Spring | Physical Systems - Astrophysics - week 1 | E17
rec. Kaufmann Ch. 19 | 31 Mar 03

Ch 1 - Ptolemaic < Copernican : limited θ of Venus & Mercury
2000 yrs   explains: - Mars retrograde
- but more epicycles

Kepler used Tycho's data.   Alt-az ($0° = N$)   vs   RA-dec (by lat)
fig $\frac{1.8}{11}$ fig $\frac{1.13}{15}$

Sidereal day + 4 min = Solar day $\alpha = 0$ @ vernal equinox
360°   361° $\delta = 0$ @ col. equator

Equinoxes precess in ~26,000 yrs. Vernal equinox moves west ~ $1 \frac{min}{yr}$

Age of Aquarius ~ 2600 ACE

Ch 2 - Celestial Mechanics

Use Physics to explain Astro. observations

1609 K1: elliptical orbits
K2: equal areas in equal times (L conservation)
K3: $P^2 = a^3$

Newtonian Mechanics - $16\overset{10}{08}$ Galileo used telescope - venus phases
supports Copernican view - Jupiter moons

1687 Principia : $\vec{F}_g = \frac{GmM}{r^2}\hat{r}$ N1: Inertia
N2: $\Sigma \vec{F} = m\vec{a}$
N3: forces = interactions

p.35 derive K3 from N2.
p.37 p.37: shell theorem: acts as if mass at center.

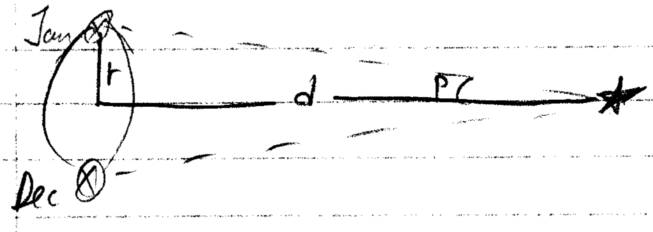
p.43 derive V_{esc}

p.53-56 Virial thm: $\langle E \rangle = \frac{1}{2}\langle U \rangle$ for any bound orbit in $F \sim \frac{1}{r^2}$

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

Distance can be measured by - parallax for close stars
- magnitude ; closer → brighter

p.64



p = parallax angle

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

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

Show that $d \simeq 2 \times 10^5$ AU

p(arcsec) ; rad $= \frac{360°}{2\pi} \left| \frac{60'}{1°} \right| \frac{60''}{1'} \Big| = \underline{\quad\quad}''$

parsec ~ 2×10^5 AU ~ π ly

ly = lightyear = $c \times 1$ yr $\simeq 3 \times 10^8 \frac{m}{s} \times \pi \times 10^7$ sec ~ $10^{1+8+7} = 10^{16}$ 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

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

$m_\odot = -26.7$

Smaller magnitude = brighter! Venus : $m_{min} = -4$

dimmest naked eye stars : $m \simeq +6$ Ap 2

3.3 <u>Wave nature of light</u> - you already know that $c = \lambda \nu$

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

$= \frac{c E_0 B_0}{8\pi}$ (cgs)

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

$x = 1$ for absorption
$x = 2$ for reflection (Prob 3.6)

3.4 <u>Black body radiation</u>: you already know that

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

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

$\sigma = 5.67 \cdot 10^{-5} \frac{\text{erg}}{\text{s cm}^2 \text{K}^4}$ (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 = UV, B = Blue, V = Visual (reddish)

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

Spring 2003 Physical Systems - Astrophysics HW Ch 3 # 2,5,6,7,8,11 due 7 Apr wk 1

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

p.77 $L_\odot = 3.826 \times 10^{33} \frac{erg}{s} \left| \frac{J}{erg} \right| =$ ______ watt

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

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

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

Let M = (absolute) (apparent magnitude) of a given star IF it were at $d = 10pc$.

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	apparent magnitude difference $(m_2 - m_1)$	ratio of apparent brightness 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

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

$$\log_{10} \frac{F_2}{F_1} = \log_{10} 10^{2(m_1 - m_2)/5} =$$

① $m_1 - m_2 =$

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

flux $F = \frac{L}{4\pi r^2}$, L is intrinsic to star.

At its actual distance $r = d$, $F =$ and magnitude $= m$

② At $d = 10pc$, $F_{10} =$ and magnitude $= M$

① $\frac{F_{10}}{F} =$ ② $\frac{F_{10}}{F} =$

Equate these and solve for d:

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

Special case: let $M = M_{\odot}$ = absolute magnitude of Sun.

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

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

3.6 A 1.2×10^4 kg $= m$ 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 $1g$ $= a$. 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 $\quad \text{Force} = \text{mass} \cdot a = F_{rad} = k \dfrac{\langle S \rangle A}{c}$ where $k = \begin{cases} 1 : \text{absorption} \\ 2 : \text{reflection} \end{cases}$

and $\langle S \rangle = \dfrac{E_0 B_0}{2\mu_0} = \dfrac{\text{power}}{\text{area}} =$ intensity of solar radiation at a distance d

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

3.7 The average person has 1.4 m^2 $=A$ of skin at a skin temperature of roughly 92°F (306 K). $=T$ Consider the average person to be an ideal radiator standing in a room at a temperature of 68°F (293 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 erg s^{-1} and in watts.

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

(b) Determine the peak wavelength λ_{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-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 erg s^{-1} and in watts.

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

(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 5.16×10^{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) $L = A\sigma T^4$

(b) Absolute bolometric magnitude. (3.8) $M = M_\odot - \frac{5}{2}\log\left(\frac{L}{L_\odot}\right)$, $M_\odot = 4.76$, $L_\odot = 3.826 \times 10^{33}\ \frac{erg}{s}$

(c) Apparent bolometric magnitude.

(d) Distance modulus. (3.6) $m - M = 5\log\left(\frac{d}{10pc}\right)$

(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 λ_{max}. (3.15) $\lambda_{max} T = 0.290$ 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_ν attains its maximum value. (*Warning:* $\nu_{\max} \neq c/\lambda_{\max}$.)

(b) What is the value of $\nu_{\max}$ for the Sun? $B_\nu \left(\frac{\text{intensity}}{\text{s} \cdot \text{sr}} \right)$

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

(3.21) 81 $$B_\nu = \frac{2h\nu^3/c^2}{e^{h\nu/kT} - 1}$$