Astronomy 45. Introduction to Astrophysics

Problem set 2 Due Wednesday, March 1

1. Angular distances

(a) M31, the Andromeda Galaxy is located in the sky at $\alpha = 0^{\mathrm{h}}40^{\mathrm{m}}0^{\mathrm{s}}$, $\delta = +41°00'$. Another galaxy, M33, is at $\alpha = 1^{\mathrm{h}}31^{\mathrm{m}}6^{\mathrm{s}}, \delta = +30°24'$. How far apart (in degrees and arcminutes) are these objects in the sky (to the nearest arcminute, say)?

(b) Proxima Centauri, the nearest star after the Sun, is at $\alpha = 14^{\mathrm{h}}26^{\mathrm{m}}, \delta = -62°28'$. Alpha Centauri, not quite as close, is at $14^{\mathrm{h}}36^{\mathrm{m}}, -60°38'$. How far apart are these stars in the sky, in arcminutes.

2. Distances

(a) A bright star of spectral type O in the Andromeda Galaxy is observed to have a magnitude $V = 18.4$. How far away is the galaxy? (Hint: look at table in section 2.2.3 of the notes.)

(b) Alpha Centauri (see above problem) has a measured parallax of 0.745 arcsec. The parallax for Proxima Centauri is 0.762 arcsec. What is the physical distance between the two in A.U. (using results from problem 1(b) as appropriate)? Prox Cen has a measured radial velocity of -16 km/s, while that of Alpha Cen is -22 km/s. Do you think they are gravitationally bound to each other?

3. Photon Counting

Since photons arrive statistically, when you expect to observe N photons on the average, you actually get a value drawn from a statistical distribution with a mean of N and a standard deviation $\sqrt{N}$.

(a) How many photons do you need to collect to measure the magnitude of a star to ± 0.02 mag?

(b) How long an exposure do you need, with a 1 m aperture telescope, to measure the B magnitude of an $m_B = 20$ star to ± 0.02 mag? (Refer to table in 2.2.1 of notes.)

For even fainter objects, the brightness of the night sky becomes a limiting factor. The darkest (ground-based) night sky has an equivalent brightness in B of one $m_B = 22.5$ star per square arcsecond.

(c) What is the night sky brightness I_λ in $\mathrm{erg}/(\mathrm{cm}^2\,\mathrm{s}\,\mathrm{sterrad}\,\text{Å})$?

(d) How many photons do you need from an $m_B = 24.0$ star to measure its magnitude to ± 0.02 mag? (Hint: photons from the star are competing with statistical fluctuations *from the night sky*, not just with their own fluctuations.) Assume that the starlight is spread out over exactly 1 square arcsecond.

(e) What is the exposure time on a telescope of aperture 4 m for the measurement of part (d)?

4. Telescopes

(a) Show that (i.e. explain why) the image seen through the telescope drawn in Section 3.4.2 of the notes is *"inverted."*

(b) Binoculars (which are basically the same figure) show not an "inverted" image but an "erect" one. How do you think they do this?

Negative lenses, instead of taking parallel rays to a point at their focus, take converging rays that *would* reach a point at their focus and make them parallel. That is the basis of Gallileo's original telescope (see figure).

(c) What is the (angular) magnification of a Gallilean telescope in terms of D, f_1, f_2? (Hint: Remember that rays through the center of a lens are undeflected. Another hint: This problem is easier if you work from the eye end to sky, not the usual reverse.)

(d) Is the image erect or inverted? (And show why.)