AST 222 Problem Set 3

Due on Fri. Feb. 26 at 11:59pm

Please submit via Quercus

Student name: *Student number:*

Problem 1: (6 points total)

Take as a given the following equation for the dark matter / nucleus cross-section:

$$\sigma_{DM,N} \propto \frac{m_{DM}^2 m_N^2}{(m_{DM} + m_N)^2} \tag{1}$$

where m_{DM} is the mass of the dark matter particle and m_N is the mass of the nucleus. The cross-section is the probability that two particles (in this case a dark matter particle and an atomic nucleus interact.

(a.) Assuming a dark matter particle with mass $10 GeV/c^2$, calculate this quantity for Xenon and Germanium nuclei. [2 pts]

(b.) Generally, how does $\sigma_{DM,N}$ scale with nucleus mass for a given a constant m_{DM}. [1 pt]

(c.) How does $\sigma_{DM,N}$ scale for $m_{DM} << m_N$? [1 pt]

(d.) How does $\sigma_{DM,N}$ scale for $m_{DM} >> m_N$? [1 pt]

(e.) In about 4 sentences or less, describe what you would conclude about the material you might use for your detector if you were building a dark matter experiment. [1 pt]

Problem 2: (4 points total)

Take as a given that the volume of the "observable universe" is $4 \times 10^{80} m^3$ (we will learn how to calculate this later in the course) and that the mass of the dark matter in the universe is $2 \times 10^{54} kg$.
This is a geometric question; you don't need any outside knowledge about dark matter.

(a.) If the dark matter was comprised of many 1 million solar mass black holes, what would be the number density of these black holes per Mpc^3? [2pts]

(b.) How many of these black holes would be in our local cluster? Would these be observable from Earth? Why or why not? Explain your reasoning in a few sentences. [2pts]

Problem 3: (2 points total)
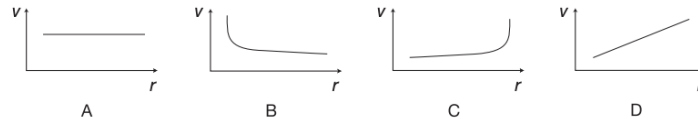
Refer to Figure 1 for this problem.

Figure 1: Rotation curves.

(a.) Which graph best shows the v versus r relationship for planets orbiting the Sun? This motion is governed by [fill in the blank] Law. [1 pt].

(b.) Which graph best shows the v versus r relationship for stars orbiting far from the centre of a galaxy? Explain your reasoning in a few sentences either citing observations of galaxy rotation curves or calculations from previous assignments. [1 pt]

How long did it take you to do this assignment?