Networking Workshop - March 2 – 4, 2015

RTG Models of Gravity 1620 and RTG Quantum and Gravitational Fields 152

Abstracts:

Ammon, Martin
Gravity meets condensed matter

The dynamics of strongly coupled condensed matter systems near quantum critical points is still poorly understood since conventional methods such as perturbation theory are not applicable. After reviewing shortly quantum phase transitions and their role in particular condensed matter systems, I will show how we may be able to get insights into such systems using gravity and the renowned AdS/CFT correspondence. AdS/CFT is considered to be one of the most exciting conceptual developments in theoretical physics within the last two decades and relates ordinary quantum field theories to gravity. Utilizing our knowledge and numerical methods within gravitational systems we can further our understanding of field theories which mimic strongly coupled condensed matter systems.

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Ansorg, Marcus
Conformal Mappings for Spectral Methods in Classical Field Theory

In this introductory talk we discuss pseudo-spectral methods as numerical techniques for solving partial differential equations in classical field theory. We address in particular the advantages of using conformal mappings in this concept. After the presentation of basic ideas and approaches, exemplary situations within General Relativity are discussed, such as the construction of binary black hole initial data and the gravitational field around black holes surrounded by rotating perfect fluid rings. At the end of the talk we sketch the applicability of spectral methods to time evolution equations appearing in classical field theory (cf. talk R. Macedo).

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Blazquez, José
Rotating black holes in Einstein-Maxwell-Chern-Simons theory with negative cosmological constant

We study 5 dimensional black holes in Einstein-Maxwell-Chern-Simons theory (EMCS), with free Chern-Simons coupling parameter, and asymptotically AdS. We consider a event horizon with spherical topology, and both angular momenta of equal magnitude. We study both extremal and non-extremal solutions. We discuss some properties of the pure Einstein-Maxwell case and compare to the EMCS case. We find that above a critical value of the Chern-Simons coupling constant there are non-static extremal solutions with vanishing angular momentum. These solutions form a sequence which can be labeled by the node number of the magnetic U(1) potential. Their global charges are different, but they all share the same near horizon geometry. We discuss several kinds of non-uniqueness found in these solutions.

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Fennen, Michael

Initial data for a black hole universe

Since the Universe is only homogeneous at the largest scales, it is necessary to develop inhomogeneous cosmological models. Therefore we consider an universe in which the matter is modelled by a discrete distribution of black holes. For a spacelike hypersurface with vanishing extrinsic curvature it is possible to solve the Lichnerowicz equation for the spatial metric exactly. The result is simply the superpostion of black hole solutions. We show that, in case of negligible amount of dust, this solution is similar to the Swiss-cheese model by Einstein and Strauss at the moment of maximal expansion.

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Giesel, Kristina

Quantum Einstein Equations in Loop Quantum Gravity

The classical starting point for loop quantum gravity is general relativity formulated in terms of Ashtekar variables, which is a particular extension of the ADM phase space. We will review how one can obtain the corresponding quantum theory by using canonical quantization and will discuss the properties of the quantum theory as well as the differences to ordinary quantum field theory. The dynamics of the quantum theory is described by the so called quantum Einstein equations, the quantum analog of Einstein's equations. We will discuss the current status of the dynamics and explain how the quantum Einstein equations can be reformulated in a gauge invariant way using a reduced phase space approach for loop quantum gravity.

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Grenzbach, Arne

The Shadow of accelerated Black Holes

In this talk I present how to calculate the shadow of black holes in the Plebański-Demiański space-time. With the resulting analytical formulas I investigate the influence of the acceleration on the shadow. Essential for the calculations is the existence of (unstable) spherical light rays in a region K around the black hole because these light rays determine the boundary of the shadow. After transformation to celestial coordinates on the observer’s sky, the shadow is viewed via stereographic projection as usual. Our observer could be located at arbitrary Boyer-Lindquist coordinates outside of the horizon.

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Gruber, Christine

Geometric thermodynamics and its application in non-equilibrium and black hole physics

We aim at developing a geometrical formulation of thermodynamics by employing contact geometry and associated notions. A geometric formulation of thermodynamics is of interest for several reasons. Firstly, geometry serves as a language in which every physical theory can be formulated, it provides geometric tools and notions which can be employed to infer new principles and ideas, and in general promotes mathematical beauty in physics. Secondly, a geometrisation of thermodynamical theories would help to systemize and unify the phenomenologically orientated formulations and derivations of thermodynamical phenomena and potentially be of great use in the description of non-equilibrium scenarios. And finally, due to the fundamental connection of the laws of black hole thermodynamics with their geometry, there is the hope that a geometric theory of thermodynamics could lead to new insights into black hole thermodynamics and the physical laws governing the physics of black holes.
After an introduction into the mathematics of the subject, we will introduce possible applications of contact geometry and its formulation of thermodynamics in non-equilibrium systems and black holes, respectively.

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Grunau, Saskia:

Thermodynamics of a rotating black hole in minimal five-dimensional gauged supergravity

We study the thermodynamics of a general non-extremal rotating black hole in minimal five dimensional gauged supergravity. We analyse the entropy-temperature diagram and the free energy. Additionally we consider the thermodynamic stability by calculating the specific heat, the isothermal moment of inertia tensor and the adiabatic compressibility.

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Janka, Hans-Thomas (Max Planck Institute for Astrophysics, Garching)

Fundamental Physics and Astrophysics Problems around the Birth and Death of Neutron Stars

The birth of neutron stars by the collapse of stellar cores and their death in violent binary mergers are catastrophic events, which are connected to spectacular phenomena like supernovae and gamma-ray bursts and to important open questions in stellar astrophysics. They also offer possibilities to probe regimes of extreme physics that are hardly accessible by laboratory experiments and direct observations. Numerical simulations are therefore indispensable to improve our understanding of the processes in the obscured interior of these explosive phenomena. The talk will review recent progress in a fast-moving field from a theorist's perspective. In particular, it will show how new insights are fostered by the enormous advances in three-dimensional computational modeling.

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Kalisch, Michael:

Pseudo-spectral solutions of non-uniform black strings in 6 dimensions

The most simple way for obtaining black hole solutions of Einstein's vacuum field equations in dimensions higher than 4 (let's say in D-1 dimensions) is to generalize the well-known Schwarzschild metric (Schwarzschild-Tangherlini solutions). From this, the (uniform) black string is constructed by adding an additional compact dimension to the metric, and stretching out the horizon uniformly over this dimension (while the spherical symmetry in the other D-2 spatial dimensions is maintained). Now, if the horizon radius varies over the compact dimension, we end up with a non-uniform black string (NBS).

In particular we are interested in NBS solutions with highly deformed horizons. To obtain those numerically, a pseudo-spectral multi-domain method was used. The talk will show, how this is applied to get high accuracy despite the fact that there are some difficulties one has to deal with (non-analytic terms, steep gradients). Addressing the controversially discussed question, whether there is a maximum of the NBS mass at a certain deformation or not, we can support the results of Kleihaus, Kunz, and Radu (see arXiv:hep-th/0603119, there is a maximum). So far the calculations are performed in D=6 dimensions.

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Kichakova, Olga

Non-Abelian axially symmetric composite configurations in AdS4 spacetime

We construct new finite energy both regular and black hole solutions in Einstein-Yang-Mills-SU(2) theory in asymptotically anti-de Sitter spacetime . They are static, axially symmetric and are related to the Bartnik-McKinnon solutions in the asymptotically flat space limit. Solutions are constructed by numerically solving the elliptic Einstein-DeTurck-Yang-Mills equations. Thermodynamical properties of the corresponding hairy black hole solutions are discussed.

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Kunst, Daniela

Isofrequency pairing of spinning particles in Schwarzschild-de-Sitter spacetime

Einstein's theory of general relativity leads to the prediction of gravitational waves, i.e. oscillations in the gravitational field propagating at the speed of light. One observable feature is the frequency of a gravitational wave. These frequencies can be related to the fundamental ones of the dynamical system representing the source. It was long thought that the frequencies uniquely describe the state of a conservative dynamical system and therefore offer clear information on the underlying source. However, it has been shown that the system of a testparticle moving around a Schwarzschild or Kerr black hole contains states with degenerate frequencies. Thus, having the frequencies is not sufficient to make a distinct deduction on the state of the dynamical system evoking obstacles for the scientists who are interpreting gravitational wave signals. In order to make the system more astrophysically relevant we investigate the system of a spinning particle moving in a Schwarzschild geometry with a positive cosmological constant.

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Lippoldt, Stefan:

Fermions in gravity with local spin-base invariance

We study a formulation of Dirac fermions in curved spacetime that respects general coordinate invariance as well as invariance under local spin-base transformations. The natural variables for this formulation are spacetime-dependent Dirac matrices subject to the Clifford-algebra constraint. In particular, a coframe, i.e. vierbein field is not required. This observation is of particular relevance for field theory approaches to quantum gravity, as it can serve for a purely metric-based quantization scheme for gravity even in the presence of fermions.

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Macedo, Rodrigo

Axisymmetric fully spectral code for hyperbolic equations

We present a fully pseudo-spectral scheme to solve axisymmetric hyperbolic equations of second order. With the Chebyshev polynomials as basis functions, the numerical grid is based on the Lobbato (for two spatial directions) and Radau (for the time direction) collocation points. We discuss how to overcome the caveats, typically appearing on pseudo-spectral schemes: (i) the inversion of a dense matrix and (ii) the acquisition of a sufficiently good initial-guess for non-linear systems of equations. For the first issue, we use the iterative bi-conjugate gradient stabilized method, which we equip with a pre-conditioner based on a singly diagonally implicit Runge-Kutta ("SDIRK"-) method. The SDIRK-method also supplies the code with a good initial-guess. The numerical solutions are correct up to machine precision and we do not observe any restriction concerning the time step in comparison with the spatial resolution. The code has been applied to solve general-relativistic wave equations on a black-hole space-time and we plan to extend its applications to problems relevant to the gauge/gravity duality.

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Mojica Gómez, Sindy

Quadrupole Moments of Rapidly Rotating Compact Objects in Dilatonic Einstein-Gauss-Bonnet Theory

Rapidly rotating compact objects are considered laboratories to test general relativity and theories beyond. We determined observables such as the mass, the angular momentum, the moment of inertia, or the quadrupole moment for neutron stars and black holes in dilatonic Einstein-Gauss-Bonnet theory, a theory motivated by string theory. We used several equations of state (EOS) for the neutron matter and considered the dependence of the observables on the EOS and on the Gauss-Bonnet coupling constant.

While there is a considerable EOS dependence for the observables themselves, the relation between the scaled moments of inertia and the scaled quadrupole moments is almost independent of the EOS, when the scaled angular momentum is held fixed.

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Moldenhauer, Niclas

Initial data for binary neutron stars with adjustable eccentricity

Binary neutron stars in circular orbits can be modeled as helically symmetric, i.e., stationary in a rotating frame. This symmetry gives rise to a first integral of the Euler equation. For eccentric orbits, however, the lack of helical symmetry has prevented the use of this method, and the numerical relativity community has often resorted to constructing initial data by superimposing boosted spherical stars, which leads to spuriously excited neutron star oscillations during the evolution. We consider eccentric configurations at apoapsis that are instantaneously stationary in a rotating frame and extend the notion of helical symmetry to eccentric orbits. We use the obtained first integrals as the basis of a self-consistent iteration of the Einstein constraints to construct conformal thin-sandwich initial data for eccentric binaries. We discuss that effect of the improved data on the evolutions, e.g. by looking at the spurious stellar oscillations and the tidally induced oscillations.

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Radu, Eugen

Kerr black holes with scalar hair

According to the conventional picture, black holes are extremely constrained objects, determined only by a few global charges. Such simplicity of black holes became immortalized in John Wheeler's mantra "black holes have no hair". In this talk, I will discuss a novel mechanism that allows black holes to have 'hair' and challenges the standard paradigm.
The Kerr black holes with scalar hair are asymptotically flat solutions of Einstein's gravity minimally coupled to a complex, massive scalar field. They are supported by rotation and have no static limit. Some possible astrophysical consequences will also be addressed.

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Palenta, Stefan

The characteristic initial value problem of colliding plane gravitational waves

Abstract: We consider the general initial value problem of colliding plane waves as search for a vacuum spacetime with 2 spacelike Killing vectors. This leads to the hyperbolic Ernst equation which can be treated by inverse scattering, showing many analogies to stationary axisymmetric spacetimes. With help of a corresponding linear Problem and a Riemann-Hilbert problem the solution to the Ernst equation can be expressed as an integral over jump functions. By expanding these jumps in Chebychev polynomials we get interesting approximative solutions.

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Panosso Macedo, Rodrigo

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We present a fully pseudo-spectral scheme to solve axisymmetric hyperbolic equations of second order. With the Chebyshev polynomials as basis functions, the numerical grid is based on the Lobbato (for two spatial directions) and Radau (for the time direction) collocation points. We discuss how to overcome the caveats, typically appearing on pseudo-spectral schemes: (i) the inversion of a dense matrix and (ii) the acquisition of a sufficiently good initial-guess for non-linear systems of equations. For the first issue, we use the iterative bi-conjugate gradient stabilized method, which we equip with a pre-conditioner based on a singly diagonally implicit Runge-Kutta ("SDIRK"-) method. The SDIRK-method also supplies the code with a good initial-guess. The numerical solutions are correct up to machine precision and we do not observe any restriction concerning the time step in comparison with the spatial resolution. The code has been applied to solve general-relativistic wave equations on a black-hole space-time and we plan to extend its applications to problems relevant to the gauge/gravity duality.

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Schwarz, Dominik

Cosmology at the largest scales
Opportunities with SKA and its pathfinders

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Vysoký, Jan
Connections and Gravity Actions via Generalized Geometry

Dorfman bracket is a natural tool in generalized geometry. It turns out that its twisting by a metric instead of a skew-symmetric two form leads to connections with skew-symmetric contorsion tensor which are compatible with this metric. A scalar curvature of such connections gives precisely the terms in Einstein-Hilbert type gravitational action appearing as a low energy closed string effective action. Non-trivially twisted Dorfman bracket is presented and its axioms are shown to give the required properties of the connection.