Astro 121, Spring 2003

Midterm exam

This exam is open book, open notes, open homework, open web, etc. However, you are not permitted to get help from another person on the exam—only from written sources (not including e-mail). You may take up to 24 consecutive hours to work on the exam. The exam is due by 5:00 PM Monday, March 24, 2003. Feel free to ask for clarification of any of these problems. If you ask me a question that I'm not willing to answer, I'll let you know, but don't hesitate to ask!

For each of the questions below, explain your answers fully and clearly, and show all steps in working out the problems. If a problem has more than one part and you get stuck, feel free to make up any numbers you need for later parts if you didn't get them in earlier parts.

1. A CCD image of the open cluster M203 is taken with a telescope having a focal length of 21 m, using a CCD with 24 micron pixels. Positions on the CCD are measured for star A at (0,0) and B at (100, –200) in units of millimeters. The measurements are made with the x-axis aligned east-west with positive x to the east and positive y to the north. The equinox 2000.0 coordinates of star A are RA = $2^h\ 00^m\ 00^s$, Dec. = –70° 00' 00".

   a. (10 points) Derive the scale in arcsec/mm at the focal plane of the telescope. (If you can't do this, at least show the dependence of scale on properties of the telescope.)

   b. (10 points) Given this scale (or use 5 arcsec/mm if you can't do part a.), what are the coordinates of star B?

   c. (5 points) If the seeing in this image is 1 arcsec, are the stellar images undersampled, oversampled, or critically sampled? Explain.

2. The James Clerk Maxwell Telescope on Mauna Kea is located at longitude 155°W and latitude +20°. Suppose that you observe the photometric standard IRC+10216 at an elevation of 40° and measure 4.4 Jy at a wavelength of 800 μm. IRC+10216 has a true flux at 800 μm of 100 Jy. (A Jansky is a unit of flux. 1 Jy = 10^{-23} erg/cm^2/sec/Hz.)

   Next you observe the pre-main-sequence star AK Sco <u>on the meridian</u> and measure a signal of 0.01 Jy at 800 μm. The coordinates of AK Sco are RA = $16^h\ 30^m\ 12^s$ Dec. = –36° 00' 00".

   a. (5 points) What is the local sidereal time of the AK Sco observation?

   b. (5 points) What are the airmasses of the IRC+10216 and AK Sco observations?

c. (10 points) What is the true flux of AK Sco at 800 μm? (If you didn't get b, take airmass of IRC+10216 to be 1.0 and the airmass of AK Sco to be 2.0.)

d. (5 points) What can you say about AK Sco and IRC+10216 from their names alone?

3. (10 points) The average rate of Type Ia supernovae (which are of great astronomical interest right now because they make good standard candles in distant galaxies) is 1 per galaxy per century. You might think this makes them hard to find, but the Supernova Cosmology Project has worked out an effective strategy to detect and observe them very close to the time when they explode. In a short observing run, they observe 50 fields, each of which contains roughly 1000 high-redshift galaxies. They then return to the same fields three weeks later, and observe them again. Since supernovae stay bright for a while, you could think of this set of observations as equivalent to monitoring these fields for the full three weeks, i.e. they will detect any supernovae that go off any time during that period. Calculate the probability that one *or more* Type Ia supernovae will explode in the sample observed during this three-week observation period.

4. (10 points) In a 1-second-exposure CCD image of a star field, you measure the flux of a star in a 4-pixel-area aperture to be 2500 ADUs. In an annulus around the star with an area of 16 pixels, you measure the sky flux to be 1600 ADUs. The read noise of the CCD is 5 e^-/pixel and the gain of the CCD is 2 e^-/ADU. Assume that there is no atmospheric extinction, no loss of light in the telescope optics, no dark current, and that the CCD has 100% quantum efficiency. The predicted flux from this star is 4100 photons/second in the bandpass used; what is the probability that your measurement is consistent with this prediction? Explain your answer and show your work.

5. (10 points) On hven, you will find a FITS CCD image of a star field in the directory /usr/data/astro121/midterm/starfield.fits. This is an image taken through the V filter. The image below shows the field. The star marked A below has a V magnitude of 11.0. Use IRAF to determine the V magnitude of the star marked B. If you have difficulties with IRAF, feel free to come find me; I will answer questions that are the result of some computer-related problem (e.g. if the file gets deleted, the disk fills up, etc.), though I won't answer general IRAF questions. In addition to giving the V magnitude of star B, give a few sentences of explanation of how you determined it. (I'm not looking for a lot of detail here; this is just a "basic skills" question.)