Gravitation and Relativity Division
Fachverband Gravitation und Relativitätstheorie (GR)

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Overview of Invited Talks and Sessions

(Lecture halls HBR 14: HS 2 and HS 3; Poster HBR 14: Foyer)

Prize Talk

GR 3.1	Tue	11:00–11:45	HBR 14: HS 2	**Enlightening the dark Universe through gravitational waves** — •Daniela Doneva

Invited Talks

GR 4.1	Tue	14:00–14:45	HBR 14: HS 2	**What if black hole spacetimes are singularity-free?** — •Piero Nicolini
GR 14.1	Thu	11:00–11:45	HBR 14: HS 2	**Modeling the strong-field dynamics of binary neutron star mergers** — •sebastiano Bernuzzi
GR 14.2	Thu	11:45–12:30	HBR 14: HS 2	**Exploring the Phase Diagram of QCD with Neutron Star Mergers in the Prompt and Non-Prompt Collapse Regime** — •Christian Ecker

Invited Talks of the joint Symposium Strong-Interaction Matter under Extreme Conditions

See SYEC for the full program of the symposium.

SYEC 1.1	Wed	9:00– 9:45	HBR 14: HS 1	**Strong-interaction Matter under Extreme Conditions: a Review** — •Guy D. Moore
SYEC 1.2	Wed	9:45–10:30	HBR 14: HS 1	**Theory of Strong-Interaction Matter** — •Gergely Endrodi
SYEC 2.1	Wed	11:00–11:45	HBR 14: HS 1	**Unravelling the phase structure of strong-interaction matter with high-energy heavy-ion experiments** — •Tetyana Galatyuk
SYEC 2.2	Wed	11:45–12:30	HBR 14: HS 1	**Neutron star mergers in numerical relativity** — •Masaru Shibata

Sessions

GR 1.1–1.4	Mon	16:45–18:05	HBR 14: HS 2	**Black Holes I**
GR 2.1–2.5	Mon	16:45–18:25	HBR 14: HS 3	**Foundations and Alternatives I**
GR 3.1–3.1	Tue	11:00–11:45	HBR 14: HS 2	**Gustav-Hertz-Preis**
GR 4.1–4.1	Tue	14:00–14:45	HBR 14: HS 2	**Black Holes II**
GR 5.1–5.2	Tue	14:45–15:25	HBR 14: HS 2	**Black Holes III**
GR 6.1–6.2	Tue	15:45–16:25	HBR 14: HS 2	**Experimental Tests**
GR 7.1–7.4	Tue	15:45–17:05	HBR 14: HS 3	**Foundations and Alternatives II**
GR 8.1–8.2	Tue	16:30–17:10	HBR 14: HS 2	**Quantum Gravity and Quantum Cosmology**
GR 9.1–9.3	Tue	17:30–18:30	HBR 14: HS 2	**Quantum Field Theory in Curved Spacetime**
GR 10.1–10.4	Wed	14:00–15:20	HBR 14: HS 2	**Relativistic Astrophysics I**
GR 11.1–11.4	Wed	15:45–17:05	HBR 14: HS 2	**Relativistic Astrophysics II**
GR 12.1–12.4	Wed	15:45–17:05	HBR 14: HS 3	**Foundations and Alternatives III**
GR 13.1–13.3	Wed	17:30–18:30	HBR 14: HS 2	**Numerical Relativity**
GR 14.1–14.2	Thu	11:00–12:30	HBR 14: HS 2	**Relativistic Astrophysics III**
GR 15.1–15.2	Thu	14:00–14:40	HBR 14: HS 2	**Classical Theory of General Relativity**
GR 16.1–16.2	Thu	14:45–15:25	HBR 14: HS 2	**Gravitational Waves I**
GR 17.1–17.3	Thu	15:45–16:45	HBR 14: HS 2	**Gravitational Waves II**

GR 18.1–18.6	Thu	17:15–18:45	HBR 14: Foyer	**Poster**
GR 19	Thu	19:00–20:30	HBR 14: HS 2	**Members' Assembly**

Members' Assembly of the Gravitation and Relativity Division

Thursday 19:00–20:30 HBR 14: HS 2

GR 1: Black Holes I

Time: Monday 16:45–18:05 Location: HBR 14: HS 2

GR 1.1 Mon 16:45 HBR 14: HS 2

Examine of Quasi-Periodic Oscillations of X-ray Flux Seen in Stellar-Mass Black Holes — •Gizem Dilara Açan Yildiz[1,2] and Ertan Güdekli[1] — [1]Istanbul University, Turkey — [2]Piri Reis University, Turkey

Stellar-mass Black Hole (BH) binaries have long been known to exhibit quasi-periodic oscillations (QPO) in their X-ray flux curves, and this phenomenon is considered one of the most effective tests of strong gravity models. In this study, we take into account the observation data of three well-known microquasars such as GRO 1655-40, XTE 1550- 564 and GRS 1915+ 105 and investigated QPOs. We successfully fit the observational data of epicyclic resonance and variants of high-frequency QPO models, investigated relativistic precession and its variants, tidal decay and warped disk models with perfect dark energy under the influence of the relevant parameter in the Kerr BH. We show that traditional geodetic models of QPOs can explain observationally generated data from microquasar models.

GR 1.2 Mon 17:05 HBR 14: HS 2

Kilometer-scale ultraviolet regulators and astrophysical black holes — •Jens Boos[1] and Christopher D. Carone[2] — [1]KIT, Karlsruhe, Germany — [2]William & Mary, Williamsburg VA, USA

Regular black hole metrics involve a universal, mass-independent regulator that can be up to $\mathcal{O}(700\,\mathrm{km})$ while remaining consistent with terrestrial tests of Newtonian gravity and astrophysical tests of general relativistic orbits. However, for such large values of the regulator scale the horizon is lost. We solve this problem by proposing mass-dependent regulators. This allows for large, percent-level effects in observables for regular astrophysical black holes. By considering the deflection angle of light and the black hole shadow, we demonstrate the possibility of large observational effects explicitly.

GR 1.3 Mon 17:25 HBR 14: HS 2

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

The Kerr-Taub-NUT-de Sitter (KTNdS) spacetime is an interesting model due to its special property of conical singularities and the so-called Misner string in the presence of a gravitomagnetic monopole, the NUT charge parameter ℓ. Gravitational lensing maps have shown that these become apparent to an observer for light- and time-like geodesics. Furthermore, the background appears "twisted" depending on the value of ℓ. Instead of describing the observation with ray-optical methods, we have already shown the observations for Schwarzschild-de Sitter as well as Kerr-de Sitter black holes for very low frequencies in a wave-optical approach. There, the scattering of a monochromatic point source was observed as seen by an observer at a larger distance from the black hole. We are interested in how the previous observations of the ray-optical approaches turn out at very low frequencies, and whether the same characteristic observations can be made, since the wave-optical approach coincides with the ray-optical approach at high frequencies. We present wave-optical images for both Taub-NUT-de Sitter (TNdS) and Kerr-Taub-NUT-de Sitter black holes and discuss the results.

GR 1.4 Mon 17:45 HBR 14: HS 2

Analytical studies of higher-order photon rings — •Oleg Tsupko[1,2], Volker Perlick[1], and Fabio Aratore[3] — [1]ZARM, University of Bremen, Bremen, Germany — [2]Moscow, Russia — [3]University of Salerno, Salerno, Italy

Higher-order photon rings can be expected to be detected in a more detailed image of the black hole found in future observations. These rings are lensed images of the luminous matter surrounding the black hole and are formed by photons that loop around it. Analytical calculations of higher-order images are possible with the use of so-called the strong deflection limit, which provides a simple logarithmic expression for large angles of gravitational deflection that is particularly suited for rays making revolutions around a black hole. In this work we compute analytically the shape of higher-order photon rings for an arbitrary spherically-symmetric metric using strong deflection limit. The shape is found as the explicit equation of the curve in polar coordinates. The formula describes the apparent shape of the higher-order image of the equatorial emission ring with the given radius around black hole as viewed by distant observer with an arbitrary inclination. Further, we discuss how the metric can be constrained through measurements of higher-order photon rings, the possible observation of which in future projects is currently being discussed. The work of Oleg Tsupko is supported by Humboldt Research Fellowship for experienced researchers.

GR 2: Foundations and Alternatives I

Time: Monday 16:45–18:25 Location: HBR 14: HS 3

GR 2.1 Mon 16:45 HBR 14: HS 3

Einstein's basement - A model of dark matter and dark energy? — •Fritz Riehle and Sebastian Ulbricht — Physikalisch-Technische Bundesanstalt, Braunschweig

The energy-momentum relationship (EMR) of a free particle in special relativity is regarded as the upper branch of an avoided crossing between the mass of the particle and its momentum. The corresponding EMR for the lower branch - a regime dubbed as Einstein's basement - is derived. From the associated Lagrangian and the conventional gravitational interaction a new kinematics in Einstein's basement is determined. It is shown that this can lead to a repulsion of the basement particles and a modified interaction with regular matter. The model suggests the identification of the basement particles with dark matter accompanied with a missing interaction with light. The expansion of the basement particles and the regular mass that is carried along could be interpreted as an expansion of the universe. Tests of the model by astronomical observations are suggested.

GR 2.2 Mon 17:05 HBR 14: HS 3

From maximum force to the emergence of space, black holes and elementary particles — •Christoph Schiller — Motion Moutain Research

It is shown that general relativity is characterized by a maximum force $c^4/4G$, in the same way that special relativity is characterized by a maximum speed c.

Combining these limits with the quantum of action $\hbar$ yields a model for space that explains and reproduces the thermodynamics of black holes. The model also explains the occurrence of elementary particles and yields a general mechanism for the appearance of elementary particle mass.

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C. Schiller, Tests for maximum force and maximum power, Physical Review D 104 (2021) 124079.

A. Kenath, C. Schiller and C. Sivaram, From maximum force to the field equations of general relativity - and implications, International Journal of Modern Physics D 31 (2022) 2242019 (honourable mention in the 2022 competition of the gravity research foundation).

C. Schiller, Testing a conjecture on the origin of space, gravity and mass, Indian Journal of Physics 96 (2022) 3047-3064.

More details at https://www.motionmountain.net/research.html

GR 2.3 Mon 17:25 HBR 14: HS 3

Kaluza ohne Klein — •Thomas Schindelbeck — thomas.schindelbeck@iraeph.de

Theodor Kaluzas Modell für eine einheitliche Beschreibung von Gravitation und Elektrodynamik liefert völlig falsche Größenordnungen für Teilcheneigenschaften, ein Problem, das weder eine Kombination mit Konzepten der Quantenmechanik, erstmals vorgeschlagen von Oskar Klein, noch Weiterentwicklungen im Rahmen der ART, z.B. der Space-Time-Matter-Theorie grundsätzlich lösen konnten. Eine präzise ab initio Beschreibung von Teilcheneigenschaften ist möglich, wenn man Kaluzas Ansatz in erster Nährung auf Elektrodynamik bezieht. Gravitative Effekte lassen sich über eine Reihenentwicklung zurückgewinnen, dabei können Terme in Größenordnung der kosmologischen Konstanten auftreten.

GR 2.4 Mon 17:45 HBR 14: HS 3

Dimensionale Physik erklärt über die Geometrie der 4D- und 3D-Raumzeit die Bedeutung von Pfadintegralen — •Christian Kosmak — Working Group Dimensional Physics, Würzburg

Nur aus unserer 4D-Raumzeit heraus, lässt sich die Quantenmechanik (QM) nicht erklären. In der neuen Theorie der Dimensionale Physik (DP) besitzt die 4D-Raumzeit eine Schnittstelle zu niederdimensionalen Raumzeiten und eine Schnittstelle zu höherdimensionalen Raumzeiten. Erst über die niederdimensionale Schnittstelle mit unendlich vielen niederdimensionalen Raumzeiten kann eine QM aufgebaut werden.

Daraus folgt, dass Pfadintegrale in der QM nicht einfach nur eine exakte Berechnung der Wahrscheinlichkeiten von Aufenthaltsorten in der 4D-Raumzeit erlauben, sondern dass Pfadintegrale in der QM die korrekte Abbildung des Aufenthaltsortes in der 3D-Raumzeit erlauben.

Internetseite: www.dimensionale-physik.de

YouTube-Kanal: www.youtube.com/@DimensionalePhysik

GR 2.5 Mon 18:05 HBR 14: HS 3

Significance of the number space $\mathbb{Q}$ and the coordinate system for energy relationships of elementary particles and the cosmos — •Helmut Christian Schmidt — LMU München

For energy relations, a system of 3 objects, each with 3 spatial coordinates (φ,r,θ) and the common time, is sufficient. The quantum information from these 10 independent parameters results in a polynomial $P(2)$. A transformation into $P(2\pi)$ provides the energy ratios.

E.g. neutron:

$E_p = (2\pi)^4 + (2\pi)^3 + (2\pi)^2$

$E_e = -((2\pi)^1 + (2\pi)^0 + (2\pi)^{-1})$

$E_{measuring\ device} = 2(2\pi)^{-2} + 2(2\pi)^{-4} - 2(2\pi)^{-6}$

derived from Christoffel symbol

$E_{time} = 6(2\pi)^{-8}$

$m_{neutron}/m_e = E_p + E_e + E_{measurement} + E_{time} = 1838.6836611$

$measured : 1838.68366173(89)m_e$

Neutrinos correspond to $\nu_\tau = \pi$, $\nu_\mu = 1$, $\nu_e = \pi^{-1}$. A photon made of neutrinos and can be viewed as two entangled electrons e^- and e^+. The charge results in an energy ratio E_C.

$E_C = -\pi^1 + 2\pi^{-1} + \pi^{-3} - 2\pi^{-5} + \pi^{-7} - \pi^{-9} + \pi^{-12}$

$m_{proton} = m_{neutron} + E_C m_e = 1836.15267363\ m_e$

$hG_N c^5 s^8/m^{10}\sqrt{\pi^4 - \pi^2 - \pi^{-1} - \pi^{-3}} = 0.999991$

Further calculations on the planetary system (Sun, Mercury, Venus, Earth, Moon) show the advantages of $P(2\pi)$ with an outlook H0 and CMB.

GR 3: Gustav-Hertz-Preis

Time: Tuesday 11:00–11:45 Location: HBR 14: HS 2

Prize Talk GR 3.1 Tue 11:00 HBR 14: HS 2

Enlightening the dark Universe through gravitational waves — •Daniela Doneva — University of Tübingen, Tübingen, Germany — Laureate of the Gustav-Hertz-Prize 2024

We already know that most of the observable Universe appears dark - from the dark energy that governs the expansion of our Universe, through the dark matter in the galaxies, to black holes where spacetime curvature reaches extreme values putting to test even Einstein's theory of gravity. Yet, we can only guess what else awaits to be discovered, whether new fundamental fields exist in nature, or strong gravity needs to be modified in its most extreme regime. Gravitational waves are our long-waited tool to unveil these mysteries. In the present talk, I will discuss some of the most interesting black hole and neutron star solutions beyond general relativity that allow us to dig deeper into our understanding of fundamental physics, especially through gravitational wave observations.

GR 4: Black Holes II

Time: Tuesday 14:00–14:45 Location: HBR 14: HS 2

Invited Talk GR 4.1 Tue 14:00 HBR 14: HS 2

What if black hole spacetimes are singularity-free? — •Piero Nicolini — Universität Triest, Triest, Italien — INFN, Triest, Italien — Johann Wolfgang Goethe-Universiät Frankfurt am Main, Frankfurt am Main, Deutschland — FIAS, Frankfurt am Main, Deutschland

Although the Penrose-Hawking singularity theorems leave little room for the fate of collapsing matter, since the 1960s there has been great interest in the possibility of deriving black hole solutions with a regular center. In this talk, after a short historical review, I will briefly discuss the main features of regular black holes. Finally, I will comment on the emerging new phenomenology and what can be learned from such spacetimes for the future.

GR 5: Black Holes III

Time: Tuesday 14:45–15:25 Location: HBR 14: HS 2

GR 5.1 Tue 14:45 HBR 14: HS 2

Light propagation in a plasma on Kerr spacetime — •Volker Perlick[1] and Oleg Tsupko[1,2] — [1]ZARM, University of Bremen, 281359 Bremen — [2]Moscow, Russia

Light propagation in a pressure-free non-magnetised plasma on Kerr spacetime is considered, which is a continuation of our previous study [Phys. Rev. D 95, 104003 (2017)]. It is assumed throughout that the plasma density is of the form that allows for the separability of the Hamilton-Jacobi equation for light rays, i.e., for the existence of a Carter constant. We start with studying spherical orbits, which are contained in a coordinate sphere $r = \mathrm{constant}$, and conical orbits, which are contained in a coordinate cone $\vartheta = \mathrm{constant}$. In particular, it is revealed that in the ergoregion in the presence of a plasma there can exist two different spherical light rays propagating through the same point. We demonstrate that, contrary to the vacuum case, circular orbits can exist off the equatorial plane in the domain of outer communication of a Kerr black hole. Considering the light deflection in the equatorial plane, we derive a new exact formula for the deflection angle which has the advantage of being directly applicable to light rays both inside and outside of the ergoregion. The possibility of a non-monotonic behavior of the deflection angle as a function of the impact parameter is demonstrated in the presence of a non-homogeneous plasma. We also add some further comments to our discussion of the black-hole shadow which was the main topic of our previous paper. - For details see arXiv:2311.10615.

GR 5.2 Tue 15:05 HBR 14: HS 2

Dynamics of nonlinear scalar field with Robin boundary con-

dition on the Schwarzschild-Anti-de Sitter background — •Filip Ficek[1,2] and Maciej Maliborski[1,2] — [1]University of Vienna, Faculty of Mathematics, Oskar-Morgenstern-Platz 1, 1090 Vienna, Austria — [2]University of Vienna, Gravitational Physics, Boltzmanngasse 5, 1090 Vienna, Austria

We explore the dynamics of conformal cubic scalar fields on a Schwarzschild-anti-de Sitter background, focusing on the impact of black hole size and Robin boundary conditions. We identify a critical curve in parameter space that demarcates regions with distinct asymptotic behaviours. Key findings include a pitchfork bifurcation of stable solutions in case of the defocusing nonlinearity and existence of thresholds for finite-time blow-ups in the focusing scenario.

GR 6: Experimental Tests

Time: Tuesday 15:45–16:25 Location: HBR 14: HS 2

GR 6.1 Tue 15:45 HBR 14: HS 2

A gravitational metrological triangle — •Claus Lämmerzahl[1] and Sebastian Ulbricht[2] — [1]ZARM, University Bremen, Germany — [2]PTB, Braunschweig, Germany

From gravitational analogues of the Josephson and the quantum Hall effect it is possibe to derive two gravitational analogues of the electric metrological triangle. This leads to a direct connection between the Planck constant and the mass of elementary particles. We also get an additional consistency relation for the electrical and gravitational definition of mass and also of Planck's constant. This provides a test of the uniqueness of $\hbar$ or of the universality of quantum mechanics, a quantum test of the equivalence principle, and may give, in principle, an alternative approach to a quantum definition of the kg.

GR 6.2 Tue 16:05 HBR 14: HS 2

Reaching the Planck scale with muon lifetime measurements and muon accelerators — •Christian Pfeifer[1] and Iarley Lobo[2] — [1]ZARM, Uni Bremen, Germany — [2]Department of Chemistry and Physics, Federal University of Paraíba, Brazil

A prominent effective description of particles interacting with the quantum properties of gravity is through modifications of the general relativistic dispersion relation. Such modified dispersion relations lead to modifications in the relativistic time dilation. A perfect probe for this effect, which goes with the particle energy cubed over the quantum gravity scale and the square of the particle mass would be a very light unstable particle for which one can detect the lifetime in the laboratory (lab) as a function of its energy measured in the lab to very high precision.

In this talk I discuss how a modified dispersion relation leads to modified time dilations and thus to modified lifetime of particles $t(E, M)$ in the detector frame as function of their mass M and their energy in the detector frame E. It will become clear that the usual special relativistic time dilation, which leads to a linear dependence of the particle lifetime on the particle energy, could just be the first order lienar approximation of a more general functional dependence of $t(E, M)$.

Furthermore, I discuss that a muon collider or accelerator would be a perfect tool to investigate the existence of an anomalous time dilation, and with it the fundamental structure of spacetime at the Planck scale.

GR 7: Foundations and Alternatives II

Time: Tuesday 15:45–17:05 Location: HBR 14: HS 3

GR 7.1 Tue 15:45 HBR 14: HS 3

Der Ursprung der dunklen Materie — •Albrecht Giese — Taxusweg 15, 22605 Hamburg

Die dunkle Materie gilt derzeit als das am wenigsten verstandene Phänomen der Physik. Zwei Theorien werden diskutiert als mögliche Lösung: (1) Die Annahme von neuen Teilchen, welche nur über Gravitation wechselwirken und (2) eine Änderung des Gravitationsgesetzes in der Weise, dass sich bei schwachen Feldern die Entfernungsfunktion ändert (MOND).

Beide Ansätze gelten als widerlegt durch Beobachtungen, und das mit jeweils hoher Signifikanz. Die Teilchenhypothese durch Galaxien, die umeinander kreisen. Der Ansatz MOND durch die Vermessung von Doppelsternen mit großem Abstand.

Ein bisher nicht beachtetes Phänomen ist nun die Gleichheit der Verteilungen des DM-Effekts mit der Verteilung der Photonen um Galaxien herum. Hier bietet sich der revolutionäre Ansatz an, dass Photonen selbst diese Teilchen sind - bei einer 'kopernikanischen' Änderung des Gravitationsgesetzes; nämlich der Unabhängigkeit der Gravitation von Masse.

Dieser Ansatz erklärt alle bekannten Beobachtungen des Phänomens dunkle Materie. Und er liefert im Falle der Gravitationskurven sogar quantitativ korrekte Ergebnisse - mittels Rohdaten, ohne jegliche Anpassung von Parametern. Und das als einziger heute existierender Ansatz.

Weitere Info: ag-physics.org/gravity

GR 7.2 Tue 16:05 HBR 14: HS 3

GR-Time dilation from (EP) why not from energy conservation. — •Manfred Geilhaupt — 41844 Wegberg

In physics, gravity is a fundamental interaction which causes mutual attraction between all things that have mass (energy). 1. Mass (energy) bends light (energy)! So light also can bend mass. 2. Clocks run faster on a mountain and slower at earth level! Conclusion: GR-time dilation explained with Einsteins equivalence principle (EP) must be basically a fact of matter due to energy conservation. (Conclusions from thermodynamic principles, see research gate pre-print)

GR 7.3 Tue 16:25 HBR 14: HS 3

The infalling observer's twofold perception — •René Friedrich — Strasbourg

Black holes, and in particular the underlying Schwarzschild metric, are associating finite and infinite time structures. In particular, the infalling observer is reaching the event horizon within finite time while according to external observers, she will never reach the event horizon. In this talk, it will be shown that up to now, the point of view of the infalling observer has been fundamentally misunderstood, because there is not taken into account the fact that every infalling observer approaching the event horizon is also an external observer, such that she disposes of two competing ways of perception.

The topic was subject of an essay that received a "honorable mention" in the essay contest 2023 of the Gravitational Research Foundation. Further information: R. Friedrich: Quantengravitation ohne Mühe

GR 7.4 Tue 16:45 HBR 14: HS 3

Only Euclidean Relativity Provides a Holistic View of Nature — •Markolf Niemz — Heidelberg University, Germany

Special and general relativity (SR/GR) describe nature "subjectively", that is, from the perspective of just *one observer at a time* (one group of observers, to be exact). Mathematically, SR/GR are correct. I show: (1) Physically, SR/GR have an issue. Despite the covariance of SR/GR, there is always just one active perspective. Because of this constraint, there is no holistic view of nature. The issue shows itself in unsolved mysteries. Still, the Lorentz factor and gravitational time dilation are correct. This is why the concepts of spacetime in SR/GR work well except for cosmology and quantum mechanics. (2) Euclidean relativity (ER) describes nature "objectively", that is, from the perspectives of *all objects at once.* Any (!) object's proper space d_1, d_2, d_3 and proper time τ span natural spacetime, which is 4D Euclidean space (ES) if we interpret $c\tau$ as d_4. All energy moves through ES at the speed c. An observer's reality is created by projecting ES orthogonally to his proper space and to his proper time. In SR, these concepts are considered coordinate space and coordinate time. Neither their reassembly to a non-Euclidean spacetime nor the parameterization in SR/GR provides a holistic view. The scalar τ, in particular, cannot factor in an object's 4D vector "flow of proper time" $\boldsymbol{\tau}$. The SO(4) symmetry of ES is incompatible with waves. This is fine because waves and particles are subjective concepts. We must distinguish between an observer's reality (described by SR/GR) and the master reality ES (described by ER). ER solves 15 mysteries (preprints.org/manuscript/202207.0399).

GR 8: Quantum Gravity and Quantum Cosmology

Time: Tuesday 16:30–17:10 Location: HBR 14: HS 2

GR 8.1 Tue 16:30 HBR 14: HS 2

Propagation of spinors on the angular deformed noncommutative black hole background — •Nikola Konjik[1], Marija Dinitrijević Ćirić[1], and Andjelo Samsarov[2] — [1]University of Belgrade-Faculty of Physics, Belgrade, Serbia — [2]Rudjer Boskovic Institute, Zagreb, Croatia

Some noncommutative (NC) theories possess a certain type of dualities that are implicitly built within their structure. In this paper we establish still another example of this kind. More precisely, we show that the noncommutative U(1) gauge theory coupled to a NC scalar/spinor field and to a classical geometry of the Reissner Nordstrom (RN) type is completely equivalent at the level of equations of motion to the commutative U(1) gauge theory coupled to a commutative scalar field and to a classical geometry background, different from the starting RN background. The new (effective) metric is obtained from the RN metric by switching on an additional nonvanishing r-phi component. Using this duality between two theories and physical systems they describe, we formulate an effective approach to studying a dynamics of spin 1/2 fields on the curved background of RN type with an abiding noncommutative structure. We calculate QNM spectrum of fermions in this type of space.

GR 8.2 Tue 16:50 HBR 14: HS 2

Compact objects from effective quantum gravity — •Salvatore S. Sirletti[1,2] and Piero Nicolini[3,4] — [1]Dipartimento di Fisica, Università di Trento, Via Sommarive 14, 38123 Povo, Trento, Italy — [2]Dipartimento di Fisica e Scienze della Terra, Università degli Studi di Ferrara, via Saragat 1, I-44122 Ferrara, Italy — [3]Institut für Theoretische Physik, Goethe-Universität, Frankfurt am Main, Germany — [4]Dipartimento di Fisica, Università degli Studi di Trieste, Via Alfonso Valerio, 2, 34127 Trieste, Italy

It has been shown that the UV finiteness of Superstring Theory can led to the derivation of a family of regular black hole solutions in the gravity-matter decoupling limit. The latter is a regime governed by stringy effects like non-commutativity and T-duality. The most natural realization of a non-local structure inheriting noncommutative geometry effects is the Gaussian profile for the energy density in the relativistic stress tensor.

In this talk, we present two interesting regular black hole/compact object alternatives that stem from postulating a smooth transition between a quantum gravity dominated region at the origin, and a corona of degenerate nuclear matter around it. The derivation of the resulting semi-classical metric allows for the description of a regular horizonless Planckian object and a neutron star with a quantum vacuum at its center.

GR 9: Quantum Field Theory in Curved Spacetime

Time: Tuesday 17:30–18:30 Location: HBR 14: HS 2

GR 9.1 Tue 17:30 HBR 14: HS 2

Particle Production by Gravitational Fields and Black Hole Evaporation — •Michael F. Wondrak[1,2], Walter D. van Suijlekom[2], and Heino Falcke[1] — [1]Department of Astrophysics/IMAPP, Radboud Universiteit, Nijmegen, The Netherlands — [2]Department of Mathematics/IMAPP, Radboud Universiteit, Nijmegen, The Netherlands

This talk presents a new avenue to black hole evaporation using a heat-kernel approach in the context of effective field theory analogous to deriving the Schwinger effect. Applying this method to an uncharged massless scalar field in a Schwarzschild spacetime, we show that spacetime curvature takes a similar role as the electric field strength in the Schwinger effect. We interpret our results as local pair production in a gravitational field and derive a radial production profile. The resulting emission peaks near the unstable photon orbit. Comparing the particle number and energy flux to the Hawking case, we find both effects to be of similar order. However, our pair production mechanism itself does not explicitly make use of the presence of a black hole event horizon and might have cosmological implications.

The presentation is based on Phys. Rev. Lett. 130 (2023) 221502.

GR 9.2 Tue 17:50 HBR 14: HS 2

Particle creation in Bianchi IX universe — •Tatevik Vardanyan and Claus Kiefer — University of Cologne, Faculty of Mathematics and Natural Sciences, Institute for Theoretical Physics, Cologne, Germany

Particle production due to the expansion of the universe is studied for the general Bianchi type IX model. The impact of anisotropies on created particles/antiparticles is presented. The results are compared to the closed FLRW model of the universe.

GR 9.3 Tue 18:10 HBR 14: HS 2

Wigner phase of photonic helicity states in curved spacetime — •Luis Adrian Alanis Rodriguez — Institute for Theoretical Physics, University of Cologne, Cologne, Germany — Institute for Quantum Computing (PGI-12), Forschungszentrum Jülich, Jülich, Germany

We study relativistic effects on polarized photons that travel in a curved spacetime. The considered scenario is one in which photons propagate in the gravitational field of the Earth on a closed path that starts at a terrestrial laboratory, is reflected at one or more satellites, and finally returns to the laboratory. A formalism that takes into account the propagation and the boundary conditions at the mirrors is introduced. We find that after propagating along a closed path as in the aforementioned scenario, a non-trivial Wigner phase is acquired by the photons already in the Schwarzschild spacetime, where previous studies have found a trivial Wigner phase.

GR 10: Relativistic Astrophysics I

Time: Wednesday 14:00–15:20 Location: HBR 14: HS 2

GR 10.1 Wed 14:00 HBR 14: HS 2

Timing of pulsars in extreme mass ratio systems — •Eva Hackmann — ZARM, Universität Bremen

Binary systems of a pulsar and a black hole are very promising laboratories to determine the features of the combined gravitational field and to test General Relativity. A pulsar orbiting Sagittarius A*, the supermassive galactic center black hole, should allow for the determination of its mass and spin to unprecedented accuracy and to test e.g. the no-hair theorem. It is therefore of great importance to accurately model the effects of General Relativity. Different from the usual post-Newtonian treatment, we present an analytical timing formula based on the test particle limit in the extreme mass ratio system. The resulting relativistic delays of the pulsar signal are discussed.

GR 10.2 Wed 14:20 HBR 14: HS 2

Radiation-hydrodynamics simulations of kilonovae with nuclear networks — •Fabio Magistrelli — Friedrich-Schiller-Universitaet Jena, TPI

I will present a new technique to simulate the long-term evolution of the material ejected during binary neutron star mergers. For the first time, we provide radiation-hydrodynamic simulations with complete nuclear network calculations to compute in real-time the energy released by nuclear reactions and keep track of the detailed matter composition. I will then describe the results obtained by applying this pipeline to a new set of numerical relativity simulations run for hundreds of milliseconds after merger. In particular, I will discuss the features induced by different equations of states for the neutron star matter on kilonovae lightcurves and r-process nucleosynthesis yields. Finally, I will consider the effects of including extra energy in the simulation in the form of a polar jet mimicking a short gamma-ray burst.

GR 10.3 Wed 14:40 HBR 14: HS 2

Accretion Induced Collapse of Rotating White Dwarfs Progenitors — •Luís Felipe Longo Micchi — Friedrich-Schiller Universitat

Studies have proposed accretion-induced collapse (AIC) of white dwarfs (WDs) as possible power engines of short GRBs with extended emission (sGRB+EE). Aware of the recent turmoil around GRB211211A (a known sGRB+EE) origins, we revisited the science case of AICs. In this talk, we will discuss the results of three models of WDs that collapse due to electron capture. Parameterized by their initial angular momentum, we study the influence of rotation in our AIC models. A careful characterization of the multi-messenger emission of these events will be dis- cussed. With a particular focus on gravitational radiation, we will examine their gravitational wave (GW) morphology and their detectability in current and future ground-based GW detectors. We provide estimates of their electromagnetic and neutrino radiation profile and compare them against other supernova-like events. All our models are fully general-relativistic three-dimensional numerical simulations containing a moment-based neutrino radiation transport. The inclusion of magnetic fields is an undergoing extension of our work.

GR 10.4 Wed 15:00 HBR 14: HS 2

Constraining the Properties of Dark Matter With Gravitational Lensing on Subgalactic Scales — •Felix Heinze — Friedrich-Schiller-Universität Jena, Theoretisch-Physikalisches Institut, Fröbelstieg 1, 07743 Jena

Gravitational lensing is a powerful tool for investigating the distribution and the total content of both luminous and dark matter in galaxies and galaxy clusters. Even small substructures in the form of subhalos can be detected by the perturbative effects they have on the lensing observables, even if no luminous matter is associated with them. It is crucial to understand the lensing effects of these subhalos in detail, as they can be used to infer the structural properties and the abundance of substructures, which in turn allow for constraining the properties of dark matter. A substantial portion of the subhalos that have been detected in the past seem to exhibit concentrations that significantly exceed the predictions made by the cold dark matter model. One possible explanation for this discrepancy that does not invoke alternative dark matter models lies in the potential inadequacy of the theoretical models that have underpinned prior analyses. State-of-the-art cosmological simulations that include the effects of baryons, such as TNG50, indicate that previously used models of subhalo density profiles might not provide an adequate description in the presence of baryons. These studies, implications for future lensing analyses and their ability to constrain dark matter models are going to be discussed in this talk.

GR 11: Relativistic Astrophysics II

Time: Wednesday 15:45–17:05 Location: HBR 14: HS 2

GR 11.1 Wed 15:45 HBR 14: HS 2

Constraining the nuclear equation of state from rotating neutron stars — •Sebastian H. Völkel[1] and Christian J. Krüger[2] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), D-14476 Potsdam, Germany — [2]Theoretical Astrophysics, IAAT, University of Tübingen, D-72076 Tübingen, Germany

Inferring the nuclear equation of state from neutron stars is a fascinating research objective that calls for accurate and efficient modeling. Due to computational and technical difficulties, most existing works that focus on equation of state inference neglect rotational effects. In this talk, I will review a Bayesian parameter estimation framework that was first introduced in [1] for slowly rotating neutron stars, and more recently extended to fast rotation in [2]. The framework allows to convert measurements of bulk properties of rotating neutron stars, e.g., their masses, radii, but also moments of inertia, and some f-mode frequencies, to bounds on the popular piecewise polytropic equation of state. The key for efficient parameter estimation is the use of novel universal relations and the construction of a template bank. While slow rotation can be well justified in the presence of large measurement uncertainties and slowly rotating stars, it can lead to significant bias for moderately rotating neutron stars and future, high accuracy measurements.

[1] Völkel and Krüger, PRD 105 124071 (2022), arXiv:2203.05555
[2] Krüger and Völkel, accepted in PRD, arXiv:2309.05643

GR 11.2 Wed 16:05 HBR 14: HS 2

Universal relations for bulk quantities of rapidly rotating neutron stars — •Christian J. Krüger[1] and Sebastian H. Völkel[2] — [1]Theoretical Astrophysics, IAAT, University of Tübingen, D-72076 Tübingen, Germany — [2]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), D-14476 Potsdam, Germany

Neutron stars are compact objects whose interior composition is largely unknown and various rather different potential compositions are being debated. Furthermore, astrophysical neutron stars rotate, causing them to be oblate and their fluid bulk quantities to differ significantly from their nonrotating counterparts. Calculating these bulk quantities requires the computationally rather expensive solution of elliptic PDEs while neglecting rotational effects will inevitably result in bias when performing parameter estimation. Despite their complex physical nature, the impact of rotation on neutron stars exhibits quite universal patterns. In this talk, I will present universal relations that allow to estimate fluid bulk quantities of rapidly rotating neutron stars based on mass M, radius R and moment of inertia I of an associated nonrotating neutron star [1], which considerably reduces the computational expense. In extension of the cited work, I will present estimates for additional fluid bulk quantities which will be based on a newly generated set of neutron star models, thereby reducing potential bias in the relations.

[1] Krüger and Völkel, accepted in PRD, arXiv:2309.05643

GR 11.3 Wed 16:25 HBR 14: HS 2

An overview of nuclear and astrophysical constraints on the equation of state for neutron-rich dense matter — •Hauke Koehn — Institut für Physik und Astronomie, Universität Potsdam, Haus 28, Karl-Liebknecht-Str. 24/25, 14476, Potsdam, Germany

At present, a multitude of different observations, experiments and theoretical considerations exist to address the nature of matter at extreme densities. We present a detailed overview across these distinct sources of information and explain why and how they impose constraints on the cold equation of state of neutron-rich dense matter (EOS). By performing Bayesian inference on a large set of candidate EOS for each input, we are able to combine the distinct constraints, which delivers stringent constraints on the radii and maximum mass of neutron stars, and further restrictions on empirical nuclear parameters or the speed of sound.

GR 11.4 Wed 16:45 HBR 14: HS 2

Effects of Quantum Gravity on the Nuclear Astrophysics

of Quark Stars: The GUP-Modified MIT Bag Model — •Marcelo Netz-Marzola[1,2], César A. Zen Vasconcellos[3,4], and Dimiter Hadjimichef[3] — [1]FIAS, Frankfurt, Germany — [2]Goethe-Uni, Frankfurt, Germany — [3]UFRGS, Porto Alegre, Brazil — [4]ICRANet, Pescara, Italy

The Generalized Uncertainty Principle (GUP) is motivated by the premise that spacetime distortions near the Planck scale impose a lower bound on the achievable resolution of distances, leading to a minimum length. Inspired by a semiclassical method that integrates the GUP into the partition function by deforming its phase space, we induce a modification on the thermodynamic quantities of the MIT bag model that we propose serves as an effective semiclassical description of deconfined quark matter in a space with minimal length. We investigate the consequences of this deformation on the zero-temperature limit, revealing a saturation limit for the energy density, pressure and baryon number density and an overall decrease of the thermodynamic quantities, alongside a slight increase in the mass-radius relation of compact objects, providing enhanced stability against gravitational collapse. These findings extend existing research on GUP-deformed Fermi gases. Finally, we briefly outline the path towards a more generalized GUP framework capable of integrating a variety of particles and interactions. Theoretical implications of our work can be tested in the future at the HADES experiment at GSI and at the CBM experiment at FAIR.

GR 12: Foundations and Alternatives III

Time: Wednesday 15:45–17:05 Location: HBR 14: HS 3

GR 12.1 Wed 15:45 HBR 14: HS 3

No Need for Dark Energy in a Variable Speed of Light Cosmology? — •Alexander Unzicker — Pestalozzi-Gymnasium München

Einstein's very first idea concerning general relativity in 1911, based on a variable speed of light, can be extended to a cosmology that implements Mach's principle (Dicke, 1957). Its predictions are compared to supernova data from the Open Astronomy Catalog (API).

GR 12.2 Wed 16:05 HBR 14: HS 3

Solving the Conundrum of Dark Matter and Dark Energy — •Thomas Wäscher — Von-Dalheim-Str. 2, 69231 Rauenberg

As a Follow-Up on the talk at the DPD-Frühjahrstagung Heidelberg 2022 "Theses for a Closed, Self Sustaining and Timeless Universe" I try now to explain how "Dark Matter" and "Dark Energy" can be mutually neutralized without any residues. It starts from the ground by a wording of Ernst Schmutzer, Jena: "Acceleration replaces Gravity" and vice versa in the field of the Equivalence Principle (EP). Applicated e.g. to the measurements of Riess et al. and Perlmutter et al.(1998), who identified the growing redshift as an accelerated expansion of the universe this would imply that they may have detected the growing redshift in an constant gravitational field instead. The very meaning of the EP is that all measurements of redshift in an isotropic and homogenious environment of accelerated expansion cannot be distinguished by no means from the redshift measurements made in a stationary gravitational field. Now exchanging the accelerated expansion by a stationary gravitational field, "Dark Energy" is omitted and instead the gravitational field delivers "Dark Matter". These considerations favour a stable, gravitationally closed, adiabatic and timeless universe with internal dynamic processes of fusion and decay of the elements in a state of equilibrium. Surprising z>10 JWST observations hint to this prospect, e.g, the existance of metal elements or the fully developed galaxies far away.

GR 12.3 Wed 16:25 HBR 14: HS 3

Mögliche physikalische Ursachen der kosmischen Raumausdehnung — •Herbert Höft — Rilkestraße 29, 09114 Chemnitz

Für die Kosmologie gilt auch im weiten Universum: Homogenität des Raumes *(Wahl des Startortes spielt keine Rolle,)

Isotropie des Raumes **(Richtung im Raum spielt keine Rolle) Die physiklischen Erhaltungsgestze gelten überall. Aktuell glaubt man, dass eine angenommene Dunkle Energie den Kosmos auseinander treibt.

Für ein Kugelmodell des Kosmos (als der beobachtbare Teil des unendlichen Universum) bestimmen die nicht abschirmbare anziehende Gravitationkraft FA = GmM/r2 = Gm4$\pi\delta$r/3 der kosmoschen Masse M = δV = 4$\pi\delta$r3/3 und die Fliehkraft durch Rotation FF = mω2r das wesentliche Geschehen im Kosmos.

Alles bewegt sich und rotiert das Elektron (Spin) und die Galaxien mit einer Rotationsachse, die sich auch durch äußere Einwirkungen neigen kann was bei einigen Galaxien durch die Absenkung der äußeren Spiralarme sichtbar ist und bei unserer Milchstraße vermutet wird. Falls die angenommene Kosmoskugel mit einer Winkelgeschwindigkeit ω rotiert, folgt aus der Differenz ΔF = FF - FA ein Gleichgewicht bei ω2 = 4$\pi\delta$G. Das ist der statische Zustand der Raumausdehnung und mit ω > (4$\pi\delta$G)* folgt eine Raumausdehnung. Eine Dunkle Energie ist dazu nicht notwendig. Vielleicht gelingt es in Zukunft in einem kosmischen Lagrange-Punkt ein rotierendes Gebilde mit einer stabilen Rotationsachse zu installieren und die Rotation des Kosmos nachzuweisen.

GR 12.4 Wed 16:45 HBR 14: HS 3

A multiversal view of reality — •Roland Schmidt — 34225 Baunatal, Deutschland

Quantum mechanics is complemented by an inertia operator. Based on this, it can be shown that the equivalence principle of the general theory of relativity is invalid. This inadequacy results from an as yet overlooked incompleteness of classical electrodynamics. Obviously, an observation can only arise from cerebrally attached electromagnetic interactions, in which a perceiving observer is involved as a realizing instance. However, as far as the process of observation is concerned, classical electrodynamics does not distinguish sufficiently between cerebrally attached and cerebrally detached electromagnetism. In particular, it cannot be explained on an exclusively classical basis how light that reaches the spatial presence of an observer finally also penetrates into the observer's cerebral presence, so that an experienced sensory impression is realized within the observer's cerebral apparatus. The interaction of light with the observer's intra-cerebral presence can only be explained on the basis of quantum theory. With this background, it is shown that no objectively valid universe is realized at all. Actually, a multiverse of cerebrally established realities takes place instead of a single universally valid reality. To put it plagatively: The cerebral apparatuses of the observers do not occur in reality, but realities occur in the cerebral apparatuses of the observers.

GR 13: Numerical Relativity

Time: Wednesday 17:30–18:30 Location: HBR 14: HS 2

GR 13.1 Wed 17:30 HBR 14: HS 2

Divergence-Free Constraint Treatment in General-Relativistic Magneto-Hydrodynamic Simulations — •Anna Neuweiler — Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Str. 24/25, 14476, Potsdam, Germany

Magnetic fields have a significant impact on the post-merger dynamics of binary neutron star systems, as they influence the lifetime of the remnant as well as the outflow of matter. Their inclusion in numerical relativity is however not trivial since additional equations have to be solved and constraints have to be fulfilled, in particular the divergence-free constraint. We have recently enabled our numerical-relativity code BAM to perform general relativistic magneto-hydrodynamic simulations with hyperbolic divergence-cleaning, which introduces a new variable to damp the divergence. Although this method is simpler than other schemes used in the literature, one advantage is that higher-order reconstruction schemes can be used straightforward. To evaluate the impact, we compare our results for simple tests with other codes using different divergence-free constraint treatments. Finally, we perform binary neutron star simulations and analyze the differences.

GR 13.2 Wed 17:50 HBR 14: HS 2

GR-Athena++: General-relativistic magnetohydrodynamics simulations of neutron star spacetimes — •William Cook — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany

We present the extension of GR-Athena++ to general-relativistic magnetohydrodynamics (GRMHD) for applications to neutron star spacetimes. This couples the constrained transport implementation of Athena++ to the Z4c formulation of the Einstein equations to simulate dynamical spacetimes with GRMHD using oct-tree adaptive mesh refinement (AMR). We consider benchmark problems for isolated and binary neutron star spacetimes demonstrating stable and convergent results at relatively low resolutions and without grid symmetries imposed. The code correctly captures magnetic field instabilities in non-rotating stars with total relative violation of the divergence-free constraint of 10^{-16}. It handles evolutions with a microphysical equation of state and black hole formation in the gravitational collapse of a rapidly rotating star. For binaries, we demonstrate correctness of the evolution under the gravitational radiation reaction and show convergence of gravitational waveforms. We showcase the use of AMR to resolve the Kelvin-Helmholtz instability at the collisional interface in a merger of magnetised binary neutron stars. GR-Athena++ shows strong scaling efficiencies above 80% in excess of 10^5CPU cores and excellent weak scaling is shown up to $\sim 5 \times 10^5$ CPU cores in a realistic production setup. GR-Athena++ allows for the robust simulation of GRMHD flows in strong and dynamical gravity with exascale computers.

GR 13.3 Wed 18:10 HBR 14: HS 2

Spectrally-tuned compact finite-difference schemes with domain decomposition and applications to numerical relativity — •Boris Daszuta — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany

Compact finite-difference (FD) schemes specify derivative approximations implicitly, thus to achieve parallelism with domain-decomposition suitable partitioning of linear systems is required. Consistent order of accuracy, dispersion, and dissipation is crucial to maintain in wave propagation problems such that deformation of the associated spectra of the discretized problems is not too severe. In this work we consider numerically tuning spectral error, at fixed formal order of accuracy to automatically devise new compact FD schemes. Grid convergence tests indicate error reduction of at least an order of magnitude over standard FD. A proposed hybrid matching-communication strategy maintains the aforementioned properties under domain-decomposition. Under evolution of linear wave-propagation problems utilizing exponential integration or explicit Runge-Kutta methods improvement is found to remain robust. A first demonstration that compact FD methods may be applied to the Z4c formulation of numerical relativity is provided where we couple our header-only, templated C++ implementation to the highly performant GR-Athena++ code. Evolving Z4c on test-bed problems shows at least an order in magnitude reduction in phase error compared to FD for propagated metric components. Stable binary-black-hole evolution utilizing compact FD together with improved convergence is also demonstrated.

GR 14: Relativistic Astrophysics III

Time: Thursday 11:00–12:30 Location: HBR 14: HS 2

Invited Talk GR 14.1 Thu 11:00 HBR 14: HS 2

Modeling the strong-field dynamics of binary neutron star mergers — •sebastiano Bernuzzi — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universitaet Jena, Max Wien Platz 1 D-07743 Jena, Germany

Binary neutron star mergers (BNSM) are associated to powerful gravitational and electromagnetic astronomical transients. Multimessenger observations of BNSMs promise to deliver unprecedented insights on fundamental physics questions, including constraints on dense matter models and the production of heavy elements. Detailed theoretical predictions of the merger dynamics are a crucial aspect for extracting information from such observations. This talk reviews recent progress in the modeling of BNSMs using simulations in 3+1 numerical general relativity. In the first part, I will discuss the first predictions for the complete (inspiral-merger-postmerger) gravitational-wave spectrum and their application in gravitational-wave astronomy. In the second part, I will discuss recent results on merger remnants and mass ejecta, the mechanisms behind kilonova light and their application to the analyses of astrophysical data.

Invited Talk GR 14.2 Thu 11:45 HBR 14: HS 2

Exploring the Phase Diagram of QCD with Neutron Star Mergers in the Prompt and Non-Prompt Collapse Regime — •Christian Ecker — Gothe University, Frankfurt am Main, Germany

Determining the phase structure of Quantum Chromodynamics (QCD) and its Equation of State (EoS) at densities and temperatures realised inside neutron stars and their mergers is a long-standing open problem. I will present a framework for the EoS of dense and hot QCD that describes the deconfinement phase transition between a dense baryonic and quark matter phase via the holographic V-QCD model. This model is then used to study the consequences on the formation of quark matter in binary neutron star mergers in the prompt and non-prompt collapse regime.

GR 15: Classical Theory of General Relativity

Time: Thursday 14:00–14:40 Location: HBR 14: HS 2

GR 15.1 Thu 14:00 HBR 14: HS 2

Gravitational field recovery via inter-satellite redshift measurements — •Jan Patrick Hackstein, Dennis Philipp, and Eva Hackmann — ZARM, University of Bremen, Germany

Satellite gravimetry is a common tool to monitor global changes in the Earth system, generally utilising accelerometers aboard satellites to measure acting forces along the orbits. In contrast, high-precision atomic clocks are used in first experiments in terrestrial gravimetry to measure physical heights. In relativistic gravity, a comparison of two clocks is sensitive to their relative positions and velocity, making clocks ideal tools to investigate Earth's gravity field. However, one important obstacle for Earth-satellite chronometry is the low measurement accuracy of satellite velocities, which enter into the redshift via the Doppler effect.

We present an alternative approach based on the framework of general relativity without velocity measurements from ground stations, instead measuring redshift between satellite pairs equipped with clocks via laser ranging. This method promises higher accuracy for gravity field recovery by improving control of the Doppler effect. We investigate this problem in analytically given spacetimes as well as in the general first post-Newtonian approximation of Earth's gravity field, and discuss the prospects for gravity field recovery.

GR 15.2 Thu 14:20 HBR 14: HS 2

General Relativistic Chronometry from Ground and in Space — •Dennis Philipp[1,2], Eva Hackmann[1], Jan Hackstein[1], and Claus Lämmerzahl[1,2] — [1]ZARM, University of Bremen, Germany — [2]Gauss-Olbers Center, University of Bremen, Germany

One of the main tasks of geodesy is to determine the gravity field of the Earth from measurements based on ground and in space.

General relativistic geodesy allows for an entirely new perspective and high-precision clock comparison has the potential to provide a new tool in the global determination of the Earth's gravito-electric potential based on the gravitational redshift. Toward this clock-based gravimetry, i.e., chronometry in stationary spacetimes, exact expressions for the relativistic redshift and the timing between observers in various configurations are discussed. These observers are assumed to be equipped with standard clocks and move along arbitrary worldlines. It is shown how redshift measurements, involving clocks on ground and/or in space, can be used to determine the (mass) multipole moments of the underlying spacetime geometry. Our results are in agreement with the Newtonian potential determination from, e.g., the energy approach in conventional geodesy. The framework of chronometric geodesy is presented and exemplified in different exact vacuum spacetimes for illustration. Gravity degrees of freedom, also involving gravito-magnetic contributions, are studied and potential experiments for their determination are investigated. Future gravity field recovery missions may use clock comparisons as an additional source for advanced data fusion.

GR 16: Gravitational Waves I

Time: Thursday 14:45–15:25 Location: HBR 14: HS 2

GR 16.1 Thu 14:45 HBR 14: HS 2

Intersatellite Ranging and Clock Synchronization for the Laser Interferometer Space Antenna — •Jan Niklas Reinhardt — Max-Planck-Institut für Gravitationsphysik, Callinstraße 38, 30167 Hannover

Ground-based gravitational wave detectors are blind below 10 Hz due to gravity gradient noise, etc. The Laser Interferometer Space Antenna (LISA) avoids these difficulties by going to space. Hence, it extends gravitational wave astronomy to the sub-hertz frequency band. LISA consists of 3 satellites in a triangular constellation trailing Earth by 20 degrees on its orbit around the sun. Gravitational waves cause pico meter variations in the 2.5 million km arm lengths. To detect them the satellites are connected by six infrared laser links, and heterodyne interferometry is performed between received and local lasers, respectively. The LISA measurements are swamped by laser frequency noise. An on-ground data processing technique called time-delay interferometry (TDI) is applied, which combines the beatnotes from the different satellites with the correct delays to virtually form equal-optical-path-length interferometers, in which laser frequency noise naturally cancels. To obtain the required delays, we combine the four LISA ranging observables in a ranging sensor fusion: PRN ranging, ranging information from the clock sideband beatnotes, TDI ranging, ground-based observations. Each satellite has its own on-board timer. We combine the intersatellite ranges with ground observations to estimate their desynchronisations from the barycentric coordinate time (TCB). Hence, we synchronize the on-board timers to TCB.

GR 16.2 Thu 15:05 HBR 14: HS 2

Systematic Differences in the Source Properties of Gravitational Wave Signals — •Max Melching — Max-Planck-Institut für Gravitationsphysik (Albert Einstein Institut), Callinstraße 38, 30167 Hannover, Deutschland

Measurements of gravitational wave source properties are conducted in the framework of parameter estimation, utilizing Bayes' theorem to compute posterior probability distributions for all parameters. In this process, one predicts gravitational wave signals for certain parameter combinations and compares them to detector data in order to infer whether the modeled signal is contained in the data. However, the waveform models are not entirely faithful representations of numerical relativity because of the high computational cost involved in generating accurate simulations. Instead, several approximate models are used, which may lead to systematic differences in the inferred results. Consequently, being able to describe and understand model-induced uncertainties is crucial.

To date, however, no universal way of doing that exists. In this talk, I will explore a data-driven approach to identify significant systematic differences between models and apply this method to confident detections of the third gravitational-wave transient catalog GWTC-3 that has been published by the LIGO-Virgo-KAGRA collaborations. Additionally, I will talk about geometric ideas from the Fisher-matrix formalism that allow for interpreting signal differences as measurement uncertainties in the associated parameter space.

GR 17: Gravitational Waves II

Time: Thursday 15:45–16:45 Location: HBR 14: HS 2

GR 17.1 Thu 15:45 HBR 14: HS 2

Gravitational waves from black-hole–neutron star coalescences — •Alejandra Renee Pillado Gonzalez — Friedrich-Schiller-University of Jena, Jena, Germany

In this talk, a brief overview on gravitational waveform templates for black-hole–neutron star mergers is given. I review an effective-one-body model designed for these waveforms, and present preliminary numerical relativity studies to produce accurate templates. The latter can potentially be used to study the dynamics of these binary mergers, among other applications.

GR 17.2 Thu 16:05 HBR 14: HS 2

Correlating Black Hole Recoils with Mode Asymmetries in Gravitational-Wave Radiation — •Jannik Mielke — Max-Planck-Institut für Gravitationsphysik (Albert-Einstein-Institut), Callinstraße 38, 30167 Hannover, Deutschland

Detections of gravitational waves from astrophysical sources such as binary black holes by LIGO and Virgo has attracted widespread attention from the scientific community, the media and the general public. Among these sources, precessing systems with a misalignment of the black hole spin and the orbital angular momentum are of particular interest because of the rich dynamics they offer. For aligned-spin systems, the energy and momentum emitted above the orbital plane is symmetric to the emission below the plane. For mis-aligned systems, however, this is not the case and amplitude and phase modulations will appear in the waveform itself. When the signal is decomposed into modes of spin-weighted spherical harmonics, we can discuss the asymmetry between the negative and positive m-modes by defining an anti-symmetric waveform, which is neglected in most waveform models used in gravitational wave data analysis to date. In this talk, we analyse the phenomenology of the anti-symmetric waveform and relate it to the physics of remnant black hole recoil, which is a consequence of asymmetric linear momentum radiation. Strong correlations were found between the intrinsic system parameters and the amplitude and phase of the anti-symmetric waveform, which in turn affects the magnitude of the out-of-plane recoil velocity.

GR 17.3 Thu 16:25 HBR 14: HS 2

Gravitational scattering with Spinning Generalized Wilson Line operators — Domenico Bonocore[1], Anna Kulesza[2], and •Johannes Pirsch[2] — [1]Theoretische Elementarteilchenphysik, TUM, München, Germany — [2]Institut für Theoretische Physik, WWU Münster, Münster, Germany

Due to the close connection between the classical limit and Regge limit of scattering amplitudes, Wilson Line operators are efficient building blocks of gravitational scattering amplitudes in the classical limit. At higher orders in the Post-Minkowskian expansion subleading corrections to the Wilson- Line operators become relevant and can be computed systematically from a first quantized point particle worldline model.

In this talk I will present the main ideas behind this approach and focus particularly on the implementation of spin in the worldline model. It is well known from the worldline approach to QFT and resummation techniques in QCD that spinning particles can be described by supersymmetric worldline actions, where the spinning degrees of freedom are described by Grassmann valued fields. The resulting path integral expression exhibits a clear separation between classical and quantum contributions to the scattering amplitude. This allows for the efficient calculation of classical observables for scattering of spinning compact astrophysical objects.

GR 18: Poster

Time: Thursday 17:15–18:45 Location: HBR 14: Foyer

GR 18.1 Thu 17:15 HBR 14: Foyer

Questionable predictions by EHT image of Sgr A*; observational evidence for Sgr A* being no BH; de Laval nozzle and its application to astrophysical jets. — •Jürgen Brandes — Karlsbad, Germany

I. The famous EHT image of Sgr A* predicts BH features in contradiction with observation: a* = 0.9375 against a* $\leq$ 0.15; spin direction face-on against edge-on; accretion light variability arising with accretion disks against variability of accretion wind. And there is a theoretical shortcut by Broderick et al.: The missing UV bump agrees with degenerate supermassive objects being no BH [1], [2]. II. Furthermore, [3] proves: If Sgr A* is a BH then its spin must be a* = 0.90. But [1] proves that the spin of Sgr A* $\leq$ 0.15. The purely logical conclusion: Sgr A* cannot be a BH (contrary to [3], its spin would be too low). **These observations of Fragione, Loeb, Daly et al. together are an obvious experimental confirmation for Sgr A* not being a BH** [1], [3]. III. Jets of supermassive objects being no BH are quite natural explained by astronomical application of a de Laval nozzle [4]. Since this does not work for BHs it should lead to observable differences between BHs and no BH stellar objects.

[1] Talk-DPG-2023 www.grt-li.de.
[2] J. Brandes, J. Czerniawski, L. Neidhart: *Special and general relativity...* VRI: 2023
[3] R. A. Daly et al., MNRAS 2024, 428 - 436
[4] P. Subramanian, *Fluid Dynamics for Astrophysics*, 2021, lec. 31

GR 18.2 Thu 17:15 HBR 14: Foyer

Lorentz-invariant quantum gravity by elimination of spacetime — •René Friedrich — Strasbourg

Spacetime is more and more often suspected of being at the origin of the problem of quantum gravity. However, it will be shown that general relativity may not only be described within a spacetime manifold, but also in Lorentz-invariant terms. In particular, gravity may not only be represented in the form of curved spacetime, but also equivalently as gravitational time dilation in flat, uncurved space.

Quantum mechanics and general relativity are harmonizing because - fundamentally speaking - they are both Lorentz-invariant. Lorentz-covariant spacetime is only the way how the universe of general relativity is perceived and measured by observers, it is a sort of "observational interface", half-way between the observer and the underlying reality. The Lorentz-invariant universe of quantum gravity is not observable, it must be retrieved from observation by calculation, exactly in the same way as the proper time of a particle is retrieved from the coordinate time measured by an observer. Further information: R. Friedrich: Quantengravitation ohne Mühe

GR 18.3 Thu 17:15 HBR 14: Foyer

Curvature of four-dimensional space due to electrical charges — •Michael Zauner[1] and Günther Hendorfer[2] — [1]University of Applied Sciences Upper Austria — [2]Buchenweg 3, 4081 Hartkirchen

The inadequacy of accurately describing phenomena in the near field of large masses led to the further development of Newton's theory into the general theory of relativity. Newton's law and Coulomb's law are both subject to the Poisson equation, so the question arises as to whether a similar theory can be developed for electrical charges.

In this thesis, the assumption that forces between charges can be traced back to curved spaces will be investigated and a Schwarzschild-like solution will be analyzed. The following postulates are to be established from the previous considerations: (1) Electric charges bend space. (2) The space curvature of opposite charges is also opposite. For example, a negative charge curves space "concavely" and a positive charge curves space "convexly". (3) Several charges move in such a way that the space merges into Minkowski space. This means that two different charges move towards each other, which cancels out the curvature of space, or two charges of the same name move away from each other, to create a minimum in the curvature of space.

The results of this work can be converted back into a Coulomb approximation, and the following results were also found: (1) The spatial extent of the space curvature depends not only on the charge, but also on the mass of the respective particle. More massive, charged particles have a smaller spatial expansion. (2) In close range is an asymmetry in the repulsive and attractive force.

GR 18.4 Thu 17:15 HBR 14: Foyer

Scalar Field on Fuzzy de Sitter Space — •Bojana Brkic[1], Ilija Buric[2], Maja Buric[1], and Dusko Latas[1] — [1]Faculty of Physics, University of Belgrade, Studentski trg 12 SR-11001 Belgrade, Serbia — [2]Department of Physics, University of Pisa and INFN, Largo Pontecorvo 3, I-56127 Pisa, Italy

First, we introduce (commutative) d-dimensional de Sitter space and write down orthonormal bases of solutions to the Klein-Gordon equation in two sets of coordinates - the usual Poincaré coordinates (η, x^i) and another coordinate system (η, y^i) that is inspired by noncommutative geometry. It is shown that the natural choice of vacuum in the (η, y^i) coordinates is invariant under the de Sitter group and the choice of positive frequency modes that gives rise to the Bunch-Davies vacuum is identified. We compute overlaps between field modes in (η, x^i) and (η, y^i) coordinates [1]. After that, we give the definition of fuzzy de Sitter space, in particular, its differential geometry and the Laplacian [2]. Our main objective is to find the eigenfunctions of the fuzzy Laplacian. We show that eigenfunctions of the Laplacian on commutative de Sitter space in four dimensions, separated in the (η, y^i) coordinates, may be directly 'quantised' to give eigenfunctions of the fuzzy Laplacian. The special choice of coordinates ensures that no issues due to operator ordering arise in the quantisation process. Also, we consider fuzzy de Sitter space in two dimensions.

[1] B. Allen, Phys. Rev. D **32**, 3136 (1985)
[2] B. Brkić *et al*, Class. Quant. Grav. **39**, 115001 (2022)

GR 18.5 Thu 17:15 HBR 14: Foyer

Visualizing the geometry of spacetime of General Relativity with sector models — •Vassilios Marakis — Universität Hildesheim

Understanding the trajectories of free-falling particles and the path of light in curved spacetime can be challenging, particularly for beginners or those with a casual interest, due to complex mathematics. The sector model simplifies this visualization by dividing the coordinate space into blocks with intuitive Euclidean geometry. Our application enhances this approach by creating sectors based on various metrics, such as the spacetime of the equatorial plane of a massive celestial body, allowing users to explore geodesics and understand phenomena like redshift, light deflection, and perihelion rotation.

GR 18.6 Thu 17:15 HBR 14: Foyer

Time transfer in stationary and general frames — •Bennet Grützner — ZARM, Bremen

Time transfer, a form of synchronization, is a necessary tool for many experiments and observations. In Special Relativity Einstein synchronization is widely accepted as the standard method of time transfer. It works just as well in static frames in General Relativity, like non-rotating frames in the Schwarzschild metric. However, in stationary or general frames, Einstein synchronization is not transitive due to effects such as the Sagnac effect.

We discuss different methods of time transfer, with particular emphasis on globally transitive methods. The concept of hyperspheres of simultaneity is introduced, and applications to time transfer on Earth and in space are discussed.

GR 19: Members' Assembly

Time: Thursday 19:00–20:30 Location: HBR 14: HS 2

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