16.7: Dark Matter and Dark Energy

All of the matter discussed so far in this chapter only makes up 5% of the energy density of the Universe. (We can talk about mass density and energy density interchangeably, as mass is a form of energy. The amount of energy E in mass m can be found through the famous conversion $E = mc^2$.) Several different lines of evidence have shown us that most of the mass in galaxy clusters is not the luminous mass we can observe. Indeed, this mass can't be baryonic at all. Dark Matter is the name given to this mass; it's not dark the way dust is, which absorbs light is. It neither absorbs nor emits light; it only interacts with light gravitationally (and has been observed partly through the gravitational lensing effect). Dark Matter interacts only via gravity and, perhaps, the Weak Force. In this way, it is similar to neutrinos. We have not identified a particle that can make up Dark Matter. We're very sure that it's there, and we're very sure that it makes up most of galaxies and galaxy clusters, but we don't know exactly what it is.

Dark Matter, however, itself only makes up about 20-25% of the energy density of the Universe. In the late 1990's, astronomers discovered that the expansion of the Universe is accelerating; this discovery was awared the Nobel Prize in Physics in 2011. This is not something you would expect from regular matter or from Dark Matter. With matter (including Dark Matter), as well as normal forms of energy such as radiation (light), the gravitational effect is attractive. The result would be to tend to slow down the expansion of the Universe. For the Universe to be accelerating, there must be something else in it. Dark Energy is the name given to this unknown substance that evidently makes up about 75% of the energy density of the Universe and that has a negative gravitational effect. Dark Energy is even more unknown than Dark Matter, and indeed some believe that it doesn't really exist as a substance, but is a pointer to our theories of gravity breaking down. Many believe that the most likely candidate for Dark Energy is vacuum energy (see Section 11.4.2), but for now nature of Dark Energy remains one of the primary outstanding unanswered questions in both astronomy and fundamental physics.