Dark Matter (WS 2017/18) - Problem sheet 3

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Tutorials: Dominick Cichon

Time: Wd. 09:15 - 11:00

Venue: Philosphenweg 12, kHS

Deadline for this sheet: 22.11.2017

1 The Standard Model

1.1 Dark matter candidates *6 Points*

a) Name all particles described by the Standard Model of particle physics and note down via which forces they are able to interact.

b) Why can interactions of a dark matter particle via the electromagnetic and/or the strong force be ruled out?

c) Which Standard Model particles remain as particle dark matter candidates if one applies known requirements, such as the one mentioned above? Why?

1.2 The Tremaine-Gunn bound *4 Points*

Presume neutrinos to be massive enough for them to be non-relativistic today. A gas of such neutrinos would not be homogenous, but clustered around galaxies instead. Assume, that such a neutrino gas almost makes up the entire mass of a galaxy (i.e. other components are negligible). Measuring how fast a star rotates at a certain radius r relative to the galactic center allows to calculate the total mass contained within this radius (see problem sheet 1). The number of neutrinos which makes up this mass is limited by the amount of available states in phase space, as they observe the Pauli exclusion principle. Use this fact, while assuming, for simplicity, that there exists only one kind of neutrino, to derive a lower limit on the neutrino mass m_ν. Postulate, that all possible states are populated (*Hint: Neutrinos can only be gravitationally bound if they are below escape velocity.*), with the number of states per unit phase space being given by:

$$n = \frac{g}{(2\pi\hbar)^3},$$

where g ($= 2$ in this case) denotes the number of relativistic degrees of freedom. Assume, in addition, spherical symmetry, that the escape velocity at r smaller than some radius R is the same as for $r = R$, and that a measurement of the galactic rotation curve at $r = 12\,\text{kpc}$ yields $v(r) = 220\,\text{km/s}$.