamental theories predict corrections to General Relativity, which can be described using Effective Field Theory (EFT). EFT can also be used as a framework for studying possible deviations from GR in the strong field regime probed by observations of gravitational waves from black hole mergers. I will discuss well-posedness of the initial value problem, and causality, in various gravitational EFTs.

Eleonora di Nezza *Singular Kähler-Einstein metrics*

After Yau's proof of the Calabi conjecture in the 80's, the Monge-Ampère operator played a central role in geometric problems, such as the existence of special metrics on a compact Kähler manifolds. In fact, it turns out that solving a complex Monge-Ampère equations is equivalent to the existence of a Kähler-Einstein metric. In the " smooth" case (when the manifold is smooth) we have a complete picture (in every dimension!): we know the obstructions and we have existence and uniqueness results as well. The "singular" case is much more complicated and still in development. In this talk I will present some results in the singular settings.

Jose Luis Jaramillo *Pseudospectrum and black hole quasi-normal modes: a universal Regge ultraviolet-instability conjecture*

Can we measure the 'effective regularity' of spacetime from the perturbation of quasi-normal mode (QNM) overtones? Black hole (BH) QNMs encode the resonant response of black holes under linear perturbations, their associated complex frequencies providing an invariant probe into the background spacetime geometry. In the late nineties, Nollert and Price found evidence of a BH QNM instability phenomenon, according to which perturbed QNMs of Schwarzschild spacetime migrate to new perturbed branches of different qualitative behaviour and asymptotics. Here we revisit this BH QNM instability issue by adopting a pseudospectrum approach. Specifically, we cast the QNM problem as an eigenvalue problem for a non-selfadjoint operator by adopting a hyperboloidal formulation of spacetime. Non-selfadjoint (more generally non-normal) operators suffer potentially of spectral instabilities, the notion of pseudospectrum providing a tool suitable for their study. We find evidence that perturbed Nollert and Price BH QNMs track the pseudospectrum contour lines, therefore probing the analytic structure of the resolvent, showing the following (in)stability behaviour: i) the slowest decaying (fundamental) mode is stable, whereas ii) (all) QNM overtones are ultraviolet unstable. Building on recent work characterizing Burnett's conjecture as a low-regularity problem in general relativity, we conjecture that (in the infinite-frequency limit) generic ultraviolet spacetime perturbations make BH QNMs migrate to 'Regge QNM branches' with a universal logarithmic pattern. This is a classical general relativity (effective) low-regularity phenomenon, agnostic to possible detailed descriptions of gravity at higher-energies and potentially observationally accessible.

Martin Taylor *The nonlinear stability of the Schwarzschild family of black holes*

I will present a theorem on the full finite codimension nonlinear asymptotic stability of the Schwarzschild family of black holes. The proof employs a double null gauge, is expressed entirely in physical space, and utilises the analysis of Dafermos–Holzegel–Rodnianski on the linear stability of the Schwarzschild family. This is joint work with M. Dafermos, G. Holzegel and I. Rodnianski.

Nicolas Besset *Scattering theory for the charged Klein-Gordon equation in the De Sitter-Reissner-Nordström spacetime.*

Scattering theory describes the long time behaviour of a physical system by comparing the underlying dynamics with a simpler one. We construct such a theory for the charged Klein-Gordon equation in the De Sitter-Reissner-Nordström spacetime. The absence of the charged Klein-Gordon field in the coupled Einstein-Maxwell system forces us to work in a Kaluza-Klein extended spacetime which contains a black ring. The starting equation then becomes a wave equation and the comparison dynamics is a simple transport along null geodesics towards the horizons. Understanding the scattering properties of scalar fields is a prerequisite for the construction of quantum fields in curved spacetimes.

Danièle Steer *TBA*

Michal Wrochna *A spectral action for gravity in Lorentzian signature*

The spectral zeta function of the Laplace-Beltrami operator on a Riemannian manifold is known to be intimately related to geometric invariants such as the Einstein-Hilbert action. A priori, however, this only applies to the case of Euclidean signature.

In this talk I will report on a joint work on this problem with Nguyen Viet Dang (Sorbonne Université). We consider perturbations of Minkowski space and more general spacetimes on which the wave operator is essentially self-adjoint by a result of Vasy. We demonstrate that a Lorentzian spectral zeta function can be defined, and it turns out to have similar local geometric content as in the Riemannian case.

The primary consequence is that gravity can be obtained from a spectral action directly in Lorentzian signature. The proofs involve ingredients that have been used previously in the context of stability of Einstein equations (Vasy's Fredholm estimates) and Quantum Field Theory on curved spacetimes (Feynman propagators).

Leonhard Kehrberger *On the Relation Between Late-time Tails, Conserved Charges and the Failure of Peeling*

I will first explain how one can use certain conservation laws to read off late-time tails of gravitational perturbations of black holes from their "peeling behaviour" near future null infinity. In particular, I will show that the late-time tails drastically change from the usual Price's law asymptotics if peeling fails, i.e. if null infinity is not conformally smooth in the sense of Penrose. Finally, building on arguments by Christodoulou and Damour, I will show that peeling should indeed be expected to fail in physical situations, and thus give an alternative prediction for late-time tails to the usual Price's law asymptotics.

Blagoje Oblak *Gyroscopic Gravitational Memory*

In this talk, I argue that gravitational waves cause freely falling gyroscopes to precess relative to fixed distant stars, extending the stationary Lense-Thirring effect. The precession rate decays as the square of the inverse distance to the source, and is proportional to a suitable Noether current for dual asymptotic symmetries at null infinity. Integrating the rate over time yields a net rotation that may be seen as a gravitational memory effect encoded by the gyroscope's orientation. Its angle reproduces the known spin memory effect but also contains an extra contribution due to the generator of gravitational electric-magnetic duality.

Grigorios Fournodavlos *The mysterious nature of the Big Bang singularity*

100 years ago, Kasner discovered the first exact cosmological solutions to Einstein's field equations, revealing the presence of a striking new phenomenon, namely, the Big Bang singularity. Since then, it has been the object of study in a great deal of research on general relativity. However, the nature of the 'generic' Big Bang singularity remains a mystery. Rivaling scenarios are abound (monotonicity, chaos, spikes) that make the classification of all solutions a very intricate problem.

I will give a historic overview of the subject and describe recent progress that confirms a small part of the conjectural picture.