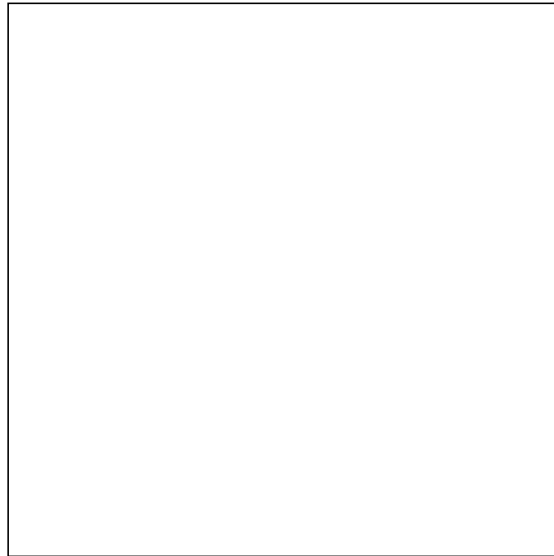
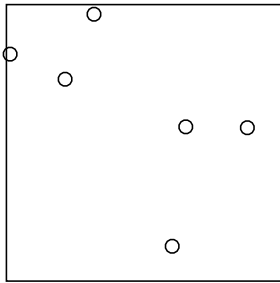
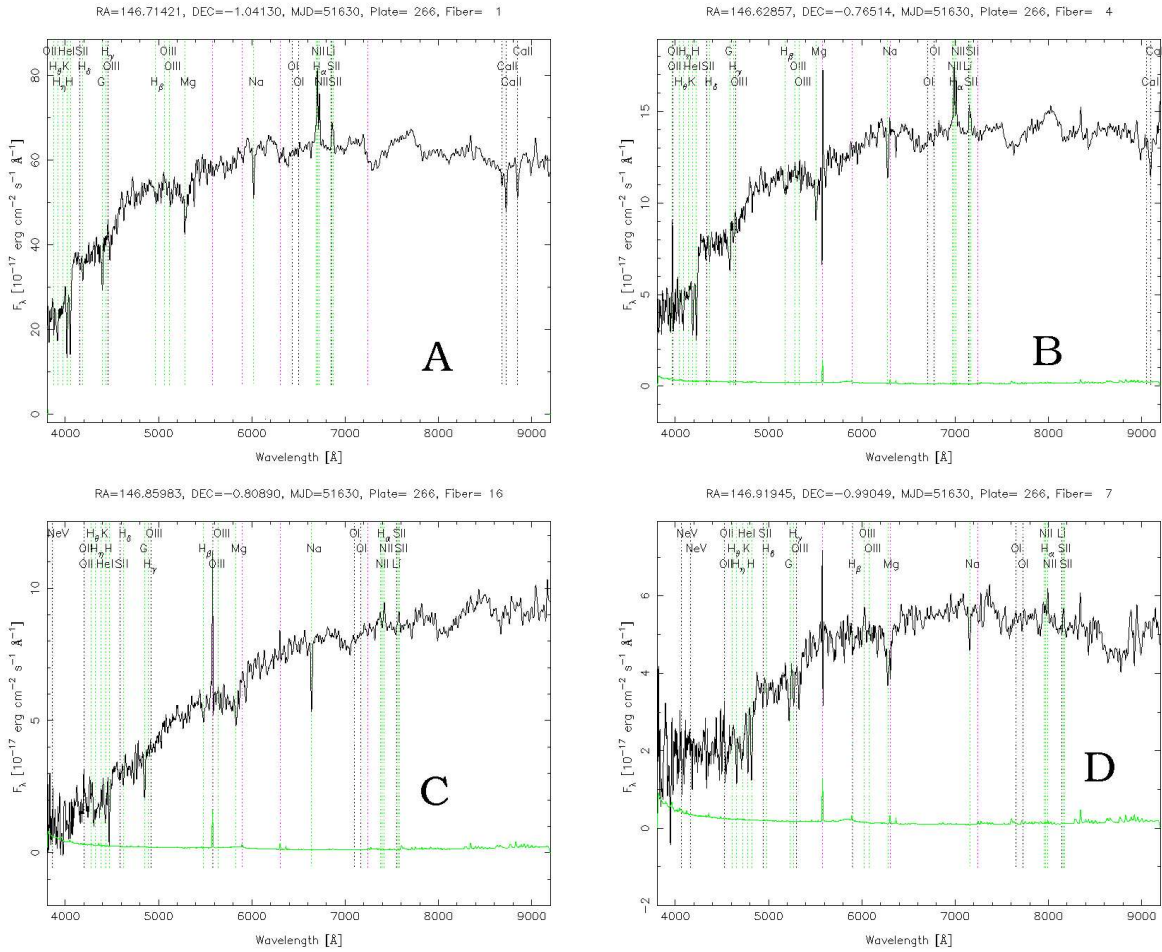


4. On the left is a schematic sketch of some galaxies in the Universe when the Universe was, say, 10 billion years old. On the right, sketch what it might look like when the Universe gets to be twice as old, 20 billion years old. Explain why you drew what you drew. [Assume that the galaxies are far enough away from each other that Hubble's law applies.]



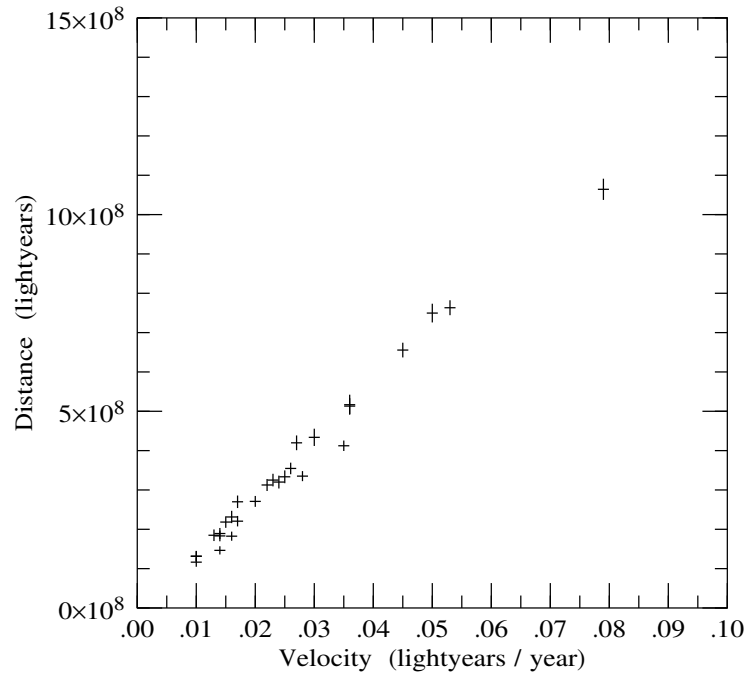
5. From our point of view living in the Milky Way, galaxies are expanding away from us in all directions. Does this mean that the Milky Way is the center of the Universe? Suppose that you lived on another galaxy half way across the Universe from the Milky Way. Would you see galaxies expanding away from you in all directions? Explain.

6. Here are some spectra of galaxies observed by the Sloan Digital Sky Survey (from <http://cas.sdss.org/dr3/en/tools/getimg/>). **Mark** the position of the H α line on each spectrum. Then **order** the galaxies A–D by redshift, from smallest to largest. [Hint: Put the galaxies in order of the wavelength of their H α line, whose unredshifted wavelength is $6563 \text{ \AA} = 656.3 \text{ nm}$.]



7. Order the above galaxies A–D by apparent brightness, from brightest to faintest. Does the ordering agree or disagree with the order in the previous question? Why might that be so? [Hint: The vertical axis measures brightness. Look at the numbers labeled on the vertical axis. Bigger numbers are brighter.]

8. Here is a Hubble diagram of thermonuclear supernovae (data from Nobili et al. 2005, <http://arxiv.org/abs/astro-ph/0504139>). Draw a straight line through the data. [Hint: Your straight line should go through the origin (the bottom left corner). Why?]



9. Why is it thermonuclear supernovae, and not some other species of astronomical object (like galaxies), that astronomers use to plot a Hubble diagram to cosmological distances?
10. Here's a final question to bend your mind. If the Universe is expanding, what is it expanding into? Justify your answer as well as you can. [Hint: General Relativity offers a definite answer to this question. However, I am looking here not for the "right" answer, but rather for your argued opinion on the subject.]