- Summary. This lecture series gives an introduction to quantum gravity from the perspective of Loop Quantum Gravity (LQG). After briefly discussing the limitations of the perturbative approach, we will develop the foundations of LQG. This includes the spin network representation of quantum geometry and the resulting dynamics in the canonical and covariant formulation. After having established the basic foundations, we will discuss a selection of current research. This includes quantum cosmology, new developments on boundary symmetries and local observables, and the oscillator representation of quantum geometry. We will also cover possible consequences of quantum gravity for future tabletop experiments. The lecture series is open to all students and researchers. No prior knowledge of general relativity or quantum field theory required.

The course will be given by Dr. Wolfgang M. Wieland, currently a researcher at IQOQI-Vienna, who will join ITP III Erlangen – Nuremberg in January 2023.

- Organisation. The course runs over five weeks, starting in the second week of January. In each week, we will have $2h$ of lectures, and $2h$ of exercises, where we solve problems in class. Each week, there is one additional hour for open discussions, where we discuss problems together and have a free exchange of ideas. Precise dates and timetable will be announced soon. The basic outline of the course is as follows:

- ***first week:** mathematical and physical foundations.* First lecture: Mathematical and physical foundations of General Relativity (differential geometry, metric, tetrads and connection, variational calculus). Second lecture: simple solutions to Einstein's equations, cosmology, elements of Quantum Field Theory. Topics for the discussion session and flipped classroom (1h): appearance of a new length scale in quantum gravity, i.e. the Planck length, limitations to our current knowledge of the functioning of nature: singularities in GR, divergencies in QFT, measurement problem.
- ***second week:** perturbative gravity and beyond.* First lecture: phase space of perturbative gravity and the concept of a graviton, limits of perturbative gravity. Second lecture: Beyond perturbative gravity, Einstein equations, covariant phase space, applications: asymptotic charges, BH thermodynamics. Topics for the discussion session and flipped classroom (1h): Possible laboratory experiments on superpositions of spacetimes.
- ***third week:** Ashtekar variables.* First lecture: self-dual Ashtekar variables, algebra of constraints. Second lecture: spinors, null surfaces, applications including Witten's proof of mass positivity. Topics for the discussion session and flipped classroom (1h): simple examples where perturbation theory fails, problems with complex variables.
- ***fourth week:** Loop Quantum Gravity.* First lecture: holonomy-flux algebra, regularisation of constraints, the phase space $T^*SU(2)^L$. Second-lecture: Cylindrical functions, Ashtekar–Lewandowski vacuum, geometric observables, spinor representation. Topics for the discussion session and flipped classroom (1h): Relational observables, Dirac observables.
- ***fifth week:** covariant approaches and applications.* First-lecture: spinfoams and Ponzano–Regge model, EPRL model, covariant formulation of the dynamics. Second lecture: Loop quantum cosmology. Topics for the discussion session and flipped classroom (1h): summing vs. refining, covariant vs. canonical approaches, recapitulation of the whole course, free discussion and exchange of ideas, possible additional topics: philosophy of science, non-empirical theory verification.

- Prerequistites. Special relativity, electrodynamics, quantum mechanics.