Gravitation, Relativistic Astrophysics, and Cosmology Division
Fachverband Gravitation, Relativistische Astrophysik und Kosmologie (GR)

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Overview of Invited Talks and Sessions

(Lecture halls KH 01.016 and KH 02.012; Poster Redoutensaal)

Invited Talks

GR 1.1	Mon	14:45–15:15	KH 01.016	**Recent Developments on Critical Collapse and Extremality** — •Daniela Cors Agullo
GR 4.1	Tue	11:00–11:30	KH 01.016	**From kinetic gases to an accelerated expanding universe - The Finsler Friedmann equation** — •Christian Pfeifer, Nicoleta Voicu, Annamaria Friedl-Szasz, Elena Popovici-Popescu
GR 7.1	Wed	11:00–11:30	KH 01.016	**Electromagnetic jets as strong-gravity probe for rapidly spinning black holes** — •Filippo Camilloni, Luciano Rezzolla
GR 11.1	Thu	11:00–11:30	KH 01.016	**Numerical Relativity for LISA and the Einstein Telescope** — •Nils Vu
GR 17.1	Fri	9:00– 9:30	KH 01.016	**Radio Cosmology and the Cosmic Dawn** — •Jonathan Pritchard

Sessions

GR 1.1–1.1	Mon	14:45–15:15	KH 01.016	**Numerical Relativity I**
GR 2.1–2.5	Mon	16:15–17:30	KH 01.016	**Gravitational Waves I**
GR 3.1–3.5	Mon	16:15–17:30	KH 02.012	**Classical General Relativity I**
GR 4.1–4.3	Tue	11:00–12:00	KH 01.016	**Cosmology I**
GR 5.1–5.5	Tue	16:15–17:30	KH 01.016	**Relativistic Astrophysics I**
GR 6.1–6.5	Tue	16:15–17:30	KH 02.012	**Black Holes I**
GR 7.1–7.3	Wed	11:00–12:00	KH 01.016	**Relativistic Astrophysics II**
GR 8.1–8.6	Wed	13:45–15:15	KH 01.016	**Gravitational Waves II**
GR 9.1–9.6	Wed	13:45–15:15	KH 02.012	**Black Holes II**
GR 10.1–10.18	Wed	16:15–18:45	Redoutensaal	**Poster**
GR 11.1–11.3	Thu	11:00–12:00	KH 01.016	**Numerical Relativity II**
GR 12.1–12.6	Thu	13:45–15:15	KH 01.016	**Relativistic Astrophysics III / Gravitational waves III**
GR 13.1–13.6	Thu	13:45–15:15	KH 02.012	**Quantum Gravity and Quantum Cosmology I**
GR 14.1–14.3	Thu	16:15–17:00	KH 01.016	**Relativistic Astrophysics IV**
GR 15.1–15.3	Thu	16:15–17:00	KH 02.012	**Quantum Gravity and Quantum Cosmology II**
GR 16	Thu	17:15–19:00	KH 01.016	**Members' Assembly**
GR 17.1–17.3	Fri	9:00–10:00	KH 01.016	**Cosmology II**
GR 18.1–18.3	Fri	11:00–11:45	KH 01.016	**Cosmology III**
GR 19.1–19.4	Fri	11:00–12:00	KH 02.012	**Numerical Relativity III**

Members' Assembly of the Gravitation, Relativistic Astrophysics, and Cosmology Division

Thursday 17:15–19:00 KH 01.016

GR 1: Numerical Relativity I

Time: Monday 14:45–15:15 Location: KH 01.016

Invited Talk GR 1.1 Mon 14:45 KH 01.016

Recent Developments on Critical Collapse and Extremality — •Daniela Cors Agullo — DAMTP, Cambrigde University

The threshold of black hole formation explored by Choptuik in 1993 contains a critical point, a codimension-1 attractor that induces nearby spacetimes to display critical phenomena. In spherical symmetry, this picture is consistent across different configurations, indicating a simple structure of extremely nonlinear spacetimes. However, taking away symmetry restrictions seems to also take away this simplicity. In this talk, I will review current efforts in the numerical relativity community to understand the complicated structure of the threshold beyond spherical symmetry. It is worth noting that, even within spherical symmetry, the critical point is not unique: it can be a naked singularity, as found by Choptuik, a metastable star or, as recent work shows, an extremal black hole. In the talk, I will also discuss the mathematical and numerical efforts undertaken to construct extremal black holes.

GR 2: Gravitational Waves I

Time: Monday 16:15–17:30 Location: KH 01.016

GR 2.1 Mon 16:15 KH 01.016

Insights from the test-mass limit for effective-one-body models: elliptic and hyperbolic motion — •Simone Albanesi for the Einstein Telescope-Collaboration — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany — INFN sezione di Torino, Torino, Italy

The effective-one-body (EOB) approach provides an accurate description of the dynamics of comparable mass binaries, including non-circularized configurations. By construction, the EOB formalism incorporates the test-mass limit and can therefore strongly benefit from results obtained in black-hole perturbation theory. In this talk, we discuss recent test-mass results for elliptic and hyperbolic motion and show how these results can be used to better understand and inform the analytical prescriptions employed in EOB models. We further analyze the merger properties of eccentric binaries and dynamical captures in the test-mass limit. These results provide guidance for the construction of a generic mass-ratio ringdown model, enabling a more complete description of non-circularized plunge-mergers. Finally, we discuss new numerical relativity simulations and highlight their analogies with the test-mass case.

GR 2.2 Mon 16:30 KH 01.016

Identifying Sub-Solar Primordial Black Holes for Einstein Telescope Using Deep Learning Methods — •Caner Bahceci, Waleed Esmail, and Alexander Kappes — Institut für Kernphysik, Universität Münster, Wilhelm-Klemm-Straße 9, 48149, Münster

The development of the third-generation gravitational-wave detectors marks a significant advance in the search for primordial black holes (PBHs). In particular, the Einstein Telescope (ET), with its excellent low-frequency sensitivity, will allow an early detection of gravitational-wave signals from compact binaries, including sub-solar-mass systems. In this talk, I will present the methodology used to simulate large-scale datasets of sub-solar-mass PBH binary coalescences developed for ET. Additionally, the talk will discuss how these datasets are employed to train deep learning models to distinguish signals originating either from astrophysical black holes or potentially primordial black holes.

GR 2.3 Mon 16:45 KH 01.016

Astrophysical insights from hierarchical black hole mergers in the era of next-generation detectors — •Angela Borchers[1,2] and Frank Ohme[1,2] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Hannover, Germany — [2]Leibniz Universität Hannover, Hannover, Germany

Black-hole binaries can form through a variety of astrophysical pathways, each leaving distinct imprints on their observable properties. One such pathway is the hierarchical formation of black holes through repeated mergers, which produces black holes with characteristic spin signatures. These spins carry information about both the escape velocity of the host environment and the spins of first-generation black holes. Currently, however, observations of binary black hole mergers by the LIGO-Virgo-KAGRA Collaborations typically have spin measurements with substantial uncertainties, limiting our ability to extract this information. The improved sensitivities of next-generation gravitational-wave detectors, such as the Einstein Telescope and Cosmic Explorer, will enable the observation of many more mergers and provide significantly more precise measurements of binary parameters, including spins. In this talk, I will present simulations of mock observations for Einstein Telescope based on the population properties inferred from the latest gravitational-wave catalog, GWTC-4, and discuss whether spin measurements from next-generation detectors can be used to gain insight into the astrophysical environments and merger histories of binary black holes.

GR 2.4 Mon 17:00 KH 01.016

Effective Gravitoelectric Lagrangian for Neutron Star Dynamical Tides — •Felix Lichtner — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam, Germany

The tidal deformations of neutron stars in binary systems can have a significant impact on the emitted waveforms of gravitational waves. Studying these effects provides a direct window into the internal dynamics of neutron stars, in particular their still unknown equation of state. We characterize the tidal dynamics of a rotating neutron star in an external gravitational field by a systematic construction of a Lagrangian in the framework of effective field theory. This Lagrangian is constructed from the degrees of freedom describing the leading order gravitoelectric effects for neutron stars modeled as a perfect fluid, as is done e.g. in [Gupta, Steinhoff, Hinderer (2021)]. Integrating out the gravitational interactions to third post Newtonian order, we produce an effective description of the gravitoelectric binary dynamics. Further, we characterize the tidal spin via an analysis of the symmetries in the Lagrangian. Finally, we show that the equations of motion as well as the stress-energy tensor attained from the Lagrangian reproduce the Mathisson–Papapetrou–Dixon (MPD) equations of motion describing general extended objects in General Relativity.

GR 2.5 Mon 17:15 KH 01.016

Accounting for the Known Unknowns: Systematic Waveform Errors in Gravitational-Wave Analyses — •Frank Ohme[1,2], Sumit Kumar[1,3], and Max Melching[1,4] — [1]Max Planck Institute for Gravitational Physics, Hannover, Germany — [2]Leibniz University, Hannover, Germany — [3]Utrecht University, Utrecht, The Netherlands — [4]California Institute of Technology, Pasadena, USA

The analysis of gravitational-wave observations relies heavily on models of the instrument noise and the expected signal shape. While models of the instrument's calibration and its noise naturally incorporate some uncertainty, the signal templates are typically treated as perfect. However, we know that this is an idealisation. In this talk, I present a versatile and robust method to incorporate systematic waveform-model uncertainties in the analysis of compact binary mergers. I show that treating signal models as uncertain may decrease the accuracy of the inferred source parameters, but otherwise ignored systematic biases are also reduced. Applying our method to real events, I illustrate that instead of losing accuracy, the main effect is to gain confidence in any results that remain robust with respect to the introduction of systematic errors.

GR 3: Classical General Relativity I

Time: Monday 16:15–17:30 Location: KH 02.012

GR 3.1 Mon 16:15 KH 02.012

What can Holography teach us about scale without conformal invariance? — •Lavish Chawla and Mario Flory — Jagiellonian University in Krakow, Poland

Whether Poincaré invariance together with scale invariance necessarily enhances to full conformal symmetry in quantum field theories remains a longstanding and subtle question. In this talk, we will present our results on this problem from the perspective of the holographic correspondence. In holography, the isometry group of the bulk spacetime corresponds to the global symmetries of a dual quantum field theory. Motivated by this relation, we study spacetimes with one warped extra dimension whose isometry group corresponds to scale without conformal invariance. We show that the Weyl tensor provides an important diagnostic: it vanishes for metrics corresponding to conformal invariance and is nonzero for those corresponding only to scale invariance. With this local geometric condition, we prove the following theorem: For putative boundary theories in two and higher dimensions, the bulk metric cannot exhibit scale without conformal invariance if its warped extra dimension is compact and the null energy condition is required to hold.

GR 3.2 Mon 16:30 KH 02.012

Formulating the complete initial boundary value problem in numerical relativity to model black hole echoes — •Conner Dailey — Institute for Theoretical Physics, Jena, Germany, Fröbelstieg 1 07743 Jena

In an attempt to simulate black hole echoes (generated by potential quantum-gravitational structure) in numerical relativity, we recently described how to implement a reflecting boundary outside of the horizon of a black hole in spherical symmetry. Here, we generalize this approach to spacetimes with no symmetries and implement it numerically using the generalized harmonic formulation. We cast the evolution equations and the numerical implementation into a Summation By Parts (SBP) scheme, which seats our method closer to a class of provably numerically stable systems. We implement an embedded boundary numerical framework that allows for arbitrarily shaped domains on a rectangular grid and even boundaries that evolve and move across the grid. As a demonstration of this framework, we study the evolution of gravitational wave scattering off a boundary either inside, or just outside, the horizon of a black hole. This marks a big leap toward the goal of a generic framework to obtain gravitational waveforms for behaviors motivated by quantum gravity near the horizons of merging black holes.

GR 3.3 Mon 16:45 KH 02.012

Revisiting Synchronisation Systems and Applications in Geodesy — •Bennet Grützner, Eva Hackmann, and Claus Lämmerzahl — ZARM, Universität Bremen

Establishment of International Atomic Time (TAI) requires a global clock network and definitions of synchronisation and simultaneity. On the rotating Earth, this is a non-trivial task due to the Sagnac effect. In geodesy and positioning, this is usually addressed within a post-Newtonian framework. In our work, we extend the synchronisation framework beyond such approximative approaches. We introduce synchronisation systems and provide them with a mathematically rigorous characterisation. We then classify them according to their properties and describe an operational realisation. Finally, we illustrate the framework by discussing synchronisation via the electronically stabilised (ELSTAB) fibre link between Braunschweig and Potsdam.

GR 3.4 Mon 17:00 KH 02.012

Discrete Spacetime Blocks for Visualizing GR: Interactive Geodesics in a (2+1D) Schwarzschild Sector Model — •Vassilios Marakis, Rahel Gabriel, Corvin Zahn, and Ute Kraus — Universität Hildesheim

We present an interactive web application that constructs sector models of curved spacetime. The spacetime is discretized into a mesh of locally flat Minkowski "blocks" in two spatial dimensions and time. Within each block, massive particles and light trajectories are represented as straight worldline segments, while block to block transition implemented as rotations and local Lorentz boosts encode the gravitational curvature. This piecewise flat approach enables an intuitive, visual treatment of general relativity. Geodesics emerge from local inertial motion plus the accumulated effect of successive boundary transformations. The result is a browser based sandbox for geodesics, that combines the concept of local flatness and global curvature understandable without requiring a full differential geometry toolkit during exploration.

GR 3.5 Mon 17:15 KH 02.012

Relativistic orbital perturbation theory — Oleksii Yanchyshen, Eva Hackmann, and •Claus Lämmerzahl — ZARM and ITP, University of Bremen

Within a Newtonian framework orbital perturbation theory is based on the Keplerian orbits as exact solution of the Kepler problem. Perturbation forces lead to time dependent orbital parameters like the semimajor axis, eccentricity, inclination, perigee, and ascending node. Within a relativistic framework we start with the exact solution of the geodesic equation in Schwarzschild space-time. Perturbation forces then lead to a time-dependence of orbital parameters, some of which we newly defined. Their time dependence is described by a relativistic generalization of the Gauß equations. In the presentation this formalism is explained and some applications to perturbations like radiation reaction will be outlined. This new approach is mathematically more challenging but leads to a faster convergence of results than post-Newtonian approaches in the strong field regime.

GR 4: Cosmology I

Time: Tuesday 11:00–12:00 Location: KH 01.016

Invited Talk GR 4.1 Tue 11:00 KH 01.016

From kinetic gases to an accelerated expanding universe - The Finsler Friedmann equation — •Christian Pfeifer[1], Nicoleta Voicu[2], Annamaria Friedl-Szasz[2], and Elena Popovici-Popescu[2] — [1]ZARM, University of Bremen, Germany — [2]Faculty of Mathematics and Computer Science, Transilvania University, Brasov, Romania

The dynamics and the gravitational field of kinetic gases are usually described by the Einstein-Vlasov/Boltzmann equations. The evolution of the gas on phase space is encoded in the 1-particle distribution function (1PDF), while the Einstein equations determine the gravitational field of the kinetic gas from an energy momentum tensor that is obtained by averaging the 1PDF over all physical gas particle velocities (or momenta). Thus, the dynamics of the kinetic gas are described on phase space, but its gravitational field is derived on spacetime through an averaging procedure, which does not take all available information of the gas into account. The immediate questions is, how does the full 1PDF of a kinetic gas gravitate?

In this talk, I will discuss that Finsler gravity naturally elevates the geometry of spacetime to the same phase space footing as kinetic gas matter. It couples the full 1PDF to gravity without loosing information through averaging. In homogeneous and isotropic symmetry, the Finsler gravity equation takes a similar form as the Friedmann equations. Remarkably we find that this Finsler Friedmann equation possesses solutions describing an accelerated expanding universe without the need of a cosmological constant or any other additional quantities.

GR 4.2 Tue 11:30 KH 01.016

The Hubble Tension: Overview, Recent Progress, and the Path Forward — •Nils Schöneberg — Ludwig-Maximilians-Universität, München, Deutschland

Cosmological observations from the early universe and the late universe have been disagreeing about the value of the Hubble constant for more than one decade now. With the nominal significance of this Hubble tension reaching 5σ, it has become one of the most pressing challenges in cosmology. Taken at face value it would signal a breakdown of the Λ + Cold Dark Matter cosmological standard model. Prior to invoking new physics, it is paramount to re-investigate our astrophysical assumptions and to obtain independent confirmations. In this talk I present recent results in the search for the possible causes of the Hubble tension in early- and late-Universe data, including a joint effort from the H_0DN collaboration of constraining the Hubble constant using local astrophysical probes. I give a critical assessment of possible issues and solutions, and highlight future efforts that will be crucial in clarifying this challenge.

GR 4.3 Tue 11:45 KH 01.016

Simulation-based inference with the integrated 3PCF — •David Gebauer — Universität Bielefeld

We present a simulation-based inference (SBI) framework for analysing a higher-order weak lensing statistic, the integrated 3-point correlation function (i3PCF). Our approach forward-models the cosmic shear field using a suite of N-body simulations, including a comprehensive set of systematic effects such as intrinsic alignment, baryonic feedback, photometric redshift uncertainty, shear calibration bias, and shape noise. Using this, we have produced a set of DES Y3-like synthetic measurements for 2-point shear correlation functions and i3PCFs across 6 cosmological and 11 systematic parameters. Having validated these measurements against theoretical predictions and thoroughly examined for potential systematic biases, we have found that the impact of source galaxy clustering and reduced shear on the i3PCF is negligible for Stage-III surveys. Furthermore, we have tested the Gaussianity assumption for the likelihood of our data vector and found that the likelihood of the combined 2PCF + i3PCF data vector including filter sizes of 90' and larger can deviate from this assumption. Our SBI pipeline employs masked autoregressive flows to perform neural likelihood estimation and is validated to give statistically accurate posterior estimates. On mock data, we find that including the i3PCF yields a substantial 63.8% median improvement in the figure of merit. These findings are consistent with previous works on the i3PCF and demonstrate that our SBI framework can achieve the accuracy and realism needed to analyse the i3PCF in wide-area weak lensing surveys.

GR 5: Relativistic Astrophysics I

Time: Tuesday 16:15–17:30 Location: KH 01.016

GR 5.1 Tue 16:15 KH 01.016

Magnetic field instabilities and late-time equilibria in isolated neutron stars — •Aurora Capobianco — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany

The late-time equilibrium geometry of magnetic fields in neutron stars remains poorly constrained, despite its importance for observable signatures. We investigate the development and long-term evolution of strong magnetic fields in isolated neutron stars using the general relativistic magnetohydrodynamics (GRMHD) code AthenaK. Our simulations follow the full general-relativistic evolution of neutron stars with an external dipole-like field and a range of initial internal magnetic-field configurations. We focus on the symmetry properties, stability, and equilibrium structure of the resulting magnetic-field. In particular, we examine the onset and nonlinear evolution of magnetic-field instabilities and assess their role in redistributing magnetic energy. We also discuss the implications of these dynamics for the gravitational-wave emission produced.

GR 5.2 Tue 16:30 KH 01.016

Curvature invariants and trace anomaly in neutron stars — •Iván Garibay[1,2], Christian Ecker[1], and Luciano Rezzolla[1,3,4] — [1]Institut für Theoretische Physik, Goethe Universität, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany — [2]Instituto de Astronomía, Universidad Nacional Autónoma de México, Ciudad de México, CDMX 04510, Mexico — [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 behaviour of curvature invariants for a large ensemble of neutron stars built with equations of state (EOSs) that satisfy constraints from nuclear theory and perturbative QCD, as well as measurements of neutron-star masses, radii, and gravitational waves from binary neutron-star mergers. Surprisingly, our analysis reveals that stars with negative Ricci scalar $\mathcal{R}$ are rather common, and about $\sim 49\%$ of our EOSs produce one or more stars with Ricci curvature that is negative somewhere inside the star. Furthermore, this negative curvature is found mostly but not exclusively at the highest densities and pressures, and predominantly for stiff EOSs. Furthermore, using a well-known relation between the Ricci scalar and the trace anomaly, Δ, our analysis also allows us to determine the general conditions under which the conformal symmetry of matter is broken and restored in neutron stars. Finally, we determine a number of correlations among the different scalar invariants and map the ranges of their allowed values inside neutron stars.

GR 5.3 Tue 16:45 KH 01.016

Photon phenomenology in the accelerated Schwarzschild black hole — •Eva Hackmann[1] and Shokoufe Faraji[1,2,3,4] — [1]Center of Applied Space Technology and Microgravity (ZARM), University of Bremen — [2]Department of Physics and Astronomy, University of Waterloo — [3]Waterloo Centre for Astrophysics, University of Waterloo — [4]Perimeter Institute for Theoretical Physics

We analyse null geodesics in an accelerated Schwarzschild black hole sustained by a cosmic string and/or strut (C-metric) in the subextremal regime, and investigate if the acceleration and, in particular, the conicity parameter induced by the string/strut can be constrained from observations. For photons the conformal Hamilton-Jacobi equation separates, and we reduce the radial and polar motion to the Bierman-Weierstrass form, yielding new forms of closed analytic solutions. We show that the conicity parameter has no impact on the location of the fixed photon cone that replaces equatorial symmetry when the acceleration is nonzero, or on the single spherical photon surface shared by all latitudes. On the observational side, we prove that the shadow seen by any observer is an exact circle: its screen radius depends on the acceleration and observer distance but not on observer inclination or the conicity, so the local shadow cannot bound the string tension. We also show how a single shadow measurement with known mass-distance relation uniquely infers the dimensionless acceleration. Finally, we provide compact expressions for the photon circle orbital frequency and Lyapunov exponent and use them to obtain eikonal quasinormal estimates.

GR 5.4 Tue 17:00 KH 01.016

mw-atlas: Bayesian reconstruction of the magnetic field from synchrotron emission — •Richa Halder[1] and Philipp Mertsch[2] — [1]RWTH Aachen University — [2]RWTH Aachen University

This project aims to build a 3D map of the Galactic magnetic field of the Milky Way from synchrotron emission, using a fully Bayesian framework. The magnetic field shapes cosmic-ray propagation, regulates interstellar gas and star formation, and distorts the signals used in precision cosmology, so its 3D structure must be known to interpret many astrophysical observations correctly. We use NIFTy, a variational inference framework, to infer the magnetic field from synchrotron data for a given distribution of cosmic-ray electrons. This provides full posterior distributions instead of single best-fit parameter sets, so uncertainties are explicitly quantified and can be propagated into other, derived quantities. Compared to previous reconstructions based on low-dimensional parametric GMF models fitted to integrated observables, our approach allows far more flexible field geometries, reduces bias from mis-specified parametric forms, and will be tested both on realistic simulations and future observational datasets.

GR 5.5 Tue 17:15 KH 01.016

Post-Newtonian N-Body Simulations — •Felix Heinze, Gerhard Schäfer, and Bernd Brügmann — Friedrich-Schiller-Universität Jena, Theoretisch-Physikalisches Institut, Fröbelstieg 1, 07743 Jena

The post-Newtonian formalism is a central tool for constructing approximate solutions of Einsteins field equations in the weak-field, slow-motion regime, in particular for gravitational systems of multiple point masses. This talk gives an overview of the current status of post-Newtonian N-body simulations and focuses on recent developments in the derivation of the N-body Hamiltonian at second post-Newtonian order, as well as on the numerical integration of the resulting equations of motion.

GR 6: Black Holes I

Time: Tuesday 16:15–17:30 Location: KH 02.012

GR 6.1 Tue 16:15 KH 02.012

Interplay of evaporating black holes with BSM particle physics — •Jens Boos and Christoph Borschensky — Karlsruhe Institute of Technology

Evaporating black holes emit Hawking radiation. The precise radiation rate depends on (i) the geometrical backreaction, described by greybody factors, and (ii) the particle spectrum of the universe. We demonstrate that both aspects of modified gravity and beyond-the-standard model particle physics need to be taken into account to model a realistic black hole lifetime. In doing so, we outline the main corrections one thereby obtains to the emitted photon spectrum (including secondary photons) that is relevant to constrain the abundance of such evaporating black holes and links them to (a part of the) dark matter relic density.

GR 6.2 Tue 16:30 KH 02.012

Microlensing of non-singular black holes at finite size: a ray tracing approach — •Hao Hu and Jens Boos — Institute for Theoretical Physics, Karlsruhe Institute of Technology, D-76128 Karlsruhe, Germany

We study the gravitational microlensing of various static and spherically symmetric non-singular black holes (and horizonless, non-singular compact objects of similar size). For pointlike sources we extend the parametrized post-Newtonian lensing framework to fourth order, whereas for extended sources we develop a ray tracing approach via a simple radiative transfer model. Modelling non-relativistic proper motion of the lens in front of a background star we record the apparent brightness as a function of time, resulting in a photometric lightcurve. Taking the star radius to smaller values, our numerical results approach the theoretical predictions for point-like sources. Compared to the Schwarzschild metric in an otherwise unmodified lensing geometry, we find that non-singular black hole models (and their horizonless, non-singular counterparts) at finite size tend to feature larger magnifications in microlensing lightcurves, contrary to the point-source prediction.

GR 6.3 Tue 16:45 KH 02.012

On the formation of black-hole mimickers within General Relativity — •Daniel Jampolski[1] and Luciano Rezzolla[1,2,3] — [1]Institut für Theoretische Physik, Max-von-Laue-Str. 1, 60438 Frankfurt, Germany — [2]School of Mathematics, Trinity College, Dublin 2, Ireland — [3]CERN, Theoretical Physics Department, 1211 Geneva 23, Switzerland

Regular black holes and horizonless black-hole mimickers offer mathematically consistent alternatives to address the challenges posed by standard black holes. However, the formation mechanism of these alternative objects is still largely unclear and constitutes a significant open problem since understanding their dynamical formation represents a first step to assess their existence. We here investigate, for the first time and without invoking deviations from general relativity, the dynamical formation of a well-known horizonless black-hole mimicker, namely, a gravastar. More specifically, starting from the collapse of a uniform dust sphere as in the case of the Oppenheimer-Snyder collapse, we demonstrate that, under suitable conditions, a gravastar can form from the nucleation and expansion of a de-Sitter region with initial zero size at the center of the collapsing sphere. Furthermore, the de-Sitter expansion naturally slows down near the Schwarzschild radius, where it meets the collapsing dust surface and gives rise to a static equilibrium. Interestingly, we also find a maximum initial compactness of the collapsing star of $\mathcal{C} = 3/8$, above which the collapse to a black hole is inevitable.

GR 6.4 Tue 17:00 KH 02.012

Formation and Time Evolution of Primordial Black Holes — Hans-Otto Carmesin[1,2,3] and •Lina Jarck[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

In the very early universe, the density has been sufficiently large, so that black holes have formed. Simultaneously, these can decay as a result of Hawking radiation.

(1) For various densities, the amount of primordial black holes is derived as a dynamical equilibrium value.

(2) A population-based simulation is developed in Python. The simulation models processes in the early universe: Photons move randomly within a defined space. When two photons meet, they can fall into the Schwarzschild radius and form a black hole. Its lifetime is determined. The black hole then decays back into two photons through Hawking radiation.

(3) The results are compared with primordial black holes observed by the James Webb Space Telescope.

Carmesin, H.-O. (2020): The Universe Developing from Zero-Point Energy - Discovered by Making Photos, Experiments and Calculations. Berlin: Verlag Dr. Köster.

GR 6.5 Tue 17:15 KH 02.012

The observer-invariant end of spacetime at the horizon of Schwarzschild black holes — •René Friedrich — Strasbourg

Time is not absolute but observer-dependent: This groundbreaking insight of Einstein in 1905 has the potential to settle the famous disagreement between external observer Bob and infalling observer Alice:

At first sight, the fact that Alice reaches the event horizon of a black hole within finite proper time prevails over Bob's "mere" observation that infalling matter does never reach the horizon. However, all external observers (even including Alice who is an external observer, too, before reaching the horizon) agree without exception that the horizon represents the ultimate simultaneity line (t = infinity), the temporal border of the spacetime manifold. Since spacetime is observer-dependent and thereby mere observation, this "concordant observation shared by all observers of the universe of spacetime" is perfectly adapted for determining the extent and the boundaries of spacetime.

As a result, there can't exist any spacetime beyond observation, and when Alice - subject to infinite gravitational time dilation - reaches the event horizon, she is leaving our observer-dependent spacetime manifold. Consequently, the mass of a Schwarzschild black hole is not inside the horizon but outside, in the approximate form of a nearby membrane, avoiding the unsolvable dilemma of a central spacetime singularity. More: Quantum gravity without trouble.

GR 7: Relativistic Astrophysics II

Time: Wednesday 11:00–12:00 Location: KH 01.016

Invited Talk GR 7.1 Wed 11:00 KH 01.016

Electromagnetic jets as strong-gravity probe for rapidly spinning black holes — •Filippo Camilloni and Luciano Rezzolla — Goethe University, Frankfurt am Main, Germany

The environment around astrophysical black holes is characterised by an abundance of plasma and intense electromagnetic fields subject to strong-gravity conditions. As indicated from analytic computations and numerical simulations this rich phenomenology range from magnetic reconnection, that can trigger a Penrose process involving structures called plasmoids, to the Blandford-Znajek (BZ) mechanism, an electromagnetic form of energy extraction that is currently considered the best theoretical candidate to explain the launching of powerful relativistic jets. We discuss the quasi-universal nature of the BZ jet power and how the higher-order perturbative corrections bear signatures of the underlying theory of gravity, thus enabling one use the jet power as a strong-gravity signature to test general relativity on future horizon-scale observations when black holes are rapidly spinning.

GR 7.2 Wed 11:30 KH 01.016

Construction of a 2d neutrino sky map — •Lukas Liland for the IceCube-Collaboration — TU Dortmund

The IceCube collaboration has during the last 15 years made important discoveries concerning high-energy astrophysical neutrinos. IceCube first presented evidence of the flux of these neutrinos in 2013, and in 2023 the collaboration presented evidence of an excess neutrino flux from the Milky Way Galaxy. This talk presents a project with the aim of constructing a 2D sky map of the astrophysical neutrino flux. A relatively new sample of IceCube neutrino events are processed with a transformer neural network, a state-of-the-art machine learning algorithm used by the famous large language models, to yield improved reconstructions of the energies and the directions of the neutrinos. A neutrino sky map is then produced using the technique of unfolding, which recovers the real neutrino flux from the calculated estimations with the help of MC simulations.

GR 7.3 Wed 11:45 KH 01.016

QCD in the cores of Neutron Stars — •Oleg Komoltsev — Institut für Theoretische Physik, Goethe Universität, Frankfurt am Main

Rapid advancements in neutron-star (NS) observations allow unprecedented empirical access to cold, ultra-dense Quantum Chromodynamics (QCD) matter. The combination of these observations with theoretical calculations reveals previously inaccessible features of the equation of state and the phase diagram of QCD. In this talk, I demonstrate how perturbative-QCD calculations at asymptotically high baryon density provide robust constraints on the equation of state at neutron-star densities, based solely on causality and stability. By comparing the calculations to multimessenger neutron-star observations using a Bayesian framework, I show that QCD input softens the equation of state at neutron-star densities, supporting the hypothesis of a first-order phase transition or a crossover to quark matter cores in the most massive neutron stars.

GR 8: Gravitational Waves II

Time: Wednesday 13:45–15:15 Location: KH 01.016

GR 8.1 Wed 13:45 KH 01.016

interaction between gravitational waves and condensed matter systems — •Michel Paulsen[1], Gudrid Moortgat-Pick[1,2], Andreas Ringwald[2], and Tom Krokotsch[1] — [1]University of Hamburg — [2]DESY

Gravitational waves have established themselves as a key tool for investigating compact astrophysical sources, but so far they have been limited to a lower frequency range. High-frequency gravitational waves (HFGW) are of particular theoretical interest, as they could potentially provide access to previously unexplored physical processes. The talk covers theoretical investigations of the interaction of gravitational waves with condensed matter systems, with a focus on high-frequency regimes. The focus is on specific physical mechanisms through which HFGW could couple with structured matter, as well as their consequences for alternative approaches to investigating such signals. Matter systems that are suitable for corresponding theoretical analyses, including superconducting systems, are considered as a frame of reference.

GR 8.2 Wed 14:00 KH 01.016

Mission Concepts for future space-based Gravitational Wave Detectors — •Jones Rosario — MPI for Gravitational Physics (AEI), Hannover, Germany

Gravitational waves are ripples in space-time caused by some of the most energetic processes in our universe. Since the first detection by LIGO in 2015, over 200 further signals have been observed. In 2035, the ESA-led space mission LISA is set to launch and will have it's highest sensitivity in the mHz band. With this, LISA's sensitivity will lie between the high-frequency window (hertz to kilohertz) of ground based detectors such as LIGO and Virgo, and the nano-hertz regime probed by PTAs. However, these detectors will not cover the gravitational wave spectrum entirely. Particularly, there are gaps in the decihertz and the microhertz regime, which could be addressed by future space missions. In the context of ongoing efforts to propose mission concepts to ESA for the 2050s, we will discuss mission concepts proposed in literature that aim to probe these bands. We further extend on this and present current developments towards realistic designs with respect to technical feasibility and affordability.

GR 8.3 Wed 14:15 KH 01.016

Gravitational wave backgrounds from trapped axion-like particles — •Daniel Schmitt — Goethe University Frankfurt

Axion-like particles (ALPs) are among the most promising dark matter candidates. While laboratory experiments and astrophysical observations have excluded parts of the viable ALP parameter space, the regime of large ALP decay constants, where the ALP becomes invisible, remains hard to access experimentally. I will discuss the conditions under which such invisible ALPs can generate a sizable primordial gravitational wave (GW) background. In particular, I will focus on ALP production via trapped misalignment, where the oscillations of the pseudoscalar are delayed compared to the conventional misalignment scenario. This can trigger resonances in the equation of motion of both the ALP and a gauge field coupled to the ALP, leading to the exponential growth of horizon-sized fluctuations in the early Universe. Such large anisotropies source stochastic GWs, enabling to probe a large part of the ALP parameter space through future GW observatories.

GR 8.4 Wed 14:30 KH 01.016

Predicting gravitational wave observations for next-generation detectors — •Per-Ingmar Laurens Schrake[1,2] and Frank Ohme[1,2] — [1]Max Planck Institute for Gravitational Physics — [2]Leibniz University Hannover

The detection of gravitational waves from merging compact binaries has revolutionized astronomy since the first observation in 2015, with the current GWTC-4.0 catalog containing 161 events. A new generation of significantly more sensitive detectors, such as the Einstein Telescope (ET) and Cosmic Explorer (CE), is already being planned. But what will these future detectors actually be able to measure in detail? This talk examines what predictions about future gravitational wave observations can be derived from the currently available population statistics. To answer this, a synthetic merger population is generated by randomly sampling from the parameter distributions reported in GWTC-4.0. Subsequently, the corresponding gravitational waveforms are generated with state-of-the-art models and evaluated depending on the sensitivity curve of next-generation detectors. The statistical distribution of the resulting signal-to-noise ratio is analyzed to estimate the anticipated occurrence of very strong signals. The framework further enables systematic comparisons among different population models and confusion noise estimates. Under realistic assumptions regarding population properties and detector sensitivities, it becomes apparent that ET enables the near-complete detection of merging compact binaries within the local universe.

GR 8.5 Wed 14:45 KH 01.016

Vacuum, surface monitoring and cleaning experiment for Einstein Telescope — •Markus Schulz-Ritz, Joachim Wolf, Adrian Schwenck, Ralph Engel, Judith Schneider, and Hendrik Weingardt for the Einstein Telescope-Collaboration — Karlsruhe Institute for Technology, Karlsruhe, Germany

The Einstein Telescope (ET) will be a third generation gravitational wave detector, consisting of a set of low frequency and high frequency interferometers. In order to mitigate thermal noise, the mirrors for the low frequency interferometer are required to be cooled down to cryo temperatures. This leads to freezing of residual gas from the vacuum chamber onto the mirror surface. This will affect the required cooling power and the sensitivity of ET. Hence R&D measurements at cryogenic temperatures are being prepared, investigating the formation of ice layers on the mirror from different gases (CO2, water, nitrogen,...) using ellipsometry and quartz micro balances (QMB) for monitoring the thickness of the layer. Further research will include the testing of different in-situ cleaning procedures of silicon surfaces with methods, such as argon plasma cleaning, low-energy electrons and UV light. The talk will be about the setup at KIT and will present first results.

GR 8.6 Wed 15:00 KH 01.016

Stimulated Emission or Absorption of Gravitons by Light — •Ralf Schützhold — Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

We study the exchange of energy between gravitational and electromagnetic waves in an extended Mach-Zehnder or Sagnac type geometry that is analogous to an optical Weber bar. In the presence of a gravitational wave (such as the ones measured by the Laser Interferometer Gravitational Wave Observatory), we find that it should be possible to observe (via interference or beating effects after a delay line) signatures of stimulated emission or absorption of gravitons with present-day technology. Apart from marking the transition from passively observing to actively manipulating such a natural phenomenon, this could also be used as a complementary detection scheme. Nonclassical photon states may improve the sensitivity and might even allow us to test certain quantum aspects of the gravitational field.

[1] R. Schützhold, *Stimulated Emission or Absorption of Gravitons by Light*, Phys. Rev. Lett. **135**, 171501 (2025)

GR 9: Black Holes II

Time: Wednesday 13:45–15:15 Location: KH 02.012

GR 9.1 Wed 13:45 KH 02.012

Gravitational lensing in a warm plasma — Barbora Bezdekova[1] and •Volker Perlick[2] — [1]Department of Physics, Faculty of Natural Sciences, University of Haifa, Haifa 3498838, Israel — [2]Faculty 1, Universität Bremen, 28359 Bremen, Germany

We consider gravitational kensing in a warm, non-magnetized electron-ion plasma, thereby extending the rather extensive literature on lensing in a cold plasma. After discussing the general equations for light rays in such a medium on a general-relativistic spacetime, we specify to the axially symmetric and stationary case which includes the spherically symmetric and static case. In particular, we calculate the influence of a warm plasma on the bending angle. In the spherically symmetric and static case, we also calculate the shadow in a warm plasma. We illustrate the general results with a static (respectively corotating) and an infalling warm plasma on Schwarzschild and Kerr spacetimes. A preprint of this work is available at arXiv:2512.09341 .

GR 9.2 Wed 14:00 KH 02.012

Rényi second laws for Charged AdS Black Hole — Alice Bernamonti[1], Federico Galli[1], and •Emiliano Rizza[2] — [1]Università degli Studi di Firenze, Florence, Italy — [2]Jagiellonian University, Krakow, Poland

Hawking's black hole area theorem offers a geometric interpretation of the second law of thermodynamics, imposing fundamental constraints on gravitational dynamics. By examining entropic inequalities following from the monotonicity of Rényi entropies, it is shown that these constraints often set stricter bounds than those imposed by the area theorem in asymptotically AdS space.

This work aims to explore in detail the case of charged AdS black holes, which exhibit rich thermodynamic phase structures in the canonical ensemble. In particular, we study the coalescence of charged black holes in AdS, establishing a lower bound on the mass of the final state and an efficiency bound on the amount of gravitational radiation.

GR 9.3 Wed 14:15 KH 02.012

Bound States of the Schwarzschild Black Hole — •Sebastian H. Völkel — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), D-14476 Potsdam, Germany

Understanding the physical significance and spectral stability of black hole quasinormal modes is fundamental to high-precision spectroscopy with future gravitational wave detectors. Inspired by Mashhoon's idea of relating quasinormal modes of black holes with their equivalent bound states in an inverted potential, we investigate, for the first time, energy levels and eigenfunctions of the Schwarzschild black hole quantitatively. While quasinormal modes describe the characteristic damped oscillations of a black hole, the bound states of the inverted potential are qualitatively more similar to those of the hydrogen atom. Although the physical interpretation of these states may initially be of more academic interest, it furthers our understanding of open problems related to quasinormal modes in a similar spirit to Maggiore's interpretation of the Schwarzschild quasinormal mode spectrum. One surprising insight from the explicit calculation of bound states is that eigenfunctions corresponding to quasinormal mode overtones become rapidly delocalized and extremely loosely bound. This observation raises immediate questions about the common interpretation of quasinormal modes as excitations of the lightring region. Closely related, as a second application, we also explore the spectral stability of bound states and demonstrate that they can provide complementary insights into the quasinormal mode spectrum.

Völkel, Phys. Rev. Lett. 134, 241401, 2025

GR 9.4 Wed 14:30 KH 02.012

Astrophysical Quantum Matter: Black-Hole and Cosmological Particle Production — •Michael Florian Wondrak — Anton Pannekoek Institute for Astronomy/GRAPPA, University of Amsterdam, The Netherlands

Energy extraction from black holes is—at first sight—a counterintuitive concept. However, black holes are known to lose mass by classical and quantum processes. In recent work, the formal analogy with particle production by electric fields (Schwinger effect) was elaborated.

Building upon this analogy, we will use independent techniques, from canonical to path-integral quantization, to predict quantum particle production in astrophysical settings, from black holes to cosmology. We will present a novel class of time profiles allowing an analytic treatment and allowing an exact prediction of particles produced. We will put the findings into context and comment on the impact of backreaction.

GR 9.5 Wed 14:45 KH 02.012

Forecasting Ground Motion with Large Sequence Models: Implications for the Einstein Telescope — •Waleed Esmail[1], Alexander Kappes[1], Stuart Russell[2], and Christine Thomas[2] — [1]Institut für Kernphysik, Universität Münster, Wilhelm-Klemm-Straße 9, 48149, Münster — [2]Institut für Geophysik, Universität Münster, Wilhelm-Klemm-Straße 9, 48149, Münster

Seismic forecasting is entering a new phase in which data-driven sequence models can learn the complex temporal structure of ground motion directly from waveform records. In this talk, I will discuss a transformer-based approach that treats seismic waveforms as a generative sequence prediction problem, allowing short-horizon forecasting.

A key motivation comes from the Einstein Telescope, where seismic noise, especially at low frequencies, can limit detector sensitivity. Accurate, low-latency forecasting enables active noise cancellation, where the detector can anticipate incoming noise and suppress it before it couples into the interferometer. I will show how transformer-based models can support this vision and why a seismic foundation model may become a core component of the next generation of gravitational-wave observatories.

GR 9.6 Wed 15:00 KH 02.012

Relativistic hydrogen spectrum of the Bopp-Podolsky electrostatic potential — •Altin Shala[1] and Volker Perlick[2] — [1]ZARM, Bremen, Germany — [2]Faculty 1 University of Bremen, Bremen, Germany

We investigate the relativistic hydrogen spectrum given by the Dirac equation when the electrostatic potential of the nucleus is described by the potential given by Bopp-Landé-Thomas-Podolsky theory of electrodynamics. Employing numerical and analytical methods, we take advantage of known measurement uncertainties in the hydrogen spectrum in order to place new constraints on the introduced parameter.

GR 10: Poster

Time: Wednesday 16:15–18:45 Location: Redoutensaal

GR 10.1 Wed 16:15 Redoutensaal

Doubly-periodic Processes in Particle Accelerators, Fusion Reactors and Artificial Photosynthesis — •Otto Ziep — Independent Scholar, 13089, Berlin, Germany

Vacuum energy for a real Lagrangian can be undercut by least squares of complex conformal fields where stress-energy resembles a Schwarzian derivative for a doubly-periodic iteration. The dynamics of zeros of holomorphic functions yields a Newton fractal quadratic in mass 0=δmδm' with phantom energy ρ(dark) which resembles spin zero fields. Local stationary states ρ-ρ(dark)=0 are predicted similar to the Dirac model of additive creation of matter ρ. For particle accelerators, fusion reactors and in artificial photosynthesis a doubly-periodic processing called breathing mode is designed which predicts cooling due to generated complex dark matter ρ(dark).

[1] O. Ziep, Cosmic Rays, Aerosol-Photosynthesis and Vegetational Air Ion, Journal of Modern Physics, Bd. 16, p. 1179-1192, 2025, https://doi.org/10.4236/jmp.2025.168059

[2] O. Ziep, Doubly- Periodic Processing in Particle Accelerators and Fusion Reactors, submitted to Journal of High Energy Physics, Gravitation and Cosmology, 2025.

[3] O. Ziep, Doubly-Periodic Atmospheric Power Plants,submitted to Discover Energy, 2025.

GR 10.2 Wed 16:15 Redoutensaal

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

The considerations of the previous year are continued.

A good overview of the numerous observations that contradict the cosmological principle of GRT can be found in [1]. These include the Hubble Tension [2] as well as the remarkable observation that the expanding universe has angular momentum, as if it were a rotating stellar object. A fundamental *theoretical* objection to the idea of GRT that space expands is its contradiction with the law of conservation of energy. The energy of background radiation (CMB) decreased from 3000°K to 2.7°K over time due to space expansion. *However, it is unclear where the lost energy remains.* The LI of GRT does explain it, given that the source and receiver move relative to each other [3]. A physical theory that contradicts the law of conservation of energy leaves some questions unanswered.

[1] Pavan Kumar Aluri et al. *Is the Observable Universe Consistent with the Cosmological Principle?* arXiv:2207.05765v4 [astro-ph.CO] 27 Feb 2023

[2] J. Brandes, J. Czerniawski, L. Neidhart: *Special and General Theory of Relativity for physicists and philosophers* VRI: 2023, chapter 24.11.2, page 324.

[3] Article (during 2026) on homepage www.grt-li.de: *DPG-2025-2026-What was before the Big Bang.*

GR 10.3 Wed 16:15 Redoutensaal

Quantum gravity via Lorentz-invariant gravity — •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, paving the way to quantum gravity: Gravity in the form of gravitational time dilation slows down the frequency of the proper time of worldlines of massive particles, corresponding to the time evolution exp -imc2$\tau/\hbar$ of their respective wave functions. - More: Quantum gravity without trouble, Quantengravitation ohne Mühe, La gravité quantique sans peine.

GR 10.4 Wed 16:15 Redoutensaal

Constraining the Mass of Ultralight Axions Using the 21-cm Signal During Cosmic Dawn — •Julian Antonio Kleff — Institute for Astrophysics and Geophysics, University of Göttingen, Germany

The aim of my master's thesis is to constrain the mass of a dark matter candidate called ultralight axions (ULAs). Compared to standard cold dark matter ULAs suppress the halo mass function below the scale of the Jeans mass $M_J(m_\alpha)$ which depends on the mass m_α of ULAs. Star formation within molecular cooling halos is expected to significantly contribute to the 21-cm signal during cosmic dawn. Efficient molecular cooling, and thus star formation, becomes possible if the critical halo mass $M_{\rm mol}(v_{cb})$ is reached, which (among other quantities) is affected by the dark-matter-baryon relative velocity v_{cb} introduced after recombination. This dependence on v_{cb} leads to so called velocity acoustic oscillations (VAOs) in the 21-cm power spectrum on scales $k \sim 0.1$ Mpc^{-1}. However, once $M_J(m_\alpha) \gg M_{\rm mol}(v_{cb})$ the dependence of the 21-cm signal on v_{cb} is effectively removed, and thus the VAOs too. As $M_J(m_\alpha)$ increases with decreasing m_α, smoothly decreasing m_α leads to a smooth decline of the amplitude of the VAOs in the 21-cm power spectrum until they vanish completely. The goal of my master's thesis is to implement the physics of ULAs into the software Zeus21, an analytical tool for the computation of the 21-cm power spectrum, and to utilize the strong dependence of the VAOs on the axion mass to improve current constrains on the axion mass.

GR 10.5 Wed 16:15 Redoutensaal

New Description of the Big Bang's Approximate Volume and Density in the Universe — •Gh. Saleh — Saleh Research Centre, Amsterdam, Netherlands

In the analysis of an atom, a nucleus is observed at the centre, with electrons orbiting around it. For every element, a specific atomic radius exists, which is certainly a constant value. Essentially, a fixed "identity card" can be defined for each element, containing constant parameters such as volume, mass, density, and so on. Consider a white dwarf: it is defined as a structure composed of a collection of protons situated close together. This creates a relatively small sphere with a high density. Generally, since the material is made of protons, the density of a white dwarf can be estimated to fall within a specific range (around 10^17).

Essentially, this form of matter consists of protons gathered together. A problem arises when attempting to define the primary matter for the Big Bang. If the building blocks were protons or neutrons the result would be a sphere with a radius roughly the distance from the Earth to Jupiter. If the Big Bang is thought to be made of protons, neutrons, or even photons, it results in a massive sphere, which requires a different definition for the Big Bang. Therefore, based on the explanation above, a particle must be defined that is significantly smaller than a photon.

In this paper we are going to show that if photons are viewed as having a structure like an atom, breaking it down yields Cidtonium particles (between one-millionth and one-billionth the size of a photon). With the high density of Cidtonium, the huge mass and tiny volume of the Big Bang can be defined.

GR 10.6 Wed 16:15 Redoutensaal

Calibration and optimization of Target CTC ASICS for enhanced phase resolution in phase cameras — •Niklas Kotschi for the Einstein Telescope-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP) Friedrich-Alexander-Universität Erlangen-Nürnberg Nikolaus-Fiebiger-Str. 2 91058 Erlangen

The Einstein Telescope is a planned gravitational wave observatory designed to detect spacetime distortions with unprecedented sensitivity. This can be achieved with a large michelson-interferometer setup.The laser needs to be well aligned to measure the phase. For this purpose, a new kind of phase camera, which uses an array of optical fibers to capture the laser was introduced. A cost efficient solution to digitize these multi-channel analog inputs are a new set of Application-Specific Integrated Circuits (ASICs), which were originally designed for the readout of signals from photosensors in cameras of Imaging Atmospheric Cherenkov Telescopes for ground-based gamma-ray astronomy. They were optimized for single photon detection. For phase cameras these ASICs need to be optimized for readout of high intensity waveforms. This is why calibration and optimization of TARGET CTC ASICs for application in phase camera systems is important. The resolution is integration time dependent. Therefore reducing the sample speed can increase the resolution by increasing the integration time. Jitter from different GPS clocks was analyzed to optimize the synchronisation stability. The results demonstrate key improvements in data acquisition stability. Testing out different calibration and timing parameters and their impact on the waveforms and phase resolution were done.

GR 10.7 Wed 16:15 Redoutensaal

Visualization of the curved spacetime of a Morris-Thorn wormhole in a sector model — •Rahel Gabriel — Universität Hildesheim

Sector models, based on Regge calculus, provide an intuitive way to visualize curved spacetimes in general relativity using locally flat sectors. Curvature is encoded at sector boundaries through deficit or excess angles, and geodesics are constructed as straight lines that continue across sector boundaries. This framework is used to explore the topology and phenomenology of hypothetical Morris-Thorn wormholes in an interactive simulation.

GR 10.8 Wed 16:15 Redoutensaal

Probing Small-Scale Structure during Cosmic Dawn with the 21 cm Forest — •Monja Begau, Mihir Kulkarni, and Jens Niemeyer — Institute for Astrophysics and Geophysics, Göttingen, Germany

Observations of the 21 cm hyperfine transition of neutral hydrogen are expected to significantly improve our understanding of the thermal and structural evolution of the intergalactic medium during cosmic dawn. The 21 cm signal measures deviations of the hydrogen spin temperature from the cosmic microwave background, leading to absorption or emission. In addition to large-scale brightness-temperature fluctuations, neutral hydrogen along individual lines of sight can imprint narrow absorption features in the spectra of distant radio-loud sources. In analogy to the Lyman-α forest, this is referred to as the 21 cm forest. These absorption features probe small-scale density structure.

Modelling the 21 cm signal is challenging due to the nonlinear and nonlocal relation between matter density, star formation, and the resulting radiative backgrounds. In this work, we employ and extend the Zeus21 framework (arXiv:2302.08506v2, Julian B Munoz), an analytic model for the 21 cm signal during cosmic dawn.This framework is applied here to the description of the 21 cm forest. Since axion dark matter can modify structure formation on small scales, such effects may be reflected in the statistics of the 21 cm forest. We explore the potential of this approach to probe axion-like dark-matter scenarios through modifications of the predicted 21 cm forest power spectrum.

GR 10.9 Wed 16:15 Redoutensaal

Bondi mass loss formula for axial symmetric systems in $f(R) = R + \lambda R^2$ gravity — •Thomas Guillermo Albers Raviola — Universität Bremen, Bremen, Germany

In General Relativity, the Bondi-Sachs formalism is used to study gravitational waves as observed at future null-infinity. It introduces the concept of the Bondi mass, whose decrease is connected to the the news tensor through the famous Bondi mass loss formula. This work investigates the changes in the Bondi mass loss formula for axial symmetric systems in $f(R) = R + \lambda R^2$ gravity, also known as the Starobinsky inflation model. We develop this result in the scalar-tensor representation as a foundation for later applying similar methods for more general scalar-tensor theories of gravity. A priori, it is expected that the addition of further degrees of freedom shall provide a measurable signature, that may manifests itself, for example, in gravitational waves observations. Also closely related to the Bondi-Sachs results is the BMS group, which plays an important role in the search for a quantum theory of gravity. As such, it is highly interesting to understand the modifications to the BMS group in theories of gravity beyond general relativity.

GR 10.10 Wed 16:15 Redoutensaal

Universe without expansion and big bang — •Roland Alfred Sprenger — Herford, Germany

The standard model of cosmology is confronted with a model of a universe which is curved within a five-dimensional spacetime. The redshift of the spectra of galaxies is explained by the curvature; the expansion of the universe and the big bang do not exist in this model. According to this the universe is a four-dimensional hypersphere within the five-dimensional spacetime. Its radius is calculated from the distance of standard candles.

GR 10.11 Wed 16:15 Redoutensaal

Electron Mass, Charge and Sommerfeld FSC — •Manfred Geilhaupt — Hs Niederrhein Mönchengladbach

Einstein: Ich wüsste gern, was ein Elektron ist. Electron restmass (energy) not zero. Charge Sommerfeld:

**e^2=2*alphah*c*eps0 (no energy!). Question: What must be known else, able to answer Einsteins question? Restmass & Charge must be derived from a principle theory. Results from GR+TD: restmass me(alpha,N) & charge e(alpha). expectation values, both depend on alpha. The r(t)-generating two differential equations - not like Schrödinger but source for mass and charge - can be found using a common Newton Einstein Equation of Motion:

**dP/dt=f1+f2+f3+f4+f5 coming up with 5 internal parts from partial derivation. The second part (f2= m*ddr/ddt) leads to restmass me(alpha,N) being an effective value from the solution m(t) if r(t) is a generating function same for all 5 parts. u(t) is a unit vector possible to rotate (du/dt). The first equation (f1=dr/dt*dm/dt) - if m(t) is known already from part two - leads to charge e(alpha) while alpha is the Sommerfeld FSC:

**alpha=(1/beta)*(1/beta)*1/g44*3/4(1+log(1/3))*(1+log(1/3)) - appears when using r(t) to get m(t) from equation f2. Beta is the Einstein SR parameter while g44 is the well known GR-metric number: while within (e/m)=..1/sqrt(N) here alpha cancels! alpha represents the continuum part and N the quantum part of nature. So GR+TD predicts QMs quantisation phenomena physically - based on causality and TD principles applied.

GR 10.12 Wed 16:15 Redoutensaal

Dimensional Physics explains the structure of the natural constants c, G, and h solely based on General Relativity — •Christian Kosmak — Working Group Dimensional Physics, Würzburg

In the theory of Dimensional Physics, the approach taken is that spacetime density is the source of spacetime curvature. Any mass-energy equivalent is a direct geometric representation in spacetime itself. This gives spacetime boundaries in a higher-dimensional spacetime and in an infinite number of lower-dimensional spacetimes. These boundaries determine the structure of the natural constants c, G, and h. Planck's quantum of action and, as a result, the Compton wavelength of any object (spacetime density) are necessarily derived from the structure of spacetime. This means that General Relativity dictates how Quantum Field Theory must be structured. Spacetime is not only a dynamic stage, but also the only actor. Website: Dimensionale Physik (dimensionale-physik.de)

GR 10.13 Wed 16:15 Redoutensaal

Why the theories of relativity are wrong though they are

right — •Hans Deyssenroth — Holzgasse 28

The two theories of relativity have been confirmed experimentally many times, most recently in spectacular fashion with the verification of the predicted gravitational waves. They must be right.

But unfortunately, the data of the lunar laser ranging project shows clearly that the photons, coming from a mirror on the Moon, appear there where the Earth was 2.55 seconds before and not - as expected - in the detector next to the laser. That means that there is no oblique light path at the light clock or from the half transparent mirror at the Michelson Morley experiment. Therefore, the time dilation cannot be derived via the Pythagoras form this oblique light path as Einstein it did and the length contraction proposed by H. Lorentz would destroy the null result. With other words: the fundament of both theories of relativity - the Lorentz transformation - is wrong.

Physics should be based on experimental facts. But can physicists accept an experimental fact that contradicts the theories of relativity?

Some other experiments and observations show that gravity can be shielded and controlled by electromagnetic processes. Why have these facts been ignored?

GR 10.14 Wed 16:15 Redoutensaal

A modified theory of gravity explains the self-interaction of dark matter. — •Albrecht Giese — Taxusweg 15, 22605 Hamburg

New investigations using the James Webb telescope have revealed inconsistencies in the explanations for the formation and distribution of dwarf galaxies in the early stages of the universe.

Current cosmological theory suggests that this can be explained by assuming that dark matter particles self-interact. However, according to our current understanding of gravity, such an interaction is impossible.

We will demonstrate that there is a model of gravity based on a different dependence of gravity on mass. This model not only solves the issue of rotation curves, but also that of the self-interaction of dark matter-related particles.

For details: www.ag-physics.org/gravity

GR 10.15 Wed 16:15 Redoutensaal

CPU - the Cyclic Process Universe — •Thomas Wäscher — IBW-Engineering, 69231 Rauenberg

Based on my 2022 and 2024 talks which take the fundament of GR, Einstein's equivalence principle into account, it was shown that the accelerated expansion a=Hc can be equivalently interpreted as a constant isotropic gravitational field, now replacing Dark Matter and eliminating Dark Energy simultaneously. The redshift z of any radiation originates from accumulating the gravity potential Φ=f(R) with Φmax=c^2. The tailored Hubble number H [km/sMpc] of expansion changes to a natural decay constant [1/s]. The dynamic of expansion is converted to the equilibrium dynamic of in- and outflow of matter and energy by the ubiquitous astrophysical objects like e.g. stars, galaxies, quasars, blazars, pulsars and black-holes. The total mass and energy flows sum up to dm/dt=c^3/2G [kg/s] and P=c^5/2G [Watt]. The curved and gravitationally closed universe exhibits a volume of V=2π^2R^3 (Einstein 1917), the same as a horn torus with r=R, a possible topology. This universe allows any individual to be located in the very center by physical justification.

GR 10.16 Wed 16:15 Redoutensaal

Adequate Coordinate System for Space Navigation and Relativity — •Hans-Otto Carmesin — Univ. Bremen, FB 1, Postfach 330440, 28334 Bremen — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Gymn. Athenaeum, Harsefelder Straße 40, 21680 Stade

The International Astronomical Union (IAU) realized, that the coordinate systems of relativity theory are insufficient for space navigation. Therefore, the IAU proclaimed the problem of finding an adequate coordinate system (ACS) for space navigation and relativity.

Here, that problem is solved:

(1) A measurement procedure is presented. (2) For each Point P in the universe, an ACS is derived, and its velocity $\vec{v}_{ACS,CS}$ relative to an arbitrary coordinate system (CS) is derived. (3) The ACS is confirmed by an observation at Earth, using two atomic clocks, one at the PTB and one at the MPQ (Max Planck Institute for Quantum Optics). (4) The universal zero of the fractional kinematic time difference $\delta t_{kin,fractional}$ is derived. (5) For each Point P, $\delta t_{kin,fractional}$ is derived. This is confirmed by observation data at Galileo satellites. As a consequence, the precision of clocks onboard spacecrafts can be improved. This can provide improvements in space navigation, remote sensing or geoinformatics.

Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta. Berlin: Verlag Dr. Köster. Carmesin, H.-O. (2025): Construction of a Physically Adequate Coordinate System with Help of an Observation on Earth's Ground. J Geosci Earth Planet Syst, 1(1), pp. 01-12.

GR 10.17 Wed 16:15 Redoutensaal

Zeitentwicklung der dunklen Energiedichte und der universellen Zeitdilatation — Hans-Otto Carmesin[1,2,3] und •Jacky David Yang[1] — [1]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — [2]Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — [3]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade

Untersucht wurden das globale Konzept und der globale Verlauf der Zeit. Für ein homogenes Universum (ΛCDM-Modell) und ein heterogenes Universum (Linear Growth Theory, Carmesin 2024) wurde mithilfe kosmologischer Planck-Messdaten (2020) das Weltalter bestimmt, wobei die Hubble-Tension berücksichtigt wurde. Aus der Zeitentwicklung des homogenen Universums wurde die im heterogenen Universum hergeleitet. Daraus wird die Zeitdilatation bestimmt. Die Ergebnisse wurden grafisch, tabellarisch und mathematisch dargestellt. Auch wird nun die Zeitentwicklung der Dunklen Energie Ω_Λ analysiert und veranschaulicht. Diese kann aus der Zeitentwicklung der globalen/universellen Zeitdilatation berechnet werden. Dabei sagen die von uns hergeleiteten Ergebnisse zukünftige Messwerte vorher und stimmen schon jetzt mit aktuellen Messwerten überein. Hierbei können sich zukünftige Messwerte auf beliebige Rotverschiebungen und entsprechende Zeitpunkte beziehen, da die Dunkle Energie und die globale Zeitdilatation als Funktion der Rotverschiebung hergeleitet wurden.

Planck Collaboration 2020: Astronomy and Astrophysics, pp. 1 - 73. H. - O. Carmesin (2024), Verlag Dr. Köster. H. - O. Carmesin (2025), Verlag Dr. Köster.

GR 10.18 Wed 16:15 Redoutensaal

A Concept of Worldview — •Boris Schapiro — Kluck Str. 25, D-10785 Berlin

The concept of worldview consists of several hypotheses:

The Space-Time is quantum object. The world consists of several universes. Number of universes and dimensionality of world are related by combinatorics. All universes originated simultaneously and are approximately the same as our own. I call the space in which the universes are located a Metaverse. The Metaverse is also a quantum object. Energy within it shouldn't be conserved because it's an open system; it generates energy through quantum fluctuations and expands due to this energy. Universes expand because they're nested within the Metaverse. Dark matter is the matter of other universes as it is gravitationally perceptible by us.

This leads to the fact that space is a quantum object, while gravity is the curvature of space, which isn't a quantum object, but a classical one. Therefore, there is no need to search for a "theory of quantum gravity", but rather to combine quantum and classical phenomena without merging them into one illogical concept, without distorting the understanding of the fundamental nature of each of them.

Comparison of the obtained formulae with the known observational data allows us to conclude that there are six universes in the Metaverse.

GR 11: Numerical Relativity II

Time: Thursday 11:00–12:00 Location: KH 01.016

Invited Talk GR 11.1 Thu 11:00 KH 01.016
Numerical Relativity for LISA and the Einstein Telescope — •Nils Vu — California Institute of Technology, Pasadena, USA

The upcoming European gravitational-wave detectors LISA and the Einstein Telescope are bound to revolutionize our understanding of black holes across the Universe, but to make sense of their data we will require extremely accurate numerical simulations of merging black holes and their gravitational waves. This is the realm of numerical relativity and requires solving Einstein's equations of general relativity to extreme precision on large supercomputers. In this talk, I will give an overview of the state-of-the-art in numerical relativity, recent advances in simulating merging binary black holes with highly efficient spectral finite-element methods, and the challenges that lie ahead to reach the requirements for the era of next-generation gravitational-wave astronomy.

GR 11.2 Thu 11:30 KH 01.016
A novel approach for the systematic study of long-lived merger remnants with neutrino radiation — •Marie Cassing[1], Luciano Rezzolla[1,2,3], Carlo Musolino[1], Konrad Topolski[1], Harry Ho-Yin Ng[1], and Keneth Miler[1] — [1]Goethe University Frankfurt, Frankfurt am Main, Germany — [2]CERN, Theoretical Physics Department, Geneva, Switzerland — [3]School of Mathematics, Trinity College, Dublin, Ireland

We introduce a novel hybrid framework for simulating binary neutron star mergers (BNS) with neutrino radiation, developed to explore the long-term evolution of postmerger remnants. The approach combines the strengths of the general-relativistic magnetohydrodynamics (GRMHD) code FIL for modeling the inspiral and merger phase with the advanced code BHAC+, which takes over in the postmerger phase. In BHAC+, we implement an M1 two-moment neutrino transport scheme and solve the stiff source terms with an implicit-explicit (IMEX) time integration strategy. This enables robust simulations of neutrino matter coupling over long timescales. Our primary aim is to study neutrino-driven winds, changes in remnant structure, and their potential to influence jet launching in scenarios involving long-lived neutron stars or delayed collapse to a black hole. We present results of M1 test problems and physical setups validating our implementation and outline the potential of this hybrid approach to systematically explore ejecta properties and electromagnetic counterparts in BNS mergers.

GR 11.3 Thu 11:45 KH 01.016
Gravitational Scattering of two Neutron Stars — •Joan Fontbuté — Friedrich-Schiller Universität, Jena, Germany

In this talk I'm going to present the first numerical relativity simulations of gravitational scattering between neutron stars and the first comparison of such simulations with analytical predictions as well as the black hole case. Constraint-satisfying initial data for two equal-mass non-spinning sequences are constructed at fixed energy and various initial angular momenta for two Equations of State. Our results probe extreme strong-field regimes up to the threshold of dynamical capture, revealing both agreement and significant tidal discrepancies with effective-one-body and post-Minkowskian predictions to the scattering angle. Together with these results obtained with the BAM code, I'm also going to present an extension to more realistic scenarios containing magnetic fields, M1 neutrino transport and a better atmosphere treatment with the GR-Athena++ code, where we also study in detail other properties of such events like the final spins, magnetic field properties and mass ejecta. The matter ejected is found to be crucial to explain the decrease in the binding energy that eventually makes the system become bound.

GR 12: Relativistic Astrophysics III / Gravitational waves III

Time: Thursday 13:45–15:15 Location: KH 01.016

GR 12.1 Thu 13:45 KH 01.016
The Thermal Index for Interacting Fermi Gases — •Timon Kleiber, Ishfaq Ahmad Rather, Selina Kunkel, Sarah Pitz, and Jürgen Schaffner-Bielich — Goethe Universität Frankfurt, Institut für Theoretische Physik

We analyze and compare the influence a simple repulsive interaction between particles has on a single component Fermi gas. Our focus is on the thermal part of the equation of state. This model can be used to calculate an EOS at nonvanishing temperature for pure neutron matter or fermionic dark matter. The coupling constant for the interactions uses the scale of strong interactions as a baseline. We additionally look at the effects of higher and lower coupling strengths with respect to the QCD baseline. A special focus is put on the isentropes within the area that is relevant for Proto-Neutron star evolution and or thermal evolution of fermonic dark matter. The inclusion of interactions leads to an increase in pressure compared to energy density along the isentropes and causes their ratio to reach values above the maximum limit without interactions.

GR 12.2 Thu 14:00 KH 01.016
Impact of in-situ nuclear networks and atomic opacities on neutron star merger ejecta dynamics, nucleosynthesis, and kilonovae — •Fabio Magistrelli — TPI, FSU Jena

Binary neutron star merger (BNSM) ejecta are key sites of rapid neutron-capture (r-process) nucleosynthesis and power kilonovae through the radioactive decay of freshly synthesized nuclei. I will present a systematic study of how nuclear burning, particle thermalization, and atomic opacity treatments impact the nucleosynthesis and electromagnetic emission from BNSM ejecta, starting from ejecta profiles extracted from ab-initio numerical-relativity simulations and evolved up to $\sim$ 30 days with radiation-hydrodynamics calculations with in-situ nuclear reaction networks (NN). I will compare simplified and composition-dependent thermalization schemes, as well as gray opacity models and frequency-dependent, atomic-physics-based opacities. Finally, I will discuss how NN coupling and detailed thermalization and opacity treatments significantly modify the temperature evolution of the ejecta, the structure of the r-process peaks, and the brightness and color evolution of the associated kilonova for realistic ejecta profiles.

GR 12.3 Thu 14:15 KH 01.016
Dynamo processes and jets from long-lived remnants from binary neutron star mergers — •Michael Mueller[1], Luciano Combi[2], and Daniel Siegel[1] — [1]University of Greifswald, Greifswald, Germany — [2]Perimeter Institute for Theoretical Physics, Waterloo, Canada

Identifying the mechanisms behind the generation of short gamma-ray bursts (GRBs) in compact object mergers, such as the one accompanying GW170817, is necessary to connect the observed GRB and merger populations. Current observations indicate that accreting neutron star remnants are a likely outcome for binary neutron star (BNS) mergers, and it is key to understand whether such systems can give rise to GRB emission. Dynamo processes and magnetic winding have been identified as critical components in producing the necessary large-scale coherent magnetic field to power the jet without a black hole central engine. We present new results from three-dimensional general-relativistic magnetohydrodynamic simulations of equal-mass binary neutron star mergers resulting in a long-lived hypermassive neutron star. The binary system is evolved without symmetry assumptions, employing a tabulated, composition-dependent, finite-temperature equation of state, a vector potential formalism for the magnetic field evolution, and approximate neutrino transport. We demonstrate that the magnetorotational instability is well resolved in the disk, and we study the dynamo action of the resulting turbulence in the disk and at the disk-star interface with new diagnostics to identify the processes involved in generating coherent field structures.

GR 12.4 Thu 14:30 KH 01.016

Fibre-based Phase Camera for the Einstein Telescope — •Stuti Sharma, Benjamin Schwab, Adrian Zink, and Stefan Funk for the Einstein Telescope-Collaboration — Erlangen Centre for Astroparticle Physics (ECAP), Friedrich-Alexander University

The Einstein Telescope (ET) is a planned third-generation underground gravitational wave observatory. The telescope requires precise monitoring of optical wavefront quality. Mode mismatches and wavefront aberrations in the sidebands used for interferometer control can lead to the excitation of higher order Gaussian modes (HOMs) which reduce detector performance. To address this, a fibre-based 56-pixel proof-of-concept phase camera has been developed. This camera is capable of simultaneously measuring the spatial amplitude and phase of multiple sidebands. Its multimode fibre array provides stable spatial phase relations between pixels at high frame rates. A dedicated digitisation setup is built via the CTC ASIC, that has been adopted from camera readout electronics for CTAO. Commissioning of such a setup at the ET Pathfinder demonstrated reliable visualisation of wavefronts and identification of HOMs.

Future work will build on enhancing the analysis of phase camera images to distinguish and classify higher order Gaussian modes. Therefore, an optical resonator capable of generating arbitrary, well-defined higher-order mode content will be added to the setup for future wavefront studies. The system will be scaled toward a 4096-pixel camera with FPGA based real-time demodulation. These developments aim to establish a robust and scalable wavefront sensing framework for ET.

GR 12.5 Thu 14:45 KH 01.016

Exploring Machine Learning Techniques for Gravitational-Wave Detection with Einstein Telescope — •Sebastian Wein, Alexander Kappes, and Waleed Esmail — Universität Münster, IKP, Wilhelm-Klemm-Str. 9, 48149

Einstein Telescope is a planned third-generation gravitational-wave observatory, that is expected to be more sensitive by at least one order of magnitude compared to current facilities such as LIGO/Virgo. With this increased sensitivity, challenges for signal detection arise due to longer signal duration and frequent signal overlap. Matched filtering, the current standard numerical signal detection algorithm, cannot be easily adapted to meet these challenges: neural networks might be a better fit instead. This talk describes the design of a machine-learning architecture for handling large inputs and detecting multiple, possibly overlapping signals.

GR 12.6 Thu 15:00 KH 01.016

RealTime Seismic Waveform Prediction Using Low-Latency Transformer-Based Models — •Kyrill Emanuel Blümer, Alexander Kappes, and Waleed Esmail for the Einstein Telescope-Collaboration — Institut für Kernphysik Uni Münster

The Einstein Telescope (ET) is a planned third-generation gravitational-wave detector, that will be built underground. It is designed to improve the detection sensitivity by up to an order of magnitude relative to existing detectors, especially at low frequencies. Because gravitational waves generates an extremely small strains, seismic and Newtonian noise becomes a limiting factor for the low-frequency sensitivity of the ET. Transformer-based deep learning models are well suited for learning long-range temporal and spatial dependencies in seismic waveform data and can provide accurate short-term forecasts of the 3D ground motion. However, for longer prediction horizons, waveform prediction quality degrades due to the error accumulation, when predictions are produced autoregressively. This talk will explore architectural and algorithmic improvements aimed at achieving stable, real-time, low-latency seismic waveform prediction.

GR 13: Quantum Gravity and Quantum Cosmology I

Time: Thursday 13:45–15:15 Location: KH 02.012

GR 13.1 Thu 13:45 KH 02.012

Measurement of the Casimir force during free fall — •Sascha Kulas — International University of Applied Sciences (IU), Schiffgraben 49-51, 30175 Hannover, Germany

The Casimir effect is an attractive interaction between two uncharged and perfectly conducting plates held a short distance apart. Its force still has a lot of unknown aspects. Here, this force is measured in a tuning fork experiment during free fall and compared with a measurement on ground. It seems like the Casimir force is strongly suppressed during free fall. This is a hint that the Casimir force does not have its origin in the Van der Waals force, which would not change in weightlessness. In the next step, drop tower experiments have to proof the results. In addition, a physical toy model is introduced, that explains these experimental results and further effects concerning gravity and quantum mechanics.

GR 13.2 Thu 14:00 KH 02.012

Gravitational collapse in effective loop quantum gravity and the formation of shell-crossing singularities — Francesco Fazzini[1], Kristina Giesel[1], Hongguang Liu[2], and •Eric Rullit[1] — [1]Institute for Quantum Gravity, Friedrich-Alexander-Universität, Erlangen-Nürnberg, Germany — [2]Institute for Theoretical Sciences, Westlake University, Hangzhou, China

In this talk the investigation of the gravitational dust collapse within the framework of effective loop quantum gravity will be addressed, with a special focus on the properties and the formation of shell-crossing singularities in these models. The specific effective model that will be discussed in this talk is based on a cosmological Hamiltonian derived from full LQG by Dapor and Liegener using coherent state techniques, which governs the FLRW-type time evolution of each radial shell in the collapsing dust sphere. This model is characterized by an asymmetric bounce as its central feature where the classical singularity is resolved due to leading-order quantum corrections encoded in the effective description. The investigation of the resulting effective dynamics will be presented in detail and differences and similarities compared to other existing models will be discussed. In a broader context, the question of the existence of shell-crossing singularities is investigated beyond the specific model, including also non-bouncing scenarios such as regular black hole models of Bardeen and Hayward.

GR 13.3 Thu 14:15 KH 02.012

The perturbative Ricci flow — Robert Harlander[1], Yannick Kluth[2], Jonas Kohnen[1], and •Henry Werthenbach[1] — [1]TTK, RWTH Aachen University, 52056 Aachen, Germany — [2]Department of Physics, University of Toronto, Toronto, ON M5S 1A7, Canada

One candidate for a quantum theory of gravity is the Asymptotic Safety conjecture, which postulates the existence of a non-trivial fixed point for the gravitational couplings. We investigate the search for such a fixed point within the framework of perturbation theory.

For this, we employ the Ricci flow as the central tool, pursuing a perturbative scheme analogous to the gradient flow formalism in QCD. In QCD, the gradient flow was introduced to bridge the gap between lattice simulations and perturbative calculations, allowing for a definition of a renormalisation scheme that is accessible in both settings. Applied to gravity the gradient flow is known as 'Ricci flow'. The core idea is to utilize this framework to compute the beta function of the gravitational coupling by explicitly defining it within the Ricci flow scheme.

In this talk, I will first provide a brief introduction to the gradient flow formalism. I will then present the first steps towards constructing a perturbative implementation of the Ricci flow and the definition of Newton's coupling in this scheme.

GR 13.4 Thu 14:30 KH 02.012

Gravitational induced decoherence and the role of reference frames: a quantum mechanical toy model — •Ashay Sathe[1] and Kristina Giesel[2] — [1]Friedrich-Alexander-Universität, Erlangen-Nürnberg, Deutschland — [2]Friedrich-Alexander-Universität, Erlangen-Nürnberg, Deutschland

In this talk, we investigate a quantum mechanical toy model of gravitationally induced decoherence, with particular emphasis on the role of reference frames in the description of open quantum systems. We analyse two complementary choices of reference frames: a classical reference frame and a quantum reference frame. For each choice, the master equation governing the effective dynamics is derived. We then compare the resulting models and discuss both their common features and their conceptual and dynamical differences.

GR 13.5 Thu 14:45 KH 02.012

Area Metric actions and equations on an AdS background
— •Mario Flory[1], Aranya Bhattacharya[1,2], Lavish Chawla[1,3], and Mateusz Kulig[1] — [1]Jagiellonian University, Cracow, Poland — [2]University of Bristol, Bristol, UK — [3]Friedrich-Schiller-Universität, Jena, Germany

Following the talk by A. Bhattacharya, we study Lagrangians governing linearised area metric fluctuations on an Anti-de Sitter (AdS) background. Our aim is to identify actions whose equations of motion respect the requirements imposed by the holographic principle, with particular emphasis on the allowed boundary behaviour of the solutions. We demonstrate that rewriting area metric fluctuations in terms of Lanczos-like potentials yields a notably elegant model. Interesting parallels with conformal (i.e., Weyl-squared) gravity naturally arise and will be discussed.

GR 13.6 Thu 15:00 KH 02.012

Exploring physical states of loop quantum gravity using neural networks
— •Waleed Sherif and Hanno Sahlmann — Institute for Quantum Gravity, Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstraße 7, 91058, Erlangen, Germany

Loop quantum gravity (LQG) is a canonical approach to the quantisation of general relativity that aims to preserve background independence. The dynamics of the theory is encoded in a set of constraints, among which the Hamiltonian constraint plays a central role. Constructing and analysing general physical states that satisfy this constraint has long remained one of the central open challenges in LQG.

In this talk, we show that this problem can be approached using modern deep learning techniques, specifically neural network quantum states (NQS). We demonstrate that these methods make it possible to construct approximate physical states in simplified models of LQG for the first time in a way that is both flexible and scalable. Using a range of models in Euclidean LQG, we illustrate how this approach enables large-scale numerical investigations of the theory's quantum dynamics, allowing for the systematic characterisation of physical states and exploring the impact of different operator orderings, regularisation choices and more.

GR 14: Relativistic Astrophysics IV

Time: Thursday 16:15–17:00 Location: KH 01.016

GR 14.1 Thu 16:15 KH 01.016

Neutron stars under the influence of dark matter
— •Sarah Louisa Pitz and Jürgen Schaffner-Bielich — Max-von-Laue-Str. 1 60438 Frankfurt am Main

Neutron stars represent ideal laboratories to test different kinds of matter under the influence of strong gravity and high magnetic fields. Due to their age and their strong gravitational field neutron stars could capture dark matter particles and thus serve indirectly as dark matter detectors. We include bosonic, self-interacting dark matter with a sufficiently stiff self-interaction potential in the form of $V \propto \phi^n$ and find that these neutron stars become ultra-compact. They are compact enough to have a stable photon orbit at their surface or even above, a property that is otherwise exclusively attributed to black holes or hypothetical boson stars. These ultra-compact neutron stars could be formed by a boson star accreting ordinary matter. We will present results on how a high compactness of the boson star affects the accretion rate and thus the mass of the resulting neutron star.

This work is supported by Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) through the CRC-TR 211 Strong-interaction matter under extreme conditions project number 315477589 TRR 211.

GR 14.2 Thu 16:30 KH 01.016

Neutrino production in blazars with extreme Doppler factors
— •Aditya Tamar — Max Planck Institute for Radio Astronomy, Bonn, Germany

There have been recent population studies supporting the idea that radio-loud blazars can be the potential source of high-energy astrophysical neutrinos. The understanding of neutrino production from these sources is intimately connected to explaining their multi-wavelength spectra as well. In this talk, ongoing work will be presented in modelling the lepto-hadronic spectral energy distribution (SED) for PKS 1749+096, a neutrino-candidate blazar with strong Doppler boosting. In the proposed framework, both the bulk properties and the particle distribution in the emission region, are anchored directly using parsec-scale very-long-baseline (VLBI) observations of its jet. When combined with physically motivated assumptions about jet stratification, this approach allows modeling the SED from radio to gamma-rays without using model-agnostic numerical fitting to archival data, whilst also using VLBI-driven inferences to probe the location and properties of the neutrino production region in the blazar jet. Thus, the talk attempts to motivate using radio observations as an anchor for improving our understanding of multi-messenger emission from neutrino-candiate blazars.

GR 14.3 Thu 16:45 KH 01.016

Hot Dark Stars: Mass-Radius Curves of an Interacting Fermi Gas at Finite Temperatures and Their Collapse to Black Holes
— •Adil-Mir Zia, Ishfaq Ahmad Rather, Selina Kunkel, Sarah Pitz, and Jürgen Schaffner-Bielich — Institute for Theoretical Physics, Goethe University, Frankfurt am Main

We investigate the mass-radius relations of dark stars using a temperature-dependent equation of state for interacting Fermi gases. Varying the entropy per baryon and the interaction strength allows us to quantify how finite-temperature effects and the underlying couplings influence the structure and stability of hot dark stars. We also compute the particle number along constant-entropy sequences to examine the possibility of a delayed collapse during the early evolution. These results clarify how thermal and interaction effects shape the properties of newly formed dark stars.

GR 15: Quantum Gravity and Quantum Cosmology II

Time: Thursday 16:15–17:00 Location: KH 02.012

GR 15.1 Thu 16:15 KH 02.012

Lorentzian Cosmological path integrals in effective spin foams — •Sebastian Steinhaus and Alexander Jercher — Friedrich-Schiller Universität Jena, Theoretisch-Physikalisches Institut, Jena, Germany

Spin foam models, also called covariant loop quantum gravity, are a non-perturbative, Lorentzian path integral approach to quantum gravity. Its expressions are regularised by replacing the continuous manifold by a triangulation, where the sum over geometries is encoded in group-theoretic area and angle variables. However, making contact back with classical, continuum gravity is challenging. In this talk, I will address this question in cosmology from two directions. First, I will solve the discrete (transcendental) equations of motion of cosmological models in Regge calculus and showcase how to relate them to continuum cosmology. Second, I translate this into an oscillatory Lorentzian path integral with effective spin foams and evaluate it numerically, e.g. using acceleration operators. I will discuss under which conditions classical physics (in terms of expectation values of observables) can be recovered and give an outlook to non-classical transitions, e.g. bouncing cosmologies.

GR 15.2 Thu 16:30 KH 02.012

Einstein equations for Area Metric geometries from entanglement — •Aranya Bhattacharya[1,2], Lavish Chawla[1,3], Mario Flory[1], and Mateusz Kulig[1] — [1]Institute of Theoretical Physics, Jagiellonian University, Lojasiewicza 11, 30-348 Krakow, Poland — [2]School of Mathematics, University of Bristol, Fry Building Woodland Road, Bristol BS8 1UG, UK — [3]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universitat Jena, Max-Wien-Platz 1, D-07743 Jena, Germany

Area metrics provide a generalised notion of geometry, in which areas are fundamental but lengths may not be defined at all. They can be motivated from string theory, loop quantum gravity, and entropic gravity alike, which we will briefly touch upon during the talk. In this work, we use the holographic duality and the first law of entanglement as first principles, from which an equation constraining area metric fluctuations around a four dimensional Anti-de Sitter (AdS) background can be derived, thus extending the linearised Einsteins equations for these generalised geometries. In the framework of the AdS/CFT correspondence, these area metric fluctuations can be interpreted as encoding the energy-momentum tensor perturbations of a holographically dual three dimensional conformal field theory (CFT). For further implications of these results, see the talk by M. Flory.

GR 15.3 Thu 16:45 KH 02.012

A Relational Model of Gravitationally induced Decoherence for Photons — •Roman Kemper[1], Kristina Giesel[1], and Max Joseph Fahn[2] — [1]Friedrich-Alexander Universität Erlangen-Nürnberg, Germany — [2]Università di Bologna, Bologna Italy

This talk discusses the formulation of a decoherence model for Maxwell theory coupled to linearised gravity. The resulting dynamics are described by a master equation, which governs the evolution of the electromagnetic subsystem under the effective influence of the gravitational environment. The master equation is derived from the underlying action using the relational formalism to access the physical sector and the open quantum system framework to describe the effective influence of linearised gravity on Maxwell theory at the quantum level. Differences and similarities with existing models in the literature, including approaches based on scalar fields or alternative methods for accessing the physical sector, are discussed.

GR 16: Members' Assembly

Time: Thursday 17:15–19:00 Location: KH 01.016

All members of the Gravitation, Relativistic Astrophysics, and Cosmology Division are invited to participate.

GR 17: Cosmology II

Time: Friday 9:00–10:00 Location: KH 01.016

Invited Talk GR 17.1 Fri 9:00 KH 01.016

Radio Cosmology and the Cosmic Dawn — •Jonathan Pritchard — Max Planck Institute for Radio Astronomy

In this talk, I will review the status of experiments attempting to detect the 21cm signal from reionization and the time of the first galaxies, In particular, I will discuss 21cm global experiments, especially REACH - a global 21 cm experiment deployed in the the Karou in South Africa. I will also discuss some of the preparation work for epoch of reionization studies with the Square Kilometre Array and describe applications of machine learning algorithms for inferring science from 21cm observations.

GR 17.2 Fri 9:30 KH 01.016

Early growth of structure with warm wave dark matter — •Simon May — Universität Bielefeld, Universitätsstraße 25, 33615 Bielefeld, Germany

I will present unique features in the growth of structure in wave dark matter models with warm white noise, where the power spectrum is peaked at sub-horizon wavenumbers. The post-inflationary production of bosonic particles, such as axions or axion-like particles, leads to an enhanced isocurvature density power spectrum on small scales. Moreover, when dark matter is extremely light, these inhomogeneities result in a non-negligible velocity dispersion and hence free-streaming suppression of the adiabatic power spectrum. Starting with the Schrödinger–Poisson system of equations as the relevant equations of motion, I will present results from analytic calculations and numerical simulations of cosmic structure formation. The results show the enhancement and evolution of the small-scale power spectrum and the formation of non-linear collapsed objects, including wave dark matter halos and Bose stars (solitons), shortly after matter–radiation equality. Using hydrodynamical simulations of warm wave dark matter with baryons, I will further show how this affects the early clustering of baryonic matter. Probes of the small-scale power spectrum (e.g. dynamical heating of stars, Ly-α forest, gravitational lensing, 21cm-line intensity mapping) can be sensitive to these effects on quasi-linear scales, making this broad class of dark matter models accessible to observations.

GR 17.3 Fri 9:45 KH 01.016

Comparing Gravitational Wave Spectra of Inflation Models — •Alexander Schneider[1], Tom Krokotsch[1], Gudrid Moortgat-Pick[1,2], and Andreas Ringwald[2] — [1]University of Hamburg, Hamburg, Germany — [2]Desy, Hamburg Germany

Inflation is currently among the most favored explanations for the horizon and the flatness problem, and there are several plausible models.

Many of them are predicted to have produced a gravitational wave background, the measurement of which could be a direct way of probing inflation.

In this talk, we present simulations of two inflation models and subsequent reheating processes with a focus on their respective gravitational wave spectra. Among the questions discussed are the prospects to measure the primordial gravitational wave backgrounds from these processes today, and how such a measurement could be used to differentiate between models.

GR 18: Cosmology III

Time: Friday 11:00–11:45 Location: KH 01.016

GR 18.1 Fri 11:00 KH 01.016

Effective Pressure and Viscosity Analogies in Schrödinger*Poisson Models of Structure Formation — •Aoibhinn Gallagher — Bielefeld University, Universitätsstraße 25, 33615 Bielefeld, Germany

Recent advances in wave-mechanical approaches to cosmic structure formation have highlighted the usefulness of the Schrödinger*Poisson (or Schrödinger*Newton) system as an alternative description of collisionless matter. Beyond its role in models of ultra-light dark matter, this framework offers a compact way to capture gravitational dynamics across linear and non-linear regimes, motivating renewed interest in how its behaviour relates to familiar concepts from classical physics.

In this talk, I explore how certain features of Schrödinger*Newton evolution can be reinterpreted through the lens of classical fluid dynamics, in particular through effective *pressure* and *viscosity* analogies. I show that the parameter \nu, often introduced in practical implementations of the formalism, can play a role akin to a kinematic viscosity, and I assess when a pseudo-Reynolds number description becomes meaningful. This reinterpretation provides intuitive insight into non-linear structure formation, especially beyond shell-crossing where standard fluid approaches fail. At the same time, I outline the fundamental limitations of the analogy: a full classical fluid correspondence would require additional physical ingredients (such as dissipation and entropy production) that do not arise in strictly unitary Schrödinger*Newton dynamics. The resulting picture is therefore not a complete fluid model, but a useful heuristic framework that clarifies the behaviour of wave-mechanical cosmological systems.

GR 18.2 Fri 11:15 KH 01.016

Exotic compact binary mergers at ultra-high redshift - parameter estimation with pulsar timing array data — •Woo-Seok Yim and Jürgen Schaffner-Bielich — Institut für Theoretische Physik, Goethe University, Frankfurt am Main, Germany

The origin of the nanohertz stochastic gravitational-wave background (SGWB) reported in 2023 remains under active discussion, with supermassive black hole binaries (SMBHBs) still being the leading astrophysical explanation. However, a discrepancy between the predicted SMBH abundance and the measured SGWB amplitude remains. This could be explained by a sub-dominant group of merging exotic compact objects (ECO), which are compact objects formed from dark matter at ultra-high redshift. We find and present combinations of binary parameters of such ECOs, namely the binary mass and merger redshift, that could significantly contribute to the total gravitational-wave energy density spectrum Ω_{gw} at nanohertz scales.

This project is supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundattion) through the CRC-TR211 "Strong-interaction matter under extreme conditions" under the project number 315477589 - TR 211.

GR 18.3 Fri 11:30 KH 01.016

Cumulants in the Cosmos: Tools for Compressing the Universe — •Cora Uhlemann — Bielefeld University

Central nonlinear physics problems in cosmology can be characterized by an infinite hierarchy of cumulants. For a simple one-dimensional probability density function, the first cumulant is the mean, the second cumulant is the variance, and the higher-order cumulants capture non-Gaussian information. Cumulants thus serve as useful compression of the underlying probability density function. I will explain why characterising the higher-order cumulants is essential for beyond 2-point statistics of dark matter and show how they can be predicted by leveraging symmetries and large-deviation theory. I will then connect this to key observables in galaxy clustering and weak lensing and discuss challenges related to their survey applications.

GR 19: Numerical Relativity III

Time: Friday 11:00–12:00 Location: KH 02.012

GR 19.1 Fri 11:00 KH 02.012

Improved Moving-Puncture Techniques for Binary Black-Hole Simulations — •Linsheng Li — Institut für Theoretische Physik, Goethe Universität, Frankfurt am Main, Germany

To fully exploit current and upcoming gravitational-wave observations, accurate numerical-relativity simulations of compact binaries require tight control of constraint violations in moving-puncture evolutions. We present a moving-puncture scheme in the CCZ4 formulation within the Einstein Toolkit that incorporates both a slow-start lapse (SSL) condition and a curvature-adjusted Hamiltonian-constraint damping (CAHD) prescription, aimed at reducing constraint violations and improving the quality of the extracted waveforms. By exploiting the constraint-propagation and damping properties of CCZ4, we re-tune the Z4 damping and gauge parameters to improve constraint control through inspiral, merger, and ringdown. For equal-mass, nonspinning binary black-hole simulations, the SSL+CAHD+CCZ4 scheme significantly reduces Hamiltonian and momentum-constraint violations in both the strong-field region and the wave-extraction zone.

GR 19.2 Fri 11:15 KH 02.012

Black hole spectroscopy of collapsing and merging neutron stars — •Oliver Steppohn[1], Sebastian H. Völkel[2], and Tim Dietrich[1] — [1]Institut für Physik und Astronomie, Universität Potsdam, Haus 28, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany — [2]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, 14476 Potsdam, Germany

Black hole spectroscopy is an important pillar when studying gravitational waves from black holes and enables tests of general relativity. Most of the gravitational wave signals observed over the last decade originate from binary black hole systems. Binary neutron star or black hole-neutron star systems are rarer but of particular interest for the next-generation ground-based gravitational wave detectors. These events offer the exciting possibility of studying matter effects on the ringdown of "dirty black holes". In this work, we ask the question: Does matter matter? Using numerical relativity, we simulate a wide range of collapsing neutron stars producing matter environments, both in isolated scenarios and in binary mergers. Qualitatively, the resulting ringdown signals can be classified into "clean", "modified", and "distorted" cases, depending on the amount of matter that is present. We apply standard strategies for extracting quasinormal modes of clean signals, using both theory-agnostic and theory-specific assumptions. Even in the presence of matter, possible modifications of quasinormal modes seem to be typically dominated by ringdown modeling systematics.

GR 19.3 Fri 11:30 KH 02.012

Numerical relativity with NRPy+ and deal.ii — •Göran Ratz[1,2] and Frank Ohme[1,2] — [1]Max Planck Institute for Gravitational Physics, Hannover, Germany — [2]Leibniz University Hannover, Hannover, Germany

Numerical Relativity has been an insightful and irreplaceable part of understanding the nonlinear dynamics of spacetime. It is also known for being a little inaccessible mainly due to its magnificent computational costs and specialisation. In my talk, I want to give a brief introduction to NRPy+ (https://nrpyplus.net/), a well documented and beginner-friendly NR python library which makes, by some smart coordinate choices, certain black-hole merger simulations accessible for the "everyday user". I will also discuss the application of the C++ FEM-library deal.ii (https://dealii.org/) for generating Bowen-York-Brandt-Brügmann initial data slices for numerical relativity.

GR 19.4 Fri 11:45 KH 02.012

Machine Learning-Accelerated HLLD Riemann Solver for GRMHD — •Keneth Miler — Institut für Theoretische Physik, Goethe Universität, Max-von-Laue-Str. 1, D-60438

We present a machine-learning-enhanced HLLD Riemann solver for

GRMHD simulations that significantly reduces computational cost. The primary bottleneck in HLLD schemes is the iterative pressure recovery from conserved variables. We replace this expensive root-finding procedure with a trained neural network that directly predicts primitive pressure.