## Abstract

Astrophysical and cosmological observations provide compelling evidence that the majority of matter in the Universe is *dark*. Showing no interactions with electromagnetic radiation, this dark matter (DM) eludes direct observations, and its nature and origin remains unknown to this day. Direct detection experiments search for interactions between halo DM and nuclei inside a detector. So far, a variety of experiments were only able to set stringent limits on the DM parameter space. These constraints weaken for sub-GeV DM masses, as light particles are not energetic enough to trigger most detectors. New experimental efforts shift the focus towards lower masses, for example by looking for inelastic DM-electron scatterings.

If scatterings between DM and ordinary matter are assumed to occur in a detector's target material, collisions will naturally take place inside the bulk of planets and stars as well. For sufficiently large cross sections, these scatterings might occur in the Earth or Sun even prior to the detection. In this thesis, we study the impact of these pre-detection scatterings on direct searches of light DM with the use of Monte Carlo (MC) simulations. By simulating the trajectories and scatterings of many individual DM particles through the Earth or Sun, we determine the local distortions of the statistical properties of DM at any detector caused by elastic DM-nucleus collisions.

Scatterings inside the Earth distort the underground DM density and velocity distribution. Any detector moves periodically through these inhomogeneities due to the Earth's rotation, and the expected event rate will vary throughout a sidereal day. Using MC simulations, we can determine the exact amplitude and phase of this diurnal modulation for any experiment. For even higher scattering probabilities, collisions in the overburden above the typically underground detectors start to attenuate the incoming DM flux. The critical cross section above which an experiment loses sensitivity to DM itself is determined for a variety of DM-nucleus and DM-electron scattering experiments and different types of interactions.

Furthermore, we develop the idea that sub-GeV DM particles can enter the Sun, gain kinetic energy by colliding on hot nuclei, and get reflected with great speeds. By deriving an analytic expressions for the particle flux from solar reflection via a single scattering, we demonstrate the prospects of future experiments to probe reflected DM and extend their sensitivity to lower masses than accessible by halo DM alone. We present first results for MC simulations of solar reflections. Including reflection after multiple scatterings greatly amplifies the reflected DM flux, and thereby the potential of solar reflection for direct searches for light DM.