Gamma-Ray Burst as source for cosmic rays

Gamma-Ray Burst are the most energetic explosions known in the Universe. They are visible for tens of seconds in γ-ray telescopes, but have been suggested also as source of ultra high energy cosmic rays (UHECR). The latter are protons or nuclei with energy up to 10^{20} eV.
A possible way to distinguish different sources of UHECRs are the statistical properties of their arrival directions: If the number of sources is small, there are many clustered and few isolated arrival directions; If the number of sources is large, the situation should be opposite. The Gamma-Ray Burst rate is known, but to compare it with the observed "effective" density of UHECR sources one has to know how much the original burst is stretched in time by deflections in the extragalactic magnetic field.
Aim of the project is to calculate the trajectories of UHECRs using magnetic fields found (earlier) in numerical simulations and to derive therefrom the dispersion of the UHECR burst. Comparison with the observed UHECR data allows one then to restrict/exclude the Gamma-Ray Burst hypothesis for certain range of magnetic field strengths.

Dark matter

Around 90% of the mass of the Milkyway consists of "dark matter" (DM). Part of this matter is not smoothly distributed, but concentrated in clumps with density profile $\rho_{\rm DM}(r) \propto r^{-\alpha}$, $\alpha \approx 1 - 1.5$, or captured by the Sun or the Earth. One way to detect dark matter particles X is to search for their visible annihilation products, $XX \to \nu, \gamma, \ldots$. Since the annihilation rate $\Gamma \propto \rho^2$, an understanding of the clumping properties and the capture rate of DM is crucial.
Possible projects in this area of research are: i) Analyzing the DM capture rate of the Sun (Transformation to an stable Hamiltonian, numerical calculations of DM trajectories), ii) Studying the fate of a DM cloud when it crosses the Galactic disc (Solving numerically the Vaslow equation in a fixed gravitational background).

Acceleration of cosmic rays

The origin of cosmic rays and the mechanism for their acceleration is 100 years after their discovery still unresolved. The leading candidate for the acceleration mechanism is "second order shock acceleration", where charged particles are accelerated in "moving" magnetic fields around supernova remnants or active galactic nuclei.
We aim to describe shock acceleration from first principles, including the back-reaction of the accelerated particles on the medium. Possible projects for students in this direction are manifold. (Supervision together with S. Ostapchenko.)

Prerequisites for all projects: No advanced knowledge in particle physics or astrophysics is necessary, the student should be willing to teach her/himself the basics of a programming language as FORTRAN or C++.