

Ay 124 Winter 2014 – HOMEWORK #1

Due Friday, January 17, 5pm

Problem 1. Observing Distant Solar-type Stars

Assume for the time being that the Galaxy has no dust, and that we are observing along a line of sight at $b = 0$ deg and $l = 180$ deg. We are interested in observing the most distant solar-type stars ($M_V \simeq +5.1$) possible, but our apparent magnitude limit for the observations is $m_V = 24.0$. The central stellar density of the halo is expected to be $\sim 1\%$ that of the disk component, but the number density of halo stars falls off as $R^{-3.5}$ whereas the stellar density in the disk decreases as $n \propto \exp(-R/R_0)$, where $R_0 \simeq 3$ kpc (also known as a disk scale length).

- a) What is the maximum distance (in kpc) out to which we can observe the stars in question?
- b) At that distance, what is the probability that the star is a member of the stellar halo rather than the stellar disk? What is the probability in the solar neighborhood of selecting a halo star from among all G5 spectral type stars?
- c) Now put some dust in the disk so that the interstellar reddening along a line of sight in the disk is $E(B - V) = 0.5(d/\text{kpc})$, where d is the distance along the line of sight to the star. Assuming a Milky Way-like extinction curve (assume $A_V \simeq 3.1E(B - V)$) in the disk, how does the answer to part a) change if we have the same limiting $m_V = 24$ for the observation?
- d) If one then observes in the direction $b = 90$ and the $100\mu\text{m}$ cirrus in that direction has 3 MJy/steradian surface brightness, what is the approximate thickness of the disk perpendicular to the plane if we assume that the same reddening per unit path length applies (i.e., assume all of the dust opacity comes from dust confined to the disk)?
- e) How do you expect the surface density of halo G5 stars to depend on apparent magnitude [hint: Imagine a fixed solid angle (e.g., 1 square degree). How does the volume probed depend on distance, how does the apparent luminosity depend on distance, and how does the space density depend on distance?]

Problem 2. Perplexing Pulsar Problem

Horrible things astronomers have to do in real life #1: Joe Bloggs has discovered a pulsar at $\alpha = 19^{\text{h}}59^{\text{m}}37^{\text{s}}, \delta = +20^\circ 40'$ (epoch 2000), which has proper motion $\mu_\alpha = -0.00114 \text{ s y}^{-1}$ $\mu_\delta = -0.026'' \text{ y}^{-1}$ and a parallax of 0.0007 arcsec. It has a companion star of $m_V = 19.0$, whose heliocentric radial velocity varies sinusoidally about a mean of $\gamma = 55 \text{ km s}^{-1}$. Calculate (using any method you like, including graphical ones, as long as your answer is accurate to better than a degree in angle):

- a) the Galactic coordinates l and b of the pulsar
- b) its transverse velocity v_t relative to the sun, and the angle that vector makes to the Galactic plane [warning: think carefully about units and types of circles when interpreting μ_α]
- c) the absolute magnitude M_V of its companion star.

Problem 3. Which Way Did We Go?

COBE (confirming earlier, less precise measurements) showed that the largest anisotropy in the CMB is a dipole anisotropy, such that the background is $\Delta T = 0.0034$ K higher in temperature than the 2.73 K average in the direction $\alpha = 11^{\text{h}}09^{\text{m}}, \delta = -7^\circ$, and an equal amount lower in the opposite direction. However, papers on the effects of cosmological density perturbations always quote the “COBE dipole” as being due to a Doppler velocity of 540 km s^{-1} toward $\alpha = 10^{\text{h}}36^{\text{m}}, \delta = -23^\circ$. Explain quantitatively the origin of the difference between the observed dipole velocity and direction, and one cosmologists discuss. What uncertainty do you think results from conversion?