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.