M. M. Kasliwal & D. Mawet

Ay 122a: Astronomical Measurements and Instrumentation

Problem Set 1

Due in TA's mailbox at **5pm** on Friday, October 7, 2016

1. **Statistics:**
   The IMB proton-decay detector in a salt mine near Cleveland, Ohio detected a burst of 8 neutrinos coincident with SN1987A (also seen by the Japanese Kamiokande II experiment). If the average number of neutrinos detected by this instrument is 2 per day, what is the probability of detecting a fluctuation of 8 or more in one day? In fact, all 8 neutrinos were detected in a 10-min period. How does this change the probability?

2. **Space-Time Reference Frames:**
   On August 15 2016, graduate student Jacob Jencson discovered a supernova in Messier 108 at RA (J2000) = 11h11m20.40s and DEC(J2000) = +55d40m17.3s with the Spitzer space telescope. Jacob was excited as a supernova so nearby only occurs once in two years and he wanted to collect additional follow-up data. What was the local sidereal time at midnight at Palomar? Was there any ground-based telescope that could observe Jacob's target before it faded away? Please plot a visibility curve (airmass vs. time between sunset and sunrise).

3. **The Signal to Noise Equation:**
   A new optical imager called WASP was commissioned on the Palomar 200-inch earlier this year. Let's work out the sensitivity in the r'-band filter for this instrument as follows:

   a) What is the brightest star you can observe before the detector saturates?
   b) What is the minimum exposure time where the sky noise dominates over the readout noise?
   c) What is the brightness of the star for which sky noise equals source noise?
   d) What is the faintest star you can detect in a 600s exposure? Assume a 5σ detection threshold for S/N.

   Make reasonable assumptions about (and discuss) the various parameters this depends on: telescope effective area given central obscuration, mirror reflectivity, instrument throughput, detector quantum efficiency, filter transmission, readout noise, dark current, atmospheric seeing, pixel scale of the detector, airmass, moon-phase etc. State your answer in both AB mag and the Vega mag system. Now repeat for the bluest u'-band filter and reddest z'-band filter.

4. **The Thirty Meter Telescope (TMT):**
   Suppose you are put in charge of designing TMT, and that the baseline configuration is a Ritchey-Chretien design with with a primary focal ratio of f/1.0. Suppose that the final ratio at the R-C focus is f/15 (this would probably be a Nasmyth focus for this telescope).

   a) What will the plate scale be at the f/15 focus (in arc-seconds per millimeter)?

b) The natural size of the field for this design is about 20 arc-minutes in diameter with good images (astigmatism is the main optical aberration for R-C designs). What is the physical size of the focal plane? Comment on what this means for instruments placed at f/15 that desire to use a substantial fraction of the field.

c) Approximately how large would the secondary mirror have to be to provide the above prescription? (see optics lecture notes).

5. **Coma As You Are:**
The Palomar 200-inch Hale telescope has a focal ratio at prime focus of f/3.3. The conic surface of the P200 primary mirror is a paraboloid (the best one could do in the 1930s), which produces good images on-axis but the image quality degrades rapidly with field angle, due primarily to coma. In general, for a parabolic mirror with focal ratio f and and diameter D, the physical size of the coma at a physical distance h off-axis in the focal plane is given by $C \approx 3h/16f^2$. In typical seeing conditions, what then is the angular size of the usable field of the Palomar 200-inch prime focus before coma begins to cause significant degradation of the images? Please state any assumptions that you make in answering.