# GR 2: Classical Theory of General Relativity 1

Time: Monday 11:15–12:45 Location: H-HS IX

**Invited Talk** GR 2.1 Mon 11:15 H-HS IX

**Relativistic geodesy** — •Claus Lämmerzahl and Volker Perlick — ZARM, University of Bremen, Am Fallturm, 28359 Bremen, Germany

Owing to new higly sensitive divices like clocks, freely falling particles, spinning tops, and laser and atom interferometers on ground and in space the relativistic gravitational field of the Earth can now be measured with unprecedented accuracy. This requires a relativistic formulation of geodesy. Here a fully general relativistic scheme for geodesy is presented. Starting from stationarity two geoids can be defined for the Earth, one related to the norm of the underlying Killing vector, the other related to its twist. The first one can be measured with clocks, falling bodies, or atom interferometry, the other can be measured with spinning tops or by measuring a Sagnac effect with laser or atom interferometry. Finally, based on analyses by Hansen, Simon, and Beig a scheme is presented for measuring the full gravitational field of the Earth using laser interferometry employed by GRACE Follow On.

GR 2.2 Mon 12:00 H-HS IX

**Relativistic Geodesy - Formalism and Concepts** — •Dennis Philipp, Eva Hackmann, Volker Perlick, and Claus Lämmerzahl — ZARM, Universität Bremen

The Earth's geoid is one of the most important fundamental concepts to provide a gravity field-related height reference in geodesy and associated sciences. To keep up with the ever-increasing experimental capabilities and to consistently interpret high-precision measurements without any doubt, a relativistic treatment of geodetic notions within Einstein's theory of General Relativity is inevitable.

Building on the theoretical construction of isochronometric surfaces and the so-called redshift potential for clock comparison, we define a relativistic gravity potential as a generalization of known (post-) Newtonian notions. It is the same as realized by local plumb lines. Thereupon, the relativistic geoid is defined in direct analogy to the Newtonian understanding. Moreover, a generalized version of the so-called normal gravity field is presented. In the respective limits, well-known results are recovered.

A comparison between the Earth's Newtonian geoid and its relativistic generalization is a very subtle problem. However, an isometric embedding into Euclidean three-dimensional space can solve it and allows a genuinely intrinsic comparison of the general relativistic, the post-Newtonian, and the Newtonian concept. We employ this method and determine the leading-order differences, which are at the mm-level.

GR 2.3 Mon 12:15 H-HS IX

**Relativistic Effects on Entanglement** — •Roy Barzel and Claus Lämmerzahl — University of Bremen, ZARM, 28359 Bremen, Germany

Quantum Entanglement is not only one of the most intriguing and counter-intuitive phenomena in physics, but also plays a key role for future technologies such as Quantum Communication. Recently, in 2017 a new milestone in large scale entanglement distribution was achieved, when the entanglement between photons was verified over a distance more than 1200 kilometers.

In such a macroscopic setup, with increasingly larger distribution distances, general relativistic effects become more and more important. In this talk it is shown that particles undergo a Lorentz-Transformation and thereby a Wigner-Rotation when they travel through space-time. This can be represented as a unitary transformation, which acts on the particles quantum states, for instance electron-spin or photon-polarization. As a consequence Observers, who want to extract EPR-correlations via Bell Measurements from these particles, have to readjust their measurement basis to recover the full violation of Bell's Inequalities, which is the main result of the talk.

GR 2.4 Mon 12:30 H-HS IX

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

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

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

Some suggestions for experimental physics are given.

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