Gravitation and Relativity Division
Fachverband Gravitation und Relativitätstheorie (GR)

Bernd Brügmann
Theoretisch-Physikalisches Institut
Friedrich-Schiller-Universität Jena
07743 Jena
bernd.bruegmann@uni-jena.de

Welcome to the annual meeting of the Gravitation and Relativity Division of the DPG in "virtual" Heidelberg. Despite the adverse circumstances, we again have a rich scientific program, including several genuine highlights. Let me also draw your attention to our General Assembly of Members on Thursday evening, starting at 19:00. I wish all of us a pleasant and informative week!

Overview of Invited Talks and Sessions

(Online lecture halls, in particular GR-H2, GR-H3)

Plenary Talk of GR

PV VII	Thu	9:00– 9:45	Audimax	**New perspectives onto the Universe in the era of multi-messenger astrophysics** — •Samaya Nissanke

Invited Talks

GR 4.1	Tue	11:00–11:45	GR-H2	**Pseudospectrum and black hole quasi-normal mode (in)stability** — •Rodrigo Panosso Macedo
GR 4.2	Tue	11:45–12:30	GR-H2	**Observable Signatures of Quantized Gravity in Quantum Optical Experiments** — •Dennis Rätzel
GR 7.1	Wed	11:00–11:45	GR-H2	**Numerical Relativity and Gravitational Wave Observations** — •Harald Pfeiffer

Invited Talks of the joint symposium SMuK Dissertation Prize 2022 (SYMD)

See SYMD for the full program of the symposium.

SYMD 1.1	Mon	14:00–14:25	Audimax	**Timeless Quantum Mechanics and the Early Universe** — •Leonardo Chataigner
SYMD 1.2	Mon	14:25–14:50	Audimax	**First tritium β-decay spectrum recorded with Cyclotron Radiation Emission Spectroscopy (CRES)** — •Christine Claessens
SYMD 1.3	Mon	14:50–15:15	Audimax	**Watching the top quark mass run - for the first time!** — •Matteo M. Defranchis, Katerina Lipka, Sven-Olaf Moch
SYMD 1.4	Mon	15:15–15:40	Audimax	**Towards beam-quality-preserving plasma accelerators: On the precision tuning of the wakefield** — •Sarah Schröder

Invited Talks of the joint symposium The Nature of Science (SYNS)

See SYNS for the full program of the symposium.

SYNS 1.1	Tue	14:00–14:30	Audimax	**The Role of Nature of Science Education for Science Media Literacy** — •Dietmar Höttecke
SYNS 1.2	Tue	14:30–15:00	Audimax	**What kinds of identities are deemed in/our of place in physics?** — •Lucy Avraamidou
SYNS 1.3	Tue	15:00–15:30	Audimax	**Some thoughts on the status of theoretical physics** — •Daniel Harlow

Prize Talks of the joint Awards Symposium (SYAW)

See SYAW for the full program of the symposium.

SYAW 1.1	Wed	14:10–14:40	Audimax	**Wie überprüft man die Ziele der Lehramtsausbildung Physik?** — •Horst Schecker
SYAW 1.2	Wed	14:40–15:10	Audimax	**Astronomy at Highest Angular Resolution - Adaptive Optics, Interferometry and Black Holes** — •Frank Eisenhauer
SYAW 1.3	Wed	15:10–15:40	Audimax	**Turbulence in one dimension** — •Alexander M. Polyakov

Sessions

GR 1.1–1.6	Mon	9:00–11:00	GR-H2	**Black Holes**
GR 2.1–2.8	Mon	16:00–18:40	GR-H2	**Classical Theory**
GR 3.1–3.6	Mon	16:15–18:15	GR-H3	**Cosmology**
GR 4.1–4.2	Tue	11:00–12:30	GR-H2	**General Relativity**
GR 5.1–5.7	Tue	16:15–18:35	GR-H2	**Gravitational Waves**
GR 6.1–6.6	Tue	16:15–18:15	GR-H3	**Cosmology**
GR 7.1–7.1	Wed	11:00–11:45	GR-H2	**General Relativity**
GR 8.1–8.2	Wed	11:45–12:25	GR-H2	**Gravitational Waves**
GR 9.1–9.7	Wed	16:15–18:35	GR-H2	**Gravitational Waves**
GR 10.1–10.7	Wed	16:15–18:35	GR-H3	**Foundations and Alternatives**
GR 11.1–11.5	Thu	11:00–12:40	GR-H2	**Relativistic Astrophysics**
GR 12.1–12.4	Thu	11:00–12:40	MP-H5	**Quantum gravity (joint session MP/GR)**
GR 13.1–13.5	Thu	14:00–15:40	GR-H2	**Numerical Relativity**
GR 14.1–14.6	Thu	16:15–18:15	GR-H2	**Gravitational Wave Detectors**
GR 15	Thu	19:00–20:30	GR-MV	**Member Assembly**

Annual General Meeting of the Gravitation and Relativity Division

Thu 19:00–20:30 GR-MV

- Bericht des Vorsitzenden
- Aktuelles und Planung des kommenden Jahres
- Verschiedenes

GR 1: Black Holes

Time: Monday 9:00–11:00 Location: GR-H2

GR 1.1 Mon 9:00 GR-H2

Photon spheres and shadows of time-dependent black holes — Jay Solanki[1] and •Volker Perlick[2] — [1]Sardar Vallabhbhai National Institute of Technology, Surat, 395007 Gujarat, India — [2]ZARM, University of Bremen, 28359 Bremen, Germany

The Vaidya spacetimes are a class of time-dependent and spherically symmetric solutions to Einstein's field equation with a null dust as the source. They describe the gravitational field around a spherically symmetric body that either gains mass by absorbing the null dust or loses mass by emitting it. Here we consider a subclass of the Vaidya spacetimes where the source is a black hole and the metric is conformally static. We demonstrate that there is an unstable photon sphere and we calculate the shadow of such black holes, first as seen by conformally static observers and then as seen by moving observers. The considered spacetimes may be viewed as simple models of black holes that are either accreting or (Hawking) radiating.

GR 1.2 Mon 9:20 GR-H2

Gravitational Lensing in the NUT Spacetime — •Torben C. Frost — ZARM, University of Bremen, 28359 Bremen, Germany — Institute for Theoretical Physics, Leibniz University Hannover, 30167 Hannover, Germany

The existence of a gravitomagnetic charge, the gravitational analogon to a hypothetical magnetic charge in electrodynamics, is a longstanding open question in physics. In my talk I will discuss how we can use gravitational lensing to identify if a black hole in nature carries a gravitomagnetic charge. For this purpose I will assume that they are described by the NUT metric. We will solve the geodesic equations using Legendre's elliptic integrals and Jacobi's elliptic functions. Then we will rederive the angular radius of the shadow, formulate a lens equation, derive redshift and travel time.

GR 1.3 Mon 9:40 GR-H2

A global view on Kerr spacetime – First person visualization of general relativity — •Thomas Reiber — Universität Hildesheim, Germany

The maximal analytic extension of slow Kerr spacetime contains an infinity of asymptotically flat "exterior" regions connected by a strongly curved "interior" region. An observer may stay in one of the exterior regions or – crossing event horizons – pass through the strongly curved region to reach one of the other asymptotically flat regions. We calculate videos of what an observer would see on different journeys through Kerr spacetime by using general relativistic ray tracing. For that purpose we use a covering of Kerr spacetime by an atlas consisting of Kerr-Schild and Kruskal-like coordinate patches.

GR 1.4 Mon 10:00 GR-H2

Non-teleology and motion of a tidally perturbed Schwarzschild black hole — •Zeyd Sam — School of Mathematical Sciences and STAG Research Centre, University of Southampton, United Kingdom — Institute for Physics and Astronomy, University of Potsdam, Germany

The prospect of gravitational wave astronomy with EMRIs has motivated increasingly accurate perturbative studies of binary black hole dynamics. Studying the apparent and event horizon of a perturbed Schwarzschild black hole, we find that the two horizons are identical at linear order regardless of the source of perturbation. This implies that the seemingly teleological behaviour of the linearly perturbed event horizon, previously observed in the literature, cannot be truly teleological in origin. The two horizons do generically differ at second order in some ways, but their Hawking masses remain identical. In the context of tidal distortion by a small companion, we also show how the perturbed event horizon in a small-mass-ratio binary is effectively localized in time, and we numerically visualize unexpected behaviour in the black hole's motion around the binary's center of mass.

GR 1.5 Mon 10:20 GR-H2

Black hole temperature in Horndeski gravity — •Kamal Hajian[1], Stefano Liberati[2], Mohammad Mehdi Sheikh-Jabbari[3], and Mohammad Hasan Vahidinia[4] — [1]Carl von Ossietzky University of Oldenburg Department of Physics D-26111 Oldenburg — [2]3SISSA, Via Bonomea 265, 34136 Trieste, Italy and INFN, Sezione di Trieste — [3]5School of Physics, Institute for Research in Fundamental Sciences (IPM), P.O.Box 19395-5531, Tehran, Iran — [4]Department of Physics, Institute for Advanced Studies in Basic Sciences (IASBS), P.O. Box 45137-66731, Zanjan, Iran

In Horndeski gravities, which are the most generic scalar-tensor theories without ghosts, the speed of graviton can be different w.r.t other massless particles/waves such as photons. We will show that this leads to a black hole temperature which is different from the standard Hawking temperature by an overall factor. The factor depends on black hole properties as well as the Lagrangian. Using this modified temperature, the first law of thermodynamics for black holes in Horndeski gravities is recovered.

GR 1.6 Mon 10:40 GR-H2

Black hole shadows enlightening quantum gravity — •Michael Florian Wondrak, Kolja Kuijpers, Jesse Daas, Frank Saueressig, and Heino Falcke — Institute for Mathematics, Astrophysics and Particle Physics (IMAPP), Radboud University, Nijmegen, The Netherlands

With the advent of the Event Horizon Telescope, the shadow of supermassive black holes could be resolved for the first time. Tests of the general theory of relativity at this strong-field regime come into reach. Probing quantum gravity is particularly interesting.

In this talk, we focus on extending the Einstein–Hilbert action by higher curvature terms which necessarily arise as counterterms upon quantization. We numerically solve the equations, find solutions with and without horizons, and extract the corresponding shadow radii. The results are discussed regarding observability.

GR 2: Classical Theory

Time: Monday 16:00–18:40 Location: GR-H2

GR 2.1 Mon 16:00 GR-H2

A covariant formulation of violations of the Equivalence Principle — •Ckaus Lämmerzahl — ZARM, University of Bremen, Germany

In the Newtonian framework a violation of the Equivalence Principle can be described by introducing inertial and graviational masses. Within General Relativity it is not obvious how to couple different particles differently to the same space-time geometry. Here we propose a scheme where in a given geometrical background a violation of the universality of free fall as well as of the frame dragging can be formulated.

GR 2.2 Mon 16:20 GR-H2

A Collapsing Mass Shell with High Angular Momentum — Andreas King[1], •Markus King[2], and Jörg Frauendiener[3] — [1]Preysingstraße 40, 81667 München, Germany — [2]Fakultät Engineering, Hochschule Albstadt-Sigmaringen, 72458 Albstadt, Germany — [3]Department of Mathematics and Statistics, University of Otago, Dunedin 9054, New Zealand

We calculate the free-fall collapse of a dust shell of mass M and radius $R(s)$, with s being proper time along the worldlines of its collisionless particles, and rotating fast in the initial angular velocity ω_0 around an axis through its center in an asymptotically flat spacetime. The Einstein equations are solved to second order perturbation theory in ω_0. We show existence of such a system with flat interior, free of gravitational waves produced by the quadrupolar deformation of the shell due to centrifugal effects. Stationary solutions of the underlying master equation of gravitational perturbations are given.

GR 2.3 Mon 16:40 GR-H2

Energy Conditions in Reverse-Engineered Metrics — •Sebastian Schuster[1], Jessica Santiago[2], and Matt Visser[3] — [1]Charles University, Prague, Czech Republic — [2]Aristotle University of Thessaloniki, Thessaloniki, Greece — [3]Victoria University of Wellington, Wellington, New Zealand

Many familiar metrics of general relativity have been achieved by integrating the Einstein equations for a particular source stress-energy tensor. In other cases, physical considerations lead to a motivation for studying metrics of a particular form; here, then, the question is to derive the stress-energy tensor from a given metric. While mathematically simpler—as differentiation is simpler than integration—this opens a long list of questions which stress-energy tensors should be considered physical. An early heuristic for such an evaluation were so-called energy conditions. In this talk, we will describe a proof for why "warp drives" will always violate pointwise energy conditions, and how even rather benign, reverse-engineered metrics ("tractor beams") will do so.

GR 2.4 Mon 17:00 GR-H2

Relativistic Geodesy: What do we know? — •Dennis Philipp — ZARM, University of Bremen

Geodesy is the science of the properties of our Earth, in particular its gravity field. Conventional geodesy builds on (the concepts of) Newtonian gravity. Thus, at the level of a relativistic theory of gravity, the underlying framework needs to be renewed and basic notions need to be generalized. This opens an entirely new perspective on the matter - chronometric geodesy - which investigates gravity by, e.g., the use of clocks and clock networks. In this talk, I will review the status of the theoretical aspects of relativistic geodesy and address concepts such as the potential, multipole moments, geoid, reference ellipsoid, and height notions in the conventional and in the relativistic framework. Moreover, observables and measurement prescriptions are discussed and an outlook on future developments is given.

GR 2.5 Mon 17:20 GR-H2

On free fall of quantum matter — •Viacheslav Emelyanov — Institute of Theoretical Physics, Karlsruhe Institute of Technology, Wolfgang-Gaede-Straße 1, 76131 Karlsruhe, Germany

According to Newton's gravitational law, any object to have a non-zero gravitational mass is a source of gravity. It is a result of numerous experiments that gravitational mass is equal with good accuracy to inertial mass of a macroscopic object. Thus, all objects fall down equally fast, assuming same initial position and velocity. This circumstance is promoted to the weak equivalence principle in General Relativity, that is related to the concept of affine connection, giving in its turn the concept of geodesic corresponding to particles' trajectories in curved spacetime. However, there is an expectation that the free-fall universality may not hold for quantum matter.

In this talk, we intend to introduce our approach to quantum particle physics in curved spacetime. It is based on quantum field theory and the general principle of relativity, which are used to build a model for quantum particles in gravity. We then obtain by its means a deviation from a classical geodesic in the Earth's gravitational field. This shows that free fall depends on quantum-matter properties. Specifically, we find that the free-fall universality and the wave-packet spreading are mutually exclusive phenomena. Assuming that the latter is more fundamental, we present the first-ever estimate of the Eötvös parameter for a pair of atoms used nowadays in quantum tests of the universality of free fall in atom interferometers and compare that with recent experimental results.

GR 2.6 Mon 17:40 GR-H2

Gravitational field recovery via inter-satellite redshift measurements — •Jan Hackstein, Eva Hackmann, Claus Lämmerzahl, and Dennis Philipp — Center of Applied Space Technology and Microgravity, Bremen, Germany

Satellite gravimetry is a promising technique to monitor global changes in the Earth system. High-precision atomic clocks are already being compared to measure physical heights in terrestrial gravimetry. In relativistic gravity, a clock comparison is sensitive to the clocks' positions and relative velocity in the gravity field. Thus, clocks are an ideal tool to investigate the Earth's gravity field. To cover the whole Earth, orbiting satellites can be equipped with clocks and observed by terrestrial ground stations. One important obstacle for Earth-satellite gravimetry, however, is the low measurement accuracy of a satellite's velocity, which enters into the redshift via the Doppler effect. Here we follow an alternative approach without absolute velocity measurements based on the framework of general relavity. We consider an idealised satellite setup in the Schwarzschild spacetime where the monopole moment is recovered from pairwise redshift measurements between multiple satellites equipped with clocks. We investigate whether or not the redshift between two satellites can be retrieved as a function depending only on relative observables between the satellites. This method promises a higher accuracy for gravity field recovery by bypassing the Doppler effect. We compare the results and error estimates of these inter-satellite measurements with conventional Earth-satellite measurements and conclude with future applications of this theoretical setup.

GR 2.7 Mon 18:00 GR-H2

Probing gravitational parity violation with compact binaries — •Hector O. Silva and Jan Steinhoff — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, 14476 Potsdam, Germany

The detection of gravitational-waves signals produced by the inspiral and coalescence of compact binaries have opened a new vista into the nonlinear, highly dynamical regime of gravity. These observations have allowed us to perform new tests of general relativity and also to probe (or constrain) modifications to Einstein's theory. In this work, we report on an ongoing effort to study the effects of higher-curvature parity violating modifications to general relativity on the inspiral of compact binaries with the goal of possibly placing (or forecasting) constraints on parity violation in gravity with present or future gravitational wave observatories.

GR 2.8 Mon 18:20 GR-H2

Konzept eines satellitengestützten Tests des gravitomagnetischen Uhreneffektes — •Jan Scheumann, Dennis Philipp, Eva Hackmann, Sven Herrmann, Benny Rievers und Claus Lämmerzahl — ZARM, Universität Bremen, 28359 Bremen, Deutschland

Die Allgemeine Relativitätstheorie besagt, dass die Rotation eines Körpers einen nicht-newtonschen Einfluss auf Objekte in seinem Orbit ausübt. Ein Beispiel für einen solchen Effekt ist die als Lense-Thirring-Effekt bekannte Drehung der Knotenlinie eines Satelliten. Ein weiterer Effekt ist der zuerst von Cohen und Mashhoon beschriebene sogenannte gravitomagnetische Uhreneffekt, der den Unterschied in der Eigenzeit zweier Uhren in gegenläufigem Orbit um den Zentralkörper beschreibt. Dieser Effekt ist bisher für verschiedene idealisierte Orbits theoretisch beschrieben worden, wurde jedoch noch nicht experimentell bestätigt.

Nachdem zwei der Galileo-Satelliten auf nicht für GNSS-Zwecke geeigneten Orbits bereits dafür genutzt werden konnten, die Unsicherheit im Nachweis der gravitativen Rotverschiebung mittels der an Bord befindlichen passiven Wasserstoffmaser zu verringern, wird die Nutzung dieser Satelliten für weitere Tests relativistischer Effekte untersucht.

In diesem Vortrag wird ein Konzept vorgestellt, mit dem der gravitomagnetische Uhreneffekt untersucht werden könnte und die hierfür notwendigen Voraussetzungen mit dem aktuellen Stand der Technik verglichen.

GR 3: Cosmology

Time: Monday 16:15–18:15 Location: GR-H3

GR 3.1 Mon 16:15 GR-H3

Through the Big Bang — •Paula Reichert — Mathematisches Institut, LMU München, Germany

This talk presents latest results regarding the evolution of the universe through the Big Bang singularity on shape space. Relationalism in the form of modern shape dynamics suggests that the Big Bang is only a turning or Janus point within an overall time-symmetric, eternal evolution - a common past in a universe with one past (i.e. the Big Bang) and two futures in both directions away from it. This idea is supported by the 2016 result that, for the quiescent Bianchi IX model of GR, the shape (i.e. angular) degrees of freedom can be evolved uniquely through the (otherwise singular) point of zero spatial volume. Studies of the total collision singularity on non-relativistic shape space further suggest that, at the point of total collision (i.e. the Big Bang of the Newtonian N-body universe), the system is exceptionally homogenous, forming a state of minimal shape complexity and minimal entropy. At the same time, both complexity and entropy increase as the system expands and galaxies form in both directions away from the Janus point, thereby marking two gravitational and entropic arrows of time.

GR 3.2 Mon 16:35 GR-H3

Graviton corrections to the Newtonian potential using invariant observables — •Markus B. Fröb, Constantin Rein, and Rainer Verch — Institut für Theoretische Physik, Universität Leipzig, Brüderstraße 16, 04103 Leipzig, Germany

We consider the effective theory of perturbative quantum gravity coupled to a point particle, quantizing fluctuations of both the gravitational field and the particle's position around flat space. Using a recent relational approach to construct gauge-invariant observables, we compute one-loop graviton corrections to the invariant metric perturbation, whose time-time component gives the Newtonian gravitational potential. The resulting quantum correction consists of two parts: the first stems from graviton loops and agrees with the correction derived by other methods, while the second one is sourced by the quantum fluctuations of the particle's position and energy-momentum, and may be viewed as an analog of a "Zitterbewegung". As a check on the computation, we also recover classical corrections which agree with the perturbative expansion of the Schwarzschild metric.

GR 3.3 Mon 16:55 GR-H3

Spatial Geometry of the Large-Scale Universe: The Role of Quantum Gravity, Dark Energy and Other Unknowns — •Marc Holman — Utrecht University, Utrecht, Netherlands

Most key features of contemporary concordance cosmology can be directly linked to observational facts, such as Hubble's law, the existence and properties of the Cosmic Microwave Background (CMB) - in particular its extreme uniformity - light element abundances and large-scale flatness. In some cases, these features first appeared in the form of further model constraints in the light of new observational data - e.g., the discoveries of distance-proportional galactic redshifts and the CMB, which were taken as irreconcilable with static and steady-state cosmological models, respectively. In other cases, they first appeared in the form of *additional* ingredients in the light of largely existent, but seemingly unaccounted for, observational data - e.g., the near-flatness of the Universe's large-scale spatial geometry and the existence of mass discrepancies, which were argued irreconcilable with standard Big Bang cosmology assuming only "normal matter" to be present. As recent work has emphasized however, the observed near-flatness of the large-scale Universe as a partial, but key motivation for assuming the existence of an ultra-short, inflationary expansion of the very early Universe, has a long and troubled history. In this respect, the present work strengthens earlier results regarding the absence of a cosmological flatness problem of the sort that could potentially be resolved by inflation.

GR 3.4 Mon 17:15 GR-H3

Compact objects from effective quantum gravity — Piero Nicolini[1,2,3] and •Salvatore Samuele Sirletti[2,4] — [1]New York University Abu Dhabi, Abu Dhabi, UAE — [2]Frankfurt Institute for Advanced Studies, Frankfurt am Main, Germany — [3]Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany — [4]Università degli Studi di Napoli Federico II, Naples, 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 metric allows for the description of a regular horizonless Planckian object and a neutron star with a quantum vacuum at its center.

GR 3.5 Mon 17:35 GR-H3

Generalized Uncertainty Relations and the Problem of Dark Energy — •Matthew J. Lake — Frankfurt Institute for Adavanced Studies, Frankfurt am Main, Germany

We outline a new model in which generalised uncertainty relations are obtained without modified commutation relations. While existing models introduce modified phase space volumes for the canonical degrees of freedom, we introduce new degrees of freedom for the background geometry. The background is treated as a genuinely quantum object, with an associated state vector, and the model naturally gives rise to the extended generalised uncertainty principle (EGUP). Importantly, this approach solves (or rather, evades) well known problems associated with modified commutators, including violation of the equivalence principle, the soccer ball problem for multi-particle states, and the velocity dependence of the minimum length. However, it implies two radical conclusions. The first is that space must be quantised on a different scale to matter and the second is that the fundamental quanta of geometry are fermions. We explain how, in the context of the model, this gives rise to an effective dark energy density, without contradicting established results including the no go theorems for multiple quantisation constants, which still hold for species of material particles, and the spin-2 nature of gravitons.

GR 3.6 Mon 17:55 GR-H3

Power spectrum for perturbations in an inflationary model for a closed universe — •tatevik vardanyan and claus kiefer — Institute for Theoretical Physics, University of Cologne, Köln, Germany

We derive the power spectrum of primordial quantum fluctuations in an inflationary universe for curvature parameter $\mathcal{K} = 1$. This is achieved through a Born-Oppenheimer type of approximation scheme from the Wheeler-DeWitt equation of canonical quantum gravity using gauge-invariant variables. Compared to the flat model, the closed model exhibits a deficit of power at large scales.

Reference: arXiv:2111.07835

GR 4: General Relativity

Time: Tuesday 11:00–12:30 Location: GR-H2

Invited Talk GR 4.1 Tue 11:00 GR-H2

Pseudospectrum and black hole quasi-normal mode (in)stability — •Rodrigo Panosso Macedo — University of Southampton

Black hole spectroscopy is as a powerful approach to extract spacetime information from gravitational wave observed signals. However, quasinormal mode (QNM) spectral instability under high wave-number perturbations has been recently shown to be a common classical general relativistic phenomenon. I will discuss these recent results on the stability of QNM in asymptotically flat black hole spacetimes by means of a pseudospectrum analysis.

Invited Talk GR 4.2 Tue 11:45 GR-H2

Observable Signatures of Quantized Gravity in Quantum Optical Experiments — •Dennis Rätzel — Institut für Physik, Humboldt Universität zu Berlin, Newtonstraße 15, 12489 Berlin, Germany

For nearly a century there has been an apparent tension between known laws of physics. The classical theory of General Relativity describes all macroscopic gravitational phenomena, while Quantum Theory is the basis for the description of matter at the microscopic scale. Yet, so far there has been no consensus on how, or even if, they can fit together. A final and conclusive answer to the question of whether gravity ought to be quantized must be based on empirical evidence.

In this talk, I will discuss the search for observable signatures of quantized gravity in quantum optics by means of two examples of gravitationally interacting quantum systems: photons in a polarization-entangled state and small masses in spatial superposition states. I will present experimental proposals and discuss their feasibility and what can be learned from them in principle.

GR 5: Gravitational Waves

Time: Tuesday 16:15–18:35 Location: GR-H2

GR 5.1 Tue 16:15 GR-H2

The scientific potential of gravitational waves from Extreme Mass Ratio Inspirals — •Lorenzo Speri — Max Planck Institute for Gravitational Physics (Albert Einstein Institute) Am Muehlenberg 1, 14476 Potsdam, Germany

One of the primary sources for the future space-based gravitational wave detector, the Laser Interferometer Space Antenna, are the inspirals of small compact objects into massive black holes in the centers of galaxies. The gravitational wave observations of such Extreme Mass Ratio Inspiral (EMRI) systems have a huge scientific potential. The compact object typically completes hundred thousand cycles in band, during which time it is orbiting in the strong field region close to the central rotating black hole. Because of this, EMRI signals encode a detailed map of the background space-time and offer a unique opportunity to measure the properties and environment of Massive Black Holes, and to test for deviations from General Relativity (GR). Properly modeling EMRIs is of paramount importance to unlock such potential. In this talk I will review how EMRI waveform models are constructed, and show how environmental and beyond GR effects can be included. I will discuss the ability of EMRI signals to constrain accretion disk and beyond GR parameters. I will conclude by highlighting the future challenges for EMRI gravitational wave modeling.

GR 5.2 Tue 16:35 GR-H2

Detecting long-duration gravitational wave signals — •Liudmila Fesik and Maria Alessandra Papa — Max Planck Institute for Gravitational Physics (Albert Einstein Institute) and Leibniz University, Callinstraße 38, 30167 Hannover, Germany

Spinning neutron stars are sources of long-duration continuous waves (CWs) that may be detected by interferometric detectors. We focus on glitching pulsars with abrupt spin-ups and long term spin-down, which imprint in CWs as transient signals from weeks to months. Standart method for identifying transient signals is the match-filtering, which combines a coherent detection statistics over time intervals of different duration. We propose a new method, where the most information from an initial search is considered in order to set up the post-following transient searches. We characterize the method by determining the false alarm and false dismissal probabilities for different signal strengths, and appropriate choices of the relative detection thresholds. We compare the sensitivity of this method with the standart match-filtering.

GR 5.3 Tue 16:55 GR-H2

Interference of strongly lensed Gravitational Waves — •Stefano Savastano[1], Filippo Vernizzi[2], and Miguel Zumalacarregui[1] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, D-14476 Potsdam-Golm, Germany — [2]Institut de Physique Theorique, Universite Paris Saclay CEA, CNRS, 91191 Gif-sur-Yvette, France

Gravitational waves (GW) can be lensed by inhomogeneities on their journey from source to observer, just as electromagnetic radiation. Lens parameters can be extracted from the phase evolution of lensed signals. Continuous GWs (CGW) have a negligible frequency evolution, so the full degeneracy between source and lens parameters limits the extraction. I will discuss how studying the interference pattern produced by strongly lensed CGWs images can enhance the inference of lens parameters. In particular, I will show that the relative motion of the lens to the source or a small frequency evolution can break this degeneracy for some systems. Finally, I will discuss detection perspectives of CGWs lensing for Earth and space-based detectors and elaborate on some possible applications of this tool.

GR 5.4 Tue 17:15 GR-H2

Scattering gravitational waves off effective spinning black holes — •Venkata Sai Saketh Muddu and Justin Vines — Max Planck institute for gravitational physics, Potsdam Science Park Am Mühlenberg 1 D-14476 Potsdam, Germany

The scattering of gravitational waves off a black hole contains valuable information characterizing the response of a black hole to an external gravitational field. We present a new method for computing scattering amplitudes for this process, using an effective worldline theory where the black hole is treated as a point particle equipped with multipole moments. These moments can be intrinsic or induced. The effective action couples the black hole's moments to an external gravitational field via interaction terms, which contain unknown coefficients. We consider a plane wave impinging on the black hole and consider its response to the incoming wave. In the effective theory, this leads to a scattered wave produced by the black hole. Comparing the scattered wave to the incident wave gives us the amplitude. We solve for the amplitude iteratively in powers of spin (the Kerr ring radius). Comparing the amplitude from the effective theory to that obtained by solving the Teukolsky equation in a Kerr background can fix the unknown coefficients in the effective action. Using our amplitude as an effective "gravitational Compton amplitude" in a triangle unitarity cut, we can also compute contributions to the relativistic scattering amplitude and subsequently the radial action for black-hole–black-hole scattering.

GR 5.5 Tue 17:35 GR-H2

Black-hole ringdown as a probe of higher-curvature gravity theories — •Abhirup Ghosh[1], Hector O. Silva[1], and Alessandra Buonanno[1,2] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, Potsdam 14476, Germany — [2]Department of Physics, University of Maryland, College Park, MD 20742, USA

Observations of gravitational waves from the mergers of compact objects like black holes have allowed us to test, for the first time, the nature of strong-field gravity. Albert Einstein's theory of General relativity (GR) remains our best description of gravitational interaction, and most of the strong-field tests of gravity demonstrated on LIGO-Virgo signals have been null tests of GR, i.e, they check for consistency between observations and predictions of GR and place bounds on possible deviations from these predictions. Issues such as the quantization of GR and the cosmological constant problem suggest that Einstein's theory might not be a complete description of gravity and might require modifications. In this work, we use observations of the black hole ringdown from the latest LIGO-Virgo catalog of gravitational wave signals (GWTC-3) in an attempt to constrain possible deviations due to well-motivated higher-curvature theories of gravity.

GR 5.6 Tue 17:55 GR-H2

Probing new physics on the horizon of black holes with gravitational waves — •Elisa Maggio — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, 14476 Potsdam, Germany

Black holes are the most compact objects in the universe. According to general relativity, black holes have a horizon that hides a singularity where Einstein's theory breaks down. Recently, gravitational waves opened the possibility to probe the existence of horizons and investigate the nature of compact objects. This is of particular interest given some quantum-gravity models which predict the presence of horizonless and singularity-free compact objects. Such exotic compact objects can emit a different gravitational-wave signal relative to the black hole case. In this talk, I overview the gravitational-wave phenomenology of exotic compact objects. I infer how extreme mass-ratio inspirals observable by future gravitational-wave detectors will allow for model-independent tests of the black hole paradigm.

GR 5.7 Tue 18:15 GR-H2

General Relativity from Worldline Quantum Field Theory — •Gustav Uhre Jakobsen — Humboldt-Universität zu Berlin, Berlin, Germany — Max-Planck-Institut für Gravitationsphysik, Potsdam, Germany

The worldline quantum field theory (WQFT) has recently been developed in order to describe classical gravitational interactions. While the goal is to analyse bound dynamics of binaries and their gravitational waves, this framework most naturally describes scattering (unbound) events. This in line with other quantum field theoretic approaches. However, several insights from this field has shown that the two regimes of unbound vs bound motion are intrinsically related.

I will present our current supersymmetric WQFT which describes spinning black holes or stars. Here, the supersymmetry encodes the symmetries of the spin degrees of freedom. I will consider several of the scattering observables that we have derived from this WQFT and how they can be related to bound ones. Examples are the eikonal, the spin kick and the total deflection.

Finally, I will consider future perspectives and challenges of the WQFT. This includes extending the WQFT in order to describe new phenomenological aspects of e.g. neutron stars and improving the integration techniques in order to increase precision of observables.

GR 6: Cosmology

Time: Tuesday 16:15–18:15 Location: GR-H3

GR 6.1 Tue 16:15 GR-H3

Psi in the sky - the cosmology window on wavelike dark matter — •Cora Uhlemann — Newcastle University, Newcastle-upon-Tyne, UK

Despite the astonishing success of cosmological probes in constraining the LCDM model, the dark matter mass remains one of the least constrained physical parameters. Wavelike dark matter is an intriguing alternative to standard cold dark matter with key particle physics motivations (like the QCD axion or ultralight axion-like particles) and distinct astrophysical signatures. With a simple dynamical model for the evolution of the dark matter wavefunction (Psi), I will demonstrate how to predict the formation of topological defects and granules arising from destructive and constructive wave interference. Together with the wave interference imprint on substructures that leads to exciting and varied probing mechanisms bridging cosmology, astrophysics and particle physics.

GR 6.2 Tue 16:35 GR-H3

The Schrödinger-Poisson Equation in One Spatial Dimension — •Nico Schwersenz[1], Tim Zimmermann[2], Victor Loaiza[3], Javier Madroñero[3], Massimo Pietroni[4,5], Luca Amendola[1], and Sandro Wimberger[4,5] — [1]Institut für Theoretische Physik, Universität Heidelberg, Germany — [2]Institutt for Teoretisk Astrofysikk, Universitetet i Oslo, Norway — [3]Departamento de Física, Universidad del Valle, Cali, Colombia — [4]Dipartimento di Scienze Matematiche, Fisiche e Informatiche, Università di Parma, Italy — [5]INFN, Sezione di Milano Bicocca, Gruppo Collegato di Parma, Italy

Despite the success of Wave-like Dark Matter [1] in explaining cosmological processes, its major issue is the high demand in computational resources. Not only does the non-linear, non-local nature of the underlying Schrödinger-Poisson equation pose a problem, but also the range of scales that have to be resolved. We construct two distinct one-dimensional toy models [2] that are less expensive from a numerical viewpoint, but still provide analogues to the phenomena observed in three dimensions. Our high-precision numerical technique is tested by an independent method. Some exemplary results will be shown for two different ways of treating the transverse dimensions, assuming uniform matter distribution in the first and strong confinement - effectively renormalizing the mass - in the second case.

[1] J. C. Niemeyer, Progress in Particle and Nuclear Physics **113**, 103787 (2020)
[2] T. Zimmermann, N. Schwersenz, M. Pietroni, S. Wimberger, Physical Review D **103**, 083018 (2021)

GR 6.3 Tue 16:55 GR-H3

The Hawking energy of a cosmic observer in linearly perturbed FLRW — •Dennis Stock and Ruth Durrer — Université de Genève, Département de Physique Théorique and Center for Astroparticle Physics, 24 quai Ernest-Ansermet, CH-1211 Genève 4, Switzerland

Addressing cosmological questions exclusively based on observations requires a formulation on the past lightcone of the cosmic observer. In this talk, the question of how to define gravitational energy associated with the past lightcone of a cosmic observer is studied by introducing Hawking's quasi-local energy as a tentative energy measure of the observable Universe. The Hawking energy phenomenologically quantifies energy in terms of light bending. This talk will mainly focus on the relation of the Hawking energy to cosmological observables within linear perturbation theory on an FLRW background.

GR 6.4 Tue 17:15 GR-H3

Influence of cosmological expansion in local experiments — •Felix Spengler[1], Alessio Belenchia[1,2], Dennis Rätzel[3], and Daniel Braun[1] — [1]Intitut für theoretische Physik, Universität Tübingen, Tübingen, Germany — [2]Centre for Theoretical Atomic, Molecular, and Optical Physics, School of Mathematics and Physics, Queens University, Belfast, United Kingdom — [3]Humboldt Universität zu Berlin, Institut für Physik, Berlin, Germany

Whether the cosmological expansion can influence the local dynamics, below the galaxy clusters scale,has been the subject of intense investigations. We consider McVittie and Kottler spacetimes, embedding a spherical object in an expanding Friedmann-Lemaître-Robertson-Walker spacetime as a rough approximation of a local environment immersed in a globally expanding universe. We then calculate the influence of the cosmological expansion on the frequency shift of a resonator moving along different trajectories and estimate its effect on the exchange of light signals between local observers. Our results show the impact of the global expansion on these local experiments and give and upper estimate on the effects we can expect in more realistic conditions below the galaxy clusters scale.

GR 6.5 Tue 17:35 GR-H3

Reaching precision cosmology faster with velocities — •Miguel Quartin — Institute of Theoretical Physics, Heidelberg University, Philosophenweg 16, Heidelberg — Instituto de Física, Universidade Federal do Rio de Janeiro, 21941-972, Rio de Janeiro, RJ, Brazil

We will show how standard candles such as type Ia supernovae and standard sirens can be used as tracers of both density and velocity fields, thus serving a new purpose in cosmology beyond mere distance indicators. We discuss how these new tracers can be combined with galaxy surveys, combining galaxy and supernova position and redshift data with supernova peculiar velocities, obtained through their magnitude scatter. The full method relies on a 6x2pt analysis which includes six power spectra. We proceed then to forecast the performance of future surveys like LSST and 4MOST with a Fisher Matrix analysis, adopting both a model-dependent and a model-independent approach. We compare the performance of the 6x2pt approach to the traditional one using only galaxy clustering and some recently proposed combinations of galaxy and supernovae data and quantify the possible gains by optimally extracting the linear information. We show that the 6x2pt method shrinks the uncertainty in growth of structure parameters significantly. The combined clustering and velocity data on the growth of structures has uncertainties at similar levels to those of the CMB but exhibit orthogonal degeneracies, and the combined constraints yield very large improvements in parameters both at the background and perturbation-level.

GR 6.6 Tue 17:55 GR-H3

First constraints on the intrinsic CMB dipole and our velocity with Doppler and aberration — •Pedro da Silveira Ferreira — Observatório do Valongo, Universidade Federal do Rio de Janeiro, Rio de Janeiro - RJ, Brazil

We test the usual hypothesis that the Cosmic Microwave Background (CMB) dipole, its largest anisotropy, is due to our peculiar velocity with respect to the Hubble flow by measuring independently the Doppler and aberration effects on the CMB using Planck 2018 data. We remove the spurious contributions from the conversion of intensity into temperature and arrive at measurements which are independent from the CMB dipole itself for both temperature and polarization maps and both SMICA and NILC component-separation methods. Combining these new measurements with the dipole one we get the first constraints on the intrinsic CMB dipole. Assuming a standard dipolar lensing contribution we can put an upper limit on the intrinsic amplitude: 3.7mK (95% CI). We estimate the peculiar velocity of the solar system without assuming a negligible intrinsic dipole contribution: $v = (300^{+111}_{-93})$ km/s with $(l, b) = (276 \pm 33, 51 \pm 19)°$ [SMICA], and $v = (296^{+111}_{-88})$ km/s with $(l, b) = (280 \pm 33, 50 \pm 20)°$ [NILC] with negligible systematic contributions. These values are consistent with the peculiar velocity hypothesis of the dipole.

GR 7: General Relativity

Time: Wednesday 11:00–11:45 Location: GR-H2

Invited Talk GR 7.1 Wed 11:00 GR-H2
Numerical Relativity and Gravitational Wave Observations — •Harald Pfeiffer — Max-Planck-Institute for Gravitational Physics

Gravitational wave detectors have observed nearly 100 mergers of compact object binaries since the ground-breaking first observation in 2015. Direct supercomputer calculations are the only means to access the highly dynamic and nonlinear merger phase of such binaries. The simulations elucidate the behavior of space-time and matter in the extreme conditions near merger and play a crucial part in detection and analysis of gravitational wave observations. This talk introduces the techniques of numerical relativity and surveys some recent results. The talk then highlights the importance of numerical relativity simulations for gravitational wave astronomy.

GR 8: Gravitational Waves

Time: Wednesday 11:45–12:25 Location: GR-H2

GR 8.1 Wed 11:45 GR-H2
On the accuracy of gravitational-wave observations — •Frank Ohme — Max-Planck-Institut für Gravitationsphysik (AEI), Hannover, Deutschland — Leibniz-Universität Hannover, Deutschland

The catalogue of gravitational-wave observations continues to grow with every LIGO-Virgo observing run. Nearly 100 signals from compact binary mergers have been identified in the first three runs. Each signal's source properties are determined by comparing theoretical models with the data. This process is subject to two categories of uncertainties (or errors): statistical errors account for the presence of detector noise; systematic errors arise from inaccuracies of the signal models. I this talk, I will highlight ways to measure and compare the two sources of errors and assess how they impact current and future gravitational-wave observations.

GR 8.2 Wed 12:05 GR-H2
Dynamical tides and gravitational scattering — •Jan Steinhoff — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam, Germany

Gravitational wave astronomy offers a promising tool to infer the nuclear physics of neutron stars from observations of inspiraling and merging binaries. This talk addresses the necessity to accurately model dynamical tidal effects during the inspiral, for instance the resonant excitation of neutron star oscillation modes, for the era of third generation detectors. For this purpose, a fully relativistic effective-field-theory model for tidal effects is put forward. Gravitational scattering is discussed as a promising Gedanken experiment to determine the tidal parameters of the model, and for modeling binary systems in general.

GR 9: Gravitational Waves

Time: Wednesday 16:15–18:35 Location: GR-H2

GR 9.1 Wed 16:15 GR-H2
Machine Learning Gravitational-Wave Search Mock Data Challenge — •Marlin Benedikt Schäfer — Albert-Einstein-Institut, D-30167 Hannover, Germany — Leibniz Universität Hannover, D-30167 Hannover, Germany

Gravitational wave astronomy is a rapidly growing field and the number of detections is rising faster with each observational period. With this come new challenges when extracting the signals from noise. A new approach to handle large quantities of data and possibly search regions of parameter space that are computationally prohibitive to search with state-of-the-art classical algorithms is the utilization of machine learning techniques. This projects aims to clarify the capabilities of current deep learning algorithms and how they compare to traditional methods. The challenge provides mock data of gradually increasing realism to aid the adoption of machine learning based algorithms in detection pipelines and wants to help establishing the wide adoption of astrophysically motivated evaluation metrics.

GR 9.2 Wed 16:35 GR-H2
New generation effective-one-body waveforms for binary black holes with non-precessing spins — Serguei Ossokine[1], Deyan Mihaylov[1], •Lorenzo Pompili[1], Alessandra Buonanno[1,2], Michael Pürrer[1], and Mohammed Khalil[1,2] — [1]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, Potsdam 14476, Germany — [2]Department of Physics, University of Maryland, College Park, Maryland 20742, USA

We present an improved inspiral-merger-ringdown gravitational waveform model for quasi-circular, spinning, non-precessing binary black holes within the effective-one-body (EOB) formalism. Compared to its predecessor SEOBNRv4HM the waveform model i) incorporates recent high-order post-Newtonian results in the inspiral, with improved factorizations ii) includes the gravitational modes $(\ell, |m|) = (3, 2), (4, 3)$, in addition to the $(\ell, |m|) = (2, 2), (3, 3), (2, 1)(4, 4), (5, 5)$ modes already implemented in SEOBNRv4HM iii) has been recalibrated to larger mass ratios and spins using a catalog of 441 numerical-relativity (NR) simulations, and to 13 additional waveforms from black-hole perturbation theory. The accuracy of the waveform model is quantified by computing the unfaithfulness against the NR catalog used for its construction. The waveform model has been implemented in a new Python framework, that makes it easily extensible to include spin-precession and eccentricity effects, thus making it the starting point for a new generation of EOB waveform models (SEOBNRv5) to be employed for upcoming observing runs of the LIGO-Virgo-KAGRA detectors.

GR 9.3 Wed 16:55 GR-H2
TEOBResumS: an advanced waveform model for O4 — •Rossella Gamba — Friedrich-Schiller-Universität Jena, Jena, Germany

The detection of Gravitational Waves by LIGO and Virgo opened a new, exceptional avenue for studying the physics of binary systems of compact objects, such as black holes and neutron stars. Source properties can be extracted from the LIGO/Virgo data via matched filtering techniques that employ waveform templates, i.e. theoretical models of the gravitational waves (GWs) emitted by the two coalescing bodies. To be able to obtain the largest amount of information from the data, such models must incorporate a large amount of physics while retaining high faithfulness to waveforms from numerical relativity simulations. In this talk I will present TEOBResumS, an efficient state-of-the-art waveform model for GWs from generic binary systems. I will detail the physics included, highlight its computational efficiency and faithfulness and show applications to real and simulated data in view of the fourth observing run O4, planned for late 2022.

GR 9.4 Wed 17:15 GR-H2
TEOBResumS for black-hole-neutron star merger waveforms — •Alejandra Gonzalez[1], Rossella Gamba[1], Matteo Breschi[1], Francesco Zappa[1], Sebastiano Bernuzzi[1], and Alessandro Nagar[2] — [1]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743, Jena, Germany — [2]INFN Sezione di Torino, Via P. Giuria 1, 10125 Torino, Italy

We present a new effective-one-body (EOB) model for black-hole-neutron-star merger waveforms based on a numerical-relativity (NR) informed model of the remnant BH state and a ringdown that deforms the EOB ringdown for binary black holes. The new model reproduces the (2,2) mode waveform of NR simulations with typical phase agreement within 0.5 rad to merger and within 1 rad including ringdown. Comparing to other available BHNS waveform models, the NR phasing is captured with a comparable accuracy. The model also includes higher modes (2,1), (2,2), (3,2), (3,3), (4,4) and (5,5). We present a full Bayesian analysis of the gravitational-wave events GW190814, GW200105, and GW200115, and find consistent results with previous studies.

GR 9.5 Wed 17:35 GR-H2

Realistic observing scenarios for the next decade of early warning detection of binary neutron stars — Ryan Magee[1] and •Ssohrab Borhanian[2] — [1]California Institute of Technology, Pasadena, USA — [2]Friedrich-Schiller-Universität Jena, Jena, Germany

We describe realistic observing scenarios for early warning detection of binary neutron star mergers with the current generation of ground-based gravitational-wave detectors as these approach design sensitivity. Using Fisher analysis, we compute both the number of detections and the sky localizations to expect from future detector network configurations. We estimate that the Advanced LIGO and Advanced Virgo facilities will detect two signals before merger in their fourth observing run, while the addition of the Kagra and LIGO-India detectors, at design sensitivites, should increase these numbers to the order of 10 early warning detections per year in the fifth observing run. More than 70% of these events will be localized to less than $100\,\mathrm{deg}^2$, with one achieving a localization of $\sim 20\,\mathrm{deg}^2$. Given uncertainties in sensitivities, participating detectors, and duty cycles, we include a data release that allows for full generalizability of future detector networks so electromagnetic observers can tailor preparations towards their preferred models.

GR 9.6 Wed 17:55 GR-H2

Quantifying modelling uncertainties when combining multiple gravitational-wave detections from binary neutron star sources — •Nina Kunert[1], Peter Tsun Ho Pang[2,3], Ingo Tews[4], Michael William Coughlin[5], and Tim Dietrich[1,6] — [1]Institute for Physics and Astronomy, University of Potsdam, D-14476 Potsdam, Germany — [2]Nikhef, Science Park 105, 1098 XG Amsterdam, The Netherlands — [3]Institute for Gravitational and Subatomic Physics (GRASP), Utrecht University, Princetonplein 1, 3584 CC Utrecht, The Netherlands — [4]Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA — [5]School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA — [6]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Muehlenberg 1, Potsdam 14476, Germany

The combined analysis of multiple gravitational-wave signals from binary neutron star sources enables to constrain the neutron-star radius with unprecedented accuracy in the near future. However, it is crucial to ensure that uncertainties inherent in the gravitational-wave models will not lead to systematic biases when multiple detections are combined. To quantify waveform systematics, we perform an extensive simulation campaign of binary neutron-star sources and analyse them with a set of four different waveform models. We find that statistical uncertainties in the neutron-star radius decrease to ±250m (2% at 90% credible interval), while systematic differences among currently employed waveform models can be twice as large emphasizing the need for waveform models with increased accuracy.

GR 9.7 Wed 18:15 GR-H2

Neutrino and viscosity effects on binary neutron star dynamics, gravitational waves and emitted material — •Francesco Zappa — Friedrich-Schiller-Universität Jena Theoretisch-Physikalisches Institut

We present a multi-resolution and multi-physics comparison of simulations performed with the `WhiskyTHC` code of a single binary*neutron star merger with component neutron star mass of 1.3 $M_\odot$ using the finite-temperature equation of state SLy4. Our simulations set consists of pure General Relativistic Hydrodynamic evolution; simulations with a leakage scheme for neutrino production; runs which include M0 treatment for the propagation of free-streaming neutrinos; simulations which include an effective treatment for magnetic-driven turbulent viscosity; simulations which make use of the `THC_M1` scheme recently implemented in the code for neutrino treatment. We find that the effect of resolution is dominant with respect to the different physics simulated regarding the gravitational wave production and the merger dynamics, as well as on the onset of black hole collapse. The post-merger disk mass, the disk composition and its thermodynamic properties are instead affected by the production of neutrinos or the presence of turbulent viscosity. The ejected mass and its proton fraction has a very strong dependence on the neutrino treatment employed. Our higher resolution runs confirm that the proton-richest matter is produced when employing M1, at small angles from the orbital plane.

GR 10: Foundations and Alternatives

Time: Wednesday 16:15–18:35 Location: GR-H3

GR 10.1 Wed 16:15 GR-H3

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 Raum-Zeit, welche die viel einfachere euklidische Geometrie ersetzten musste. Sie (Einsteins Ansatz) führt dabei zu logischen Konflikten, sobald es nicht um lineare Bewegung, sondern um Drehung geht. Einstein hat diese Konflikte sogar gegenüber seinem Kollegen Lorentz eingeräumt. Doch hat er 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 Materie und dunkle Energie entfallen gänzlich. Dabei sind die Ergebnisse die gleichen wie bei Einstein, sowohl für die spezielle als auch die allgemeine Relativität.

Further info: www.ag-physics.org/relat

GR 10.2 Wed 16:35 GR-H3

Relativitätstheorie 2.0 — •Ralf R. Lenke — 73466 Lauchheim

Das Relativitätsprinzip ist eine fundamentale Eigenschaft unseres Universums. Albert Einstein leitete daraus auf 'mathematischem' Weg seine Relativitätstheorie (RT) ab. Bis heute ungeklärt ist allerdings, warum unser Universum dem Relativitätsprinzip folgt. Bis heute gibt es dafür kein in sich geschlossenes, 'physikalisch anschauliches' Modell.

Das grundlegende Experiment für die RT war das Michelson-Morley-Experiment (MME). Aus ihm leitet sich u.a. die 'Lichtuhr' ab, als anschauliche Erklärung für die relativistische Zeitdilatation. Aber darüber hinaus gibt es keine weiteren, wirklich anschaulichen Erklärungen; weder für die Gleichzeitigkeit, und schon gar nicht für die relativistische Längenkontraktion. Diese Asymmetrie in der Anschauung sollte eigentlich verwundern, angesichts der ansonsten herrschenden Symmetrie in Raum und Zeit, der sogenannten 4-dimensionalen Raumzeit.

Tatsächlich steckt im MME mehr: Eine rigorose Betrachtung des MME mit den Mitteln der klassischen Optik führt zum 'seitlich driftenden' Lichtstrahl, welcher Zeitdilatation, Längenkontraktion und Gleichzeitigkeit auf einen Blick offensichtlich werden lässt. Daraus folgt unmittelbar, dass die spezielle RT eine direkte Folge des Wellencharakters der Natur ist und die Lorentz-Transformationen nichts weiter sind als der Doppler-Effekt.

Diese Arbeit geht weit über einen didaktischen Aspekt hinaus. Relativitätstheorie und Quantenmechanik erscheinen unter einem ganz neuen Blickwinkel.

Weitere Informationen unter: https://die-neue-relativitaetstheorie.de/

GR 10.3 Wed 16:55 GR-H3

Noether's Theorem and Gravitation in Multi-Particle Systems — •Walter Smilga — Geretsried, Deutschland

According to Noether's theorem, the total momentum of an isolated multi-particle system (of massive particles) is conserved as consequence of translational invariance. In agreement with the inverse of Noether's theorem, the individual particle momenta are in general not conserved but time-dependent. The conservation of the total momentum constrains the temporal variability of the particle momenta. Constraints on the particle momenta imply constraints on the particle trajectories. The constrained particle trajectories define a pseudo-Riemannian spacetime described by the field equations of Conformal Gravity. This spacetime is 'quantised' without problems, leading to a consistent quantum gravity.

GR 10.4 Wed 17:15 GR-H3

Theses for a Closed, Self Sustaining and Timeless Universe — •Thomas Wäscher — IBW Engineering, 69231 Rauenberg

To overcome the persistent non-detectability of presumed Dark Matter and Dark Energy theses are given which implicate the need for a strong paradigm shift in the standard model of cosmology.

1. The universe is curved and closed by its own gravity, it is in the mean homogenious, isotropic and adiabat (Einstein universe) with a constant all over visible CMB-event horizon short before $R = c/H$ [m].

2. The universe is dominated by a stabilizing internal process cycle of the stationary power emission of radiation $P = c^5/2G$ [W] balanced by the equivalent mass flow of $\dot{m} = c^3/2G$ [kg/s]

3. Normalised by the lookback time $t = r/c$ the Hubble eqn. $v = Hr$ results in $|a| = Hc$ [m/s^2], a scalar background field creating gravity deviations e.g. rotation anomalies.

4. Crossing the universe the radiation is subject to redshift z by gathering the grav. potential $z = \Phi/\Phi o = ar/c^2$ (linear up to $z \approx 0.1$, relativistic $z = ((1 + ar/c^2)/(1 - ar/c^2))^{0.5} - 1)$

5. The understanding of the Hubble parameter H changes from a velocity per distance (≈70km/sMpc) to a decay constant $H \approx 2.27 \times 10^{-18}$ [s^{-1}], which might be the real origin of gravity.

6. Theses 1-5 demand recycling of elements Z>1 to generate fresh hydrogen. Most probably this happens in the core of millions of neutron stars (i.e. pulsars) where nuclei can be unlocked down to the scale of quarks by the extreme gravity. As observed for long, huge clouds of H are outflowing bidirectional from the disc level of galaxies.

GR 10.5 Wed 17:35 GR-H3

Zur Sommerfeld Feinstrukturkonstante aus der Sicht Einsteins — •Geilhaupt Manfred — Mönchengladbach, Webschulstr. 31

Einstein (1923) zu seinem Kollegen Dirac: "Eine Theorie die Ladung und Masse des Elektrons a priori setzt ist unvollständig." Das gilt nun seit 100 Jahren sowohl für die ST also auch für die ART. Dirac (1965 in Scientific American) mit seiner Hypothese, Elektron-Masse (m) und Ladung (e) und Lichtgeschwindigkeit (c) sind DIE fundamentalen Naturkonstanten, die Gravitationskonstante (G) und die Planck-Konstante (h) aber nicht, hatte mit diesen Annahmen keine Chance, eine Lösung zu finden. Wenn man die ART mit den Prinzipien der TD verbindet, liefert die Bewegungsgleichung der ART für ein RUHENDES Elektron, sowohl Masse, Ladung und überraschenderweise auch die Sommerfeld FSK (siehe DPG 2019). Es zeigt sich, dass diese FSK auch mit der Ruhemasse in Beziehung steht und nicht nur mit der Elementarladung. Darüberhinaus hängt die FSK von der Metrik des Einstein-Raumes ab. Wenn Parker (1/137.035999048(27)) und Morel (1/137.035999206(11)) beide im Januar und im Juli ihre Messungen wiederholen, wird der Unterschied in der Metrik aufgrund des Sonnenstandes um +-(46) variieren. (The last word has the experiment.)

GR 10.6 Wed 17:55 GR-H3

Explanation of Quantum Physics by Gravity and Relativity — •Hans-Otto Carmesin — Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen — Studienseminar Stade, Bahnhofstraße 5, 21682 Stade

Since Planck discovered quantization in 1900, the nature of quanta was a mystery. That problem has now been resolved [1]. For it, I derived the postulates of quantum physics from the equivalence principles, gravity and relativity, whereby I analyzed the vacuum.

Using that derivation, I explain many quantities and properties of quantum physics in a precise manner. Examples are the nature of nonlocality, the physical quantity corresponding to the wave function ψ, the mathematical transformation describing the particle wave duality and the origin of the dynamics inherent to the Schrödinger equation. Moreover, I propose and derive the generalized Schrödinger equation. Especially, I solve the EPR paradox. Furthermore, I identify the physical basis of the Planck constant h.

Altogether, quantum physics has now been derived, explained and extended in a direct and transparent manner on the basis of space, time and gravity. As an additional and global test of that explanation, I derive the density parameter Ω_Λ of the vacuum or of dark energy in the universe by using the wave function ψ. The result is in precise accordance with observation, whereby I do not apply any fit.

[1] Carmesin, H.-O. (February 2022): Explanation of Quantum Physics by Gravity and Relativity. Berlin: Verlag Dr. Köster.

GR 10.7 Wed 18:15 GR-H3

5th edition of "Special and general theory of relativity for ..." — •Jürgen Brandes — Karlsbad, Germany

Exactly and comprehensibly are discussed in [1]: The experimental proofs of relativity theory, the solutions of the paradoxes and the EINSTEIN- and LORENTZ-interpretation of special and general relativity. Included are the twin paradox and the paradoxes of BELL, EHRENFEST and SAGNAC.

THORNE, Nobel Prize 2017, calls these interpretations the *curved spacetime paradigm* and the *flat spacetime paradigm* and states: "It is extremely useful, in relativity research, to have both paradigms at one's fingertips." Consenting, both interpretations are discussed in equal rights.

An important point in [1] concerns energy conservation. Within NEWTON's theory there is a negative gravitational potential, on account of the famous relation $E = mc^2$ this means negative masses. Negative masses don't exist. Neither NEWTON's nor EINSTEIN's theory can explain the meaning of the negative energy of particles resting in the gravitational field. Additionally, in certain limiting cases there exist contradictious formulas of total energy. In both cases LORENTZ-interpretation gives a clear, experimentally verifiable answer.

[1] J. Brandes, J. Czerniawski, L. Neidhart: *Spezielle und Allgemeine Relativitätstheorie für Physiker und Philosophen - Einstein- und Lorentz-Interpretation, Paradoxien, Raum und Zeit, Experimente*, 5th edition, VRI: 2022. [2] homepage www.grt-li.de

GR 11: Relativistic Astrophysics

Time: Thursday 11:00–12:40 Location: GR-H2

GR 11.1 Thu 11:00 GR-H2

Constraining supranuclear-dense matter with nuclear physics and multi-messenger astrophysics — •Tim Dietrich — Institute of Physics and Astronomy, University of Potsdam, Potsdam, Germany — Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Potsdam, Germany

Our knowledge about dense matter explored in the cores of neutron stars remains limited. Fortunately, the detection of gravitational waves emitted from the merger of neutron stars and the corresponding electromagnetic signals allows us to place constraints on the properties of matter at supranuclear densities. Furthermore, such densities are not only probed in astrophysical observations, but also in terrestrial experiments. In this work, we use Bayesian inference to combine a large set of data from astrophysical multi-messenger observations of neutron stars and from heavy-ion collisions of gold nuclei at relativistic energies with microscopic nuclear theory calculations. Our findings show that constraints from heavy-ion collision experiments show a remarkable consistency with multi-messenger observations and provide complementary information on nuclear matter at intermediate densities. This work combines nuclear theory, nuclear experiments, and astrophysical observations from multiple messengers. Such joint analyses will be the key to shed light on the properties of neutron-rich supranuclear matter over the density range probed in neutron stars.

GR 11.2 Thu 11:20 GR-H2

Tidally-driven crustal failure in coalescing binaries of neutron stars as triggers for precursor flares of short gamma-ray burst — •Hao-Jui Kuan[1,2], Arthur Suvorov[3], and Kostas Kokkotas[1]

— [1]Theoretical Astrophysics, IAAT, University of Tübingen, Tübingen, D-72076, Germany — [2]National Tsing Hua University, Hsinchu 300, Taiwan — [3]Manly Astrophysics, 15/41-42 East Esplanade, Manly, NSW 2095, Australia

In some short gamma-ray bursts, precursor flares occurring ∼ 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. Among other possible modes, the typical frequencies of g-modes being ∼ 100 Hz warrant further investigation since their resonances with the orbital frequency match the precursor timings. Adopting realistic equations of state (EOS) 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, and also some EOS are more likely to cause the crustal cracks.

GR 11.3 Thu 11:40 GR-H2

Non-thermal electromagnetic counterparts to binary neutron star mergers and supernovae — •Vsevolod Nedora — Max-Planck-Institut für Gravitationsphysik, Potsdam, Germany — Universität Potsdam, Potsdam, Germany

In 2017 the merger of two neutron stars was observed in gravitational waves and across the electromagnetic spectrum. The event was associated with the short gamma-ray burst (GRB) GRB170817A, the afterglow from which peaked 160 days after the burst, before starting to decay in agreement with short GRB models. Much later, 1234 days after the burst, a change in the GRB170718A light curve behavior was observed, inconsistent with most GRB models.

We design a new numerical tool to model the synchrotron radiation arising from interactions between the ejected matter and the interstellar medium, employing the recent theoretical advancements in our understanding of relativistic jetted and oblate mildly relativistic outflows.

Assuming that the change of the afterglow is due to an emerging new component (e.g., kilonova ejecta), we investigate the properties of this component by modeling kilonova and GRB afterglows simultaneously. This allows us to take advantage of all the gathered data and obtain new constraints on the dynamics of the ejected matter and NS EOS.

GR 11.4 Thu 12:00 GR-H2

Fast Rotating Relativistic Stars: Spectra and Stability without Approximation — •Christian Krueger and Kostas Kokkotas — Universitaet Tuebingen, Auf der Morgenstelle 10, 72076 Tuebingen

The oscillations and instabilities of relativistic stars are studied by taking into account, for the first time, the contribution of a dynamic spacetime. The study is based on the linearised version of Einstein's equations and via this approach the oscillation frequencies, the damping and growth times as well as the critical values for the onset of the secular (CFS) instability are presented. The ultimate universal relations for asteroseismology are derived which can lead to relations involving the moment of inertia and Love numbers in an effort to uniquely constrain the equation of state via all possible observables. The results are important for all stages of neutron star's life but especially to nascent or post-merger cases.

GR 11.5 Thu 12:20 GR-H2

Exploring black holes as particle accelerators: hoop-radius and escaping conditions — Stefano Liberati[2], •Christian Pfeifer[1], and Javier Relancio[3] — [1]University of Bremen, Bremen, Germany — [2]SISSA and INFN, Trieste, Italy — [3]Università di Napoli Federico II, Napoli, Italy

The possibility that rotating black holes could be natural particle accelerators has been subject of intense debate. While it appears that for extremal Kerr black holes arbitrarily high center of mass energies could be achieved, several works pointed out that both theoretical as well as astrophysical arguments would severely dampen the attainable energies. In this talk I study particle collisions near Kerr black holes, in particular collision between an infalling particle from infinity and a target particle that is already in the near vicinity of the black hole horizon. Most importantly, I will show how to implement the hoop conjecture and discuss the astrophysical relevance of these target particle collisional Penrose processes. The outcome is that the center of mass energy in such collisions can be ultra high. Moreover, I discuss that for nearly extremal black holes, the energy of the particles escaping the black hole region can be similarly large. Thus, these target particle collisional Penrose processes could contribute to the observed spectrum of ultra high-energy cosmic rays, even if the hoop conjecture is taken into account.

GR 12: Quantum gravity (joint session MP/GR)

Time: Thursday 11:00–12:40 Location: MP-H5

Invited Talk GR 12.1 Thu 11:00 MP-H5

Reduced phase space quantisation in Loop quantum gravity and loop quantum cosmology — •Kristina Giesel[1], Bao-Fei Li[2], and Parampreet Singh[2] — [1]Institute for Quantum Gravity, Department of Physics, FAU Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen, Germany — [2]Department of Physics and Astronomy, Louisiana State University, Baton Rouge, LA 70803, USA

In this talk an overview over results that apply a reduced phase space quantisation to formulate the dynamics of loop quantum gravity and loop quantum cosmology will be presented. It will be briefly discussed how a reduced phase space for GR can be derived by coupling additional reference matter. The reduced phase space for GR is taking as a starting point for a loop quantisation either in full LQG or in the symmetry reduced case of LQC. Different choices of reference matter yield in general different quantum models and several existing models will be compared. In the framework of LQC it will be analysed how different choices of reference matter can lead to different physical properties of the models and it will be discussed what kind of conditions appropriate reference matter should satisfy in this context.

Invited Talk GR 12.2 Thu 11:30 MP-H5

Quantum fields propagating on curved backgrounds and their influence on spacetime curvature — •Nicola Pinamonti — Department of Mathematics, University of Genova, Italy

We shall review the theory of quantum fields propagating on curved backgrounds in the semiclassical approximation. Within this approximation matter is described by quantum fields propagating on a classical curved spacetime and their influence on spacetime curvature is taken into account by means of semiclassical Einstein equations. Typical known effects in this approximation are particle creation on cosmological spacetime, Hawking radiation in the case of black hole backgrounds and their evaporation. The semiclassical analysis we would like to present requires a careful study of the form of the correlation functions of the state which describes matter. The thorough analysis of their ultraviolet divergences and their renormalization is necessary to obtain meaningful expressions for the expectation values of the matter stress energy tensor. The resulting stress energy tensor will have nontrivial effects on the curvature on cosmological spacetimes too. In the latter case, semiclassical Einstein equations give origin to a well posed dynamical system provided the quantum state for matter is chosen in an appropriate way. The question of existence of exact solutions of such system will be discussed and some implication for cosmology will be presented. In the case of black hole physics, exploiting the stress tensor properties, we will give a local model of black hole evaporation.

GR 12.3 Thu 12:00 MP-H5

A master equation for gravitationally induced decoherence of a scalar field — •Max Joseph Fahn, Kristina Giesel, and Michael Kobler — Institute for Quantum Gravity, Department of Physics, FAU Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen, Germany

In the talk, we present the derivation of a decoherence model containing a scalar field coupled to a gravitational environment. With such a model, one can predict quantum gravity effects in the scalar field's dynamics that arise due to the presence of gravity. Starting with full general relativity in Hamiltonian form expressed in Ashtekar's connection formulation, we focus on weak gravitational interactions in an asymptotically flat universe, modelled by gravitational waves propagating on a fixed background, and the scalar field as matter component. Firstly, we construct appropriate observables (gauge invariant quantities) for the model which become elementary variables in the reduced phase space of the model. Afterwards a reduced phase space quantisation using Fock quantisation is performed. With the help of the projection operator technique, we derive a second order time-convolutionless master equation, that is an effective evolution equation which predicts the temporal evolution of the scalar field, including the gravitational interaction effectively in terms of certain operators, whose form is a result of the model under consideration and several physical assumptions. These additional terms lead to physical effects like dissipation or decoherence of the matter field induced by gravity. Finally, we briefly discuss possible applications of the model's master equation.

GR 12.4 Thu 12:20 MP-H5

Quantum (supersymmetric) black holes in loop quantum gravity — •Konstantin Eder — FAU Erlangen-Nürnberg

Black holes are immediate and unavoidable consequences of Einstein's theory of gravity whose existence nowadays has been confirmed with remarkable accuracy. Albeit leading to a huge success of the theory, there are also various open questions that point out its incompleteness. One of them is about the huge amount of microstates needed to explain the entropy of black holes as predicted by Bekenstein and Hawking: What are these micostates? Answering it poses a challenge for any formulation for quantum theory of gravity. In loop quantum gravity a very intriguing picture has been developed that suggests an answer in terms of topological Chern-Simon degrees of freedom induced by quantized geometry on the horizon. In this talk, we first give a general review on the description of black hole horizons in LQG. Then, we will give an outlook on recents results towards their generalization to the supersymmetric context. There, it turns out, using tools from super Cartan geometry, that the unique boundary theory in chiral supergravity corresponds to that of a super Chern-Simons theory. This enables one to transfer ideas from the bosonic to the supersymmetric setting.

GR 13: Numerical Relativity

Time: Thursday 14:00–15:40 Location: GR-H2

GR 13.1 Thu 14:00 GR-H2

GRHD simulations with GR-Athena++ — •William Cook — Theoretisch-Physikalisches Institut, Friedrich-Schiller Universitat Jena, 07743, Jena, Germany

For the first time we demonstrate the performance of the code GR-Athena++ in evolving general relativistic hydrodynamics (GRHD) in a dynamically evolving spacetime. GR-Athena++ utilises the task-based parallelism and block based adaptive mesh refinement of the Athena++ code, as well as its approach to solving GRHD problems in stationary spacetimes; combined with new functionality to solve the Einstein equations in the Z4c formulation. We demonstrate the performance of this new code by simulating the evolution of Neutron Stars in GR-Athena++, removing the Cowling approximation assumed in previous work, presenting a fully dynamical spacetime evolution.

GR 13.2 Thu 14:20 GR-H2

Evolution of mixed binaries initial data produced with Elliptica — •Francesco Maria Fabbri[1], Alireza Rashti[2], Bernd Brügmann[1], Swami Vivekanandji Chaurasia[3], Tim Dietrich[4,5], Maximiliano Ujevic[6], and Wolfgang Tichy[2] — [1]Theoretical Physics Institute, University of Jena, 07743 Jena, Germany — [2]Department of Physics, Florida Atlantic University, Boca Raton, FL 33431, USA — [3]The Oskar Klein Centre, Department of Astronomy, Stockholm University, AlbaNova, SE-10691 Stockholm, Sweden — [4]Institut für Physik und Astronomie, Universität Potsdam, Haus 28, Karl-Liebknecht-Strasse 24/25, 14476, Potsdam, Germany — [5]Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, Potsdam 14476, Germany — [6]Centro de Ciências Naturais e Humanas, Universidade Federal do ABC, 09210-170, Santo André, São Paulo, Brazilx

In this work, we present the evolution of black hole - neutron star initial data produced with the new pseudo spectral code Elliptica. The code makes use of Schur complement domain decomposition method with a direct solver using cubed sphere coordinate maps and the fields are expanded using Chebyshev polynomials of the first kind. To stress the capability of the code we designed different configurations of mass ratios and spin orientations and we made use of the BAM code to evolve such initial data. Arbitrary spin magnitudes and orientations are evolved, with a maximum adimensional spin of 0.8 for the black hole and an arbitrary high spin for the neutron star.

GR 13.3 Thu 14:40 GR-H2

Comparison of eccentric numerical relativity simulations to small mass-ratio perturbation theory — •antoni ramos-buades, maarten van de meent, and harald pfeiffer — Max Planck Institute for Gravitational Physics, Potsdam, Germany

During the third observing run of the LIGO and Virgo detectors a few gravitational wave (GW) signals from binary black hole (BBH) mergers with unequal masses have been detected. As detectors' sensitivity continues to increase, more systems with more asymmetric masses are expected to be detected, and therefore modelling of BBHs at all mass ratios is of preeminent relevance. In this work we compare two approaches to modeling binary black holes (BBHs): 1) small mass-ratio (SMR) perturbation theory, and 2) numerical relativity (NR). We extend recent work on combining information from quasicircular nonspinning NR simulations of BBHs with results from SMR perturbation theory to nonspinning eccentric BBHs. We produce a dataset of long and accurate eccentric nonspinning NR simulations with the Spectral Einstein Code (SpEC) from mass ratios 1 to 10, and eccentricities up to 0.7. We analyze these NR simulations, compute gauge invariant quantities from the gravitational radiation, and develop tools to map points in parameter space between eccentric NR and SMR waveforms. Finally, we discuss discrepancies between SMR and NR predictions for the energy and angular momentum fluxes due to eccentricity, and limitations of such comparisons due to the limited parameter space in mass ratio covered by the NR simulations.

GR 13.4 Thu 15:00 GR-H2

Critical Collapse with bamps. — Daniela Cors Agulló[1], •Sarah Renkhoff[1], Isabel Suárez Fernández[2], Hannes Rütter[3], David Hilditch[2], and Bernd Brügmann[1] — [1]Theoretisch-Physikalisch Institut, Friedrich-Schiller-Universität, Jena, Germany — [2]CENTRA, Instituto Superior Tecnico, Lisbon, Portugal — [3]Max-Planck-Institut für Gravitationphysik, Potsdam, Germany

Our pseudo-spectral code bamps, with its new adaptive mesh refinement, allows us to tune closer to the critical point between gravitational collapse and dispersed fields. We study, on the one hand critical phenomena in spherical symmetry by evolving scalar fields using generalised harmonic gauge and compare among several gauge source functions. On the other hand, we can assess critical phenomena in an axisymmetric setting by evolving gravitational waves in vacuum. 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 13.5 Thu 15:20 GR-H2

A new approach to helical Killing vectors — •Hannes Rüter — Potsdam, Germany

Helical Killing Vectors are an important ingredient for the description of binary systems in quasi-equilibrium, which makes them one of the central quantities in the construction of numerical-relativity initial data of compact binaries. Current approaches to helical Killing vectors and their generalisations to eccentric orbits are defined in a foliation-dependent manner. In this presentation I will a discuss a new approach that attempts to break this foliation dependence.

GR 14: Gravitational Wave Detectors

Time: Thursday 16:15–18:15 Location: GR-H2

GR 14.1 Thu 16:15 GR-H2

Options for ultra-high-frequency gravitational wave detection at DESY — Axel Lindner, Krisztian Peters, •Christoph Reinhardt, Andreas Ringwald, and Aaron Spector — DESY, Hamburg, Germany

Fueled by recent achievements of km-scale gravitational-wave observatories, efforts towards the development of "down to lab-scale" detectors are currently gaining momentum. By virtue of their smaller dimensions, these detectors target gravitational-waves above the established observation window (i.e., 10 to 10^4 Hz) at "ultra-high-frequencies" (i.e., 10^4 to 10^{19} Hz). The sources proposed for generating potentially observable signals in this frequency range are of cosmological origin or require new physics beyond the Standard Model.

Current work at DESY towards three on-site experiments for axion searches (ALPS II, BabyIAXO, and MADMAX) provides the unique opportunity to exploit synergies with regard to the development of ultra-high-frequency gravitational wave detectors: On the one hand, these axion experiments are also sensitive to gravitational waves via "graviton-to-photon conversion" in the presence of a magnetic field. On the other hand, the underlying infrastructure of the axion experiments, comprising, e.g., a distribution system for liquid helium, can be a prerequisite for implementing dedicated detectors. This talk will present options for ultra-high-frequency gravitational wave searches at DESY, Hamburg.

GR 14.2 Thu 16:35 GR-H2

The implementation of stray light simulation tool for the Einstein Telescope — •Hanna Marozava and Thomas Bretz — RWTH Aachen University

The Einstein Telescope will be the first gravitational wave detector of the third generation. Stray light is a severe problem for modern interferometers with high sensitivity, as another noise source contributing to the interferometer output. Simulation is requied to optimize detector settings to avoid undesirable light paths. Stray light simulation can be done with special optical analysis software, but existing tools are not ideally suited for general application, or require expensive licences. Therefore ET optical simulation task is still urgent.

The goal of this work is development of dedicated free tool for stray light simulation, easy to use and including higher precision and different aspects of stray light. Simulation involves modelling the system design, calculating the intersection points of the rays with the surfaces and simulating of stray light paths, and algorithms for some of this steps are already found.

This talk will present the progress of stray light simulation tool development, including the analysing of existing optical software, implementation of simulation and first results.

GR 14.3 Thu 16:55 GR-H2

Development and testing of composite vacuum tubes for Einstein Telescope — •Purnalingam Revathi[1], Ralf Schleichert[2], Achim Stahl[1], Tim Kuhlbusch[1], Robert Joppe[1], and Oliver Pooth[1] — [1]III. Physikalisches Institut B, RWTH Aachen — [2]Institut für Kernphysik, Forschungszentrum Jülich

The Einstein Telescope, a proposed third generation gravitational wave detector, requires 120 km long vacuum tubes in total with a diameter of 1 m. Due to the vacuum requirements and mechanical integrity, stainless steel tubes are the standard for ultra high vacuum applications. Composite vacuum tubes are a promising alternative that could reduce material cost and opens possibilities for easier on site production.This talk presents the details of development and testing of prototypes made of Glass Fiber Reinforced Plastic wound around a stainless steel liner. Pressure stability and aging tests are performed and the possibility of integrating sensors to measure temperature and pressure will be discussed.

GR 14.4 Thu 17:15 GR-H2

Test setup for cryogenic sensors and actuators working towards the Einstein Telescope — •Robert Joppe[1], Tim Kuhlbusch[2], Thomas Hebbeker[1], Vivek Pimpalshende[2], Oliver Pooth[2], Achim Stahl[2], and Franz-Peter Zantis[1] — [1]III. Physikalisches Institut A, RWTH Aachen — [2]III. Physikalisches Institut B, RWTH Aachen

The Einstein Telescope will be the first gravitational wave detector of the third generation. The sensitivity goal, especially in the low frequency region, will be achieved among other improvements by cooling the main parts of the interferometer. The required electronic components, sensors and actuators needed for mirror alignment and active dampening of suspension resonances have to perform at cryogenic temperatures.

The talk presents the progress on the development of electronics and mechanics within the E-TEST project. The performance of our cryogenic ultra high vacuum test setup will be furthermore explicated.

GR 14.5 Thu 17:35 GR-H2

A cryogenic displacement sensor and actuator for the E-TEST project — •Kuhlbusch Tim[1], Thomas Hebbeker[2], Robert Joppe[2], Vivek Pimpalshende[1], Oliver Pooth[1], Achim Stahl[1], and Franz-Peter Zantis[2] — [1]III. Physikalisches Institut B, RWTH Aachen — [2]III. Physikalisches Institut A, RWTH Aachen

The Einstein Telescope will be the first third generation gravitational wave detector. In achieving a sensitivity increase of more than one order of magnitude at low frequencies compared to current detectors, mitigating thermal noises is essential. Cooling the mirrors to cryogenic temperatures is thus required. This also creates the need for parts of the vibration isolations systems of the mirrors to be working at low temperatures.

This talk will present the developement of an actuator with an integrated absolute displacement sensor operating below 20 K as part of the E-TEST project. The sensitivity of the sensor, the forces of the actuator and the thermal design will be discussed.

GR 14.6 Thu 17:55 GR-H2

Commissioning and characterization of a shadow sensor — •Vivek Pimpalshende[1], Thomas Hebbeker[2], Robert Joppe[1,2], Tim Kuhlbusch[1], Oliver Pooth[1], Achim Stahl[1], and Franz-Peter Zantis[2] — [1]III. Physikalisches Institut B, RWTH Aachen — [2]III. Physikalisches Institut A, RWTH Aachen

The Einstein Telescope will be the first gravitational wave detector of the third generation. It will extend the detection sensitivity in the low frequency domain by more than an order of magnitude compared to current second generation detectors. An essential factor in achieving the sensitivity goals is to mechanically decouple the optic system from the ground. For this, a seismic isolation system is in place in the interferometric gravitational wave detectors. This talk will discuss one of the essential position sensors in this system: a shadow sensor.

Displacement sensors are a part of a control loop that monitors the relative motion of the components of the suspension system and controls the absolute motion of these components. This talk will present the commissioning of a shadow sensor along with its characteristics at room temperature.

GR 15: Member Assembly

Time: Thursday 19:00–20:30 Location: GR-MV

MV-GR Member Assembly