Gravitation and Relativity Division
Fachverband Gravitation und Relativitätstheorie (GR)

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Overview of Invited Talks and Sessions

(Lecture halls ZHG008 and ZHG007; Poster ZHG Foyer 1. OG)

Invited Talks

GR 1.1	Mon	16:45–17:30	ZHG008	**Classical post-newtonian gravitational fields in quantum mechanics** — •Domenico Giulini
GR 2.1	Tue	13:30–14:15	ZHG008	**Beyond the thick accretion disk model: external influences and their observational consequences** — •Audrey Trova, Eva Hackmann, Vladimir Karas, Jiří Kovář
GR 6.1	Wed	11:00–11:45	ZHG008	**Black hole dynamics from a mathematical perspective** — •Dejan Gajic
GR 10.1	Thu	13:30–14:15	ZHG008	**Probing the cosmic large-scale structure beyond the average** — •Cora Uhlemann

Invited Talks of the joint Symposium SMuK Dissertation Prize 2025 (SYMD)

See SYMD for the full program of the symposium.

SYMD 1.1	Mon	14:15–14:45	ZHG011	**Fluid-dynamic description of heavy-quark diffusion in the quark-gluon plasma** — •Federica Capellino
SYMD 1.2	Mon	14:45–15:15	ZHG011	**Fast and faithful effective-one-body models for gravitational waves from generic compact binaries** — •Rossella Gamba
SYMD 1.3	Mon	15:15–15:45	ZHG011	**Nuclear Structure Near Doubly Magic Nuclei** — •Lukas Nies
SYMD 1.4	Mon	15:45–16:15	ZHG011	**Optimisation strategies for proton acceleration from thin foils with petawatt ultrashort pulse lasers** — •Tim Ziegler

Invited Talks of the joint Symposium Quantum Mechanics and Gravity: Current Status (SYDK)

See SYDK for the full program of the symposium.

SYDK 1.1	Thu	10:45–11:15	ZHG008	**String Theory at the Edges of Relativity** — •Niels Obers
SYDK 1.2	Thu	11:15–11:45	ZHG008	**The Quantum Einstein Equations in Loop Quantum Gravity** — •Kristina Giesel
SYDK 1.3	Thu	11:45–12:15	ZHG008	**Causal Dynamical Triangulations: Lattice quantum gravity reloaded** — •Renate Loll
SYDK 1.4	Thu	12:15–12:45	ZHG008	**Taming Quantum Gravity: insights from Asymptotic Safety** — •Alessia Platania

Sessions

GR 1.1–1.4	Mon	16:45–18:30	ZHG008	**CQG I**
GR 2.1–2.5	Tue	13:30–15:35	ZHG008	**Relastro I**
GR 3.1–3.4	Tue	14:15–15:35	ZHG007	**Rel. Geodesy**
GR 4.1–4.5	Tue	16:15–17:55	ZHG008	**GW I**
GR 5.1–5.4	Tue	16:15–17:35	ZHG007	**CQG II**

GR 6.1–6.3	Wed	11:00–12:25	ZHG008	**BH Physics I**
GR 7.1–7.7	Wed	13:30–15:50	ZHG008	**Cosmo I, Relastro II, GW II**
GR 8.1–8.4	Wed	13:30–14:50	ZHG007	**GW III**
GR 9.1–9.19	Wed	16:15–18:15	ZHG Foyer 1. OG	**Poster**
GR 10.1–10.5	Thu	13:30–15:35	ZHG008	**Cosmo II**
GR 11.1–11.4	Thu	14:15–15:35	ZHG007	**BH Physics II, GW IV**
GR 12.1–12.2	Thu	16:15–16:55	ZHG008	**GW V**
GR 13	Thu	17:00–18:15	ZHG008	**Members' Assembly**
GR 14.1–14.4	Fri	9:00–10:20	ZHG008	**Relastro III**
GR 15.1–15.4	Fri	11:00–12:20	ZHG008	**Cosmo III**

Members' Assembly of the Gravitation and Relativity Division

Thursday 17:00–18:15 ZHG008

GR 1: CQG I

Time: Monday 16:45–18:30 Location: ZHG008

Invited Talk GR 1.1 Mon 16:45 ZHG008

Classical post-newtonian gravitational fields in quantum mechanics — •Domenico Giulini — Leibniz Universität Hannover — ZARM Bremen

The problem of coupling classical gravitational fields to quantum-mechanical systems is considered within post-newtonian approximation schemes. I will show how to compute the approximate Hamiltonian for the centre-of-mass and internal dynamics of an electromagnetically bound two-particle system. This, in turn, can be used to derive algebraic expressions for phases in light-pulse atom-interferometers of various geometries. Finally I will comment on some conceptual issues that we encountered in this field. The talk will be based on doi: 10.1103/PhysRevA.100.052116, 10.1103/PhysRevD.109.022008, 10.1088/1361-6382/ad079c.

GR 1.2 Mon 17:30 ZHG008

Understanding gravitationally induced decoherence parameters in neutrino oscillations using a microscopic quantum mechanical model — Alba Domi[1], Thomas Eberl[1], Max Joseph Fahn[2], Kristina Giesel[1], Lukas Hennig[1], Ulrich Katz[1], •Roman Kemper[1], and Michael Kobler[1] — [1]Friedrich-Alexander Universität Erlangen-Nürnberg, Germany — [2]Università di Bologna, Italy

In this talk, the role of gravitationally induced decoherence in open quantum systems is explored in the context of neutrinos. A microscopic quantum mechanical model introduced by Blencowe and Xu is applied to neutrino oscillations, motivated by the coupling between neutrinos and the gravitational wave environment suggested by linearised gravity. The analysis demonstrates that, for neutrino oscillations in vacuum, gravitationally induced decoherence matches phenomenological models, with decoherence parameters exhibiting an inverse quadratic energy dependence. When matter effects are included, the decoherence parameters depend on the varying matter density across the Earth's layers. Moreover, the form of the decoherence parameters is explicitly derived from the microscopic model, providing a physical interpretation. This talk is based on the work in "Understanding gravitationally induced decoherence parameters in neutrino oscillations using a microscopic quantum mechanical model", published in JCAP, 2024, 11, 006.

GR 1.3 Mon 17:50 ZHG008

The nature of gravity — •Piero Nicolini — Universität Triest, Triest, Italien — INFN, Triest, Italien — Johann Wolfgang Goethe-Universiät Frankfurt am Main, Frankfurt am Main, Deutschland

Gravity is well known at the classical level, both in Newtonian and GR terms. However, understanding gravity at the fundamental level requires a quantum formulation. In this talk I will review recent findings on the static interaction between two point-like masses to reveal that the conventional attractive nature of gravity is only a low-energy effect.

GR 1.4 Mon 18:10 ZHG008

LISA - a data perspective — •Sarah Paczkowski — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), D-30167 Hannover, Germany — Leibniz Universität Hannover, D-30167 Hannover, Germany

The Laser Interferometer Space Antenna (LISA) is an ESA-led mission to observe gravitational waves from space. In this presentation, I will introduce LISA from a data perspective, focusing on the anticipated characteristics of the data in terms of gravitational wave signals and noise sources from the instrument. I will also discuss the strategies employed to mitigate noise during data processing on Earth and the projected timeline for data availability.

GR 2: Relastro I

Time: Tuesday 13:30–15:35 Location: ZHG008

Invited Talk GR 2.1 Tue 13:30 ZHG008

Beyond the thick accretion disk model: external influences and their observational consequences — •Audrey Trova[1], Eva Hackmann[1], Vladimir Karas[2], and Jiří Kovář[3] — [1]University of Bremen, Center of Applied Space Technology and Microgravity (ZARM), 28359 Bremen, Germany — [2]Astronomical Institute, Czech Academy of Sciences, Boční II 1401, Prague, 141 00, Czech Republic — [3]Research Centre for Theoretical Physics and Astrophysics, Institute of Physics, Silesian University in Opava, Bezručovo nám. 13, 746 01, Opava, Czech Republic

The strong gravity regime near black holes and neutron stars provides an exceptional laboratory for testing General Relativity. Accretion disks extend deep into this regime, reaching down to the horizon scale. Various accretion disk models have been developed to better understand the complex phenomena at play. Among them, the thick accretion disk, the simplest analytical model, that considers only gravity and a perfect fluid, captures key features of these objects.

In this talk, we will explore different variants of the thick accretion disk model, incorporating additional effects such as an external magnetic field influencing the charge of the fluid, the deformation of the central object, and the presence of an external mass distribution that can mimic the self-gravity of the disk itself. We will discuss the implications of these factors on the disk's geometry, density, and pressure distribution. Furthermore, we will analyze their impact on observational signatures of black hole accretion disks, particularly in the context of high-frequency quasi-periodic oscillations (HFQPOs).

GR 2.2 Tue 14:15 ZHG008

Magnetic field dynamics in isolated neutron stars: insights from GRMHD simulations — •Aurora Capobianco — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany

The internal magnetic field topology and equilibrium configurations of neutron stars are thought to play a fundamental role in determining the nature and strength of astrophysical phenomena. We model the development of the super strong magnetic fields in neutron stars using the General Relativistic MagnetoHydroDynamic (GRMHD) code AthenaK. In this talk, I will present the long-term evolutions of isolated neutron stars with an outer dipole-like field and various initial internal magnetic-field configurations, exploring the growth times of the various instability-driven oscillation modes and turbulence. I will highlight how resolution impacts the magnetic field evolution due to instabilities that arise from small-scale effects and discuss future developments.

GR 2.3 Tue 14:35 ZHG008

Realistic models of general-relativistic differentially rotating stars — •Marie Cassing[1] and Luciano Rezzolla[1,2,3] — [1]Institute for Theoretical Physics, Frankfurt am Main, Germany — [2]Frankfurt Institute for Advanced Studies, Frankfurt am Main, Germany — [3]School of Mathematics, Trinity College, Dublin, Ireland

General-relativistic equilibria of differentially rotating stars are expected in a number of astrophysical scenarios, from core-collapse supernovae to the remnant of binary neutron-star mergers. The latter, in particular, have been the subject of extensive studies where they were modelled with a variety of laws of differential rotation. Starting from accurate and fully general-relativistic simulations of binary neutron-star mergers with various equations of state, we establish the time when the merger remnant has reached a quasi-stationary equilibrium and extract in this way realistic profiles of differential rotation. This allows us to explore how well traditional laws reproduce such differential-rotation properties and to derive new laws of differential rotation that better match the numerical data. In this way, we have obtained a novel and somewhat surprising result: the stability line computed from the turning-point criterion can have a slope that is not necessarily negative with respect to the central rest-mass density, as previously found with traditional differential-rotation laws. For stellar models reproducing well the properties of the merger remnants, the slope is actually positive, thus reflecting remnants with angular momentum at large distances from the rotation axis, and hence with cores having higher central rest-mass densities and slower rotation rates.

GR 2.4 Tue 14:55 ZHG008

Can a collapsing White Dwarf power a long GRB with kilonova? — •Luis Felipe Longo Micchi — Friedrich-Schiller Universität, Jena, Deutschland

In this talk, I will present the results of axisymmetric simulations of accretion-induced collapse (AIC) of rapidly rotating, magnetized white dwarfs. Using general relativistic neutrino magnetohydrodynamics, we explore how strong magnetic fields and rotation during collapse drive the formation of relativistic jets and neutron-rich outflows. These findings offer a compelling explanation for the observed properties of long gamma-ray bursts (LGRBs) like GRB 211211A and GRB 230307A, including their associated kilonovae. I will discuss how our models reproduce the energy and duration of these LGRBs and their accompanying kilonovae without fine-tuning, highlighting AIC as a significant astrophysical site for heavy r-process element production.

GR 2.5 Tue 15:15 ZHG008

Listening to the long ringdown: a novel way to pinpoint the equation of state in neutron star cores — •Christian Ecker — Goethe University Frankfurt

Multimessenger signals from binary neutron star (BNS) mergers are promising tools to infer the largely unknown properties of nuclear matter at densities that are presently inaccessible to laboratory experiments. The gravitational waves (GWs) emitted by BNS merger remnants, in particular, have the potential of setting tight constraints on the neutron-star equation of state (EOS). In this talk I will present a novel and tight correlation between the ratio of the energy and angular momentum losses in the late-time portion of the post-merger signal, i.e., the *long ringdown*, and the properties of the EOS at the highest pressures and densities in neutron-star cores. By applying this correlation to post-merger GW signals, I will show a significant reduction of the EOS uncertainty at densities several times the nuclear saturation density, where no direct constraints are currently available.

GR 3: Rel. Geodesy

Time: Tuesday 14:15–15:35 Location: ZHG007

GR 3.1 Tue 14:15 ZHG007

Synchronization and Simultaneity in Geodesy — •Bennet Grützner — ZARM, Universität Bremen

A crucial task in geodesy is the synchronization of extended clock networks. For synchronization of these networks a transitive, global notion of simultaneity is needed. As is standard in geodesy and astrophysics, the time coordinate is most commonly used to provide a foliation of space-time into hypersurfaces of simultaneity. Here, we look at the mathematical background and explore the most general formulation of simultaneity in general relativity, extending the concepts used so far. In particular, the differences between time coordinates and synchronization coordinates will be discussed, including some counter-intuitive examples, as well as applications in geodesy such as synchronization with ACES on the ISS.

GR 3.2 Tue 14:35 ZHG007

Chronometry in spacetime: a clock-based global height system — •Dennis Philipp[1,2], Asha Vincent[3], Christian Lisdat[4], and Juergen Mueller[3] — [1]ZARM, University of Bremen, Germany — [2]Faculty of Physics, University of Bremen, Germany — [3]Institute for Geodesy, Leibniz University Hannover, Germany — [4]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

Ongoing efforts aim at achieving a globally uniform and consistent International Height Reference System as a global standard for accurately determining physical (height-)coordinates across the world. Near the Earth's surface, two stationary standard clocks that are separated by 1 cm in height have a redshift of about 10^{-18} according to Einstein's theory of General Relativity (GR).

We present a definition of clock observables and chronometry in GR, leading towards a relativistic definition of i) a gravity potential, ii) a notion of chronometric height, and iii) generalized geopotential numbers. Clock comparison in this framework allows for accurate height determination in high-performance clock networks, in which frequency differences can be observed between clock sites and corresponding gravity potential differences can be derived. Height values can be represented by geopotential numbers and measured potential differences between clock locations in a dedicated clock network can be used to estimate the transformation parameters between regional reference frames to resolve distortions. A simulation study is presented that focusses on height systems in Europe and South America to demonstrate the potential impact and benefit of clock-based height systems.

GR 3.3 Tue 14:55 ZHG007

General relativistic geodesy: description of GRACE constellations — •Florian Seemann, Eva Hackmann, and Claus Lämmerzahl — ZARM, University of Bremen, Bremen, Germany

For a global coverage of geodetic measurements one has to go to space. The most succesful geodesy missions are the completed GRACE mission and the ongoing GRACE Follow On mission which revealed many unknown facts about the system Earth. Further geodesy missions using intersatellite laser ranging are under development worldwide. With laser ranging changes of the distance between two satellites can be determined better than 1 nm precision. In this presentation a general relativistic description of this type of geodetic measurement is developed. This includes also perturbation forces which originate, e.g., from the atmospheric drag.

GR 3.4 Tue 15:15 ZHG007

Laser Interferometry in Space for Gravity Recovery: Current and Future Missions — •Pallavi Bekal[1,2], Vitali Müller[1,2], Malte Misfeldt[1,2], Martin Weberpals[1,2], Reshma Krishnan Sudha[1,2], Laura Müller[1,2], and Gerhard Heinzel[1,2] — [1]Max Planck Institute for Gravitational Physics (AEI), Hannover, Germany — [2]Leibniz University Hannover (LUH), Hannover, Germany

The Gravity Recovery and Climate Experiment (GRACE) mission's success in measuring the Earth's gravity field provided a path for future twin-satellite gravity missions with more accurate instrumentation. Consequently, after 15 years of operation, GRACE was succeeded by GRACE follow-on (-FO) in 2018. GRACE and GRACE-FO use the conventional microwave instrument (MWI) to measure the distance between the two spacecraft. Since the range is sensitive to the temporal and spatial changes in the Earth's gravity, its measurement calculates global monthly maps of Earth's mass distribution. GRACE-FO, additionally, hosts the first-ever space laser interferometer, the laser ranging interferometer (LRI). The LRI is a technology demonstrator that measures the range of three orders of magnitude more accurately than the MWI, i.e., at the sub-nanometer scale over short timescales. Hence, the future gravity missions GRACE-C(ontinuity) and Next Generation Gravity Mission (NGGM) will only host an evolved LRI-like instrument. We will present our research activities in analysing the LRI data to detect and remove short disturbances, as well as the experiments on the scale factor measurement system (SFMS) and steering mirror (FSM) that improve its implementation for future missions.

GR 4: GW I

Time: Tuesday 16:15–17:55 Location: ZHG008

GR 4.1 Tue 16:15 ZHG008

Predicting black-hole spins from hierarchical mergers of binary black holes — •Angela Borchers[1,2], Claire Ye[3], and Maya Fishbach[3] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Callinstraße 38, 30167 Hannover, Germany — [2]Leibniz Universität Hannover, Callinstraße 38, 30167 Hannover, Germany — [3]Canadian Institute for Theoretical Astrophysics, 60 St George St, University of Toronto, Toronto, ON M5S 3H8, Canada

Stellar black holes often form binaries in dense stellar clusters. When these binaries merge, they produce remnant black holes, which, after some time, might find a black hole companion and merge again. We call these hierarchical mergers. Previous studies have shown that the spin distribution of black holes in hierarchical mergers peaks at 0.69, independent of the initial black hole spins and the merger generation. However, these mergers can produce recoil kick velocities large enough for remnants to be ejected from their clusters, which means they will not contribute to the black-hole spin distribution in the cluster. We have investigated what are the spins of black holes from hierarchical mergers when recoil kicks are considered. In this talk, I will show that the distribution of retained black holes is not identical to the distribution of all black holes. Besides, I will discuss how the distribution depends on the black-hole birth spins and the merger generation. Our results complement earlier studies in understanding the characteristics of black holes formed in hierarchical mergers, which is essential when identifying the formation origin of black holes from gravitational-wave observations.

GR 4.2 Tue 16:35 ZHG008

Fixing the dynamical evolution of self-interacting vector fields — •Marcelo Rubio — GSSI - L'Aquila, Italy

I will discuss the Cauchy problem of self-interacting massive vector fields, and explain why they often face instabilities and apparent pathologies. After showing that these issues are due to the breakdown of the well-posedness of the corresponding initial-value problem, I will characterize the well-posedness breakdowns and explicity show that they can be avoided by fixing the equations in a suitable way. As an application, I will numerically show that no Tricomi-type breakdown takes place in the quadratic case, and investigate initial configurations which lead to gravitational collapse and the formation of black holes.

GR 4.3 Tue 16:55 ZHG008

Full-spectrum analysis of gravitational waves from binary neutron star mergers — •Giulia Huez — Friedrich-Schiller-University of Jena, Jena, Germany

The gravitational-wave (GW) observation of the full-spectrum (inspiral-merger-postmerger) of a binary neutron star (BNS) merger can convey unique information on the nuclear matter that constitutes these compact objects. BNS are optimal targets for next-generation ground-based GW detectors, which would give the possibility to measure the astrophysical parameters with a higher precision with respect to current detectors. Thus, the development of waveform models for the full GW spectrum of BNS mergers is fundamental in order to minimize biases in the parameter estimation processes.

In this talk, a full Bayesian analysis of GWs from inspiral to postmerger is presented. I will review the waveform template used, based on effective-one-body model and numerical relativity simulations, and show preliminary results on neutron star matter properties.

GR 4.4 Tue 17:15 ZHG008

Probing gravity using black hole ringdown — •Pratik Wagle[1], Dongjun Li[2], Yanbei Chen[3], and Nicolas Yunes[2] — [1]Max Planck Institute for Gravitational Physics, Potsdam, Germany — [2]University of Illinois at Urbana Champaign, Urbana, IL, USA — [3]California Institute of technology, Pasadena CA, USA

The detection of gravitational waves from compact binary mergers by the LIGO/Virgo collaboration has opened new avenues for testing relativistic gravity. With future ground- and space-based gravitational wave detectors, we are poised to extract further insights into astrophysical events and investigate the implications for Einstein's theory of relativity in contexts where gravitational fields are both strong and dynamical. In this presentation, I will discuss recent advancements in the study of gravitational perturbations related to gravitational wave ringdown. I will highlight the necessity for these investigations and outline prospective research directions. Central to my discussion will be a novel approach that enables us to derive a "modified Teukolsky equation", a set of linear, decoupled differential equations that characterize the dynamical perturbations of non-Kerr black holes through the radiative Newman-Penrose scalars Ψ_0 and Ψ_4. This foundational work facilitates the examination of gravitational waves emitted during the ringdown phase of black hole coalescence within beyond GR frameworks applicable to black holes of any spin. Additionally, I will discuss the application of this approach in the context of a quadratic theory of gravity, where the metric and scalar fields exhibit non-minimal coupling, and calculate the QNM frequencies.

GR 4.5 Tue 17:35 ZHG008

Neural Network Assisted Reduced Order Modeling of Black Hole Mergers — •Julian Luca Berg[2], Frank Ohme[1], and Thomas Wick[2] — [1]Max Planck Institute for Gravitational Physics, Hannover, Germany — [2]Leibniz University Hannover, Germany

Since 2015, the detection of gravitational waves gives us the possibility to study objects in the universe such as black holes and neutron stars. By parameter estimation, we can approximate properties of these objects. This includes the masses, spins, and distances. To perform reliable parameter estimation, it is important to have precise and fast models for the corresponding gravitational waves. One approach to speed up numerical computations is reduced order modeling. In this presentation, an approach by J.S. Hesthaven and S. Ubbiali is applied to gravitational wave models that performs reduced order modeling with neural networks. Therein, a neural network is built that can quickly compute a reduced order model for a given set of parameters such that the solution is still a reliable approximation. Our approach is substantiated with some numerical simulations.

GR 5: CQG II

Time: Tuesday 16:15–17:35 Location: ZHG007

GR 5.1 Tue 16:15 ZHG007

Circular light rays in a general-relativistic medium — •Volker Perlick — Faculty 1, University of Bremen

In the 1970s Marek Abramowicz introduced a potential on spherically symmetric and static spacetimes whose corresponding equipotential surfaces he called the "relativistic Von Zeipel cylinders" because they are the relativistic analogues of the Von Zeipel cylinders known from Newtonian gravity. A characteristic feature of this potential, and of its generalisation to axisymmetric and stationary spacetimes which was introduced a few years later, is in the fact that its critical points give the location of circular lightlike geodesics. In this talk I will discuss a further generalisation of this potential whose critical points are the circular light rays in an isotropic medium. The medium may be non-dispersive or dispersive. The case of a cold plasma will be treated in particular. With the help of this potential several known theorems on the existence or non-existence of circular light rays can be extended from the case of light propagation in vacuum to the case of light propagation in a medium.

GR 5.2 Tue 16:35 ZHG007

Low velocity test of the speed of gravity — Eva Hackmann and •Claus Lämmerzahl — ZARM and GOC, University of Bremen, Bremen, Germany

The weak field approximation of the Einstein field equations are similar to the Maxwell equations. Furthermore, in analogy to the Maxwell equations also the Einstein equations cann be given a pre-metric form with a constitutive tensor. On the one hand, from this constitutive tensor the wave propagation can be derived. On the other hand, the various parts of the constitutive tensor can be measured by observing particle motion in the gravitational field. Restricting to isotropic constitutive quantities one obtains as a particular consequence, that from the gravitational attraction together with the Lense-Thirring effect the constitutive tensor can be determined. That means the speed of gravity can be calculated from the constritutive tensor and compared to the speed of light which agree on the level of 1%. This provides an independent test of the speed of gravity compared with the measurements provided by multimessenger observations of gravitational wave events.

GR 5.3 Tue 16:55 ZHG007

Standing waves in Bopp-Landé-Thomas-Podolsky generalised electrodynamics — •Altin Shala[1] and Volker Perlick[2] — [1]Center of applied space technology and microgravity — [2]University of Bremen

We investigate the feasibility probing BLTP generalized electrodynamics with standing wave experiments in terms of energy requirements. Two kinds of media are researched vacuum and two fluid cold plasma. Dispersion relations are found and compared. A new transversal plasma mode is found which has a lower energy requirement than the thick plasma like BLTP vacuum.

GR 5.4 Tue 17:15 ZHG007

relativistic dynamics of electrical matter in minkowski force — •Bin Su — Institut für Theoretische Physik TU-Berlin, Germany

Based on invariant and objectivity of physical law is an invariant formulation of the dynamics proposed for the interaction of the electrical matter under electromagnetic field, which may be completely called the relativistic dynamics in Minkowski force of electrical matter of points mass . Starting from these two relativistic principles - invariant physical law and constant light velocity [1] an initial charge beyond the initial mass of moving electrical matter is at first put forward according to corresponded relativistic dynamical equation. The dependence of the moving charge on its movement, velocity, leads the initial charge into the kinetic charge of the matter accompanied by its kinetic mass. We discuss then a relativistic mass to charge ratio of electron under a magnetic field as an application of this dynamical equation and get a new formulation of the mass to charge ratio, which might be more precisely than that in classical formulation [2]: if the Electrons move very more slowly than that of light then it approximates to classic one well-known.

[1] A. Einstein, *Grundzüge der Relativitätstheorie*, S42-S50, Springer Verlag, 12.1954 [2] Metzler Physik, S 232, www.schroedel.de

GR 6: BH Physics I

Time: Wednesday 11:00–12:25 Location: ZHG008

Invited Talk GR 6.1 Wed 11:00 ZHG008

Black hole dynamics from a mathematical perspective — •Dejan Gajic — Institut für Theoretische Physik, Universität Leipzig, Brüderstraße 16, 04103 Leipzig

I will present an overview of recent mathematical results on the dynamics of spacetimes arising from initial data perturbations of Kerr black holes, both from linear and nonlinear point of view. An important role is played by extremal black holes, which exhibit novel dynamical features, such as instabilities and criticality.

GR 6.2 Wed 11:45 ZHG008

Unmasking Black Hole Mimickers in Higher-Curvature Gravity — •Michael Florian Wondrak — Department of Astrophysics/IMAPP, Radboud Universiteit, Nijmegen, The Netherlands — Department of Mathematics/IMAPP, Radboud Universiteit, Nijmegen, The Netherlands

In higher-curvature gravity, Birkhoff's theorem no longer applies, i.e. the Schwarzschild black hole is no longer unique, but widens to a family of black hole mimickers, namely naked singularities and wormholes. Some naked singularities seem undistinguishable from Schwarzschild when the accreted matter is treated as pressureless in a simple analytical way. Closer to reality, however, with (beyond-GR)MHD simulations, those naked singularities can be ruled out by BH imaging as they dynamically form a hot and bright mass accumulation around the would-be horizon. So not only impacts the accuracy in modeling accreted matter the potential of ruling out BH mimickers, it also allows to constrain a variety of quantum-gravity theories based on their low-energy predictions.

GR 6.3 Wed 12:05 ZHG008

Wave optical imaging by a point-source scattering for a TNdS black hole — •Felix Willenborg[1,2], Dennis Philipp[1,2], and Claus Lämmerzahl[1,2] — [1]Zentrum für angewandte Raumfahrt und Mikrogravitation (ZARM), University of Bremen, 28359 Bremen, Germany — [2]Gauss-Olbers Center, c/o ZARM, University of Bremen, 28359 Bremen, Germany

The Taub-NUT spacetime is a curious solution of the Einstein's vacuum field equation due to the presence of conical singularities and their different interpretations for NUT charges $N \neq 0$. Gravitational lensing maps have shown the twisting of a background for light- and time-like geodesics, as well as the observation of the conical singularity in the Bonnor interpretation.

Several methods offer a theoretical description of these observations. Already mentioned are ray-optical methods by geodesics or the calculation of the scattering by the so-called amplification factor F by the description of time-delays t_d. In our work, we describe the calculation by a full wave equation using the Teukolsky equation, which allows access to all frequencies. To obtain fully analytical solutions, a small cosmological constant is considered, generalising the solution to Taub-NUT-de Sitter (TNdS). We observe the scattering of a monochromatic point source to an observer at a larger distance from the black hole. Afterwards, we briefly discuss the method and present results for Schwarzschild-de Sitter at very low frequencies in a wave-optical approach as a simple model. Finally, we present results for TNdS and how these change with the parameter variation.

GR 7: Cosmo I, Relastro II, GW II

Time: Wednesday 13:30–15:50 Location: ZHG008

GR 7.1 Wed 13:30 ZHG008

Backreaction and Cosmic Butterflies: what simulations can tell us about inflation — •Angelo Caravano — Institut d'Astrophysique de Paris, France

In this talk, I will describe how lattice simulations can improve our understanding of the inflationary epoch of the Universe. I will focus on two examples: first, a model of axion inflation where the inflaton couples to a gauge field via a Chern-Simons interaction; and second, a single-field inflation model with a localized deviation from slow-roll. I will demonstrate how nonlinear effects significantly impact the inflationary dynamics and their predictions, even in cases conventionally believed to be under perturbative control. This makes lattice simulations essential for interpreting both large-scale observables (like large-scale structure and the CMB) and small-scale observables (such as primordial black holes and gravitational wave backgrounds).

GR 7.2 Wed 13:50 ZHG008

Non-linear structure formation in Horndeski gravity — •Ashim Sen Gupta — Bielefeld University, Bielefeld, Germany

Precision cosmology is poised to enter a new era with the advent of Stage IV surveys, such as the Legacy Survey of Space and Time (LSST) and the Euclid satellite. With it will come the ability to probe scales of the universe where non-linear gravitational physics plays a strong role in the formation of large-scale structures (LSS). This provides an opportunity to constrain the elusive set of Modified Gravity (MG) theories with screening mechanisms, theories which can evade classical tests of General Relativity (GR). In this talk, I shall discuss my development of the hybrid particle-mesh code, Hi-COLA. It can rapidly simulate matter clustering for the Horndeski class of scalar-tensor theories. I will also discuss the phenomenology uncovered through the use of Hi-COLA, and present an analysis of the effects that give rise to the enhancements of the Horndeski matter power spectrum relative to GR. I shall additionally touch on my work to extend the scope of Hi-COLA to include the rarely-simulated K-mouflage gravity. Finally, I will conclude with an evaluation of the cutting edge in numerically predicting matter clustering for modified gravity, through which we will see the promise in the prospects of bridging theory and observation that will enable the application of Stage IV constraints.

GR 7.3 Wed 14:10 ZHG008

Resolving σ_8 tension with time-varying gravitational constant — •Tilek Zhumabek[1], Azamat Mukhamediya[2], Hrishikesh Chakrabarty[1], and Daniele Malafarina[1] — [1]Department of Physics, School of Sciences and Humanities, Nazarbayev University, Astana 010000, Kazakhstan — [2]Department of Electrical and Computer Engineering, School of Engineering and Digital Sciences, Nazarbayev University, Astana 010000, Kazakhstan

We consider a modified gravity model, dubbed GCDM, with running gravitational constant $G(a)$, to test its imprints on the growth of structure. Using Redshift Space Distortion (RSD) measurement results, we show a tension at the 3σ level between the best fit ΛCDM and the corresponding Planck18/ΛCDM parameters ($w_0 = -1$, $\Omega_m = 0.31$, $\sigma_8 = 0.81$). Unlike many modified gravity based solutions that overlook the scale dependence and model specific background evolution, we study this problem in the broadest possible context by incorporating both factors into our investigation. We obtain the model specific background quantities and perform a full perturbation analysis of the model to demonstrate a scale dependence in the growth equation. Fixing the scale to $k = 0.1h$ Mpc^{-1} and introducing a specific functional form for $G(a)$ with one free parameter, we conducted likelihood analysis of RSD selected data. This analysis reveal that GCDM can bring the tension level within 1σ while maintaining the deviation from Newton's gravitational constant at the fifth order.

GR 7.4 Wed 14:30 ZHG008

Tidal resonances of stars in precessing orbits around a spinning black hole — •Matteo Stockinger[1] and Masaru Shibata[1,2] — [1]Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Am Mühlenberg 1, D-14476 Potsdam-Golm, Germany — [2]Center for Gravitational Physics and Quantum Information, Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto, 606-8502, Japan

Tidal disruptions of stars on the equatorial plane orbiting Kerr black holes have been widely studied. However thus far, there have been fewer studies of stars in inclined precessing orbits around a Kerr black hole.

We use the tensor virial equations to analyze perturbatively the influence of the precession on the star.

We show the presence of possible resonances in these systems for typical physical parameters of black hole-neutron star binaries in close orbits or of a white dwarf/an ordinary star orbiting a supermassive black hole.

This suggests the presence of a new instability before the tidal disruption limit is encountered in such systems.

GR 7.5 Wed 14:50 ZHG008

Simulating Relativistic Binary-Single and Binary-Binary Encounters — •Felix Heinze and Bernd Brügmann — Friedrich-Schiller-Universität Jena, Theoretisch-Physikalisches Institut, Fröbelstieg 1, 07743 Jena

The motion of N bodies under their mutual gravitational interaction has been a central problem in astrophysics and celestial mechanics for centuries, dating back to 1687, when Isaac Newton published his Principia. Despite centuries of progress, gravitational N-body systems remain a rich and active field of research, with binary-single and binary-binary encounters forming an important subset of interest in astrophysics. For N>2, even Newtonian systems generally defy analytical solutions, exhibiting complex dynamics and chaotic behavior. For the problem of N black holes moving in close proximity and at high speeds, relativistic effects must be taken into account, introducing additional complexity to the solutions.

In this talk, we will present the first results of a series of fully relativistic simulations of black hole binary-single and binary-binary encounters using the numerical relativity code BAM. These simulations reveal intricate dynamics and characteristic waveforms that are absent in (Post-)Newtonian N-body simulations or fully relativistic simulations limited to two black holes. The results highlight the importance of relativistic effects in shaping the outcomes of close black hole interactions and provide new insights into their gravitational wave phenomenology.

GR 7.6 Wed 15:10 ZHG008

Stochastic gravitational wave background from Cosmic B-L Symmetry breaking — •Alexander Schneider, Gudrid Moortgart-Pick, and Tom Krokotsch — University of Hamburg, Hamburg, Germany

The stochastic gravitational wave background could be a window in the early universe, possibly even before the decoupling of the cosmic microwave background. Studying in detail such a stochastic gravitational background is therefore also a possible way to find physics beyond the standard model.

A proposed background rises due to the spontaneous B-L symmetry breaking, occurring around the grand unification scale in certain cosmogical models.

In the talk, we concentrate in particular on the question, whether the gravitational waves produced in such an event could be detected with future high frequency detectors.

GR 7.7 Wed 15:30 ZHG008

Scattering and dynamical capture of two black holes — •Simone Albanesi — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany — INFN sezione di Torino, Torino, 10125, Italy

All gravitational wave (GW) events detected by the LIGO-Virgo-KAGRA collaboration have been generated by the coalescence of compact binaries, mostly binary black holes. The dynamics of these systems typically circularize by the time they enter the detector's sensitivity band, resulting in signals with monotonically increasing frequency. However, dense astrophysical environments, such as globular clusters, may host populations of black holes undergoing scatterings and dynamical captures, resulting in significantly richer phenomenologies that strongly deviate from the quasi-circular scenario. Full Bayesian analysis suggest that the event GW190521 may have originated from such a system, highlighting the need for accurate descriptions to fully exploit the scientific potential of current and future gravitational wave detectors. We study scatterings and dynamical captures for comparable mass spin-aligned systems, using the semi-analytical effective-one-body model TEOBResumS-Dalí and numerical relativity simulations performed with the code GR-Athena++. We focus, in particular, on the transition from unbound to bound orbits in the low energy regime. Challenges and future steps, both on the numerical and analytical fronts, are also discussed.

GR 8: GW III

Time: Wednesday 13:30–14:50 Location: ZHG007

GR 8.1 Wed 13:30 ZHG007

Systematic Errors In Gravitational Waveform Models — •Max Melching[1], Frank Ohme[1], and Sumit Kumar[1,2] — [1]Max Planck Institute for Gravitational Physics, Callinstraße 38, 30167 Hannover, Germany — [2]Utrecht University, Heidelberglaan 8, Utrecht 3584 CS, Netherlands

Measurements of gravitational wave source properties rely on waveform models in order to compare the detector data with theoretical signal predictions and find the best-fitting parameters. However, the waveform models used today are not entirely faithful representations of numerical relativity due to the high computational cost of generating accurate simulations. Instead, several approximate models are used, which can lead to differences in the inferred results. Therefore, it is crucial to be able to describe and understand model-induced uncertainties, so-called systematic errors.

To date, however, there is no universal way to do so. In this talk, I will introduce geometric ideas from the Fisher-matrix formalism that allow interpreting signal differences as measurement uncertainties in the associated parameter space. This includes a discussion of the estimates derived in this formalism, e.g. about their accuracy. Additionally, I will talk about the interplay between systematic errors and the calibration uncertainty of gravitational wave detectors, addressing questions like: How to build up a reliable framework to account for them in parameter estimation? Can the two types of errors be distinguished? Which of them is dominant?

GR 8.2 Wed 13:50 ZHG007

Systematic Biases in Estimating the Properties of Black Holes Due to Inaccurate Gravitational-Wave Models: Part I — Arnab Dhani[1], •Sebastian H. Völkel[1], Alessandra Buonanno[1,2], Hector Estelles[1], Jonathan Gair[1], Harald P. Pfeiffer[1], Lorenzo Pompili[1], and Alexandre Toubiana[1] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, Potsdam 14476, Germany — [2]Department of Physics, University of Maryland, College Park, MD 20742, USA

Gravitational-wave observations of binary black-hole coalescences are expected to address outstanding questions in astrophysics, cosmology, and fundamental physics. Realizing the full discovery potential of upcoming LIGO-Virgo-KAGRA observing runs and new ground-based facilities hinges on accurate waveform models. We present a comprehensive state-of-the-art analysis of binary black hole waveform systematics. Using linear-signal approximation methods and Bayesian analysis, we start to assess our readiness for what lies ahead using two state-of-the-art quasi-circular, spin-precessing models: `SEOBNRv5PHM` and `IMRPhenomXPHM`. Future progress in analytical calculations and numerical-relativity simulations, crucial for calibrating the models, must target regions of the parameter space with significant biases to develop more accurate models. Only then can precision gravitational wave astronomy fulfill the promise it holds. In this talk, part 1 of 2, we outline the importance of such studies, introduce waveform modeling and statistical methods. Review and discussion of our results will be provided in another talk as part 2. [arXiv:2404.05811]

GR 8.3 Wed 14:10 ZHG007

Systematic Biases in Estimating the Properties of Black Holes Due to Inaccurate Gravitational-Wave Models: Part II — Arnab Dhani[1], Sebastian H. Völkel[1], Alessandra Buonanno[1,2], Hector Estelles[1], Jonathan Gair[1], •Harald P. Pfeiffer[1], Lorenzo Pompili[1], and Alexandre Toubiana[1] — [1]Max-Planck-Institute for Gravitational Physics, Am Mühlenberg 1, 14476 Potsdam — [2]Dept. of Physics, University of Maryland, College Park, MD 20742, USA

Gravitational-wave observations of binary black-hole coalescences are expected to address outstanding questions in astrophysics, cosmology, and fundamental physics. Realizing the full discovery potential of upcoming LIGO-Virgo-KAGRA observing runs and new ground-based facilities hinges on accurate waveform models.

This talk is part 2 of two talks presenting an in-depth study of the impact of parameter estimation biases due to imperfect waveform models. Using the techniques presented in part 1, we analyse in depth three prototypical binaries expected to occur in future GW detectors, and find potentially large errors in the estimated parameters (among them component masses and distance) if today's waveform models are utilised. We furthermore highlight were in BBH parameter space significant parameter estimation errors are most likely, and how widespread and how severe they are.

GR 8.4 Wed 14:30 ZHG007

Fighting Gravity Gradient Noise with Gradient-Based Optimization at the Einstein Telescope — •Patrick Schillings and Johannes Erdmann — III. Physikalisches Institut A, RWTH Aachen University

The Einstein Telescope is a third-generation, underground gravitational wave detector that will allow us to measure gravitational waves with significantly improved precision. Its 'xylophone' arrangement is designed to extend the frequency range down to a few Hertz. To improve the sensitivity of the low-frequency interferometer, one needs to mitigate the gravitational effect of density fluctuations in the surrounding rock caused by seismic activity, which result in so-called Newtonian noise in the detector. To achieve that, an array of seismometers will be installed around the mirrors. Expensive boreholes will have to be drilled in order to place these seismometers, which will limit the total number of seismometers that can be placed for a given budget. Therefore, the available resources should be used optimally in terms of predicting the Newtonian noise from the seismometer data. This talk will focus on a differential approach to this optimization problem, which leads to an improvement in terms of noise reduction and runtime compared to methods that were used before.

GR 9: Poster

Time: Wednesday 16:15–18:15 Location: ZHG Foyer 1. OG

GR 9.1 Wed 16:15 ZHG Foyer 1. OG

Quantum gravity without trouble — •René Friedrich — Strasbourg

Lorentzian spacetime, incredibly, proves to be a 100-year-old optical illusion, an impossible object: The banal fact of the non-zero length of worldlines of lightlike light rays shows us that spacetime diagrams and spacetime manifolds have Euclidean metric, because if they were Lorentzian (pseudo-Riemannian), the length of lightlike phenomena would be zero. Accordingly, spacetime is not fundamental, it is mere observation, and the underlying Lorentz-invariant real universe (compatible with quantum mechanics) consists of worldlines in absolute 3D space, each worldline being parameterized by its respective proper time. - Regarding gravity, we can use the fact that gravity may be described not only as curved spacetime, but also equivalently as gravitational time dilation in threedimensional flat space: A comparison Schwarzschild metric / Minkowski metric shows that the difference between flat and curved spacetime can be entirely reduced to gravitational time dilation. - Quantum gravity in only one sentence: Gravity in the form of gravitational time dilation slows down the proper time frequency of the worldlines of quantum systems with mass that are parameterized by their respective proper time. - More: Quantum gravity without trouble, Quantengravitation ohne Mühe, La gravité quantique sans peine.

GR 9.2 Wed 16:15 ZHG Foyer 1. OG

Comment on the Sommerfeld Fine Structure Constant tension — •Manfred Geilhaupt — HS Niederrhein Mönchengladbach

In todays physics, the fine-structure constant (alpha) is a fundamental physical constant which quantifies the strength of the electromagnetic interaction between elementary charged particles. The constant alpha was introduced in 1916 by Arnold Sommerfeld. However, alpha still is an unsolved theoretical and even experimental physical problem up to now! Alpha from atomic interferometric experiments shows a large difference compared to their high accuracy:

1. 2018 Parker et al. 1/137.035999046(27), atomic interferometer experiment
2. 2020 Morel et al. 1/137.035999206(11), atomic interferometer experiment
3. 2011 More et al. 1/137.035999084(15), quantum hall experiment. The 2011 last experimental von Klitzing constant RK=25812.807442(30)Ohm accuracy can be increased by an order of magnitude today. So the RK=e^2/h makes the difference.
4. 2019 form Codata given alphaC= 1/137.035999177
5. 2019 from Codata given alphaRKC=1/137.035999127 based on RKC= 25812.807450(00)Ohm (exact defined) does not match. The presentation contains two answers to the question about tension. Critics appreciated. (A. Einstein: Ein Problem kann man nicht mit der Denkweise lösen, durch die es entstanden ist.)

GR 9.3 Wed 16:15 ZHG Foyer 1. OG

What was before the Big Bang? — •Jürgen Brandes — Karlsbad, Germany

The Einstein interpretation (EI, classical general theory of relativity) says: Before the Big Bang there was nothing, neither space, nor time, nor space-time. But the EI is contradicted by the measurement of two different Hubble constants, because the expansion of the universe cannot take place at two different speeds at the same time. That leaves the Lorentz interpretation (LI): The Big Bang is the explosion of a supermassive object. Its mass must come from somewhere. The simplest assumption: by accretion from emissions from neighboring galaxy clusters on a large scale analogous to the growth of galaxy nuclei on a small scale. This is supported by the observation of galaxies older than the Big Bang [1]. **The main objection:** Supermassive objects are black holes and cannot explode. The proposed solution can also be found at *www.grt-li.de* or [2].

[1] Labbé, I., van Dokkum, P., Nelson, E. *et al.* A population of red candidate massive galaxies 600 Myr after the Big Bang. *Nature* 616, 266*269 (2023) and Olivia Dittrich Berliner Morgenpost 6.3.2023

[2] J. Brandes, J. Czerniawski, L. Neidhart: *Special and general relativity for physicists and philosophers* VRI: 2023, chapter 21, 22, page 279

GR 9.4 Wed 16:15 ZHG Foyer 1. OG

Die Dimensionale Physik erklärt den Aufbau der Naturkonstanten c, G und h nur aus der ART heraus — •Christian Kosmak — Working Group Dimensional Physics, Würzburg

In der Theorie der Dimensionale Physik wird der Ansatz gewählt, dass eine Raumzeitdichte die Quelle der Raumzeitkrümmung ist. Jegliches Masse-Energie-Äquivalent ist eine direkte geometrische Abbildung in der Raumzeit selbst. Dadurch erhält die Raumzeit Grenzen zu einer höherdimensionalen Raumzeit und in unendlich vielen niederdimensionalen Raumzeiten. Diese Grenzen bestimmen den Aufbau der Naturkonstanten c, G und h. Das Plancksche Wirkungsquantum und dadurch die Compton-Wellenlänge eines beliebigen Objektes (Raumzeitdichte) ergeben sich zwingend aus der Struktur der Raumzeit. Dies bedeutet, dass die Allgemeine Relativitätstheorie vorgibt, wie die Quantenfeldtheorie aufgebaut sein muss. Die Raumzeit ist nicht nur eine dynamische Bühne, sondern der einzige Akteur. Internetseite: https://dimensionale-physik.de/ YouTube-Kanal: https://www.youtube.com/@DimensionalePhysik

GR 9.5 Wed 16:15 ZHG Foyer 1. OG

Relativity. Exclusively a speed problem. — •Osvaldo Domann — Stephanstr. 42, 85077 Manching, Germany

Space and time are variables of our physical world that are intrinsically linked together. Laws that are mathematically described as *independent of time*, like the Coulomb and gravitation laws, are the result of repetitive actions of the *time variations* of linear momenta. To arrive to the relativistic transformation equations Einstein omitted the physical interaction of light with the measuring equipment, interaction which makes that light speed is the same in all inertial frames. The results of the omission are transformation rules that show the unphysical time dilation and length contraction. The Lorenz transformation applied on speed variables instead of space and time, as shown in the proposed approach, is formulated with absolute time for all frames and integrates the physical interactions at measuring instrument, which produce the constancy of light speed in all inertial frames. Special relativity with its wrong time dilation and length contraction is used by our theorists to explain experimentally measured data that cannot be explained with the standard model. The results are models like general relativity as the theory for gravitation, a wrong geometric theory not compatible with quantum mechanics. The methodology used by our theorists is equal to the one used to defend geo-centrism. Instead of accepting the new approach of helio-centrism, wrong epicycles were added to geo-centrism resulting in a catastrophic standard model. More at www.odomann.com

GR 9.6 Wed 16:15 ZHG Foyer 1. OG

Impact of Topological Structures on Neutron Star Rotation and Their Observational Significance — •Debojoti Kuzur — Raghunathpur College, Purulia, West Bengal, India

Rotational irregularities are an important observational feature of most pulsars, often manifesting as glitches which are sudden increases in spin angular velocity. Despite extensive study, the underlying mechanism of these glitches remains unresolved. In this research, we explore the role of nontrivial topological defects, specifically Nambu-Goto type cosmic strings, in influencing pulsar spin irregularities. These one-dimensional defects, formed during symmetry-breaking phase transitions, can interact with neutron stars when trapped within their cores.

Our findings suggest that such cosmic strings can couple their tension with the star's angular velocity, resulting in abrupt rotational changes characteristic of pulsar glitches. Additionally, we examine how this coupling could generate detectable gravitational waves, comprising both continuous and burst-like components. The evolution of string cusps within neutron star cores and changes in the star's mass quadrupole moment due to rotation may produce distinctive gravitational wave signatures, potentially detectable by advanced LIGO (advLIGO) within its noise threshold.

This study establishes a possible link between cosmic strings, pulsar glitches, and gravitational wave emissions, offering a framework to test the existence and astrophysical effects of topological defects through observational data.

GR 9.7 Wed 16:15 ZHG Foyer 1. OG

The identification of dark matter — •Albrecht Giese — Taxusweg 15, 22605 Hamburg

The main theme of the dark matter phenomenon is that the galaxies, and also the stars around the galaxies, are rotating at too high a speed. It is considered to be one of the biggest problems in modern physics. This is because the traditional explanation of dark matter as particles, or alternatively a modified law of gravity (MOND), has been largely disproved. This concerns the assumption of special particles due to 'dynamical friction' around big galaxies with orbiting dwarfs, and MOND due to the motion distribution in dwarf galaxies.

The observable spatial distribution of the dark matter effect around galaxies and clusters leads to a solution, because it is identical to the distribution of photons. The result is a different - mass-independent - law of gravity. This contradicts Newton's law of gravity and Einstein's GRT, but is consistent with all observations. And so it is also a test of Einstein's interpretation of relativity.

This solution gives correct quantitative results where data exist, without using free parameters.

Further info: ag-physics.org/gravity

GR 9.8 Wed 16:15 ZHG Foyer 1. OG

Quantum gravity by elimination of spacetime - From the 4D manifold to Lorentz-invariant 1D worldlines — •René Friedrich — Strasbourg

The current interpretation of general relativity (based on the concept of Einstein and Grossmann in 1913) is a sort of "astrometry": Curved spacetime is perfect for astronomical observation and experimental physics, but not for theoretical physics because it is complex, redundant and does not admit the smooth decantation of fundamental conclusions (including quantum gravity). Moreover, since 1905 we know that each particle is following its own clock, that there is no common absolute time axis, and, by consequence, that spacetime is no longer a fundamental notion as it was within Newtonian spacetime. - And gravity? It will also be shown that gravity is perfectly equivalent to gravitational time dilation, acting on onedimensional worldlines in uncurved threedimensional space, paving the way for a worldline-based concept that is compatible with quantum mechanics: Worldlines of quantum systems with mass are parameterized by their respective proper time frequency, and gravity in the form of gravitational time dilation is just modifying this frequency of the worldline. - Book: Quantum gravity without trouble, Quantengravitation ohne Mühe, La gravité quantique sans peine.

GR 9.9 Wed 16:15 ZHG Foyer 1. OG

Über den Wirklichkeitsgehalt der Materie — •Roland Schmidt — Schwalbenweg 21, 34225 Baunatal

In der Newtonschen Theorie ist Wirklichkeit der determinierte Ablauf eines objektiven und allgemein geltenden Geschehens. In der relativistischen Nachbesserung geht dieser absolute Charakter verloren. Es lassen sich nunmehr ausschließlich subjektiv erlebte Wirklichkeiten gegeneinander abgleichen. Der Umstand, dass diese Subjektivierung durch die klassische Elektrodynamik erzwungen wird, scheint keineswegs zufällig; spielt doch bei der metaphysischen Betrachtung subjektiver Wahrnehmung die Idee vom Licht eine ganz entscheidende Rolle. Allerdings sind subjektive Wahrnehmungen allein auf klassischer Grundlage nicht erklärbar. Das abschließende Vordringen elektromagnetischer Potenzialität in die zerebralen Zusammenhänge eines Subjekts erfordert nämlich Ansätze quantenphysikalischer Art. Ich werde zeigen, dass sich die Aufspaltung der physikalischen Theorie in einen klassischen und quantenmechanischen Zweig durch eine Subjektivierung der elektromagnetischen Wechselwirkungen beheben lässt. Demnach resultieren alle klassischen Kategorien wie Raum, Gegenwart oder das Dasein gegenständlicher Bedeutsamkeiten aus einem grundlegenden Symmetriebruch, der mit dem Erleben zerebral-feststellender Zustandssysteme einhergeht. Empirischer Ausdruck davon ist die kosmologische Rotverschiebung, die in meiner subjektivierten Auslegung aus dem Umstand folgt, dass die elektromagnetische Trägheit grundlegender Teilchen gegen den kosmologischen Ereignishorizont hin allmählich verschwindet.

GR 9.10 Wed 16:15 ZHG Foyer 1. OG

Zur Dynamik des Raumes, oder: Was ist Zeit? — •Heinrich Feuerbach — Warschau,Polen

Die Frage danach, was "Zeit" eigentlich ist, ist die wohl tiefgründigste Frage der Physik. Bisher wurden Zeit und Raum als ein globaler, statischer Hintergrund betrachtet oder als eine Bühne, vor der sich die physikalischen Prozesse abspielen. Der Autor stellt das Gegenteil vor: Raum und Zeit als aktive Mitspieler. Dazu wird der Raum als äußerst dynamisch angenommen.

Mit diesen vier Postulaten:

1. Der Raum expandiert in vier Dimensionen mit Lichtgeschwindigkeit; 2. Diese Expansion ist Zeit; 3. Zeit ist äquivalent zur Lichtgeschwindigkeit; 4. Masse ist ein Widerstand zur Raumexpansion und antivalent zur Zeit

entsteht eine erweiterte geometrische Erklärung für die Gravitation.

Die gravitative Zeitdilatation und -Feldstärke ergeben sich inhaltlich und mathematisch direkt aus diesen Postulaten. Darüberhinaus werden folgende Begriffe eingeführt:

- Relative Lichtgeschwindigkeit; - Geschwindigkeitserhaltungssatz; - Strömungs-Widerstands-Prinzip; - Lokale Zeit; - Zeitliche Höhe; - Oberraum; - Gravitativer Widerstand.

Mathematisch wird aus den Postulaten eine DGL formuliert und deren Lösung für den Schwarzschildfall vorgestellt. Die Vierdimensionalität der Raumzeit selbst wird über Quaternionen abgebildet. Abschliessend werden mögliche Tests, neue Vorhersagen, und der Zusammenhang zur ART beschrieben.

GR 9.11 Wed 16:15 ZHG Foyer 1. OG

Kaluza from particles to galaxies — •Thomas Schindelbeck — IRAEPH Mainz

Reducing Kaluzas original ansatz to inserting the electromagnetic potentials into a 5D metric and dropping all other assumptions provides a coherent, consistent and quantitative description of phenomena related to particles and particle interaction, e.g.

1) with boundary condition spin 1/2 a convergent series of quantized particle energies, with limits given by the energy values of the electron and the Higgs vacuum expectation value,

2) electromagnetic and gravitational terms will be linked by a series expansion,

3) minor terms in the metric will give a term in the order of magnitude of vacuum density / cosmological constant,

4) the interpretation as a 5D deSitter space gives an expression for the Baryonic Tully Fisher Relation of galactic rotation curves that can be traced back to the particle level.

The model can be expressed ab initio, i.e. without free parameters. https://zenodo.org/record/3930485

GR 9.12 Wed 16:15 ZHG Foyer 1. OG

Visualizing Curved Spacetime: Curvature Approximation with Cosmological Sector Models via a Web App — •Vassilios Marakis, Corvin Zahn, and Ute Kraus — Universität Hildesheim

The sector model provides a visualization of curved spacetime by dividing the coordinate space into discrete blocks of flat Minkowski space. By applying the Regge calculus and block-to-block transformations, it is possible to approximate the curvature values of the Riemann curvature tensor at specific points in spacetime. Through a web application, we study the effectiveness of this visual approach in estimating these values and examine how increasing the refinement of the coordinate space improves the accuracy of the approximation. This method is demonstrated using a cosmological example featuring a positive cosmological constant.

GR 9.13 Wed 16:15 ZHG Foyer 1. OG

Discoveries at the Time Triangle of Sun, Earth and Moon — •Hans-Otto Carmesin — Athenaeum, Harsefelder Str. 40, 21680 Stade — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

Navigation in space requires reliable and precise clocks on spacecrafts and celestial bodies. For instance, these are essential in order to measure the light travel distance in an interplanetary mission. In order to achieve such time standards in the interplanetary space, general relativity is used, and convenient as well as appropriate frames of reference must be developed (Ashby 2024).

An analysis of the triple Sun, Earth and Moon exhibits an unrealistic idealization inherent to present - day relativity (Carmesin 2025). This analytic result is equivalently transferred to GPS satellites, and these permanently confirm this result empirically.

In general, physically realistic frames can obtained with help of a classical key measurement. This overcomes the idealization and provides precise and reliable frames for interplanetary navigation and beyond. More generally, a wave function is provided that is fundamental in the dynamics of space. Literature: Ashby, Neil; Patla, Bijunath R. (2024): A Relativistic Framework to estimate Clock Rates on the Moon. The Astronomical Journal, 168 (112), 14pp. Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta. Berlin: Verlag Dr. Köster. More information: https://www.researchgate.net/profile/Hans-Otto-Carmesin

GR 9.14 Wed 16:15 ZHG Foyer 1. OG

Solar-like Flares Generated in Strongly Magnetised Binary Neutron Star Merger Remnants — •Jinliang Jiang[1], Harry Ho-yin Ng[1], Michail Chabanov[1,2], and Luciano Rezzolla[1,3,4] — [1]Institute for Theoretical Physics, Goethe University, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany — [2]Center for Computational Relativity and Gravitation School of Mathematical Sciences, Rochester Institute of Technology, 85 Lomb Memorial Drive, Rochester, New York 14623, USA — [3]School of Mathematics, Trinity College, Dublin 2, Ireland — [4]Frankfurt Institute for Advanced Studies, Ruth-Moufang-Str. 1, 60438 Frankfurt am Main, Germany

We investigate the impact of the magnetic-field strength on the long-term (i.e., 200ms) and high-resolution (i.e., 150m) evolutions of the "magnetar" resulting from the merger of two neutron stars with a realistic equation of state. For sufficiently large magnetic fields, we observe the loss of differential rotation in the merger remnant and the generation of magnetic flares in the outer layers of the remnant that have several similarities with solar flares. These flares, that are driven by various magneto-hydrodynamics instabilities and in particular by the Parker instability, are responsible not only for intense and collimated Poynting flux outbursts, but also for low-latitude emissions. The novel long-term phenomenology presented here offers the possibility of seeking corresponding signatures from the observations of short gamma-ray bursts and hence revealing the existence of a long-lived strongly magnetized remnant.

GR 9.15 Wed 16:15 ZHG Foyer 1. OG

Artemis, the Lunar Standard Time and Beyond — •Hans-Otto Carmesin — Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

The currently running Artemis project includes the implementation of a Moon station. For it, a Standard Lunar Time is currently being developed. For that purpose, and in general, appropriate reference frames must be developed (Ashby 2024, p. 1). I present a symmetry transformation that provides appropriate reference frames in general (Carmesin 2025). These symmetry based frames provide especially simple laws of general relativity: essentially the laws proposed by Einstein. These appropriate frames are confirmed by the Spacelab and by GPS satellites. I predict the times shown by clocks at various places in the universe: at Earth, at spacecrafts, at the Moon, at planets and at other celestial bodies. The Artemis mission can test some typical predictions.

Literature:

Ashby, Neil; Patla, Bijunath R. (2024): A Relativistic Framework to estimate Clock Rates on the Moon. The Astronomical Journal, 168 (112), 14pp.

Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta. Berlin: Verlag Dr. Köster.

More information: https://www.researchgate.net/profile/Hans-Otto-Carmesin

GR 9.16 Wed 16:15 ZHG Foyer 1. OG

Analysis of Global Time Dilation — •Yang Jacky[1] and Hans-Otto Carmesin[1,2,3] — [1]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — [2]Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — [3]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

We analyze the global concept of time. Firstly, we use the global flatness of space, in order to derive a global uniform evolution of time. Thereby, we use the ΛCDM model with a homogeneous universe.

Secondly, we extend that theory by heterogeneity. For it, we apply the linear growth theory. As a theoretical tool, we use the volume dynamics, see Carmesin (2024).

Thirdly, we analyze the data of the Hubble tension, in order to derive a global time evolution therefrom.

In all cases, we evaluate the age of the universe. Thereby, we use cosmological parameters achieved by the Planck collaboration (2020).

Fourthly, we analyze the global time evolution by comparing and critically discussing the above three methods.

Literature:

Carmesin, H.-O. (2024): How Volume Portions Form and Found Light, Gravity and Quanta. Berlin: Verlag Dr. Köster.

Planck Collaboration (2020): Planck 2018 results. VI. Cosmological parameters. Astronomy and Astrophysics, pp 1-73.

GR 9.17 Wed 16:15 ZHG Foyer 1. OG

Investigation of the Dynamics of Space and Energy at a Black Hole — •Renner Ivan[1], Neumann Jeremy[1], and Carmesin Hans-Otto[1,2,3] — [1]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — [2]Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — [3]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

We investigate the dynamics of space and energy at a black hole. For it, we use the exactly derived dynamics of volume in nature (Carmesin 2024). Thereby, we use computer experiments. In particular, we study the simultaneous formation, annihilation and propagation of volume portion in a statistical manner at a black hole. Hereby, we discover critical values that characterize the dynamics at a macroscopic level. We compare our findings with observation.

Literature:

Carmesin, H.-O. (2024): How Volume Portions Form and Found Light, Gravity and Quanta. Berlin: Verlag Dr. Köster.

Akiyama, Kazunori and others (2019): First M87 Event Horizon Telescope Results. IV. Imaging the Central Supermassive Black Hole. The Astrophysical Journal. 875, pp 1-17.

GR 9.18 Wed 16:15 ZHG Foyer 1. OG

Universal Quantization Discovered with Special Relativity — •Hans-Otto Carmesin — Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

Quantum physics is a very successful field of science with omnipresent relevant applications in everyday life. An exciting question is still, what is the fundamental reason for the fact of quantization.

Curved space, light waves and gravity provide the fact of quantization with a universal constant of quantization (Carmesin 2023). This result is improved here: The used conditions are minimized. Thus, the achieved insight is maximized. Here, the only used conditions are flat space, light waves and reflection. The result shows that quantum physics is a very fundamental and ideal fact of nature (Carmesin 2025).

In teaching, the Doppler effect is analyzed in the context of a radar control.

Literature

Carmesin, H.-O. (2023): Students Exactly Derive Quantization and its Universality. PhyDid B, FU Berlin, pp 39-44.

Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta. Berlin: Verlag Dr. Köster.

More information: https://www.researchgate.net/profile/Hans-Otto-Carmesin

GR 9.19 Wed 16:15 ZHG Foyer 1. OG

Discovery of Real and Idealized Frames with GPS Satellites — •Hans-Otto Carmesin — Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

The GPS navigation system is omnipresent in modern traffic and navigation (Ashby 2024). Moreover, the GPS satellites provide very precise and multiply related measurements of space and time. Students from class 10 can analyze such relations with linear and quadratic equations, including their inverse terms.

Thereby, they discover an idealization inherent to the present - day theory of special relativity and of general relativity (Carmesin 2025). This analytic result is permanently confirmed empirically by the working of the GPS navigational system.

In general, a symmetry transformation provides realistic frames. This provides fundamental insights about time, space and frames that are essential for the navigation of spacecrafts in interplanetary space and beyond.

Literature

Ashby, Neil; Patla, Bijunath R. (2024): A Relativistic Framework to estimate Clock Rates on the Moon. The Astronomical Journal, 168 (112), 14pp.

Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta. Berlin: Verlag Dr. Köster.

GR 10: Cosmo II

Time: Thursday 13:30–15:35 Location: ZHG008

Invited Talk GR 10.1 Thu 13:30 ZHG008

Probing the cosmic large-scale structure beyond the average — •Cora Uhlemann — Bielefeld University, Germany

The cosmic web of structure arises from the delicate interplay between the gravitational pull of dark matter and the accelerated expansion driven by dark energy. Galaxies form within this intricate skeleton of dark matter, making galaxy surveys powerful laboratories for exploring fundamental physics. The Euclid space telescope will map the distribution of galaxies across most of the sky, spanning over 10 billion years of cosmic history. Analysing billions of galaxies across vast cosmic volumes poses a significant big-data challenge, involving complex nonlinear physics and non-Gaussian statistics often simplified by relying on averages. I will describe how we can squeeze out more information by probing the cosmic large-scale structure beyond the average of standard forward models and statistical analyses. I will illustrate how ultralight dark matter creates quantum wave effects that dress the cosmic web and explain how it can help us to go beyond the average of standard forward models. Additionally, I will highlight the power of one-point statistics, which provide unique and complementary information to the commonly used two-point statistics, and show how these can be accurately predicted and utilised.

GR 10.2 Thu 14:15 ZHG008

Betti Functionals as Probes for Cosmic Topology — Ralf Aurich and •Frank Steiner — Institute for Theoretical Physics, Ulm University, Albert-Einstein-Alle 11,89060 Ulm

The question of the global topology of the Universe (cosmic topology) is still open. In the LCDM concordance model,it is assumed that the space of the Universe possesses the trivial topology of R^3, and thus that the Universe has an infinite volume. We study one of the simplest non-trivial topologies given by a cubic 3-torus describing a universe with a finite volume. To probe cosmic topology, we analyze certain structures in the cosmic microwave background (CMB) using Betti functionals and the Euler characteristic evaluated on excursion sets, which possess a simple geometrical interpretation. Since the CMB temperature fluctuations are observed on the sphere S^2 surrounding the observer, there are only 3 Betti functionals, beta_k(nu), k=0,1,2 (nu is the temperature threshold). Analytic approximations of the Gaussian expectations for the Betti functionals and an exact formula for the Euler characteristic are given. It is shown that beta_0 and beta_1 decrease with an increasing volume of the cubic 3-torus universe. Comparing with 4 Planck 2018 sky maps, it is found that the betas of the Planck maps lie between those of the torus universes with side-lengths L=2.0 and L=3.0 in units of the Hubble length. These results give a further hint that the Universe has a non-trivial topology. Ref.: Universe 2024, 10, 190

GR 10.3 Thu 14:35 ZHG008

Connecting Field-level and Summary Statistics — •Ivana Nikolac, Fabian Schmidt, and Beatriz Tucci — Max Planck Institut fur Astrophysik, Karl Schwarzschild Straße 1, 85748 Garching, Germany

Current methods for extracting cosmological information from galaxy distributions typically involve modelling and analysing the power spectrum or the 2-point correlation function. Expanding beyond the power spectrum can unveil significantly more information, including better constraints on dark energy and inflation models. Employing a Lagrangian EFT-based forward model, LEFTfield, other summary statistics can be investigated. These can then be used to obtain the posterior of the cosmological and bias parameters through simulation-based inference (SBI). A primary goal is to assess how the cosmological constraints obtained through SBI compare with those derived from field-level inference.

GR 10.4 Thu 14:55 ZHG008

Simulation-based inference has its own Dodelson-Schneider effect (but it knows that it does) — •Jed Homer[1,2], Oliver Friedrich[1,2,3], and Daniel Gruen[1,2,3] — [1]University Observatory, Faculty of Physics, Ludwig-Maximilians-Universität, Scheinerstr. 1, 81677 Munich, Germany — [2]Munich Center for Machine Learning (MCML) — [3]Excellence Cluster ORIGINS, Boltzmannstr. 2, 85748 Garching, Deutschland.

Making inferences about physical properties of the Universe requires knowledge of the data likelihood. A Gaussian distribution is commonly assumed with a covariance matrix estimated from a set of simulations. The noise in such estimates causes two problems: it distorts the parameter contours, and it adds scatter to the location of those contours. For non-Gaussian likelihoods, an approximation may be derived via Simulation-Based Inference (SBI). It is often implicitly assumed that parameter constraints from SBI analyses are not affected by the same problems as parameter estimation, with a covariance matrix estimated from simulations. We investigate whether SBI suffers from effects similar to those of covariance estimation in Gaussian likelihoods. SBI suffers an inflation of posterior variance that is equal or greater than the analytical result in covariance estimation for Gaussian likelihoods for the same number of simulations. The assumption that SBI requires a smaller number of simulations than covariance estimation for a Gaussian likelihood analysis is inaccurate. Despite these issues, we show that SBI correctly draws the true posterior contour given enough simulations.

GR 10.5 Thu 15:15 ZHG008

Constraining Mixed Dark Matter Scenarios in the Framework of Perturbation Theory — •Safak Celik and Fabian Schmidt — Max Planck Institute for Astrophysics, Garching bei München, Germany

In this study, we explore the dynamics of mixed dark matter scenarios, focusing on the interplay between cold dark matter (CDM) and warm dark matter (WDM) components. Utilizing perturbation theory techniques, we analyze the evolution of perturbations in a cosmological context where CDM constitutes the primary dark matter component, while WDM, characterized by a weakly interacting, thermally produced mass in the eV-keV range, serves as a secondary component. While the effects of WDM on the linear power spectrum, governed by its mass and abundance, are well-documented, our research delves into the non-linear evolution of these systems. We particularly investigate the role of isocurvature perturbations between the two dark matter components and their impact on the evolution process. Employing a 1-loop galaxy power spectrum, we conduct a Fisher forecast analysis to constrain key parameters, including the fraction and mass of the WDM component and galaxy bias parameters, while examining the degeneracies among them. Our findings enhance the understanding of mixed dark matter models and their implications for cosmological observations.

GR 11: BH Physics II, GW IV

Time: Thursday 14:15–15:35 Location: ZHG007

GR 11.1 Thu 14:15 ZHG007

Autoparallels around a Schwarzschild black hole with GM/r^2-torsion profile — •Jens Boos — KIT, Karlsruhe, Germany

We consider the autoparallel motion of test bodies around a Schwarzschild black hole endowed with a non-trivial torsion field scaling as GM/r^2, where M denotes the ADM mass of the black hole. By explicitly constructing a set of four orthogonal and commuting generalized Killing vectors and deriving their autoparallel conserved quantities we demonstrate the complete integrability of the equations of motion. Additionally, we study the qualitative orbital dynamics via effective potentials. Throughout, we compare the properties of the autoparallels (straightest possible paths) to that of the geodesics (shortest possible paths) and find notable discrepancies.

GR 11.2 Thu 14:35 ZHG007

Perturbations on Schwarzschild Geodesics — •Merlin Böschen and Eva Hackmann — ZARM, Universität Bremen

In binary systems with extreme or intermediate mass ratios, the motion of the secondary object is approximately geodesic. However, perturbations from the gravitational self force as well as from material in the vicinity of the central object can significantly influence the trajectory of the secondary particle. In this presentation we first discuss the framework of osculating geodesics in a Schwarzschild spacetime for different parametrisations of the worldline. Subsequently, we analyse several sources of perturbations in an astrophysical extreme mass ratio system, in particular perturbations due to an accretion disc.

GR 11.3 Thu 14:55 ZHG007

Investigation of the Impact of Wind Turbines on the Einstein Telescope — Marc Boxberg[2], •Tom Niggemann[1], Niklas Nippe[1], Achim Stahl[1], and Florian Wagner[2] for the Einstein Telescope-Collaboration — [1]III. Physikalisches Institut B, RWTH Aachen University — [2]Geophysical Imaging and Monitoring RWTH Aachen University

Wind turbines, critical to renewable energy production, can generate seismic noise that may interfere with highly sensitive observatories, such as the planned Einstein Telescope (ET). Direct and gravitational couplings are a limiting factor for detection of gravitational waves in the low-frequency range. The importance of selecting and adapting wind turbine designs to minimize seismic noise is highlighted. This talk will discuss and evaluate the influence of various wind turbine tower constructions—namely, lattice (girder) masts, wooden towers, steel towers of different heights, and hybrid towers—on seismic noise propagation, with a particular focus on their impact on the ET.

GR 11.4 Thu 15:15 ZHG007

Forecasting Seismic Noise with Deep Learning for Gravitational Wave Detection — •Waleed Esmail[1], Alexander Kappes[1], Stuart Russell[2], and Christine Thomas[2] — [1]Institut für Kernphysik, Universität Münster, 48149 Münster, Germany — [2]Institut für Geophysik, Universität Münster, 48149 Münster, Germany

The Einstein Telescope (ET) is a third-generation gravitational wave observatory. As a ground-based detector, it is susceptible to seismic noise, particularly at low frequencies. Accurately predicting seismic waveforms can help mitigate the impact of seismic noise, thereby enhancing the detector's sensitivity. This study utilizes the power of deep learning algorithms for their ability to model complex systems, to precisely predict the 3-component seismic waveforms. Our approach focuses on training a model to use initial earthquake waves (P-waves) to predict subsequent, more destructive waves (S-waves and surface waves). The training process utilizes synthetic seismograms embedded in realistic noise, with the synthetic data generated using realistic source parameters and Green*s function databases derived from a 1D Earth model.

GR 12: GW V

Time: Thursday 16:15–16:55 Location: ZHG008

GR 12.1 Thu 16:15 ZHG008

Close, but no Merger: Challenges in Parameter Estimation for Black Hole Hyperbolic Orbits — •Joan Fontbuté — Friedrich-Schiller Universität

In this talk, I will be introducing a surrogate numerical-relativity model for close hyperbolic encounters between equal-mass black holes with aligned spins. This model spans a range of impact parameters and spin components, focusing on key gravitational wave emission multipoles. It closely matches numerical relativity simulations, with mismatches below 0.1%. Despite the model's accuracy, I'll argue that parameter estimation proves challenging due to strong degeneracies in the parameter space, even for high signal-to-noise ratios (SNRs). This suggests that detecting such events may require third-generation detectors. However, certain parameter combinations proposed in this project may still provide evidence of these encounters using the current ground-based detectors, provided they are astrophysically meaningful.

GR 12.2 Thu 16:35 ZHG008

Subdominant multipole asymmetries in gravitational waves from binary black-hole mergers — •Jannik Mielke[1,2], Shrobana Ghosh[1,2], and Frank Ohme[1,2] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), D-30167 Hannover, Germany — [2]Leibniz University Hannover, D-30167 Hannover, Germany

In some binaries, the spins of the black holes are not aligned with the system's orbital angular momentum. This causes the spins to precess and leads to an asymmetric emission of gravitational waves. Interestingly, multipole asymmetries which describe this asymmetric emission, are strongly related to the final kick of the remnant black hole and are the critical element in fully describing precession. Despite the astrophysical significance of kicks and precession, multipole asymmetries contribute only minimally to the overall signal strength. Consequently, the majority of current gravitational-wave models do not incorporate them. Moreover, the role of subdominant multipole asymmetries has not been investigated exhaustively. Therefore, this talk discusses the physics of multipole asymmetries, which I present through a systematic study of numerical relativity simulations. In addition, the importance of subdominant multipole asymmetries for the kick calculation will be demonstrated and I give a short outlook for their detectability with third generation detectors.

GR 13: Members' Assembly

Time: Thursday 17:00–18:15 Location: ZHG008

All members of the Gravitation and Relativity Division are invited to participate.

GR 14: Relastro III

Time: Friday 9:00–10:20 Location: ZHG008

GR 14.1 Fri 9:00 ZHG008

Magnetic field configurations in Binary Neutron Star Mergers — •William Cook — Theoretisch-Physikalisches Institut, Friedrich-Schiller Universitat, Fröbelstieg 1, 07743 Jena

Magnetic field configurations inside isolated neutron stars are poorly constrained, and purely poloidal configurations are known to suffer from instabilities. We perform simulations of isolated neutron stars to investigate the development of these instabilities and the growth of toroidal field components. We then investigate the impact of the magnetic field configurations that develop in isolated stars in the context of binary neutron star mergers. Simulations are performed using the exascale-ready numerical relativity codes GR-Athena++ and AthenaK, the designs of which we also discuss

GR 14.2 Fri 9:20 ZHG008

^{56}Ni production in neutrino-driven winds from long-lived binary neutron star merger remnants — •Maximilian Jacobi[1], Fabio Magistrelli[1], Eleonora Loffredo[2], Giacomo Ricigliano[3], Sebastiano Bernuzzi[1], David Radice[4], Almudena Arcones[3,5], Albino Perego[6], and Domenico Logoteta[7] — [1]Friedrich-Schiller-Universität Jena, Germany — [2]INAF - Osservatorio Astronomico d'Abruzzo, Teramo, Italy — [3]Technische Universität Darmstadt, Germany — [4]The Pennsylvania State University, USA — [5]GSI Helmholtzzentrum für Schwerionenforschung GmbH, Darmstadt, Germany — [6]Universitá di Trento, Italy — [7]Università di Pisa, Italy

We investigate the nucleosynthesis and kilonova light curve based on long-term binary neutron star merger simulations incorporating a two-moment neutrino-transport scheme. The ejecta are evolved up to 100 days using axisymmetric radiation-hydrodynamics simulations coupled in-situ to a complete nuclear network. We find that the neutrino-driven wind from the post-merger remnant is proton-rich, resulting in the production of iron-group elements. We explore the consequences of the altered nucleosynthesis on the kilonova light curve and spectrum. The observation of features associated with proton-rich nucleosynthesis could serve as a smoking gun for the presence of a long-lived neutron-star remnant in future kilonova observations.

GR 14.3 Fri 9:40 ZHG008

Simulations of BNSM ejecta with online nuclear calculations and atomic opacities — •Fabio Magistrelli — TPI, FSU Jena

Understanding the details of r-process nucleosynthesis in binary neutron star mergers (BNSM) ejecta is key to interpreting kilonova observations and identifying the role of BNSM in the origin of heavy elements. I will present predictions for light curves and composition results obtained from ray-by-ray radiation-hydrodynamic simulations of BNSM ejecta (extracted from hundreds-of-ms long ab-initio numerical relativity simulations) with an online nuclear network. The ejcta evolution includes charged particles and gamma-rays thermalization, and composition-dependent opacities obtained from atomic calculations. Comparing the results with other initialization procedures and opacity models, I will discuss the correspondent systematic uncertainties on the final predictions for kilonova light curves and element production.

GR 14.4 Fri 10:00 ZHG008

Robustness of the FO-CCZ4 Formulation Compared to GHG — •Mads Sørensen[1], Daniela Cors[2], David Hilditch[3], and Bernd Brügmann[1] — [1]Theoretisch-Physikalisches Institut , Jena, Germany — [2]Department of Applied Mathematics and Theoretical Physics (DAMTP), University of Cambridge, Cambridge, United Kingdom — [3]Center for Astrophysics and Gravitation (CENTRA), Instituto Superior Técnico, University of Lisbon, Lisbon, Portugal

Numerical relativity relies on robust formulations of Einstein's field equations to simulate strong gravitational fields, like black-hole mergers, and for example extract gravitational-wave signals from them. We are interested in the stability of our simulations and thus on the hyperbolicity of the formulations we use. A first-order conformal covariant Z4 (FO-CCZ4) formulation has shown to succesfully manage to simulate moving puctures in 3 dimensions with a higher-order discontinuous Galerkin (DG) scheme. Making the FO-CCZ4 of high interest for various simulations. In this work, we focus on testing the robustness of this formulation by comparing it with the Generalised Harmonic Gauge (GHG) formulation. We have implemented FO-CCZ4 in the pseudospectral code *bamps*, with different shift and slicing conditions. We then compare the behaviour of FO-CCZ4 versus GHG for simple initial data.

GR 15: Cosmo III

Time: Friday 11:00–12:20 Location: ZHG008

GR 15.1 Fri 11:00 ZHG008

Self-similarity of small-scale cosmic structures — •Matthias Bartelmann — Institut für Theoretische Physik, Universität Heidelberg

Based on the saddle-point method within kinetic field theory, and independently on the asymptotic analysis of solutions of the Liouville equation, it has been possible to show that the power spectrum of cosmic density fluctuations necessarily develops an asymptotic behaviour with the wave number k proportional to k^{-3}. I will outline the arguments leading to this result, and discuss implications for virialization and for the self-similarity of cosmic structures.

GR 15.2 Fri 11:20 ZHG008

Velocity statistics of cosmic large-scale structure from Hamiltonian particle dynamics — •Marvin Sipp — Institut für Theoretische Physik, Universität Heidelberg, Deutschland

We present a novel approach to analytically calculating the evolution of velocity statistics of cosmic large-scale structure in cold dark matter.

It is based on a path-integral formulation for the Hamiltonian dynamics of an ensemble of classical particles, specialised to the self-gravitating case on an expanding background. Density and momentum statistics can be extracted by applying suitable operators to the generating functional. The full theory contains the complete phase-space information of the interacting particle ensemble. In practice, we solve the free theory and include interactions perturbatively, reminiscent of other statistical or quantum field theories. The theory can be reformulated in terms of macroscopic fields, leading to an efficient partial resummation of the microscopic perturbative series. Going to higher orders in this perturbation theory is equivalent to integrating higher moments of the BBGKY hierarchy. We thus avoid the shell-crossing problem of standard Eulerian perturbation theory (without introducing effective parameters), allowing for the generation of vorticity in initially irrotational systems and making our framework particularly interesting for studying the evolution of velocity statistics.

We show how n-point momentum statistics can be extracted from the free theory, how gravitational interactions can be included and partially resummed, and present the resulting two-point statistics of the momentum density and density-momentum cross-correlations.

GR 15.3 Fri 11:40 ZHG008

Orientation systematics in the multi-messenger inference of the Hubble constant — •Michael Müller — Universität Greifswald, Greifswald, Germany

Multi-messenger observations of coalescing binary neutron stars are a direct probe of the expansion history of the universe and carry the potential to shed light on the disparity between low- and high-redshift measurements of the Hubble constant H_0. To measure the value of H_0 with such observations requires pristine inference of the luminosity distance and the true source redshift with minimal impact from systematics. A significant uncertainty in the measurement of the former with gravitational waves (GWs) arises from the poorly constrained orientation of the merging binary system relative to the observer. However, observations of the electromagnetic (EM) counterpart emission from the highly collimated relativistic jet, present in the post-merger phase, can provide strong constraints on the orientation of the source and thus inform the distance inference from the GW data. In **arXiv:2406.11965**, we investigate the consequences of a potential disparity between system orientations obtained from the EM and GW data, which, if not carefully treated when combining observations, can bias the inferred value of H_0. Already small misalignments of $3° - 6°$ between the inherent system orientations for the GW and EM emission can bias the inference by $\mathcal{O}(1 - 2\sigma)$ if not taken into account. I will discuss complications with the interpretation of the system orientation in the post-merger phase and present a summary of the core findings of this investigation.

GR 15.4 Fri 12:00 ZHG008

FLRW Constants of the Motion and the Issue of Their Fine-tuning — •Marc Holman — Utrecht University, Utrecht, Netherlands

It seems to be contended at times that quantum gravity considerations could in principle provide justification for a "blindfolded creator" view on the initial value of the curvature parameter, Ω, in FLRW models. That is, even though there are no sound classical motivations for adopting a uniform probability distribution on initial values of Ω, according to such a line of thought, there could in principle exist quantum gravity motivations to that extent. Here it is shown explicitly - in agreement with previous assertions made by the author - that for the radiation- and dust-filled FLRW models of nonzero curvature, a uniform measure on Ω for Planck-scale initial conditions necessarily entails large amounts of fine-tuning in FLRW constants of the motion. This means that, unless there exist specific reasons for fine-tuning these physical constants, a flatness problem in the fine-tuning sense does not exist, whether quantum gravity motivated or not. Time permitting, comments will also be made on more recent arguments, which purport to establish the existence of a flatness problem in the above sense using Bayesian analysis.