

Long Problems

Long Problem 1 [30]

Use the given table to answer the following questions.

Star	Right Ascension	Declination
Aldebaran	4 ^h 36 ^m	16° 31'
Miaplacidus	9 ^h 13 ^m	-69° 42'
Deneb	20 ^h 41 ^m	45° 20'
Regulus	10 ^h 08 ^m	12° 18'
Hadar	14 ^h 04 ^m	-60° 24'

- If the star Deneb crosses your local meridian, how long must you wait until Miaplacidus crosses your local meridian? [3]
- The coordinates of Jakarta, Indonesia is 6.17 degrees South and 106.82 degrees East . Which of these stars would never be visible to an observer in Jakarta? [4]
- At the instant Miaplacidus crosses the local meridian of an observer in Jakarta, what is its altitude and azimuth? [3]
- At the instant Miaplacidus crosses the local meridian of an observer in Jakarta, what is the latitude and longitude of an observer who will see Aldebaran at the zenith? [3]
- For an observer at Jakarta, how long will Aldebaran be above the horizon, from sunset to sunrise? [6]
- What is the angular separation between Regulus and Hadar? [6]
- When Aldebaran is rising, what is the altitude of Miaplacidus as seen by an observer in Jakarta? [5]

Long Problem 2 [37]

The energy density of blackbody radiation is given by $u = 4\sigma T^4/c$, where σ is the Stefan-Boltzmann constant. Assuming the temperature of the CMB today is $T_{CMB} = 2.73K$ and the critical density today is $\rho_{crit} = 0.921 * 10^{-29} h_0^2 gcm^{-3}$.

- What is the energy density of the CMB? What is the corresponding Ω_{CMB} ? [6]
- What are the typical photon energies of the CMB, and the corresponding number density of photons per cm^3 ? [6]
- Assuming $\Omega_{CMB} = 0.3$ what was the redshift z_{eq} of the transition from the radiation dominated to the matter dominated universe? [7]

d. Assuming the age of the universe at the epoch of decoupling to be 380,000 years, and knowing its redshift, estimate the age at z_{eq} . You can assume the expansion laws appropriate for an $\Omega = 1$ universe. [8]

e. How old was the universe at the time when the temperature was comparable to the temperature in the Solar core, $T_c = 1.5 * 10^7 K$? [5]

f. What were typical photon energies then? [5]