# Astronomy 350 Fall 2012
# Homework #9

Due in class: Friday, Nov. 16

1. *Dark Energy.*

   (a) [**5 points**]. Why is dark energy "dark"? Why it is "energy?"

   (b) [**5 points**]. Give at least one way that dark energy is *different* from dark matter. Also give at least one way that dark energy is *similar* to dark matter.

   (c) [**5 points**]. What is the difference between the cosmological constant and dark energy?

   (d) [**5 points**]. How can we test whether our universe has a cosmological constant?

   (e) [**5 points**]. What would it mean if a cosmological constant *can* explain the acceleration of the universe? What question(s) would that raise?

   (f) [**5 points**]. What would it mean if a cosmological constant *cannot* explain the acceleration of the universe? What question(s) would that raise?

2. [**5 points**]. *Cosmic Inventory.* What are the three largest contributors to the density of the universe today? What fraction of the cosmos today is made of material that has been studied in a laboratory? Briefly comment on this result.

3. *The Cosmic Microwave Background and Prizewinning Cosmology*

   (a) [**5 points**]. What is the CMB? In what ways is it cosmic? microwave? background? radiation?

   (b) [**5 points**]. How can we see the CMB if the photons were released 14 billion years ago? Shouldn't those photons be billions of light years away by now?

   (c) [**5 points**]. Who was awarded the 2006 Nobel Prize for Physics? What was the prize for–what were the results, and how were they obtained?

   (d) [**5 points**]. Why are these results from part (c) important?

4. [**5 bonus points**]. *Alternative Gravity versus the Dark Universe.* The observations that point to both dark matter and dark energy in the universe could instead point to a failure of our current theory of gravity–General Relativity. It is possible that dark matter exists, but that dark energy does not and instead points to modified gravity on cosmic scales. Similarly it could be that dark energy is real and dark matter is not. However, the simplest and thus most appealing picture would be that one theory of "alternative" or "modified" gravity would explain the observed universe in such a way that there is no need for either dark matter or dark energy.

   What would be required for the modified behavior of gravity if it is to explain both dark matter and dark energy, as well as other observations explained by our current (unmodified) theory of gravity. What kinds of existing observations must be explained? How must the modified theory behave to explain them? *Hint*–it will be useful to think of how gravity behaves on different lengthscales. For example: on the scales of galaxy halos, how would gravity have to act (compared the usual theory) in order to explain rotation curves without the need for dark matter?