12th Central European Relativity Seminar

February 21-23, 2022, Budapest (hybrid)

Schedule

Monday, February 21

8:30 – 9:50 Registration

9:50 – 10:00 Opening

Chair: Piotr T. Chruściel

10:00 – 11:00 **Zoe Wyatt** (University of Cambridge) – *Relativistic fluids on cosmological spacetimes*

11:00 – 11:20 Coffee break

11:20 – 11:40 **Alejandro Penuela Diaz** (Potsdam Uni-AEI) – *Local foliations of surfaces characterizing the center of mass*

11:40 – 12:00 **Áron Szabó** (Nicolaus Copernicus University) – *Optimal coordinates for Ricci-flat conifolds* – online

12:00 – 12:20 **Argam Ohanyan** (University of Vienna) – *The Hawking-Penrose singularity theorem for C^1-Lorentzian metrics*

12:20 – 14:00 Lunch break

Chair: István Rácz

14:00 – 14:20 **Gustav Nilsson** (Albert Einstein Institute, Golm) – *On the topology of gravitational instantons with symmetry*

14:20 – 14:40 **Markus Wolff** (Universität Tübingen) – *A note on non timesymmetric Initial Data sets* – online

14:40 – 15:00 **János Östör** (BME & Wigner RCP) – Λ-*vacuum initial data on compact Cauchy surfaces*

15:00 – 15:40 Coffee break and poster session

15:40 – 16:00 **Filip Ficek** (Jagiellonian University) – *The Schrödinger-Newton-Hooke equation - existence and stability of the bound states* – online

16:00 – 16:20 **Florian Steininger** (University of Vienna) – *On massive photons in dielectrics*

Tuesday, February 22

Chair: Peter C. Aichelburg

10:00 – 11:00 **Leor Barack** (University of Southampton) – *Self-force approach to the two-body problem in GR*

11:00 – 11:20 Coffee break

11:20 – 11:40 **Siyuan Ma** (Albert Einstein Institute) – *Sharp asymptotics of Teukolsky equation on Kerr spacetimes* – online

11:40 – 12:00 **Dániel Barta** (Wigner RCP) – *Radial and non-radial oscillation modes of compact stars*

12:00 – 12:20 **Viktor Skoupý** (Charles University) – *Adiabatic equatorial inspirals of a spinning body into a Kerr black hole*

12:20 – 14:00 Lunch break

Chair: Zoltan Bajnok

14:00 – 14:20 **Bernardo Araneda** (Albert Einstein Institute, Potsdam) – *Twistor geometry, non-linear structures, and perturbation theory*

14:20 – 14:40 **Albachiara Cogo** (Eberhard-Karls-Universität Tübingen) – *Equipotential Photon Surface Uniqueness in Electrovacuum*

14:40 – 15:00 **Barbora Bezdekova** (Charles University, Prague) – *Necessary Conditions for the Existence of the Carter Constant in a General Axially Symmetric Stationary Spacetime in Plasma and its Applications* – online

15:00 – 15:40 Coffee break and poster session

15:40 – 16:00 **Alberto Roper Pol** (APC) – *The gravitational wave signal from primordial magnetic fields in the Pulsar Timing Array frequency band*

16:00 – 16:20 **Károly Csukás** (The University of Mississippi) – *Superradiant scattering of wave packets with compact initial support* – online

Wednesday, February 23

Chair: Herbert Balasin

9:30 – 9:50 **Mariem Magdy Ali Mohamed** (Queen Mary, University of London) – *Asymptotic charges for spin-1 and spin-2 fields at the critical sets of null infinity* – online

9:50 – 10:10 **Sajad Aghapour** (AEI) – *Nonlocal charges in linearized gravity*

10:10 – 10:30 **Marica Minucci** (Queen Mary University of London) – *The Maxwell-scalar field system near spatial infinity* – online

10:30 – 11:10 Coffee break

Chair: András László

11:10 – 11:30 **Edgar Gasperin** (Instituto Superior Técnico, Lisbon) – *Staticity and regularity for zero rest-mass fields near spatial infinity on flat spacetime* – online

11:30 – 11:50 **Thomas Mieling** (University of Vienna) – *Interferometry of Entangled Quantum States of Light in Curved Space-Time* – online

11:50 – 12:10 **Shalabh Gautam** (ICTS, Bengaluru, India) – *Some ongoing Efforts for Evolving Einstein Field Equations on Hyperboloidal Slices* – online

12:10 – 12:30 **Mario Hudelist** (University of Vienna) – *Relativistic Theory of Elastic Bodies in the Presence of Gravitational Waves* – online

Abstracts

Talks

Nonlocal charges in linearized gravity

Sajad Aghapour, AEI, sajad.aghapour@aei.mpg.de

We demonstrate how a two-potential variational formulation of linearized gravity can be used to define a set of nonlocal conserved quantities, most notably the classical helicity and spin angular momentum, of the linearized gravitational field. We derive these quantities as Noether charges associated to symmetries of a duality-symmetric action. We comment on how the electric and magnetic parts of the Weyl curvature tensor can be used in a gauge invariant nonlocal interpretation of these charges.

Twistor geometry, non-linear structures, and perturbation theory

Bernardo Araneda, Albert Einstein Institute, Potsdam, bernardo.araneda@aei.mpg.de

Black hole perturbation theory involves a number of interesting mathematical constructions associated to hidden symmetries, Killing-like objects, Teukolsky equations, metric reconstructions, integrability, etc. We will show that all of these can be understood as different aspects of a unified, mathematically clear and deep framework based on complex geometry and twistor theory. Moreover, our framework is conformally invariant, coordinate-free, and valid at the full non-linear level. This allows us to describe non-linear aspects of the geometry of the Teukolsky system and its connections with the conformal Einstein equations. Our approach is deeply inspired by works from Penrose and Plebanski.

Optimal coordinates for Ricci-flat conifolds

Áron Szabó, Nicolaus Copernicus University, aron.szabo@uni-hamburg.de

We compute the indicial roots of the Lichnerowicz Laplacian on Ricci flat Riemannian cones and give a detailed description of the corresponding radially homogeneous tensor fields in its kernel. For a Ricci-flat Riemannian conifold (M, g) which may have asymptotically conical as well as conically singular ends, we compute at each end a lower bound for the order with which the metric converges to the tangent cone. This research is joint work with Klaus Kröncke.

Self-force approach to the two-body problem in GR

Leor Barack, University of Southampton, leor@soton.ac.uk

The radiative dynamics in a gravitationally-bound two-body system with a small mass ratio can be described using a perturbative approach, whereby corrections to the geodesic motion of the smaller object (due to radiation reaction, internal structure, etc.) are accounted for order by order in the mass ratio, invoking the notion of "gravitational self-force". The prospect of observing Extreme Mass Ratio Inspirals (EMRIs) with LISA is motivating a long-running program to obtain a rigorous formulation of the self-force and apply it numerically to model the gravitational-wave signature of astrophysical EMRI systems. I will review the theory of gravitational self-force in curved spacetime, describe how this theory is being implemented in actual calculations, and discuss current status and open problems.

Radial and non-radial oscillation modes of compact stars

Dániel Barta, Wigner RCP, barta.daniel@wigner.hu

We study the radial and non-radial oscillations of relativistic neutron and hybrid stars constructed from various types of cold nucleonic and hybrid nucleon–hyperon–quark matter. We present the fundamental and first two lowest-frequency excited modes of radial oscillations for a set of seven realistic EoS. We also present a method for computing the eigenfrequencies of the non-radial oscillations of non-rotating neutron stars.

Necessary Conditions for the Existence of the Carter Constant in a General Axially Symmetric Stationary Spacetime in Plasma and its Applications

Barbora Bezdekova, Charles University, Prague, baja@etranslator.biz

When dealing with light rays propagating around compact relativistic objects (e.g. a black hole), usually a vacuum background is assumed. However, in many astrophysical applications this assumption is not sufficient. More precise picture is obtained when a medium (plasma) surrounding the black hole is considered. The problem is typically solved in terms of the separation of the Hamilton-Jacobi equation. To be able to find a solution of such system, a Carter constant has to exist. We derive general conditions for both axially symmetric stationary metric and plasma density function which are required in order to define the Carter constant. Furthermore, we gain general formulas for photon region and black hole shadow for light rays around an axially symmetric stationary object in plasma. Obtained general expressions are then applied to find the boundary of photon region and shadow for particular examples, such as Kerr metric or Teo metric.

Equipotential Photon Surface Uniqueness in Electrovacuum

Albachiara Cogo, Eberhard-Karls-Universität Tübingen, albachiara.cogo@uni-tuebingen.de

Equipotential Photon Surfaces are timelike and totally geodesic hypersurfaces in a static electrovacuum spacetime such that the lapse function and the electric potential are spatially constant at each time. They are very interesting objects from the physical point of view and they have mathematical properties that allow us to analyse them adapting techniques developed for the study of Black Hole Horizons. As a result of a joint project with Borghini and Cederbaum, I will discuss static electrovacuum spacetimes in presence of a connected Equipotential Photon Surface, providing a characterization of the Reissner–Nordström spacetime. For this purpose, an approach via potential theory developed by Agostiniani and Mazzieri will be adopted, allowing not to assume a regular foliation of the spacetime by the lapse function, necessary for some other methods. In addition, this strategy yields a complete characterization of the spatial slices of the equipotential photon surfaces not only in sub-extremal Reissner–Nordström spacetimes, but also in the extremal and super-extremal cases, which have not been fully tackled in the existing literature.

Superradiant scattering of wave packets with compact initial support

Károly Csukás, The University of Mississippi, csukask@gmail.com

The existence of ergoregion in Kerr spacetime in principle allows us to extract large amounts of energy from the rotation of the black hole via superradiant scattering. This process-which most probably plays a crucial role in some of the most energetic astrophysical events-was studied by numerically integrating Teukolsky's equation for bosonic fields in time domain. The main feature of the study is the use of compact supported initial data. Our results suggest that in case of the physically most plausible infalling wave packets the effect of superradiance gets significantly suppressed. The talk is based on arXiv:2101.05530. This research was supported in part by the NKFIH Grant No. K-115434.

The Schrödinger-Newton-Hooke equation - existence and stability of the bound states

Filip Ficek, Jagiellonian University, filip.ficek@doctoral.uj.edu.pl

I will start this short talk by motivating the investigations of higher dimensional Schrödinger-Newton-Hooke equation by its connection with such open problems as the soliton resolution conjecture and anti-de Sitter spacetime stability. Then I will present some results regarding spherically symmetric bound states of this equation. In particular, I will discuss how the spatial dimension affects such properties as uniqueness of solutions with prescribed frequency or existence of windows of stability for excited states.

Staticity and regularity for zero rest-mass fields near spatial infinity on flat spacetime

Edgar Gasperin, Instituto Superior Técnico, Lisbon, edgar.gasperin@tecnico.ulisboa.pt

Linear zero-rest-mass fields generically develop logarithmic singularities at the critical sets where spatial infinity meets null infinity. Friedrich's representation of spatial infinity is ideally suited to study this phenomenon. These logarithmic singularities are an obstruction to the smoothness of the zero-rest-mass field at null infinity and, in particular, to peeling. In the case of the spin-2 field it has been shown that these logarithmic singularities can be precluded if the initial data for the field satisfies a certain regularity condition involving the vanishing, at spatial infinity, of a certain spinor (the linearised Cotton spinor) and its totally symmetrised derivatives. In this article we investigate the relation between this regularity condition and the staticity of the spin-2 field. It is shown that while any static spin-2 field satisfies the regularity condition, not every solution satisfying the regularity condition is static.

Some ongoing Efforts for Evolving Einstein Field Equations on Hyperboloidal Slices

Shalabh Gautam, ICTS, Bengaluru, India, shalabh.gautam@icts.res.in

One of the challenges in numerical relativity is to include future null infinity in the computational domain with a well-posed formulation. Success will not only enable us to evolve any system of astrophysical interest, e.g. binary black holes and extracting the gravitational wave signal at future null infinity, with any desired accuracy, but also help in studying various phenomena of fundamental interest. One proposal is to use hyperboloidal slices. In this talk, I will present our ongoing efforts for obtaining a well-posed formulation of the Einstein Field Equations on hyperboloidal slices, all in spherical symmetry. The natural extension will be to generalize these methods to full 3d.

Relativistic Theory of Elastic Bodies in the Presence of Gravitational Waves

Mario Hudelist, University of Vienna, a01414109@unet.univie.ac.at

In this talk an overview of the theory of general relativistic elasticity in a gravitational wave background will be presented. The topic of interest is the response of elastic materials or bodies to the incidence of a gravitational wave in the transverse-traceless gauge. Starting from the concept of an action principle, the primary object in question is the energy-momentum or stress-energy tensor $T\mu\nu$ coming from a Lagrangian field theory. The vanishing divergence of $T\mu\nu$ leads to a wave equation, where the gravitational wave in these coordinates enters solely through the boundary conditions (as an effective force). A one-dimensional example for an elastic material in a gravitational wave background is provided, where an exact solution is obtained.

Sharp asymptotics of Teukolsky equation on Kerr spacetimes

Siyuan Ma, Albert Einstein Institute, siyuan.ma@aei.mpg.de

Teukolsky equation in Kerr spacetimes governs the dynamics of the spin s components, $s = 0, \pm 1, \pm 2$ corresponding to the scalar field, the Maxwell field, and the linearized gravity, respectively. I will discuss recent joint work on proving the precise asymptotic profiles for these spin s components in Kerr spacetimes.

Asymptotic charges for spin-1 and spin-2 fields at the critical sets of null infinity

Mariem Magdy Ali Mohamed, Queen Mary, University of London, mariemmagdy015@gmail.com

The asymptotic BMS charges of spin-1 and spin-2 fields are studied near spatial infinity. We evaluate the charges at the critical sets where spatial infinity meets null infinity with the aim of finding the relation between the charges at future and past null infinity. To this end, we make use of Friedrich's framework of the cylinder at spatial infinity to obtain asymptotic expansions of the Maxwell and spin-2 fields near spatial infinity which are fully determined in terms of initial data on a Cauchy hypersurface. Expanding the initial data in terms of spin-weighted spherical harmonics, it is shown that only a subset of the initial data, that satisfy certain regularity conditions, gives rise to well-defined charges at the point where future (past) infinity meets spatial infinity. Given such initial data, the charges are shown to be fully expressed in terms of the freely specifiable part of the data. Moreover, it is shown that there exists a natural correspondence between the charges defined at future and past null infinity.

Interferometry of Entangled Quantum States of Light in Curved Space-Time

Thomas Mieling, University of Vienna, thomas@mieling.at

Precision quantum interferometry provides a viable way to probe the behaviour of single photons and entangled photon pairs in gravitational fields: a domain that defies a purely Newtonian description. While currently planned experiments aiming to detect such effects at the laboratory-scale are explicable using the weak equivalence principle, larger-scale experiments have the potential to detect gravitationally induced quantum interference in which space-time curvature is not negligible. In this talk, I present the basic mechanisms underlying such experiments and explain how maximally path-entangled NOON states could be used to demonstrate Riemann curvature.

The Maxwell-scalar field system near spatial infinity

Marica Minucci, Queen Mary University of London, m.minucci@qmul.ac.uk

We make use of Friedrich's representation of spatial infinity to study asymptotic expan- sions of the Maxwell-scalar field system near spatial infinity. The main objective of this analysis is to understand the effects of the non-linearities of this system on the regularity of solutions and polyhomogeneous expansions at null infinity and, in particular, at the critical sets where null infinity touches spatial infinity. The main outcome from our analysis is that the nonlinear interaction makes both fields more singular than what is seen when the fields are non-interacting. In particular, we find a whole new class of logarithmic terms in the asymptotic expansions which depend on the coupling constant between the Maxwell and scalar fields.

On the topology of gravitational instantons with symmetry

Gustav Nilsson, Albert Einstein Institute, Golm, gustavn64@gmail.com

Gravitational instantons are 4-dimensional Ricci-flat manifolds with Riemannian signature and curvature decaying sufficiently fast. We discuss gravitational instantons with symmetry (S^1 or toric symmetry). Applications of the G-signature theorem as well as the Hitchin-Thorpe inequality will be considered, with a view towards classifying such gravitational instantons.

The Hawking-Penrose singularity theorem for C^1-Lorentzian metrics

Argam Ohanyan, University of Vienna, argam.ohanyan@univie.ac.at

Singularity theorems are central in General Relativity. Under physically reasonable assumptions, they give the existence of an incomplete causal geodesic. This alone, however, cannot necessarily be interpreted as a "physical" singularity. The geodesic may very well be complete, albeit in a low regularity extension of the original spacetime. This has motivated the study of singularity theorems for spacetimes with metrics of regularity $C^{1,1}$ over the past decade. Most recent results have lowered the regularity further to C^1, where the curvature is merely a distribution. The corresponding theorems of Hawking and Penrose have been proven by Graf, and the Gannon-Lee theorem by Schinnerl and Steinbauer. Here we report on the recent proof of the most refined of the classical singularity theorems, namely the one by Hawking & Penrose. The main new features are (1) the development of a theory of tensor distributions of finite order which allows for a sensible generalization of the genericity condition, which plays a central role in the theorem, and (2) a careful analysis of geodesic branching to deal with loss of uniqueness of solutions to the geodesic equation. The latter adds a further alternative to causal geodesic incompleteness to the result, namely the branching of maximizing causal geodesics.

Λ-vacuum initial data on compact Cauchy surfaces

János Östör, BME & Wigner RCP, janos.ostor@gmail.com

Initial data sets are usually constructed by the conformal method, where one solves an elliptic system for a conformal factor and a vector potential. However, it has recently been shown that the constraint equations can be cast into evolutionary systems for certain geometrically distinguished variables, allowing the construction of a large class of initial data sets. We studied these in the context of Λ-vacuum cosmological spacetimes with compact spatial topologies and various levels of symmetry. These included the standard and the conformally deformed Friedmann–Lemaître–Robertson–Walker model, as well as a variation of the Lemaître–Tolman-Bondi model. Our eventual goal is to study the time-evolution of such highly perturbed initial data sets to get insight concerning inflation and large-scale structure formation.

Local foliations of surfaces characterizing the center of mass.

Alejandro Penuela Diaz, Potsdam Uni-AEI, alejandro.penuela@aei.mpg.de

Inspired by the small sphere limit for quasi-local masses we study local foliations of constant spacetime mean curvature surfaces (surfaces characterizing the center of mass in general relativity) and also foliations of constant expansion surfaces. Using a Lyapunov Schmidt reduction in an hypersurface of a N+1-spacetime, we construct the foliations around a point, prove their uniqueness and show their nonexistence conditions. Joint work with J. Metzger.

The gravitational wave signal from primordial magnetic fields in the Pulsar Timing Array frequency band

Alberto Roper Pol, APC, roperpol@apc.in2p3.fr

The NANOGrav, Parkes and European pulsar timing array (PTA) collaborations have reported evidence for a common-spectrum process that can potentially correspond to a stochastic gravitational wave background (SGWB) in the 1–100 nHz frequency range. I will present the scenario in which this signal is produced by magnetohydrodynamic (MHD) turbulence in the early universe, induced by a non-helical primordial magnetic field at the energy scale corresponding to the quark confinement phase transition. I will present the results of MHD simulations studying the dynamical evolution of the magnetic field and the resulting SGWB. The SGWB output from the simulations can be very well approximated by assuming that the magnetic anisotropic stress is constant in time, over a time interval related to the eddy turnover time. The analytical spectrum derived under this assumption features a change of slope at a frequency corresponding to the GW source duration that is confirmed with the numerical simulations. The SGWB signal can be compared with the PTA data to constrain the temperature scale at which the SGWB is sourced, as well as the amplitude and characteristic scale of the initial magnetic field. The generation temperature is constrained by PTA to be in the 2-200 MeV range, the magnetic field amplitude must be $> 1\%$ of the radiation energy density at that time, and the magnetic field characteristic scale is constrained to be $> 10\%$ of the horizon scale. The turbulent decay of this magnetic field will lead to a field at recombination that can help to alleviate the Hubble tension and can be tested by measurements in the voids of the Large Scale Structure with gamma-ray telescopes like the Cherenkov Telescope Array.

Adiabatic equatorial inspirals of a spinning body into a Kerr black hole

Viktor Skoupý, Charles University, vskoupy@gmail.com

The detection of gravitational waves from Extreme mass Ratio Inspirals (EMRIs) by the future space-based gravitational-wave detectors demands the generation of accurate enough waveform templates. Since the spin of the smaller secondary body cannot be neglected for the detection and parameter estimation of EMRIs, we study its influence on the phase of the gravitational waves from EMRIs with spinning secondary. We focus on generic eccentric equatorial orbits around a Kerr black hole. To model the spinning secondary object, we use the Mathisson-Papapetrou-Dixon equations in the pole-dipole approximation. Furthermore, we linearize in spin the orbital variables and the gravitational-wave fluxes from the respective orbits. We obtain these fluxes by using the Teukolsky formalism in the frequency domain. We derive the evolution equations for the spin induced corrections to the adiabatic evolution of an inspiral. Finally, through their numerical integration we find the gravitational-wave phase shift between an inspiral of a spinning and a non-spinnig body.

On massive photons in dielectrics

Florian Steininger, University of Vienna, f.steininger@univie.ac.at

Established work on massive photons in waveguides erroneously concludes with only minor modifications as compared to the Maxwell case. We show that the standard formulation of the Proca equation in dielectric media is fundamentally incompatible with experimental evidence. Further, we propose a modified Proca action which remedies the problem and present the solution space for a coaxial cable.

A note on non timesymmetric Initial Data sets

Markus Wolff, Universität Tübingen, markus.wolff@student.uni-tuebingen.de

We consider a class of initial data sets (M, g, K), such that we can decompose g and K with respect to an underlying special foliation of coordinate spheres, where the induced metrics become asymptotically round. We study Penrose-type total energy bounds for such metrics in the asymptotically flat case, assuming the dominant energy condition and a strictly outer untrapped condition on the foliation. Motivated by the work of Rácz (and Bartnik in time-symmetry), within special subclasses, we are able to obtain results related to the existence of asymptotically flat solutions of the constraint equations.
This is joint work with Armando Cabrera Pacheco.

Relativistic fluids on cosmological spacetimes

Zoe Wyatt, University of Cambridge, zw253@cam.ac.uk

On a background Minkowski spacetime, the relativistic Euler equations are known, for a relatively general equation of state, to admit unstable homogeneous solutions with finite-time shock formation. By contrast, such shock formation is suppressed on background cosmological spacetimes whose spatial slices expand at an accelerated rate. The critical case of linear, ie zero-accelerated, spatial expansion, is not as well understood. In this talk, I will outline some results from the last 15 years that have studied the relativistic Euler and the Einstein relativistic-Euler equations for cosmological spacetimes.

Posters

The orbital evolution and gravitational waves of OJ 287 in the 4th post-Newtonian order

Kacskovics Balázs, University of Pécs and Wigner RCP,
kacskovics.balazs@wigner.hu

We computed the orbital evolution and the emitted gravitational radiation of the supermassive black hole binary OJ 287. Here we used the initial data provided by the outburst structure of the system. We considered the spin-spin, spin-orbit, and the next-to-next leading order fourth post-Newtonian (4PN) corrections in our analysis. In this way, we could make an accurate examination of unstable orbits ($3M < r < 6M$) of the secondary black hole. We tested the 4PN terms by analyzing the total and radiated energy, compared the post-Newtonian parameters and the separation of the two black holes for 3PN and 4PN. In conclusion, the 4PN corrections provided a significantly more accurate tool for analyzing unstable orbits than earlier 3PN terms. Furthermore, in this paper, we show the strain of gravitational waves emitted by OJ 287 during its complete orbital evolution including unstable orbits.

Conformally-unimodular metric as a basis for astrophysics and cosmology

Sergey Cherkas, Institute for Nuclear Problems, cherkas@inp.bsu.by

Basis of the general relativity is a notion of the manifold, i.e. metric space, which could be covered by the coordinate maps. When a concrete space-time, possessing some symmetry, is considered one intends to introduce system of coordinates allowing maximal covering of this particular manifold. For instance, Schwarzschild solution describes only region before horizon, and one has to introduce Kruscal coordinates to cover entire region. This leads to collapsing solution and leads to formation of singularity. Nevertheless, one could admit an opposite point of view, namely, to restrict manifold by “sewing” all the black holes by some coordinate transformation. In such a way one comes to the conformally-unimodular metric [1]. Real compact astrophysical objects look as non singular balls -“eicheons” in this metric [1]. It is interesting, that in the conformally-unimodular metric vacuum energy problem turns out to be partially solved if one built gravity theory admitting an arbitrary choice of the energy density level. This is possible because equations for evolution of the Hamiltonian H and momentum constraints $\mathcal{P}$ admit not only trivial solution $\mathcal{H} = 0$, $\mathcal{P} = 0$, but also $\mathcal{H} = const$, $\mathcal{P} = 0$ solution. The *constant* compensates main part of the vacuum energy density proportional to the Planck mass in the fourth degree. Residual vacuum energy, remaining after the omitting of the main part of the vacuum energy density results to some interesting cosmological picture [2].

[1] S. L. Cherkas, V. L. Kalashnikov // Phys. Scr. – 2020. – Vol. 95, No. 8. – P. 085009.
[2] B. S. Haridasu, S. L. Cherkas, V. L. Kalashnikov // Fortschr. Phys.– 2020. – Vol. 68, No. 7. – P. 2000047.

Topology change with Morse functions

Leonardo Garcia-Heveling, Radboud University Nijmegen, l.heveling@math.ru.nl

We will start this talk with an overview of topology change: what is it, and what is its physical relevance? Then we will discuss a theorem by Geroch, which states that topology changing spacetimes always contain closed timelike curves. This theorem can only be avoided if one allows the metric to degenerate at certain points. A concrete construction of such degenerate metrics was proposed by Sorkin, using Morse functions. Borde and Sorkin then conjectured that these Morse metrics have nice causal properties. We will end the talk by presenting some recent progress on this conjecture.

Static thin discs with power-law density profiles

Petr Kotlařík, Charles University, kotlarik.petr@gmail.com

We revisit the task to find the potential of thin circular discs with power-law density profiles. First, using a method suggested by Conway (2000), we obtain the potential generated by elementary density terms – even powers in radial coordinate. Then, by suitable combinations of several powers, we cover more generic cases of finite solid or infinite annular thin discs and finite annular discs whose density is of a "bump"-type radial shape. All results are obtained in closed form. Finally, we numerically check several specific cases against the series-expansion form in Semerák (2004) and discuss some physical properties.

Asymptotic Gravitational Charges in the First Order Formalism

George Long, Queen Mary University of London, g.long@qmul.ac.uk

In this presentation, I will discuss how asymptotic gravitational charges can be constructed in the first order formalism of General Relativity by adding terms to the Einstein-Hilbert action that do not affect the equations of motion. We will then see how, in principle, this framework can be used to yield all charges in a gravitational theory. We will briefly look at how some existing charges fit into this framework, as well as considering additional contributions to the action that produce novel charges.

Extremal isolated horizons with Λ and the related unique type D black holes

David Matejov, Charles University, d.matejov@gmail.com

We extend our previous work in which we derived the most general form of an induced metric describing the geometry of an axially symmetric extremal isolated horizon (EIH) in asymptotically flat spacetime. Here we generalize it to EIHs in asymptotically (anti-)de Sitter spacetime. The resulting metric conveniently forms a 6-parameter family which, in addition to a cosmological constant Λ, depends on the area of the horizon, total electric and magnetic charges, and two deficit angles representing conical singularities at poles. Such a metric is consistent with results obtained in the context of near-horizon geometries. Moreover, we study extremal horizons of all black holes within the class of Plebański-Demiański exact (electro)vacuum spacetimes of the algebraic type D. In an important special case of non-accelerating black holes, that is the famous Kerr-Newman-NUT-(A)dS metric, we were able to identify the corresponding extremal horizons, including their posi- tion and geometry, and find explicit relations between the physical parameters of the metric and the geometrical parameters of the EIHs.

Spherically symmetric, static black holes with scalar hair, and naked singularities in nonminimally coupled k-essence

Cecília Nagy, University of Szeged, lawrencesterne92@gmail.com

We investigate spherically symmetric, static spacetimes in an effective field theory action of scalar-tensor theory. For the description we apply a 2+1+1 spacetime decomposition. Detailed analysis is carried out in the k-essence subclass of Horndeski theories where $G_2 = G_2(\phi, X), G_4 = G_4(\phi)$ (while $G_3 = 0, G_5 = 0$) and when the metric is characterized by one independent function depending on the radial coordinate. Specializing $G_4(\phi)$ and the radial dependence of the scalar field we have obtained new spacetime solutions characterized by a parameter, which in the simplest case has the interpretation of mass or tidal charge, the cosmological constant and a third parameter. These solutions represent naked singularities, black holes with scalar hair or have the double horizon structure of Schwarzschild-de Sitter spacetime. One of the solutions obtained for the function G_4 linear in the curvature coordinate, in certain parameter range exhibits an intriguing logarithmic singularity lying outside the horizon. The hairy black hole solutions evade the unicity theorems by being asymptotically nonflat even in the absence of the cosmological constant.

Variational formalism for thin shells in general relativity

Bence Racskó, University of Szeged, racsko@titan.physx.u-szeged.hu

We investigate the variational principle for the gravitational field in the presence of thin shells of completely unconstrained signature (generic shells). Such variational formulations have been given before for shells of timelike and null signatures separately, but so far no unified treatment exists. We identify the shell equation as the natural boundary condition associated with a broken extremal problem along a hypersurface where the metric tensor is allowed to be nondifferentiable. Since the second order nature of the Einstein–Hilbert action makes the boundary value problem associated with the variational formulation ill-defined, regularization schemes need to be introduced. We investigate several such regularization schemes and prove their equivalence. We show that the unified shell equation derived from this variational procedure reproduce past results obtained via distribution theory by Barrabès and Israel for hypersurfaces

of fixed causal type and by Mars and Senovilla for generic shells. These results are expected to provide a useful guide to formulating thin shell equations and junction conditions along generic hypersurfaces in modified theories of gravity.

Scalar-tensor gravity from GR reveals relationship between gravity and geometry

György Szondy, private, gyorgy.szondy@gmail.com

General relativity (GR) is considered being the best theory of gravitation so far. However, over the past 100 years, more than 50 alternative theories or modifications have been proposed to improve GR, indicating that majority of scientists do not believe it will be the ultimate theory of gravity. Because of its nonlinearity, we must use approximations; the complexity of the calculations and the different definition of time and distance measurement; it is not useful in everyday life and engineering practice; it has no decent quantum theory, it is not suitable for multi-body problems and only a few people really understand it. After reviewing the relevant proposals, some of them were applied to a restricted, spherically symmetric case to transform GR into a more suitable form. Following the suggestion of Weyl (1917), the Schwarzschild solution was transformed from standard to conformal Euclidean coordinates, and then the conformal transformation published by Brans and Dicke (1960) was applied using the natural rate defined by Novobátzky (1950s). The result is a GR-equivalent scalar-tensor gravity, which satisfies the requirements of satellite navigation, and where scalar (Newtonian) gravity and curvature effects are separated. We show that in this form (in contrast to the finding of Brans and Dicke) the scalar potential can be unambiguously related to the curvature scalar, raising the possibility of a geometry-based quantum gravity. Another important advantage of this approach is that the use of conformal Euclidean coordinates can bring us closer to an analytical solution of the many-body problem.

One-way null solution of non-homogeneous Maxwell equations in Kerr space-time

Yurii Taistra, Pidstryhach IAPMM NAS of Ukraine, ythelloworld@gmail.com

We consider non-homogeneous Maxwell equations in the spinor approach with an outgoing one-way null condition for the solution. One-way null condition implies that 4-current is also null. Such Maxwell fields are sub-case of force-free electrodynamics of Blandford-Znajek. We found a general solution to such a system, which consists of a part for free wave, and a part for wave induced by null 4-current. We also apply the Brennan, Gralla, Jacobson method for obtaining more wider class of axisymmetric outgoing solutions.