Gravitation and Relativity Division
Fachverband Gravitation und Relativitätstheorie (GR)

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Welcome to the annual meeting of the *General-Relativity and Gravitation* division of the DPG at - virtually - Jena. Despite the adverse circumstances, forcing us to hold this meeting in a purely online format, we have again a rich scientific program, including some outstanding highlights. We will take part in two symposia, one on “Entanglement” (Monday) the other on “Neutron Stars” (Thursday). There will be two distinguished plenary-like talks, one by Alessandra Buananno (MPI Golm), who would have been our plenary speaker last year and who will speak on “News from the Gravitational-Waves Sky”, the other by Heino Falcke (Radboud U.) on how Black-Holes look like. Last not least, on Tuesday evening, this year’s Nobel-Prize laureate Reinhard Genzel will deliver an evening talk on the Galctic Black-Hole. Let me also draw your attention to our General Assembly of Members on Thursday evening, starting at 19:00. Finally, I wish all of you a pleasant and informative week!

Overview of Invited Talks and Sessions

(Lecture halls H2, H4, H6, and H9)

Plenary Talk of the Gravitation and Relativity Division

PV II	Mon	9:45–10:30	Audimax	**What’s in a Shadow** — •Heino Falcke

Invited Talks

GR 2.1	Tue	11:00–11:45	H6	**The Sagnac effect in General Relativity** — •Jörg Frauendiener
GR 4.1	Tue	16:30–17:15	H6	**News from the Gravitational-Wave Sky** — •Alessandra Buonanno

Invited talks of the joint symposium Entanglement (SYEN)

See SYEN for the full program of the symposium.

SYEN 1.1	Mon	16:30–17:10	Audimax	**Squeezed and entangled light - now exploited by all gravita-tional-wave observatories** — •Roman Schnabel
SYEN 2.1	Mon	17:10–17:50	Audimax	**Entanglement and Explanation** — •Chris Timpson
SYEN 3.1	Mon	17:50–18:30	Audimax	**Entanglement and complexity in quantum many-body dynamics** — •Tomaz Prosen

Invited talks of the joint symposium Neutron stars (SYNS)

See SYNS for the full program of the symposium.

SYNS 1.1	Thu	14:00–14:40	Audimax	**Binary neutron stars: from gravitational to particle physics** — •Luciano Rezzolla
SYNS 1.2	Thu	14:40–15:20	Audimax	**Probing subatomic physics with gravitational waves** — •Tanja Hinderer
SYNS 1.3	Thu	15:20–16:00	Audimax	**A NICER view of neutron stars** — •Anna Watts

Sessions

GR 1.1–1.6	Mon	11:00–12:30	H2	**Black Holes**
GR 2.1–2.4	Tue	11:00–12:30	H6	**Classical GR-1**
GR 3.1–3.8	Tue	14:00–16:00	H6	**Classical GR-2**
GR 4.1–4.6	Tue	16:30–18:30	H6	**Gravitational waves**
GR 5.1–5.7	Wed	14:00–15:45	H6	**Alternative aspects and formulations**
GR 6.1–6.8	Wed	16:30–18:30	H6	**Numerical relativity**
GR 7.1–7.4	Thu	11:00–12:00	H9	**Experimental tests**
GR 8.1–8.2	Thu	12:00–12:30	H9	**Quantum field theory in curved spacetimes**
GR 9.1–9.4	Thu	16:30–17:30	H9	**Cosmology**
GR 10.1–10.2	Thu	17:30–18:00	H9	**Scalar-tensor and non-local gravity theories**
GR 11.1–11.2	Thu	18:00–18:30	H9	**Didactical and heuristic aspects**
GR 12	Thu	19:00–20:30	MVGR	**Annual General Meeting**
GR 13.1–13.5	Fri	11:00–12:15	H4	**Quantum gravity and cosmology**

Mitgliederversammlung des Fachverbands Gravitation und Relativitätstheorie

Donnerstag 19:00–20:30 MVGR

- Bericht des Vorsitzenden
- Wahl zur Neubesetzung des Vorsitzes
- Wahl des Beirats
- Verschiedenes

GR 1: Black Holes

Time: Monday 11:00–12:30 Location: H2

GR 1.1 Mon 11:00 H2

Microlensing in terms of an exact lens map — •Volker Perlick — ZARM, University of Bremen, Germany

In spherically symmetric and static spacetimes, gravitational lensing can be formulated in terms of an exact lens map, in close analogy to the weak-field formalism of lensing. Whereas in the latter case the lens map is a map from a lens plane to a source plane, the exact lens map is a map from the celestial sphere of the observer to a sphere where the light sources are thought to be situated. It is demonstrated that, with the help of the exact lens map, microlensing light curves can be calculated exactly. Several examples are presented, including microlensing by a Barriola-Vilenkin monople and by a Schwarzschild black hole.

GR 1.2 Mon 11:15 H2

Gravitational Lensing by Charged Accelerating Black Holes — •Torben Frost — ZARM, Universität Bremen, Bremen, Germany — ITP, Leibniz Universität Hannover, Hannover, Germany

Current astrophysical observations show that on large scale the Universe is electrically neutral. However, locally this may be quite different. Black holes enveloped by a plasma in the presence of a strong magnetic field may have acquired a significant electric charge. We can also expect that some of these charged black holes are moving. Consequently to describe them we need spacetime metrics describing moving black holes. In general relativity such a solution is given by the charged C-de Sitter-metric. In this talk we will assume that it can be used to describe moving charged black holes. We will investigate how to observe the electric charge using gravitational lensing. First we will use elliptic integrals and functions to solve the geodesic equations. Then we will derive lens equation, travel time and redshift. We will discuss the impact of the electric charge on these observables and potential limitations for its observation.

GR 1.3 Mon 11:30 H2

Photon region and shadow in a spacetime with a quadrupole moment — •Jan Hackstein and Volker Perlick — ZARM, University of Bremen, Germany

A black hole's shadow is expected to deform under the influence of an external gravitational field caused by matter present in its vicinity. This talk aims to characterise the distortion of a Schwarzschild black hole shadow due to a non-zero quadrupole moment c_2 by qualitatively investigating the behaviour of light rays close to the black hole horizon. In particular, the numerical investigation in the meridional plane for $1 \gg c_2 > 0$ finds four non-circular closed geodesics and their neighbouring geodesics exhibit chaotic behaviour that is not present in the undistorted Schwarzschild spacetime. The black hole shadow is therefore approximated by restricting the observational setup accordingly. In that case, the black hole shadow's eccentricity indicates a prolate deformation for static observers. The photon sphere in the Schwarzschild spacetime deforms into a photon region with a crescent-shaped projection on the meridional plane. Furthermore, the resulting boundary curve of the black hole shadow is visualised.

GR 1.4 Mon 11:45 H2

Application of the Gauss-Bonnet theorem to lensing in the NUT metric — •Mourad Halla and Volker Perlick — ZARM, Universität Bremen

We show with the help of Fermat's principle that every lightlike geodesic in the NUT metric projects to a geodesic of a two-dimensional Riemannian metric which we call the optical metric. The optical metric is defined on a (coordinate) cone whose opening angle is determined by the impact parameter of the lightlike geodesic. We show that, surprisingly, the optical metrics on cones with different opening angles are locally (but not globally) isometric. With the help of the Gauss-Bonnet theorem we demonstrate that the deflection angle of a lightlike geodesic is determined by an area integral over the Gaussian curvature of the optical metric. A similar result is known to be true for static and spherically symmetric spacetimes. The generalisation to the NUT spacetime, which is neither static nor spherically symmetric (at least not in the usual sense), is rather non-trivial.

GR 1.5 Mon 12:00 H2

Spin-Induced Scalarized Black Holes — Emanuele Berti[1], Lucas Collodel[2], Burkhard Kleihaus[3], and •Jutta Kunz[3] — [1]Johns Hopkins University Baltimore — [2]University of Tübingen — [3]University of Oldenburg

When General Relativity is supplemented with a Gauss-Bonnet term coupled to a scalar field, scalarized black holes arise. For appropriately chosen coupling functions Kerr black holes remain solutions of the field equations, but undergo a tachyonic instability, where curvature induced scalarized black holes arise. For slow rotation, these scalarized rotating black holes are connected to the static black holes. However, for fast rotation a second set of scalarized black holes arises, which exist only above the value of the Kerr rotation parameter $a = 0.5\,M$. In this talk such even and odd parity black hole solutions with spin-induced scalarization are presented, and their properties are discussed.

GR 1.6 Mon 12:15 H2

Quasinormal modes of hot, cold and bald Einstein-Maxwell-scalar black holes — Jose Luis Blázquez-Salcedo[1], Carlos A. R. Herdeiro[2], •Sarah Kahlen[3], Jutta Kunz[3], Alexandre M. Pombo[2], and Eugen Radu[2] — [1]Universidad Complutense de Madrid, Spain — [2]Universidade de Aveiro, Portugal — [3]Universität Oldenburg, Germany

In Einstein-Maxwell-scalar (EMs) theory, gravity is coupled to a Maxwell field and a scalar field ϕ, with some function f coupling the two fields. The choice of that function strongly influences the properties of the resulting black hole solutions. In the talk, static spherically symmetric EMs black hole solutions with coupling function $f(\phi) = 1 + \alpha\phi^4$ are dealt with. For fixed coupling constant α, there are two branches of solutions. The quasinormal modes, the eigenvalues of the linearly perturbed field equations, that can be categorized into axial and polar modes, are presented for both these branches. This allows for statements about their stability, and it is furthermore demonstrated how the presence of the scalar field influences different types of modes and breaks the isospectrality between polar and axial modes, which e.g. holds for Reissner-Nordström black holes in Einstein-Maxwell theory and for Schwarzschild black holes.

GR 2: Classical GR-1

Time: Tuesday 11:00–12:30 Location: H6

Invited Talk GR 2.1 Tue 11:00 H6

The Sagnac effect in General Relativity — •Jörg Frauendiener — University of Otago, Dunedin, New Zealand

The Sagnac effect can be described as the difference in travel time between two photons traveling along the same path in opposite directions. In this talk we explore the consequences of this characterisation in the context of General Relativity. We derive a general expression for this time difference in an arbitrary space-time for arbitrary paths. In general, this formula is not very useful since it involves solving a differential equation along the path. However, we also present special cases where a closed form expression for the time difference can be given. We discuss the effect in a small neighbourhood of an arbitrarily moving observer in their arbitrarily rotating reference frame. Time permitting we may also discuss the special case of stationary spacetimes and point out the relationship between the Sagnac effect and Fizeau's "aether-drag" experiment.

GR 2.2 Tue 11:45 H6

Gravitational Properties of Light — •Dennis Rätzel — Humboldt Universität zu Berlin, Institut für Physik, Newtonstraße 15, 12489 Berlin, Germany

The properties of light are premises in the foundations of modern physics: they were used to derive special and general relativity and are the basis of the concept of time and causality in many alternative models. Therefore, it is worthwhile to study the gravitational field of light with its rich phenomenology, even though the effects are in general very weak. In this talk, an overview is given of the gravitational properties of light, in particular, of laser pulses and focused laser beams with well-defined angular momentum. The time-dependence in the case of a laser pulse enables the investigation of the formation of the gravitational field of light. The stationary case of the gravitational field of a focused laser beam shows effects of the fundamental wave properties of light. I will also present results on the effect of angular momentum of light: frame dragging, the gravitational Faraday effect and gravitational spin-spin coupling of light.

GR 2.3 Tue 12:00 H6

General Relativistic Geodesy — •Claus Lämmerzahl and Volker Perlick — ZARM, University of Bremen

Geodesy in a Newtonian framework is based on the Newtonian potential. The general relativistic gravitational field, however, possesses more degrees of freedom. Accordingly, the full gravitational field of a stationary source can be decomposed into two scalar potentials and a tensorial spatial metric, which together serve as basis of a general relativistic geodesy. One of the scalar potentials is a generalization of the Newtonian potential while the second is related to the rotational degree of freedom of gravitating masses for which no non-relativistic counterpart exists. The operational realizations of these two potentials are discussed, as well as of the spatial metric. For analytically given space-times the two potentials are exemplified and their relevance for practical geodesy on Earth are discussed.

GR 2.4 Tue 12:15 H6

Chronometric Height: a genuine general relativistic definition of height in geodesy — •Dennis Philipp — ZARM, Universität Bremen

The Newtonian gravity potential is one of the main objects for conventional geodesy and employed for basic concepts, such as the definition of heights. A modern height definition in terms of geopotential numbers can offer a variety of advantages. Moreover, from the theoretical point of view, such a definition is considered more fundamental. We know, however, that relativistic gravity (General Relativity) requires to reformulate basic geodetic notions and to develop a consistent theoretical framework, relativistic geodesy, to yield an undoubtedly correct interpretation of contemporary and future (high-precision) measurement results. The new framework of chronometric geodesy that builds on the comparison of clocks at different positions in the gravitational field offers fundamental insight into the spacetime geometry if a solid theoretical formulation of observables is underlying all observations. For chronometry, high-performance clock networks, i.e., optical clocks connected by dedicated frequency transfer techniques, are capable to observe the mutual redshift with incredible accuracy. Here we approach a genuine relativistic definition of the concept of height. Based on the relativistic generalization of geopotential numbers, a definition of chronometric height is suggested, which reduces to the well-known notions in the weak-field limit. This height measure is conceptually based on the so-called time-independent redshift potential, which describes the gravitoelectric degree of freedom in General Relativity.

GR 3: Classical GR-2

Time: Tuesday 14:00–16:00 Location: H6

GR 3.1 Tue 14:00 H6

Geometrically thick tori around compact objects with a quadrupole moment — •Jan-Menno Memmen and Volker Perlick — Znetrum für angewandte Raumfahrttechnologien und Mikrogravitation, Bremen, Deutschland

We study geometrically thick perfect-fluid tori with constant specific angular momentum, so-called "Polish doughnuts", orbiting deformed compact objects with a quadrupole moment. More specifically, we consider two different asymptotically flat, static and axisymmetric vacuum solutions to Einstein's field equation with a non-zero quadrupole moment, the q-metric and the Erez-Rosen spacetime. It is our main goal to find features of Polish doughnuts in these two spacetimes which qualitatively distinguish them from Polish doughnuts in the Schwarzschild spacetime. As a main result we find that, for both metrics, there is a range of positive (Geroch-Hansen) quadrupole moments which allows for the existence of double tori. If these double tori fill their Roche lobes completely, their meridional cross-section has the shape of a fish, with the body of the fish corresponding to the outer torus and the fish-tail corresponding to the inner torus. Such double tori do not exist in the Schwarzschild spacetime.

GR 3.2 Tue 14:15 H6

A wild doughnut chase: Polish doughnuts around boson stars and their peculiarities — •Matheus C. Teodoro[1], Lucas G. Collodel[2], and Jutta Kunz[1] — [1]Institute of Physics, University of Oldenburg 26111 Oldenburg, Germany — [2]Theoretical Astrophysics, University of Tübingen 72076 Tübingen, Germany

In this talk we shall investigate and analyse some examples of polish doughnuts with a uniform constant specific angular momentum distribution in the space-times of rotating boson stars. These thick tori can exhibit peculiar features not present in Kerr space-times, specially in the context of retrograde tori. They may be endowed with two centers connect or not by a cusp or even present static surfaces. Inside these surfaces the fluid moves in prograde direction, while outside in the retrograde direction. All these features and how they appear will be the topic of this talk.

GR 3.3 Tue 14:30 H6

Influence of the relativistic Frequency-Shift on Continuous Variable Quantum Key Distribution — •Roy Barzel and Claus Lämmerzahl — ZARM, Universität Bremen

Quantum-Key-Distribution (QKD) offers the possibility to exchange confidential information unconditionally secure between two or more parties, in the sense that the security of the protocol does not depend on the computational or material limitations of a potential adversary intending to break the key. Since the quantum repeater technology is still far from being applicable to intercontinental quantum communication in the short term satellite-based free-space links today look like the most promising solution to achieve long-distance QKD. Therefore space-qualified, robust optical components, that will allow for stable data flow of high performance are required. Only making use of approved standard telecommunication technology for state preparation and detection continuous variable quantum key distribution (CV-QKD) today is one of the most promising ways of implementation of a globaly operating network of secure quantum communication. Apart from atmospheric distortion effects like absorbtion recent studies revealed the sensitivity of CV-QKD against relativistic effects like the relativistic Doppler-shift and the gravitational redshift. In this talk it is shown how to quantify the influence of relativistic effects on the performance of CV-QKD in a quantum field theoretical framework. Methods are shown how to derive analytic formulas for the secret key rates in CV-QKD protocolls between satellites and ground stations, which depend on the orbital parameters of the communicators.

GR 3.4 Tue 14:45 H6

Tidal g-mode resonances in coalescing binaries of neutron stars as triggers for precursor flares of short gamma-ray bursts — •Hao-Jui Kuan — University of Tübingen

In some short gamma-ray bursts, precursor flares occurring $\sim$ seconds prior to the main episode have been observed. These flares may then be associated with the last few cycles of the inspiral when the orbital frequency is a few hundred Hz. During these final cycles, tidal forces can resonantly excite quasi-normal modes in the inspiralling stars, leading to a rapid increase in their amplitude. It has been shown that these modes can exert sufficiently strong strains onto the neutron star crust to instigate yieldings. Due to the typical frequencies of g-modes being ~ 100 Hz, their resonances with the orbital frequency match the precursor timings and warrant further investigation. Adopting realistic equations of state and solving the general-relativistic pulsation equations, we study g-mode resonances in coalescing quasi-circular binaries, where we consider various stellar rotation rates, degrees of stratification, and magnetic field structures. We show that for some combination of stellar parameters, the resonantly excited g_1- and g_2-modes may lead to crustal failure and trigger precursor flares.

GR 3.5 Tue 15:00 H6

On the properties of metastable hypermassive hybrid stars — •Matthias Hanauske[1,2], Horst Stöcker[1,2], and Luciano Rezzolla[1,2] — [1]Institut für Theoretische Physik, Max-von-Laue-Straße 1, 60438 Frankfurt, Germany — [2]Frankfurt Institute for Advanced Studies, Ruth-Moufang-Straße 1, 60438 Frankfurt, Germany

Hypermassive hybrid stars (HMHS) are extreme astrophysical objects that could be produced in the merger of a binary system of two neutron stars. In contrast to their purely hadronic counterparts, hypermassive neutron stars (HMNS), these highly differentially rotating objects contain deconfined strange quark matter in their slowly rotating inner region. HMHS and HMNS are both metastable configurations and can survive only shortly after the merger before collapsing to rotating black holes. The properties of a HMHS/HMNS (e.g. rotational property, density and temperature distribution) and the space-time distortion it causes, have been computed by fully general-relativistic hydrodynamic simulations and the complicated dynamics of the collapse from a HMNS to a more compact HMHS have been analysed in detail. The interplay between the density and temperature distributions and the differential rotational profiles in the interior of the HMHS, produces a clear gravitational wave signature of the production of quark matter, if the hadron-quark phase transition is strong enough. During the collapse of the HMHS to a Kerr Black the color degrees of freedom of the pure strange quark matter core gets macroscopically confined by the formation of the event horizon.

GR 3.6 Tue 15:15 H6

Consistent solution of Einstein-Cartan equations with torsion outside matter — •Klaus Morawetz — Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics- UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil

The Einstein-Cartan equations in first-order action of torsion are considered. From Belinfante-Rosenfeld equation special consistence conditions are derived for the torsion parameters relating them to the metric. Inside matter the torsion is given by the spin which leads to an extended Oppenhaimer-Volkov equation. Outside matter a second solution is found besides the torsion-free Schwarzschild one with the torsion completely determined by the metric and vice-versa. This solution is shown to be of non-spherical origin and its uniqueness with respect to the consistence is demonstrated. Unusual properties are discussed in different coordinate systems where the cosmological constant assumes the role of the Friedman parameter in Friedman-Lamaître-Robertson-Walker cosmoses. Parameters are specified where wormholes are possible. Transformations are presented to explore and map regions of expanding and contracting universes to the form of static metrics. The autoparallel equations are solved exactly and compared with geodesic motion. The Weyl tensor reveals that the here found solution is of Petrov-D type. [arXiv:2010.01393]

GR 3.7 Tue 15:30 H6

The gravitating kinetic gas - Lifting the Einstein Vlasov system to the tangent bundle — •Christian Pfeifer — ZARM, University of Bremen, Bremen, Germany

In this talk I will present a new model for the description of a gravitating kinetic gas, by coupling the 1-particle distribution function (1PDF) of the gas directly to the gravitational field, described directly by the geometry of the tangent bundle of spacetime. This procedure takes the influence of the velocity distribution of the kinetic gas particles on their gravitational field fully into account, instead of only on average, as it is the case for the Einstein-Vlasov system.

By using Finsler spacetime geometry I construct an action for the kinetic gas on the tangent bundle, which is added as matter action to a canonical Finslerian generalisation of the Einstein-Hilbert action. The invariance of the kinetic gas action under coordinate changes gives rise to a new notion of energy-momentum conservation of a kinetic gas in terms of an energy-momentum distribution tensor. The variation of the total action with respect to the spacetime geometry defining Finsler Lagrangian yields the gravitational field equation, which determines the geometry of spacetime directly from the full non-averaged 1PDF.

GR 3.8 Tue 15:45 H6

Teleparallel Newton–Cartan gravity — •Philip K Schwartz — Institute for Theoretical Physics, Leibniz University Hannover, Appelstraße 2, 30167 Hannover, Germany

We discuss a teleparallel version of Newton–Cartan gravity. This theory arises as a formal large-speed-of-light limit of the teleparallel equivalent of general relativity (TEGR). Thus, it provides a geometric formulation of the Newtonian limit of TEGR, similar to standard Newton–Cartan gravity being the Newtonian limit of general relativity. We show how by a certain gauge-fixing the standard formulation of Newtonian gravity can be recovered.

GR 4: Gravitational waves

Time: Tuesday 16:30–18:30 Location: H6

Invited Talk GR 4.1 Tue 16:30 H6

News from the Gravitational-Wave Sky — •Alessandra Buonanno — Max Planck Institute for Gravitational Physics, Potsdam

The solution of the two-body problem in General Relativity is playing a crucial role in observing gravitational waves from binary systems composed of black holes and neutron stars, and inferring their astrophysical, cosmological and gravitational properties. After reviewing the synergistic approach that successfully combines analytical and numerical relativity to produce highly accurate waveform models, I will discuss the most compelling and puzzling findings from the most recent LIGO-Virgo observing run.

GR 4.2 Tue 17:15 H6

GW190521: A dynamical capture of two black holes — •Rossella Gamba — TPI, Friedrich-Schiller-Universität Jena

We analyze the gravitational-wave signal GW190521 under the hypothesis that it was generated by the merger of two nonspinning black holes on hyperbolic orbits. The best configuration matching the data corresponds to two black holes of source frame masses of $81^{+62}_{-25} M_\odot$ and $52^{+32}_{-32} M_\odot$ undergoing two encounters and then merging into an intermediate-mass black hole. Under the hyperbolic merger hypothesis, we find an increase of one unit in the recovered signal-to-noise ratio and a 14 e-fold increase in the maximum likelihood value compared to a quasi-circular merger with precessing spins. We conclude that our results support the first gravitational-wave detection from the dynamical capture of two stellar-mass black holes.

GR 4.3 Tue 17:30 H6

Training Strategies for Deep Learning Gravitational-Wave Searches — Marlin Benedikt Schäfer[1,2], •Ondřej Zelenka[3,4], Alexander Harvey Nitz[1,2], Frank Ohme[1,2], and Bernd Brügmann[3,4] — [1]Max-Planck-Institut für Gravitationsphysik, Albert-Einstein-Institut, D-30167 Hannover, Germany — [2]Leibniz Universität Hannover, D-30167 Hannover, Germany — [3]Friedrich-Schiller-Universität Jena, D-07743 Jena, Germany — [4]Michael Stifel Center Jena, D-07743 Jena, Germany

Deep learning may be capable of finding gravitational wave signals where current algorithms hit computational limits. We restrict our analysis to signals from non-spinning binary black holes and systematically test different strategies by which training data is presented to the networks. To assess their impact, we re-analyze the first published networks and directly compare them to an equivalent matched-filter search. We find that the deep learning algorithms can generalize low signal-to-noise ratio (SNR) signals to high SNR ones but not vice versa. As such, it is not beneficial to provide high SNR signals during training, and fastest convergence is achieved when low SNR samples are provided early on. We found that the networks are sometimes unable to recover any signals when a false alarm probability $< 10^{-3}$ is required. We resolve this by applying a modification we call unbounded Softmax replacement (USR) after training. With this alteration we find that the machine learning search retains $\geq 97.5\%$ of the sensitivity of the matched-filter search down to a false-alarm rate of 1 per month.

GR 4.4 Tue 17:45 H6

A Deep Learning Gravitational-Wave Coincidence Search — •Marlin Benedikt Schäfer[1,2] and Alexander Harvey Nitz[1,2] — [1]Albert-Einstein-Institut, D-30167 Hannover, Germany — [2]Leibniz Universität Hannover, D-30167 Hannover, Germany

Gravitational waves emitted by a coalescing binary system of compact objects are now routinely observed by Earth bound detectors. The most sensitive search algorithms convolve many different precalculated waveform models with the detector data and look for coincident matches between different detectors. Machine learning is now being explored as an alternative search algorithm that has the prospect to reduce computational costs and target more complex signals. In this work we construct a two detector machine learning search from a neural network trained on non-spinning binary black hole data from a single detector. The network is applied to the data from both observatories independently and we check for events coincident in time between the two. We compare our findings to an equivalent matched filter search and a comparable two-detector neural network search.

GR 4.5 Tue 18:00 H6

Search for lensing signatures in the gravitational-wave observations from the first half of LIGO-Virgo's third observing run — •David Keitel for the LIGO-Virgo-Collaboration — Departament de Física, Edifici Mateu Orfila, Universitat de les Illes Balears, Carretera de Valldemossa, km 7,5, 07122 Palma de Mallorca, Illes Balears, Spain

The Advanced LIGO and Advanced Virgo detectors are now observing large numbers of gravitational-wave signals from compact binary coalescences, with 50 entries in the latest catalogue GWTC-2. With this rapidly growing event rate, our chances become better to detect rare astrophysical effects on these novel cosmic messengers. One such rare effect with a long and productive history in electromagnetic astronomy and great potential for the future of GW astrophysics is gravitational lensing. This presentation covers the first LIGO-Virgo collaboration search for lensing signatures in data from the O3a observing run. We study: 1) the expected rate of lensing at current detector sensitivity and the implications of a non-observation of strong lensing or a stochastic gravitational-wave background on the merger-rate density at high redshift; 2) how the interpretation of individual high-mass events would change if they were found to be lensed; 3) the possibility of multiple images due to strong lensing by galaxies or galaxy clusters; and 4) possible wave-optics effects due to point-mass microlenses. Overall, we find no compelling evidence for lensing in the observed gravitational-wave signals from any of these analyses.

GR 4.6 Tue 18:15 H6

Dark Sirens to Resolve the Hubble-Lemaître Tension — •Ssohrab Borhanian[1,2], Arnab Dhani[2], Anuradha Gupta[3], K.G. Arun[4], and Bangalore Sathyaprakash[2] — [1]Friedrich-Schiller-Universität Jena, Jena, Germany — [2]Institute for Gravitation and the Cosmos, State College, USA — [3]University of Mississippi, Oxford, USA — [4]Chennai Mathemartical Institute, Chennai, India

The planned sensitivity upgrades to the LIGO and Virgo facilities could uniquely identify host galaxies of dark sirens, compact binary coalescences without any electromagnetic counterparts, within a redshift of $z = 0.1$. This is aided by the higher-order spherical harmonic modes present in the gravitational-wave signal, which also improve distance estimation. In conjunction, sensitivity upgrades and higher modes will facilitate an accurate, independent measurement of the host galaxy's redshift in addition to the luminosity distance from the gravitational-wave observation to infer the Hubble-Lemaître constant to better than a few percent in five years. A possible Voyager upgrade or third-generation facilities would further solidify the role of dark sirens for precision cosmology in the future.

GR 5: Alternative aspects and formulations

Time: Wednesday 14:00–15:45 Location: H6

GR 5.1 Wed 14:00 H6

The Dark Matter Problem and a General Solution — •Albrecht Giese — Taxusweg 15, 22605 Hamburg

The problem of dark matter in the rotation of galaxies has existed for 90 years. Further unexplained phenomena in astronomy are also related to this title, such as gravitational lensing, structure formation, the excessive number of small galaxies and the Bullet Cluster.

The solutions attempted by contemporary physics assume invisible 'dark' particles, or else modified Newton dynamics (MOND). But neither yields a solution for all cases. And even worse: Each theory is in conflict with observations covered by the other solution. This means: no solution exists. - And no evidence of dark matter particles has been found despite intense efforts.

A general solution may be provided by an approach to gravity which was initially pursued by Einstein in 1911, before switching to his spacetime structure. In it, Einstein used the variation of the speed of light c in a gravitational field. - If this variation is applied to the internal oscillations in a particle, it causes grav. acceleration. Now, the cause of the variation in c is not plausibly the mass of the source, because light particles, as neutrinos and photons, reduce c equally as all other objects around them and so contribute to the gravitational field.

This alternative view on gravity can be shown to explain all aspects of dark matter. In particular, rotation curves can be calculated quantitatively. It also covers those cases for which both the present solutions provide nothing, such as luminosity-dependent phenomena (Renzo / Tully-Fisher). And it conforms to GR.

GR 5.2 Wed 14:15 H6

Time velocity - handling time dilation between two points in space-time — •Bjørn Ebbesen — Hamburg, Germany

Combining SRT with static gravitation, as done in the following, could have been a forerunner to the ART.

This approach leads to a concept of time velocity, which not only simplifies handling time dilation. Without relying on ART we get straight forward a variety of old and new insights on gravitation, energy, matter and space.

Some suggestions for theoretical and experimental physics are given.

Finally, concept of time velocity enables a new interpretation of cosmological red-shift.

GR 5.3 Wed 14:30 H6

Re-defining the basic concept of Time and Space — •Harjeet Singh — HCL Technologies, Vilnius, Lithuania

This paper aims at a new understanding on the basic concept of *Time and Space* dimension that can supersede the present *Spacetime* dimension. Hence, it can contribute in exploring time beyond the Big Bang * the edge of Spacetime dimension.

The approach in this research is based on scientific skepticism, which is further based on interpretation of relevant theories related to Time and Space. The present research not only introduces and proves the hypothesis that the Entire-Existence is the sole all-inclusive entity comprising of all the physical entities, but also changes the entire notion of Spacetime from being a physical entity to being two different physical dimensions *Time and Space*. The term *dimension* is the measure of a particular property of any physical entity such as Mass, Length, Temperature etc. Thereby, this research redefines *Time* as a dimension to measure the change of state of Entire-Existence and *Space* as a dimension to measure the spatial expanse of Entire-Existence. This research eventually solves several paradoxes concerning time travel and examines the possibility and scope of actual time travel.

Nevertheless, the testable predictions have been observed based on the proved hypothesis, as per which the empirical investigations can be performed further. This research will certainly expand the horizons of our current known Universe.

GR 5.4 Wed 14:45 H6

Gravitation represented as a physical interaction of subatomic particles instead of a geometrical space-time curvature model. — •Osvaldo Domann — Stephanstr. 42, 85077 Manching

GR is the theory of gravitation of the SM. It is a mathematical approach from 1915, based on the representation of subatomic particles as isolated entities in space, arriving to the wondrous concept of space-time curvature. GR resists all intents of integration into a unified field theory and is not compatible with quantum mechanics. An approach is presented for a gravitation theory that is based on the representation of a subatomic particle (SP) as a focal point of rays of Fundamental Particles (FPs) that move from infinite to infinite. The energy of a subatomic particle is stored at its FPs as rotation defining angular momenta. With this representation all SPs interact permanently through the angular momenta of their FPs, according to the Mach principle that postulates that physical laws are determined by the large-scale structure of the universe. The approach explains gravitation as the result of the physical reintegration of migrated electrons and positrons to their nuclei. Gravitation is so composed of a Newton and an Ampere component, with the Newton component dominant at sub galactic distances and the Ampere component at galactic distances. A positive Ampere component explains the speed flattening of galaxies and a negative Ampere component the expansion. More at: www.odomann.com

GR 5.5 Wed 15:00 H6

Methode um die Bewegung zum Gravitationsfeld zu messen. — •Karl-Herbert Darmer — Meyertwiete 7, 22848 Norderstedt

Haben wir die Relativität schon richtig verstanden? Dazu zwei grundlegende Fragen: Gibt es etwas im *leeren Raum* das bestimmt, ob ein Körper rotiert? Wenn es etwas gibt, zu dem man rotieren kann, dann kann man sich auch geradlinig dazu bewegen. Was haben Uhren mit der *Zeit* zu tun? Atomuhren gehen auf dem Berg schneller und Pendeluhren langsamer als im Tal. Ich gehe davon aus, dass beide mit der Zeit gleichviel zu tun haben. Nur die angezeigten Messwerte werden durch Umgebungs- veränderungen unterschiedlich beeinflusst, weil sie unterschiedliche Messprinzipien haben. Ein anderes Beispiel: Man misst eine Masse mit einer Balkenwaage und einer Federwaage. Das wiederholt man auf dem Mond und erhält bei der Federwaage ein anderes Ergebnis. Die Frage ist: Was haben Waagen mit der Masse zu tun? Bei der Rotation zeigen die Uhren einen eindeutig unterschiedlichen Gang. Siehe Universal Time Coordinated und die Satellitennavigation. Unter Einsteins Gleichzeitigkeitsdefinition sind die Verhältnisse identisch zu Inertialsystemen. Bei der Rotation kann aber gezeigt werde, dass hier die räumliche Gleichzeitigkeit nicht Einsteins Gleichzeitigkeitsdefinition entsprechen kann. Aus dem Gang von Licht- oder Atomuhren kann eine Methode abgeleitet werden, mit der man die Relativbewegung zu dem messen kann, was den Gang der Uhren bestimmt. Das geht dann nicht nur bei der Rotation, sondern auch bei der geradlinigen oder inertialen Bewegung. Mehr dazu unter www.darmer.de/2021SMuK

GR 5.6 Wed 15:15 H6

Relativity expressed as a speed problem instead of a spacetime problem, as done in special relativity. — •Osvaldo Domann — Stephanstr. 42, 85077 Manching

Variables of one physical event expressed in two relative moving inertial reference systems are defined by the constant relative speed. Special relativity is built on space and time instead of only the relative speed to get the constant light speed in both reference systems. Unphysical relative variables of time and space and contradictions (twin paradox) are the results. The present paper is a work where relativity is treated exclusively as a speed problem to get the constant light speed in both reference systems. The result is that time and space are absolute variables without contradictions. The Lorentz transformation gives the well-known relativistic equations for the momentum, acceleration, energy and longitudinal Doppler-Effect. The approach also concludes that light is emitted with light speed in the reference system of its source and that it arrives to the second inertial reference system with the speed c+-v, contrary to Einstein*s postulate, that light moves always with light speed independent of its source. More at www.odomann.com

GR 5.7 Wed 15:30 H6

Lorentzianische Relativität — •Albrecht Giese — Taxusweg 15, 22605 Hamburg

Warum lorentzianisch? Die Relativität von Einstein beruht auf der Annahme, dass die gemessene Konstanz der Lichtgeschwindigkeit eine physikalische Realität ist, kein bloßes Messergebnis. Sie führt jedoch zu Komplikationen. Sie erforderte den Ansatz einer verwobenen Raumzeit, welche die viel einfachere euklidische Geometrie ersetzten musste. Einsteins Ansatz führt dabei zu logischen Konflikten, sobald es sich nicht um lineare Bewegung, sondern um Drehung handelt. Einstein hat diese Konflikte sogar gegenüber seinem Kollegen Lorentz eingeräumt, und er hat nie eine echte Lösung dafür angeboten.

Folgt man dem Ansatz von Lorentz, werden sowohl die mathematische Behandlung als auch die Vorstellbarkeit grandios einfacher. Die logischen Konflikte bei Einstein werden vermieden. Offene Probleme der heutigen RT wie vor allem die Dunkle Energie entfallen gänzlich.

GR 6: Numerical relativity

Time: Wednesday 16:30–18:30 Location: H6

GR 6.1 Wed 16:30 H6

The rotating mass shell in general relativity — •Florian Atteneder[1], Tobias Benjamin Russ[2], Reinhard Alkofer[3], and Helios Sanchis-Alepuz[3] — [1]Theoretical Physics Institute, University of Jena, Jena, Germany — [2]Theoretical Physics, Ludwig Maxmillians University, Munich, Germany — [3]Institute of Physics, University of Graz, Graz, Austria

The model of a rotating mass shell (RMS) was initially introduced to judge if rotation has only relative meaning. It comprises a description of a spacetime with an energy-matter content that is assembled in a statically rotating quasi-spherical shell with zero radial extension. Latest perturbation theory (PT) calculations have shown that relativity of rotation is indeed realized in such a spacetime. However, because this conclusion was based on PT, its validity is limited to slowly RMSs. This work pursues a numerical treatment of the problem, where the mathematical formulation involves a splitting of the spacetime into a region that is flat and one that is asymptotically flat. The latter is used as a reference to define relative rotation. The RMS forms at the common boundary of these two regions. On the basis of previous work, we formulate Einstein's equations as a free-boundary value problem and solve them numerically using a pseudo-spectral method. As a result we obtain a three-parameter solution that is characterized by the shell's polar radius, its gravitational mass and angular momentum. The existence of the solution is enough to positively answer the question if Mach's idea of relativity of rotation can be extended for rapidly RMSs.

GR 6.2 Wed 16:45 H6

Hyperbolic-like Encounters of Binary Black Holes — •Hannes Rüter and Harald Pfeiffer — Albert Einstein Institute, Potsdam, Germany

We present results on the encounter of two black holes that are initially on a hyperbolic-like orbit simulated with the numerical relativity code SpEC. The two black holes either become bound due to the emission of gravitational waves or they escape to infinity. We present trajectories and waveforms for both cases and extract the scattering angle for the latter.

GR 6.3 Wed 17:00 H6

Prompt Collapse - The Effect of Mass Ratio — •Maximilian Kölsch[1], Tim Dietrich[2,3], Maximiliano Ujevic[4], and Bernd Brügmann[1] — [1]Theoretisch-Physikalisches Institut, FSU Jena — [2]Institut für Physik und Astronomie, Universität Potsdam — [3]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam — [4]Centro de Ciências Naturais e Humanas, Universidade Federal do ABC, Brazil, São Paulo

The outcome of a binary neutron star merger dominantly depends on the total mass of the system and the equation of state describing the matter. However, the mass ratio also influences the postmerger evolution, in particular, whether there is a prompt or delayed collapse. Furthermore, the mass ratio influences which fraction of the initial baryonic mass ends up in a disc around a so formed black hole, and the mass of the latter. We investigate with a new set of general relativistic simulations the prompt collapse threshold for various total masses, mass ratios, and three equations of state. We propose a fitting formula for the dependence of the threshold mass on the mass ratio.

GR 6.4 Wed 17:15 H6

Axisymmetric gravitational wave collapse with bamps. — •Sarah Renkhoff[1], David Hilditch[2], Daniela Cors Agulló[1], Isabel Suárez Fernández[2], and Bernd Brügmann[1] — [1]Friedrich-

Schiller-Universität Jena, 07743 Jena, Germany — [2]CENTRA, University of Lisbon, 1049 Lisboa, Portugal

The new adaptive mesh refinement in our pseudospectral code bamps allows us to improve on previous results near the threshold of black hole formation. In particular, by leveraging the increased performance and scaling behaviour of the code, we can fine tune closer to the critical point between gravitational collapse and dispersed fields. We evolve six one-parameter families of Brill wave initial data: three prolate and three oblate, including two centred and four off-centred. Time permitting, we will discuss the relevance of our results in the context of critical collapse beyond spherical symmetry.

GR 6.5 Wed 17:30 H6

GR-Athena++: puncture evolutions on vertex-centered oct-tree AMR — •Francesco Zappa — Friedrich Schiller Universität, Jena, Germany

Numerical relativity is key to explore the strong-field gravity regime of black hole and compact binary systems. Multi-messenger astronomy requires accurate numerical relativity simulations in order to construct and develop precise gravitational-wave models and to study the outcome of black hole and neutron star mergers in regions of the parameter space which have not been explored yet. Such simulations can be very costly and thus highly performant and scalable codes, capable of efficiently using the modern massively-parallel architectures available nowadays, are needed.

We present GR-Athena++, an extension of the astrophysical code Athena++ which solves the Z4c equations to evolve the dynamical spacetime employing an oct-tree based adaptive mesh refinement strategy. We test our code comparing results from simulations of binary black hole mergers against other numerical relativity codes and performing comparisons against state-of-the-art effective-one-body waveforms. GR-Athena++ exhibits excellent scalability properties, inherited from Athena++ task-based parallelism strategy. Our tests show strong scaling efficiencies above 90% for up to $\sim 10^4$ CPUs and almost perfect weak scaling up to $\sim 10^5$ CPUs.

These results demonstrate that GR-Athena++ can perform accurate binary black hole evolution efficiently on a large number of CPUs, providing a viable option for exascale numerical relativity.

GR 6.6 Wed 17:45 H6

A discontinuous Galerkin elliptic solver with task-based parallelism for the SpECTRE code — •Nils Fischer — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam, Germany

I present the solver for linear and nonlinear elliptic partial differential equations for SpECTRE, the next-generation numerical relativity code currently in development by the SXS collaboration. The solver combines nodal discontinuous Galerkin methods and task-based parallelism to target challenging elliptic problems in numerical relativity and beyond. In particular, I report on first results solving for black-hole binary and neutron-star binary initial data using our new numerical technology and I demonstrate the code's ability to scale to the capacity of the Minerva supercomputer at AEI Potsdam.

GR 6.7 Wed 18:00 H6

Long term simulations of magnetic fields in isolated neutron stars — •William Cook[1], Ankan Sur[2], Brynmor Haskell[2], David Radice[3,4,5], and Sebastiano Bernuzzi[1] — [1]Theoretisch-Physikalisches Institut, Friedrich-Schiller Universitat Jena, 07743, Jena, Germany — [2]Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, Bartycka 18, 00-716 Warsaw, Poland — [3]Institute for Gravitation & the Cosmos, The Pennsylvania State University, University Park, PA 16802, USA — [4]Department of Physics, The Pennsylvania State University, University Park, PA 16802, USA — [5]Department of Astronomy & Astrophysics, The Pennsylvania State University, University Park, PA 16802, USA

We present the results of long term simulations of magnetised, isolated, neutron stars in the Cowling approximation, performed with the Athena++ code, lasting 490ms. By evolving neutron stars with initially poloidal and toroidal magnetic fields we investigate the long term development of the relative strengths of these components, as well as the onset of turbulent behaviour driven by an initial instability. We further investigate how the scaling of the energy spectrum evolves through the course of the simulation.

GR 6.8 Wed 18:15 H6

Binary neutron star merger simulations: ejecta, nucleosynthesis, EM counterparts — •Vsevolod Nedora — Theoretisch-Physikalisches Institut, Jena, Germany

GW170817 provided a plethora of information on binary neutron star (BNS) mergers and properties of matter at supranuclear densities. We further explore the remaining open questions with long-term numerical relativity (NR) BNS merger simulations with state-of-the-art numerical methods. Simulations include neutrino emission and reabsorption, the magnetic field induced viscosity via an effective model, and microphysical equations of state (EOSs) with finite temperature effects.

We find that (i) post-merger evolution is accompanied by massive outflows, spiral-wave wind, driven by complex dynamical interaction between the remnant NS and the disk and finite temperature effects; (ii) the electromagnetic (EM) signature of this new outflow corresponds to the "blue" kilonova (kN); (iii) the rapid neutron capture, r-process, nucleosynthesis final abundances in total ejecta from our simulations are compatible with solar; (iv) non-thermal kN afterglow, emitted by the ejecta interacting with the interstellar medium is compatible with the recently observed change in GRB170817A afterglow.

Overall, our results highlight the importance of the ab-initio NR BNS merger simulations with microphysical EOSs and allow to place certain tentative constraints on the properties of GW170817 and, ultimately, NS EOS.

GR 7: Experimental tests

Time: Thursday 11:00–12:00 Location: H9

GR 7.1 Thu 11:00 H9

Perspectives of measuring gravitational effects of laser light and particle beams — Felix Spengler[1], •Dennis Rätzel[2], and Daniel Braun[1] — [1]Eberhard-Karls-Universität Tübingen, Institut für Theoretische Physik, 72076 Tübingen, Germany — [2]Humboldt Universität zu Berlin, Institut für Physik, Newtonstraße 15, 12489 Berlin, Germany

We can expect the gravitational field of light to be extremely weak. However, studying the gravitational field of light could give new fundamental insights to our understanding of space and time as well as classical and quantum gravity and it is worthwhile to investigate if gravitational effects of light may be experimentally accessible in the near future. Similarly, the gravitational properties of relativistic particle beams have not been experimentally tested. Their total relativistic mass is dominated by their kinetic energy and the same dominance for the gravitational field is predicted by general relativity. Therefore, the gravitational field of particle beams shows strong similarities to that of laser beams. In addition, both can be brought into non-trivial quantum states. We present a short overview of the gravitational properties of light and relativistic particle beams and the prospects to measure them in experiments by means of sensors based on resonant mechanical oscillators. With an optimized pendulum or torsion balance combined with the planned high-luminosity upgrade of the LHC as a source, a signal-to-noise ratio substantially larger than 1 should be achievable in principle.

GR 7.2 Thu 11:15 H9

Constraining modified gravity with quantum optomechanics — •Sofia Qvarfort[1,2], Dennis Rätzel[3], and Stephen Stopyra[2] — [1]QOLS, Blackett Laboratory, Imperial College London, SW7 2AZ London, United Kingdom — [2]Department of Physics and Astronomy, University College London, Gower Street, WC1E 6BT London, United Kingdom — [3]Institut für Physik, Humboldt-Universität zu Berlin, 12489 Berlin, Germany

In this talk, I will present some recent results on estimating the performance of quantum optomechanical sensors for searches of modified gravity. Specifically, I will show how we derive the best possible bounds that can be placed on Yukawa– and chameleon–like modifications to the Newtonian gravitational potential with a cavity optomechanical quantum sensor. We do so by modelling the effects from an oscillating spherical source on the optomechanical system from first-principles. To then estimate the sensitivity to chameleon-like modifications, we take into account the size of the optomechanical probe and quantify the resulting screening effect for the case when both the source and probe are spherical. Our results show that an optomechanical system in high vacuum could, in principle, further constrain the parameters of chameleon-like modifications to Newtonian gravity.

GR 7.3 Thu 11:30 H9

BECs with Yukawa-type gravitational selfinteraction — •Sandro Gödtel and Claus Lämmerzahl — ZARM, University of Bremen, Germany

The theories of Newtonian and Einsteinian gravity are extremely powerful in describing the macroscopic world. On the other side, however, we still do not have a widely accepted description of short-range gravity. Nowadays many theories going beyond the standard model predict deviations from Newtonian gravity, commonly in the form of a Yukawa-like potential. Different experiments so far have found upper boundaries for the strength and the range of this deviation. However, most of the experiments are focused on a test body in an external gravitational field.

In this talk we present a model for a Bose-Einstein condensate which particles interact via a Newton and a Yukawa potential. In a selfconsistent manner, we determine the influence of such gravitational potentials onto the condensate. We derive the changes in the width of the cloud and the frequencies of the collective oscillations. With this, we are able to set boundaries for the parameters of the Yukawa potential and compare them to the results of current experiments.

GR 7.4 Thu 11:45 H9

The secret of planets perihelion between Newton and Einstein — •Christian Corda — Istituto Livi, via Marini 9, 59100 Prato, Italy

It is shown show that,contrary to a longstanding conviction older than 160 years, the advance of Mercury perihelion can be achieved in Newtonian gravity with a very high precision by correctly analyzing the situation without neglecting Mercury mass. General relativity remains more precise than Newtonian physics, but Newtonian framework is more powerful than researchers and astronomers were thinking till now, at least for the case of Mercury. The Newtonian formula of the advance of planets perihelion breaks down for the other planets. The predicted Newtonian result is indeed too large for Venus and Earth. Therefore, it is also shown that corrections due to gravitational and rotational time dilation, in an intermediate framework which analyzes gravity between Newton and Einstein, solve the problem. By adding such corrections, a result consistent with the one of general relativity is indeed obtained. Thus, the most important results of this Lecture are two: (i) It is not correct that Newtonian theory cannot predict the anomalous rate of precession of the perihelion of planets orbit. The real problem is instead that a pure Newtonian prediction is too large. (ii) Perihelion precession can be achieved with the same precision of general relativity by extending Newtonian gravity through the inclusion of gravitational and rotational time dilation effects.

GR 8: Quantum field theory in curved spacetimes

Time: Thursday 12:00–12:30 Location: H9

GR 8.1 Thu 12:00 H9

Quantum fields near Cauchy horizons of charged black holes — •Christiane Klein, Jochen Zahn, and Stefan Hollands — Institut für theoretische Physik, Universität Leipzig, Germany

Reissner-Nordström-de Sitter spacetimes contain a Cauchy horizon: beyond it, the evolution of the spacetime is no longer governed solely by the initial data. A combination of analytical and numerical results indicate that there is a range of the physical parameter space for which the metric can be extended across the Cauchy horizon even when considering generic classical perturbations of the initial data. This is a violation of Penrose's strong cosmic censorship conjecture. However, it has been demonstrated by Hollands et.al., that in these cases the energy flux of a real scalar quantum field will diverge quadratically at the Cauchy horizon for any Hadamard state, rendering the metric inextendible. In this talk we present numerical results indicating that the described quadratic divergence of the energy flux is present for a wide range of parameters, and that it can change its sign. In addition, we extend the results by considering charged scalar fields. Apart from the energy flux, we derive and study the current of these fields. We demonstrate that the current diverges at the Cauchy horizon and that its leading divergence can have either sign, in contrast to naive expectations.

The talk is based on Phys.Rev.D 102 (2020) 8, 085004, arXiv:2104.06005 and arXiv:2103.03714, which is joint work with S. Hollands and J. Zahn.

GR 8.2 Thu 12:15 H9

Effective Quantum Dust Collapse via Surface Matching — •Johannes Münch — Aix-Marseille Universite, Universite de Toulon, CNRS, CPT, Marseille, Frankreich

The fate of matter forming a black hole is still an open problem, although models of quantum gravity corrected black holes are available. In loop quantum gravity (LQG) models were presented, which resolve the classical singularity in the centre of the black hole by means of a black-to-white hole transition, but neglect the collapse process. The situation is similar in other quantum gravity approaches, where eternal non-singular models are available. A strategy is presented to generalise these eternal models to dynamical collapse models by surface matching. Assuming 1) the validity of a static quantum black hole spacetime outside the collapsing matter, 2) homogeneity of the collapsing matter, and 3) differentiability at the surface of the matter fixes the dynamics of the spacetime uniquely. It is argued that these assumptions resemble a collapse of pressure-less dust and thus generalises the Oppenheimer-Snyder-Datt model. The junction conditions and the spacetime dynamics are discussed generically for bouncing black hole spacetimes, as proposed by LQG, although the scheme is approach independent. A global spacetime picture of the collapse for a specific LQG inspired model is discussed.

GR 9: Cosmology

Time: Thursday 16:30–17:30 Location: H9

GR 9.1 Thu 16:30 H9

Intensity Mapping Observables of Cosmology — •Caroline Heneka — Hamburg Observatory, UHH

Intensity Mapping (IM) of line emission targets the Universe from present time up to redshifts beyond ten when the Universe reionized and the first galaxies formed, from small to largest scales. Similar to CMB measurements, the power spectra of intensity fluctuations inform about the underlying cosmology; imagine the information encoded in thousands of intensity maps at different redshifts and for multiple emission lines, forming full tomographic lightcones. In this talk I review IM as a test for cosmology and fundamental physics during cosmic dawn and the epoch of reionization. I show how power and cross-power spectra as well as global temperature measurements probe our cosmology, properties of dark matter and of astrophysical sources. The measurement of deviations from the gravitational constant G and a possible dark matter – dark energy coupling are highlighted in general modified gravity scenarios. The ability of upcoming instruments like the SKA to constrain these modifications is demonstrated. Going beyond 'traditional' summary statistics, I furthermore show how 3D neural networks are able to directly infer e.g. dark matter and astrophysical properties from such tomographic line fluctuation lightcones without an underlying Gaussian assumption.

GR 9.2 Thu 16:45 H9

The functional renormalisation group of dark matter gravitational dynamics — •Alaric Erschfeld and Stefan Flörchinger — Institut für Theoretische Physik Heidelberg

While standard cosmological perturbation theory is applicable for the description of cosmic structure formation on large scales, it fails to accurately describe the mildly non-linear regime. The functional renormalisation group of the effective action describing the gravitational dynamics of dark matter, naturally allows for non-perturbative approximation schemes, either by the use of underlying symmetries or via a truncation of the effective action theory space. We show that Galilean invariance of the system gives rise to a Ward identity which allows to solve the renormalisation group flow equations in the limit of small scales and is related to the so-called 'sweeping effect'. Further, we study the flow of an ansatz similar to a derivative expansion of the effective action, which describes dark matter in an effective theory with local dynamics. We find attractive ultraviolet fixed point solutions for the relevant flow parameter, which naturally capture the sweeping effect observed in Eulerian response functions. Further, the full renormalisation group flow is solved for the density and velocity power spectra in the perfect pressureless fluid approximation.

GR 9.3 Thu 17:00 H9

Mori-Zwanzig formalism for general relativity: a new approach to the averaging problem* — •Michael te Vrugt[1], Sabine Hossenfelder[2], and Raphael Wittkowski[1] — [1]Institut für Theoretische Physik, Center for Soft Nanoscience, Westfälische Wilhelms-Universität Münster, D-48149 Münster, Germany — [2]Frankfurt Institute for Advanced Studies, D-60438 Frankfurt am Main, Germany

Cosmology provides a coarse-grained description of the universe that is valid on very large length scales. However, the Einstein field equations are not valid for coarse-grained quantities since, due to their nonlinearity, they do not commute with an averaging procedure. Thus, it is unclear in which way small-scale inhomogeneities affect large-scale cosmology (backreaction). In this work, we address this problem by extending the Mori-Zwanzig projection operator formalism, a highly successful coarse-graining method from statistical mechanics, towards general relativity. This allows to derive a dynamic equation for the Hubble parameter in which backreaction is taken into account through memory and noise terms. Our results are linked to cosmological observations.

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GR 9.4 Thu 17:15 H9

Considering cosmological red-shift originated in an increase of universes time velocity — •Bjørn Ebbesen — Hamburg, Germany

Thus far, the imagination of an expanding universe is widely accepted. But some physical laws claimed are not approved by local experiments.

This approach considers cosmological red-shift as effect of universes time velocity increasing in time. (Two time velocities spans a time dilation.)

Reevaluating observations so far leads to the perspective of a shrinking universe.

It is stated that a cosmological process takes place, where universes time velocity evolves from and influences universes gravitation. A simplified model of the process is derived.

GR 10: Scalar-tensor and non-local gravity theories

Time: Thursday 17:30–18:00 Location: H9

GR 10.1 Thu 17:30 H9

Core collapse in scalar-tensor theory with massive fields — •Roxana Rosca-Mead — FSU, Jena, Germany

Though General Relativity has been successfully tested so far, concepts such as dark energy and string theory suggest the need of modifying it. Scalar-tensor theory is one of the most popular alternatives discussed. The key motivation for looking at the ones with massive fields is that they are far less constrained by binary pulsar observations, in contrast to the massless case. In this talk, I will demonstrate studies in stellar core collapse in spherical symmetry, that were performed by adapting the numerical code GR1D to the case of massive scalar-tensor gravity. The addition of a mass term allows, within present constraints, much stronger gravitational wave emission than in the massless case, while the dispersion in the propagation of the scalar leads to a quasi-monochromatic signal, potentially detectable by LIGO /Virgo with existing analysis pipelines.

GR 10.2 Thu 17:45 H9

Topological defects and regularity in non-local gravity — •Jens Boos — William & Mary, Williamsburg, United States

Non-local gravitational theories with infinitely many derivatives may solve the gravitational singularity problem without introducing ghost-like degrees of freedom that one typically encounters in higher-order gravity. However, due to the complexity of the non-linear non-local field equations, so far only the linear regime is understood well. In this talk I will focus on cosmic string solutions obtained in weak-field non-local gravity. These have an interesting feature: non-locality regularizes the curvature defect at the location of the cosmic string. Since spacetime is now simply connected one might assume that the angle deficit vanishes, but this is not true: asymptotically one recovers the string solution of General Relativity. Non-locality hence challenges the way we think about topological defects in connection with topological properties of spacetime. If time permits, I shall also comment on similar effects regarding Aharanov–Bohm phases in non-local quantum mechanics, and their possible observational signatures.

GR 11: Didactical and heuristic aspects

Time: Thursday 18:00–18:30 Location: H9

GR 11.1 Thu 18:00 H9

2+1D-sector models of curved spacetimes — •Corvin Zahn and Ute Kraus — Hildesheim University

Sector models can represent curved surfaces, spaces, and spacetimes. The basic principle is the subdivision of the surface/space/spacetime into small parts, and the approximation of each small part by a small flat part. Sector models can be used to study geometry, e.g. to determine curvature and to construct geodesics.

We present sector models of several spacetimes (with one spatial dimension suppressed) and illustrate the test for curvature components.

References:

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GR 11.2 Thu 18:15 H9

Liegt der Schlüssel zur Neuen Physik unter der Laterne des Althergebrachten? — •Thomas Görnitz — FB Physik, Goethe-Univ. Frankfurt/M

Erklären bedeutet Komplexes aus Einfacherem zu konstruieren. Quantenfeldtheorien - Systeme einer unbegrenzten Anzahl von Feldquanten (Teilchen) - sind das Beste für komplexe Situationen. Teilchen sind somit einfacher als Quantenfelder. Seit dem Higgs-Teilchen wurde von unzähligen prognostizierten Quantenfeldern (GUT, SUSY, Strings, Inflation, Dunkle Materie, Dunkle Energie) kein Feldquant nachgewiesen.

Immer höhere Energien sollen bei immer kleineren Strukturen Auswege aus der aktuellen Krise der Physik eröffnen - ohne über diese Absurdität zu reflektieren. Erst neue Vorstellungen führen aus der Sackgasse des räumlich Kleinen heraus.

Die Quantentheorie konstruiert aus einfachen Strukturen komplexe mit dem Tensorprodukt der Zustandsräume. Dem "atomaren" Vorurteil (einfachste Strukturen sind am wenigsten ausgedehnt) entgegnet sie, dass diese dann die größten Energiekonzentrationen enthielten.

Die mathematisch einfachste Quantenstruktur besitzt einen zweidimensionalen Zustandsraum. Man kann sie ein AQI (Abstract Bit of Quantum Information) nennen. Im Vortrag werden mit den AQIs neue mathematisch fundierte Antworten für Kosmologie, Gravitation, Teilchen und quantische Wechselwirkungen gegeben.

GR 12: Annual General Meeting

Time: Thursday 19:00–20:30 Location: MVGR

Annual General Meeting

GR 13: Quantum gravity and cosmology

Time: Friday 11:00–12:15 Location: H4

GR 13.1 Fri 11:00 H4

Solution of the H0 Tension — •Hans-Otto Carmesin — Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — Bahnhofstraße — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

In the standard model of cosmology, the Hubble constant should not vary as a function of the time.

However, when the Hubble constant H0 is measured, then probes that have been emitted at an earlier time or at a corresponding redshift z are used, and it turns out that the observed values of H0 depend on that redshift z, H0=H0(z,observation). That discrepancy is called H0 tension.

I derive a theory of dark energy, based on quantum physics and gravity. With my theory, I derive a term for the above function, H0(z,theory). That term is in precise accordance with observation, so my theory of the dark energy solves the H0 tension. I emphasize that the only numerical input used in my theory is the present day time after Big Bang combined with the universal constants G, c, kB and h.

Moreover, my theory solves various other fundamental problems of physics, see Carmesin, Hans-Otto (2021): Quanta of Spacetime Explain Observations, Dark Energy, Graviton and Nonlocality. Berlin, Dr. Köster Verlag, see also Carmesin, Hans-Otto (2019): Die Grundschwingungen des Universums - The Cosmic Unification - With 8 Fundamental Solutions based on G, c and h. Berlin: Dr. Köster Verlag.

GR 13.2 Fri 11:15 H4

Solution of the Horizon Problem — •Philipp Schöneberg[1] and Hans-Otto Carmesin[1,2,3] — [1]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — [2]Studienseminar Stade, Bahnhofstraße 5, 21680 Stade — [3]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

In the early universe, the density was very high. As a consequence, there occurred gravitational instabilities and dimensional phase transitions. These have been derived in three very different physical systems, see Carmesin, Hans-Otto (2021): Quanta of Spacetime Explain Observations, Dark Energy, Graviton and Nonlocality. Berlin, Dr. Köster Verlag.

Using these phase transitions, the light horizon as a function of time R(t) can be calculated, ranging from the Planck length to the present day value. With it we derive the solution of the horizon problem.

GR 13.3 Fri 11:30 H4

The equivalence of gravity and gravitational time dilation in general relativity and in quantum mechanics — •René Friedrich — Strasbourg

The curved spacetime of the Schwarzschild metric seems to be incompatible with quantum mechanics. But gravity may not only be represented by curved spacetime, it is also entirely described by gravitational time dilation in flat, uncurved space.

This talk is the third part of the concept of quantum gravity without need for any additional theory: Gravity modulates in the form of gravitational time dilation the proper time parameter of the worldlines of quantum systems.

GR 13.4 Fri 11:45 H4

Für ein einheitliches Weltbild der Physik — •Helmut Hille — Heilbronn, Fritz-Haber-Straße 34

Es ist nur menschliche Sehgewohnheit, getrennt Gesehenes als definitiv getrennt Existierendes zu halten, obgleich schon das System Sonne-Erde-Mond das Gegenteil beweist. Keiner dieser Körper hätte ohne den anderen seine Bahn und es gäbe auf der Erde keine Gezeiten. Verschränkte Quanten haben gezeigt, dass ihr gemeinsamer Ursprung sie sich als Eines verhalten lassen. Ebenso ist der Big Bang der gemeinsame Ursprung aller Materie unseres Kosmos zu einer neuen immanenten Einheit, die sich in Form der Gravitation zusammenhalten möchte, während sie äußerlich gleichzeitig expandiert. Die Gravitation ist nur ein weiterer Beleg über die Macht des Unsichtbaren, die es endlich zu akzeptieren gilt. Heute sucht man als Ausweg das Unsichtbare in dunkler Materie und Energie. Aber das Unsichtbare, um das es mir geht, ist kein Teilchen. Es ist nur die Rückseite des Sichtbaren, die wir mit der Gravitationskonstante erfassen. So ist die Gravitation eine Form der Verschränkung aller betroffenen Materie (auch Strahlung ist Materie), von mir hier Superverschränkung genannt. In der Verbindung mit drei weiteren Prämissen ergibt sich ein einheitliches Weltbild der Physik von großer Schönheit, das ein rationales ist, das auf klaren, einsichtigen Prämissen beruht, die jedermann nachvollziehen kann.

GR 13.5 Fri 12:00 H4

Quantum gravity by elimination of spacetime — •René Friedrich — Strasbourg

General relativity without curved spacetime? Unconceivable, you might say. But why? For Marcel Grossmann, the Riemannian geometry was nothing more than an efficient tool for the description of Einstein's main postulates of general relativity, in particular the equivalency principle. And today, spacetime turns out to be the only reason why things are going wrong in quantum gravity.

Eliminating spacetime means to restitute to the universe its absolute, observer-independent character. In spacetime, particle worldlines are parameterized by the coordinate time of the observer, and different observers with different spacetime coordinate systems get different results. Instead, we must parameterize each worldline by its respective proper time, in order to get a universe on which all observers agree and which complies with quantum mechanics.

The result is a completely Lorentz-invariant description of the universe: In a manifold of absolute space without common time axis, worldlines are parameterized by their respective proper time. Accordingly, lightlike phenomena such as electromagnetic and gravity fields with zero proper time are reduced to zero. But what about gravity? Gravity may not only be expressed as curved spacetime but equivalently also as gravitational time dilation in absolute, flat space, modulating the proper time parameter of worldlines.