Master projects

Galactic Magnetic field

The Galactic magnetic field (GMF) consists of a regular and a turbulent component. Since charged particles diffuse in this field, the GMF influences the interpretation of many phenomena in the Milky Way, reaching from the astrophysics of high-energy cosmic rays, the interpretation of anisotropies in the cosmic microwave background to the detection of dark matter. Aim of this project is to improve the description of the regular component of the GMF, modeling its spiral structure analogous to the one of matter. Morover, our local envirement—the Local Superbubble—should be implemented. As constraint, measurements of Faraday rotation using pulsars and synchrotron maps have to be taken into account.
The project is well-suited for a student interested in astrophysics and the numerical modeling of data.

Non-Gaussian fields

Turbulent field magnetic fields are usually modelled as Gaussian random fields. Such a field is fully described by a single function, its power spectrum. Realistic fields are more complicated, and therefore also more complicated to produce on a computer. Aim of this project is to use a recently proposed approach [1] to model such fields, and then to compare the propagation of charged particles in Gaussian and non-Gaussian fields
The project is well-suited for a student interested in astrophysics and the numerical modeling of data.
Reference: [1] `https://arxiv.org/abs/arxiv:2005.11972`

Comparing transport equations

The transport of particles (from pollen immeresed in water to cosmic rays in the Milky Way) can often modelled as a diffusion process. The equation describing such a transport can be derived either from Fick's law, giving a diffusion equation $\partial/\partial t - \vec{\nabla}(D\vec{\nabla}n) = 0$. Or as an expansion of the Boltzmann equation, giving a Fokker-Planck type equation $\partial/\partial t - \Delta(Dn) = 0$. While very similar, these equations differ for non-constant D. Moreover, the interpretation of D is different. Aim of this project is to study the resulting phenomenological differences, and to understand the applicability range of the two equations.

Indirect Dark Matter Searches

Dark matter (DM) annihilations or decays produce the same amount of matter and antimatter, while "normal stuff" consists only of matter. Antimatter can be used therefore as a tool to search for DM in our galaxy. In particular, antiprotons and antideuterons offer an

opportunity to search for DM at low energies. A major uncertainty in testing such model is the progagation of these charged particles in the Galaxy. Aim of this project is to study existing propagation models and to develop alternative ones.
The project requires interest in computing, astrophysics and particle physics.
Reference: https://arxiv.org/abs/2002.10481

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, gamma-ray bursts or active galactic nuclei. Aim of this project is to generalise an existing frame-work [1] for the acceleration of cosmic rays for non-relativstic shocks to the case of shocks moving with arbitrary velocities. Possible applications are the physics of gamma-ray bursts.
The project requires interest in computing and astrophysics.
Reference: [1] https://arxiv.org/abs/1103.5765