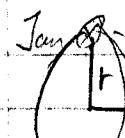


A 3- Light tells us - temperature (size, size)  
 - composition, magnetic field, pulsations,  
 - distance

Distance can be measured by - parallax for close stars  
 - magnitude : closer  $\rightarrow$  brighter

p.64



$d$        $p$

$p$  = parallax angle

Dec  $\odot$

$$\frac{r}{d} = \tan p \approx p \text{ (rad)}$$

If  $p = 1'' = 1 \text{ arcsec} = \frac{1}{60} \text{ min} = \frac{1}{3600} \text{ degree}$ , and  $r = 1 \text{ AU}$   
 then define  $d = 1 \text{ parsec} = \frac{r}{p} = 1 \text{ AU}$

$$p \text{ (arcsec)} : \text{rad} = \frac{360^\circ}{2\pi} \left| \frac{60'}{1^\circ} \right| \left| \frac{60''}{1'} \right| = \dots$$

Show that  $d = 2 \cdot 10^5 \text{ AU}$

$$p \text{ (arcsec)} : \text{rad} = \frac{360^\circ}{2\pi} \left| \frac{60'}{1^\circ} \right| \left| \frac{60''}{1'} \right| = \dots$$

parsec  $\sim 2 \cdot 10^5 \text{ AU} \sim 1 \text{ ly}$

$$\text{ly} = \text{light year} = c \times 1 \text{ yr} = 3 \cdot 10^8 \text{ m} \cdot \pi \cdot 10^7 \text{ sec} \sim 10^{18+7} = 10^{16} \text{ m}$$

Magnitude : apparent magnitude  $m$  = observed brightness

absolute magnitude  $M$  depends on type of star.  
 (integrate over all wavelengths ...)

p.66 Luminosity  $L$  = power emitted by star

$$\text{Radiant Flux } F = \frac{L}{4\pi r^2} = \frac{\text{power}}{\text{area}} = \text{intensity}$$

$$M_{\odot} = -26.7$$

Smaller magnitude = brighter! Venus :  $m_{\min} = -4$   
 dimmest naked eye stars :  $m \approx +6$  Ap. 2

3.3 Wave nature of light - you already know that  $C = \lambda v$

p.73 and  $E^{\text{energy}} = h\nu = \frac{hc}{\lambda}$ . Poynting vector  $\langle S \rangle = \langle \vec{E} \times \vec{B} \rangle = \frac{E_0 B_0}{c}$   
 $= \frac{CE_0 B_0}{8\pi(\text{cgs})} \frac{2\mu_0}{(\text{cgs})}$

Radiation pressure (not flux!)  $F_{\text{rad}} = \frac{\langle S \rangle A \cos^x \theta}{c}$

$x=1$  for absorption

$x=2$  for reflection (Prob 3.6)

3.4 Black body radiation : you already know that

$$\lambda_{\text{max}} T = 0.29 \text{ cm} \cdot \text{K} \approx 3 \cdot 10^{-3} \text{ mK} \quad (\text{Wien's law})$$

Stefan-Boltzmann: Luminosity  $L = \text{Area} \cdot \sigma T^4 = \frac{\text{energy}}{\text{time}}$

$$\sigma = 5.67 \cdot 10^{-5} \frac{\text{erg}}{\text{s cm}^2 \text{K}^4} \quad (\text{Prob 3.7})$$

3.5 You know PLANCK relation ... (Prob. 3.11)

3.6 Color INDEX and Bolometric magnitude : (Prob. 3.8)

measure the amount of light from a star in 3 colors:

$U = U\text{V}$ ,  $B = \text{Blue}$ ,  $V = \text{Visual (reddish)}$

Don't worry about "vegan's of (bolometric) magnitude" (corrections) and color indices - important for observers, but tedious for theorists

3.2 At what distance from a  $P_b = 100$  watt light bulb is the radiant flux equal to solar constant?

$$p.77 L_0 = 3.826 \times 10^{33} \frac{\text{erg}}{\text{s}} / \frac{1}{\text{erg}} = \underline{\hspace{2cm}} \text{watt}$$

$$p.67 \text{ Flux received} = \frac{L}{4\pi d^2} \text{ where } d = \text{distance from source}$$

$$F_{\text{bulb}} = F_{\text{sun}} \text{ (at earth)} = 1.36 \times 10^6 \frac{\text{erg}}{\text{s} \cdot \text{cm}^2}$$

$$\text{Prob 3.5: Derive } m = M_0 - 2.5 \log_{10} \left( \frac{F}{F_{10,0}} \right)$$

Let  $M$  = (absolute magnitude) of a given star. If it were at  $d = 10\text{ pc}$ .

| Kaufmann box 19-3 | apparent magnitude<br>428 | apparent magnitude<br>difference ( $m_1 - m_2$ ) | ratio of apparent<br>brightnesses $b_1/b_2$ |
|-------------------|---------------------------|--|---|
| 1                 |                           |  | $100^{1/5} \approx 2.512$                   |
| 2                 |                           |  | $100^{2/5} = 6.31$                          |
| 3                 |                           |  | $100^{3/5} = 15.85$                         |
| 4                 |                           |  | $100^{4/5} = 39.82$                         |
| 5                 |                           |  |   |
| 10                |                           |  |   |
| 15                |                           |  |   |
| 20                |                           |  |   |

Flux ratio = brightness ratio

$$\frac{F_2}{F_1} = \frac{b_2}{b_1} = 100^{(m_1 - m_2)/5}$$

$$\log_{10} \frac{F_2}{F_1} = \log_{10} 10^{(m_1 - m_2)/5} =$$

$$\textcircled{1} \quad m_1 - m_2 =$$

Find relation between apparent  $m$ , absolute  $M$ , & distance  $d$ :

$$\text{Flux } F = \frac{L}{4\pi d^2}, \quad L \text{ is intrinsic to star.}$$

At its actual distance,  $d$ ,  $F =$

and magnitude =  $m$ .

$$\textcircled{2} \quad \text{At } d = 10\text{ pc}, \quad F_{10} =$$

and magnitude =  $M$

$$\textcircled{1} \quad \frac{F_{10}}{F} =$$

$$\textcircled{2} \quad \frac{F_{10}}{F} =$$

Equate these and solve for  $d$ :

Finally, write  $m-M$  in terms of  $d$ :

Special Case: let  $M = M_0$  = absolute magnitude of Sun.

then  $F_{10} = F_{10,0}$  = flux if Sun were at  $d=1\text{ pc}$ .

Use  $\textcircled{1}$  to find  $m$  of a given star in terms of  
 $M_0$ ,  $F_{10,0}$ , and  $F$  from the star  
(flux we receive)

- 3.6 A  $1.2 \times 10^4$  kg spacecraft is launched from Earth and is to be accelerated radially away from the Sun using a circular solar sail. The initial acceleration of the spacecraft is to be  $1g$ . Assuming a flat sail, determine the radius of the sail if it is

- (a) black, so it absorbs the Sun's light.
- (b) shiny, so it reflects the Sun's light.

Hint: The spacecraft, like Earth, is orbiting the Sun. Should you include the Sun's gravity in your calculation?

$$p. 74 \text{ force} = \text{mass} \cdot a = F_{\text{rad}} = k \frac{\langle S \rangle A}{c} \quad \text{where } k = \begin{cases} 1 & \text{: absorption} \\ 2 & \text{: reflection} \end{cases}$$

$$\text{and } \langle S \rangle = \frac{E_0 B_0}{2\pi d_0} = \frac{\text{power}}{\text{area}} = \text{intensity of solar radiation at a distance } d$$

$$\text{Intensity} = \frac{\text{power}}{\text{area}} = \frac{L_0}{4\pi d^2}$$

- 3.7 The average person has  $1.4 \text{ m}^2$  of skin at a skin temperature of roughly  $92^\circ\text{F}$  ( $306 \text{ K}$ ). Consider the average person to be an ideal radiator standing in a room at a temperature of  $68^\circ\text{F}$  ( $293 \text{ K}$ ). =  $T_0$

- (a) Calculate the energy per second radiated by the average person in the form of blackbody radiation. Express your answer both in units of  $\text{erg s}^{-1}$  and in watts.

$$\textcircled{a} \quad \text{Power radiated} = L_{\text{out}} = A \sigma T^4 \quad \text{where } \sigma = 5.67 \times 10^{-5} \frac{\text{erg}}{\text{s cm}^2 \text{K}^4}$$

- (b) Determine the peak wavelength  $\lambda_{\max}$  of the blackbody radiation emitted by the average person. In what region of the electromagnetic spectrum is this wavelength found?

$$\lambda_{\max} = \frac{0.29 \text{ cm.K}}{T}$$

- (c) A blackbody also absorbs energy from its environment, in this case from the  $293\text{-K}$  room. The equation describing the absorption is the same as the equation describing the emission of blackbody radiation, Eq. (3.16). Calculate the energy per second absorbed by the average person, expressed both in units of  $\text{erg s}^{-1}$  and in watts.

$$\text{Power absorbed} = L_{\text{in}} = A \sigma T_0^4 =$$

- (d) Calculate the net energy per second lost by the average person due to blackbody radiation.

3.8 Consider a model of a star consisting of a spherical blackbody with a surface temperature of 28,000 K and a radius of  $5.16 \times 10^{11}$  cm. Let this model star be located at a distance of 180 pc from Earth. Determine the following for the star:

- (a) Luminosity.  $(3.16) L = A\pi T^4$
- (b) Absolute bolometric magnitude.  $(3.8) M = M_0 - \frac{5}{2} \log\left(\frac{L}{L_0}\right)$ ,  $M_0 = 4.76$   
 $L_0 = 3,826 \times 10^{33} \frac{\text{erg}}{\text{s}}$
- (c) Apparent bolometric magnitude.
- (d) Distance modulus.  $(3.6) m - M = 5 \log\left(\frac{d}{10 \text{ pc}}\right)$
- (e) Radiant flux at the star's surface.  $(3.2) F = \frac{L}{4\pi r^2}$
- (f) Radiant flux at Earth's surface (compare this with the solar constant).
- (g) Peak wavelength  $\lambda_{\max}$ .  $(3.15) \lambda_{\max} T = 0.290 \text{ cm k}$

This is a model of the star Dschubba, the center star in the head of the constellation Scorpius.

- (3.11) (a) Use Eq. (3.21) to find an expression for the frequency  $\nu_{\max}$  at which the Planck function  $B_\nu$  attains its maximum value. (Warning:  $\nu_{\max} \neq c/\lambda_{\max}$ .)

- (b) What is the value of  $\nu_{\max}$  for the Sun?

- (c) Find the wavelength of a light wave having frequency  $\nu_{\max}$ . In what region of the electromagnetic spectrum is this wavelength found?

$$B_\nu \left( \frac{\text{Intensity}}{\text{J} \cdot \text{sr}} \right)$$

(3.21)

81

$$B_\nu = \frac{2h\nu^3/c^2}{e^{h\nu/kT} - 1}$$