ASTR 422
Problem Set 3
Due Friday, October 12, 2007

1. The very best velocity resolution in astronomy exists in searches for extrasolar planets. Doppler shifts of down to $\sim$1 m s^{-1} can be detected in some cases. Given this:

If you could measure redshifts to that accuracy for a $z = 0.1$ quasar (i.e., a single point source, with a unique redshift at any given time), derive how long would you have to wait between observations such that the acceleration of the universe produced a change in recession speed of 1 m s^{-1}. Note that the current Hubble parameter is $H_0 = 72$ km s^{-1} Mpc^{-1}, and assume $\Omega = 0.27$, $\Omega_k = 0$, and $\Omega_\Lambda = 0.73$.

2. The Phillips relation for white dwarf supernovae is that longer supernovae have a higher peak luminosity. Do some Web research to determine the state of the *theoretical* understanding of this correlation. Use any Web resources you like, but you must write the final description in your own words (no more than one short paragraph, please!). Good places to start are Google, the Astrophysics Data Service (http://adsabs.harvard.edu/abstract_service.html), and astro-ph (http://www.arxiv.org/find/astro-ph). Note that the official name for white dwarf supernovae is "Type Ia supernovae", where that is a Roman numeral I. Please also give me the URLs for the one or two references you found most helpful.

3. Suppose that the universe currently has $\Omega = 0.3$ (composed entirely of pressureless matter), $\Omega_k = -0.05$ (so that the geometry is of a closed universe) and $\Omega_\Lambda = 0.75$. Demonstrate that the universe will expand forever. Note that you do *not* have to take on the far more difficult task of following the evolution in detail; all you need to prove is that despite the closed geometry, expansion will continue indefinitely.

4. Dr. I. M. N. Sane has been applying his deep intellect to the study of gravitational lensing. He is especially interested in strong lensing (i.e., multiple imaging) of background quasars by the supermassive black holes found in the centers of essentially all big galaxies. His calculations suggest that there will be hundreds of such lensing events in the Sloan Digital Sky Survey, and he has issued a press release announcing the revolution in cosmology and black hole astrophysics that will be precipitated by his discovery.

Ron Cowen, the main astronomy writer for Science News, has called you to determine whether he should run with this story. Following Dr. Sane's calculations, we assume that the number density of big galaxies is 0.003 Mpc^{-3} and that the relevant volume of the

universe is a 4 Gpc radius sphere centered on us. We also assume that each galaxy has a $10^7\,M_\odot$ black hole (where 1 $M_\odot = 2 \times 10^{30}$ kg). In addition, Dr. Sane assumes (and you should as well) that for these lensing situations $D_L = D_{LS} = 2$ Gpc, and $D_S = 4$ Gpc. The Sloan Survey has roughly 10^6 quasars. Given this, calculate the expected number of multiple images by supermassive black holes, and write your response to Ron Cowen based on this.