lecture 10

Stars apparent and absolute magnitude

Hipparcus made a catalog of stars with apparent magnitude spanning from 1 to 6

1 — brightest
6 — barely visible (dim).

To put some scientific merit it was agreed that if apparent brightness changes by 5 it correspond to change of flux = 100

flux: $\frac{\text{energy}}{\text{time} \cdot \text{area}} = \left[\frac{W}{m^2}\right]$

$$\alpha \log_{10}\left(\frac{F_0 \cdot 100}{F_0}\right) = -5 = \Delta m$$

!

$$\alpha \cdot 2 = -5 \Rightarrow \alpha = -2.5$$

$$m_1 - m_2 = \Delta m = -2.5 \log_{10}\left(\frac{F_1}{F_2}\right)$$

$$\underline{\Delta m} = -1 \Rightarrow \frac{F_1}{F_2} = \cancel{10} = 10^{1/2.5} = 10^{0.4} = \underline{2.51}$$

ratio of fluxes

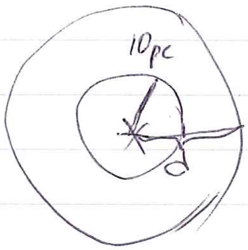
p2

Absolute magnitude is given by the flux of a star as if it placed at the distance of 10pc

$M_{\odot} = 4.74.$

$m = -2.5 \log_{10} F_{*}(d)$

↑star



$$M = -2.5 \log_{10} \frac{F_{*} \cdot d^2}{10^2_{pc}} =$$

$$= \underbrace{\left(-2.5 \log_{10} F_{*}\right)}_{m} - 2.5 \log_{10} \frac{d^2}{10^2_{pc}}$$

$$= m - 5 \log\left(\frac{d}{10pc}\right)$$

So if we put sun at the position of the nearest star (proxima centauri) $d = 1.3$ pc it would appear as

$$m_{\odot} = M + 5 \log\left(\frac{d}{10pc}\right) =$$

$$= 4.74 + 5 \log\left(\frac{1.3}{10}\right) \simeq 4.74 - 0.88 =$$

$$= \boxed{3.85}$$

Q: ~~which~~ Are stars with the same temperature equaly bright?

Going back to black body radiation.

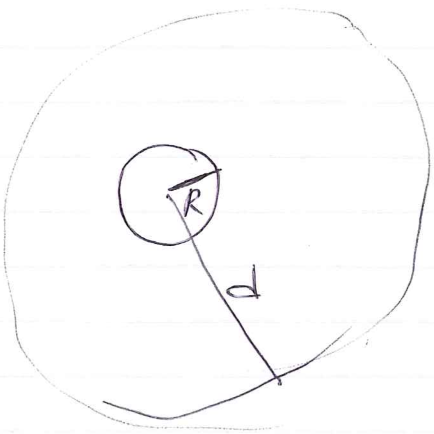
Luminocity – Energy / time emited by object

Stars are round so we can use stefan – Boltzman Equation

$$~~Ener~~ \quad L = A \cdot \sigma T^4 = [W] \leftarrow \text{unit}$$

$$\sigma = 5.67 \cdot 10^{-8} \frac{W}{m^2 K}$$

So Flux emitted by star at distance d: All energy emited per second over shell area



$$F = \frac{L}{4\pi d^2} = \frac{4\pi R^2}{4\pi d^2} \sigma T^4$$

$$\boxed{F = \frac{R^2}{d^2} \sigma T^4}$$

So large stars appear brighter.

|| So if we know star temperature and distance to it we can find its size, even if we cannot resolve it with telescope. ||

Example

Betelgeuse $\Rightarrow$ $d = \cancel{131\,pc}$ $200\,pc$

$M_V = -5.85$

$T = 3200\,K$

↑ depends, since it is variable star (text book value 3600 K)

$$-(M_{Betelgeuse} - M_{\odot}) =$$

$$= 2.5 \log_{10} \left(\frac{R_{\odot}^2}{10_{pc}^2} \sigma T_{\odot}^4 \Big/ \frac{R_B^2 \sigma T_B^4}{10_{pc}^2} \right) =$$

$T_{\odot}$: 5800K

$R_{\odot} = 7 \cdot 10^8\,m$

$$-(M_B - M_S)$$

$$-(-5.85 - 4.74) = -2.5 \log_{10} \left(\frac{T_{\odot}^4 \, R_{\odot}^2}{T_B^4 \, R_B^2} \right)$$

$$10.59 = \cancel{-2.5 \log_{10}}$$

$$= -10 \log_{10}\left(\frac{T_{\odot}}{T_B}\right) - 5 \log_{10}\left(\frac{R_{\odot}}{R_B}\right)$$

$$R_B = \frac{R_{\odot}}{10^{\frac{-(M_B - M_{\odot}) + 10 \log_{10}(T_{\odot}/T_B)}{-5}}} =$$

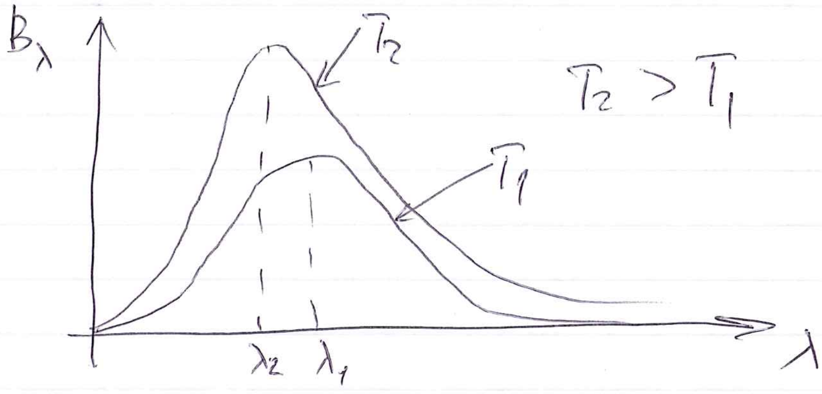
$$= \frac{R_{\odot}}{0.0023} \approx 431 \cdot R_{\odot}$$

Wiki says $(950 - 1200) R_{\odot}$

Note that B. is variable star

p5

All of it great but how do we know a star temperature?



$T_2 > T_1$

$$B_\lambda = \frac{2hc^2/\lambda^5}{e^{hc/\lambda kT} - 1}$$

Wein's displacement law

$$\lambda_{max} T = 0.00289 \text{ m}\cdot\text{K}$$

Sun has $\lambda_{max} = \frac{0.0029 \text{ m}\cdot\text{K}}{5800 \text{ K}} =$

$= 5 \cdot 10^{-7}$ m $\simeq$ 500 nm

green!

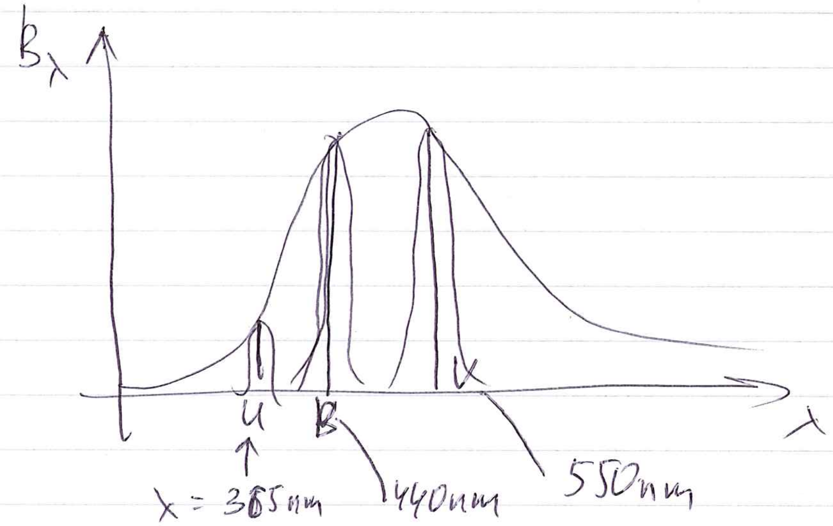
Q: why there are, white, yellow, red, blue stars but no green stars!

A: physiology: we are sensitive to overall shape of B_λ so it percieved as yellow por sun

white

A bit about experimental difficulties
now days we can do the whole
spectr of B_λ

But in the old days it was limited
to a few detectors with fixed bands

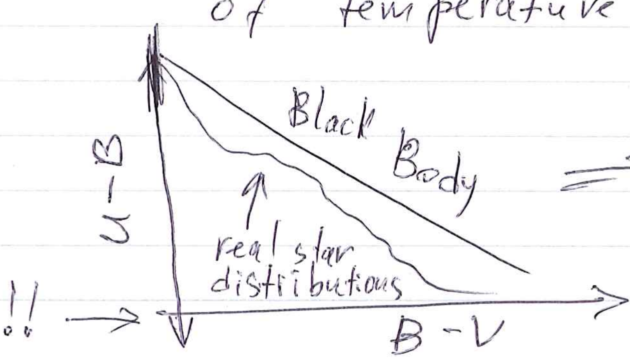


Now we measure absolute magnitudes
within some envelope around these bands

M_u M_B M_V

for short $\Rightarrow$ U B V

U - B and B - V is function
of temperature only for B.B.



$\Longrightarrow$ So stars are not
ideal B.B.
but quite closer to it

Sun luminocity $L = 3.8 \cdot 10^{26}$ W

Per $1\,m^3$ we have

$$\frac{L}{\frac{4\pi}{3} R_{\odot}^3} = \frac{3.8 \cdot 10^{26}\ W}{\frac{4\pi}{3} \cdot (7 \cdot 10^8)^3} = 0.26\ \frac{W}{m^3}$$

typical cell phone generate

Power $= V \cdot I = 4V \cdot 0.5\,\text{Å} \simeq 2W$