Lund DM School 2016
Direct Dark Matter Detection Exam

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- **Problem 1**:
  Self-Interacting Dark Matter (SIDM) cross section

Proponents of SIDM would like the dark matter (DM) self-interaction to be effective at dwarf galaxy scales but not at the scales of large galaxies and galaxy clusters.

- 1.1) - Estimate the characteristic (virial) speeds of DM particles bound to a dwarf galaxy and to a galaxy cluster (you will need the characteristic mass and radius of dwarf galaxies and galaxy clusters)

- 1.2) - Using these estimates show that the cross section generated by a "dark photon" exchange (similar to the cross section in Rutherford scattering) could be large enough in dwarf galaxies and negligible in galaxy clusters.

- **Problem 2**:
  Evaluation of the differential recoil rate in Ge due to DM interactions mediated by a vector boson with the Standard Halo Model (SHM)

2.1) - Compute the function I called $\eta(v_{min}, t)$ (namely the average inverse speed) in the SHM, disregarding the existence of a escape velocity (i.e. with a non-truncated Maxwellian velocity distribution). v_{min} is the minimum

2.2) - Show that the exchange of a vector mediator induces a Spin-Independent scattering interaction in the non-relativistic limit (which applies to our situation).

2.3) - Estimate the differential rate of nuclear recoil events in a germanium (Ge) detector in units of number of events / (kg keV yr) for the following parameters:

- DM particle mass $m = 100$ GeV

- Recoil energy $E_R = 10$ keV

- Spin-independent interaction with equal DM particle couplings with protons and neutrons $f_n/f_p = 1$. Assume elastic scattering (i.e. that the final DM particle after the scattering is the same as the incoming DM particle). For simplicity set the nuclear form factor to 1.

2.4) - Same as in 2.3 but now assume inelastic scattering (which will change only the value of v_{min}) in which the difference in mass between the final and the initial DM particles is $m' - m = \delta = 100$ keV

2.5) - Which would be the value f_n/f_p which mostly weakens an upper limit obtained with Ge?

- **Problem 3:**
  Care in combining limits coming from different types of DM searches.

  Consider a set of limits on the cross section derived from

  1) collider searches,

  2) direct detection and

  3) indirect detection searches

  in a particular DM particle model. Assume that the indirect detection limits come from annihilation in the dark halo of the Galaxy and that the direct detection and indirect detection limits assume that the DM particle accounts for 100% of the DM.

  3.1) - How would the three types of limits on the cross section change if the DM particle constitutes instead only 0.01 of the DM?

  3.2) - Which are the caveats to each of these limits that would invalidate it?