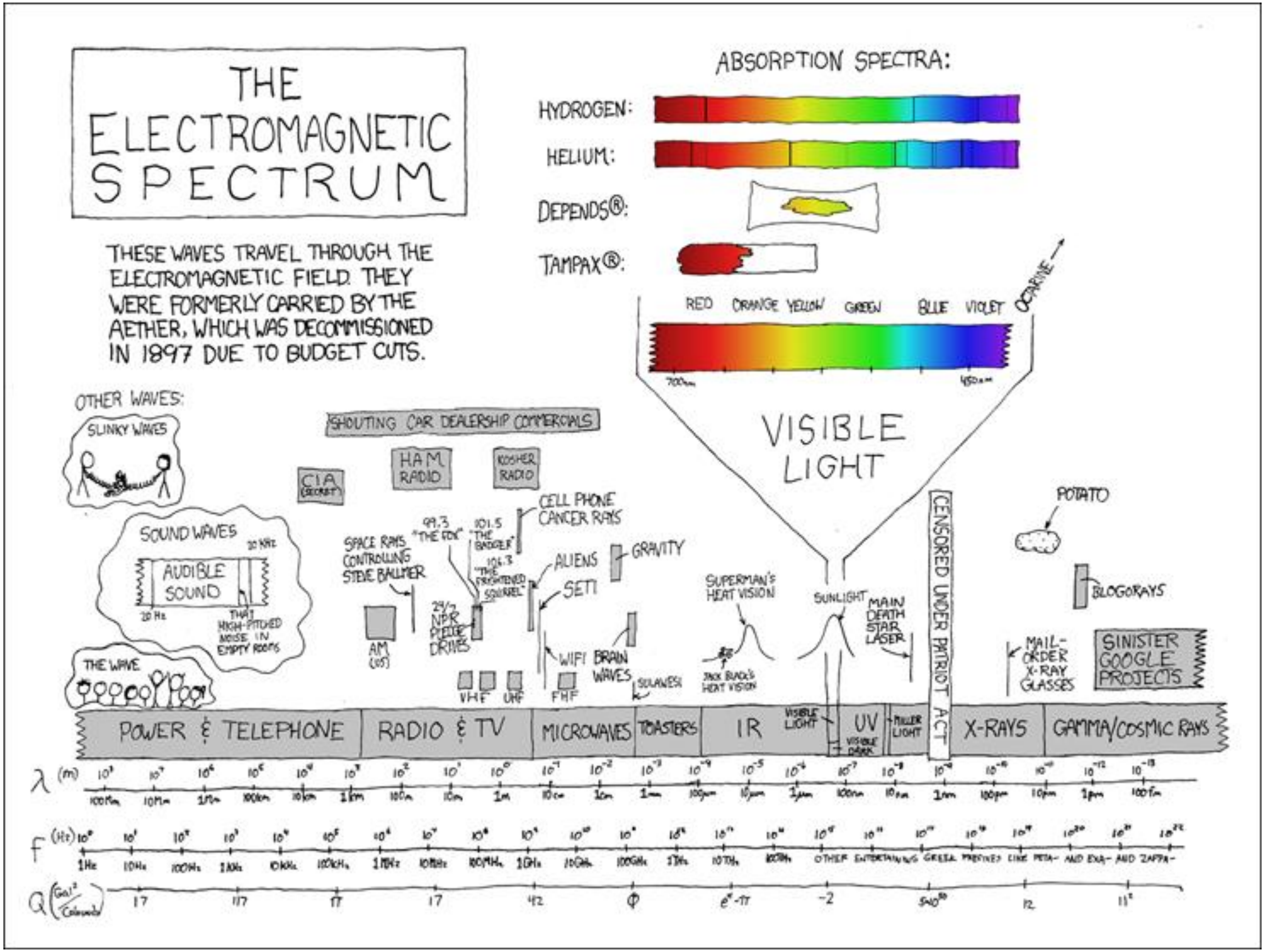


THE ELECTROMAGNETIC SPECTRUM
THESE WAVES TRAVEL THROUGH THE ELECTROMAGNETIC FIELD. THEY WERE FORMERLY CARRIED BY THE AETHER, WHICH WAS DECOMMISSIONED IN 1897 DUE TO BUDGET CUTS.
ABSORPTION SPECTRA:
HYDROGEN:
HELIUM:
DEPENDS®:
TAMPAX®:
RED
ORANGE
YELLOW
GREEN
BLUE
VIOLET
OCTARINE
700nm
450nm
VISIBLE LIGHT
OTHER WAVES:
SLINKY WAVES
SOUND WAVES
AUDIBLE SOUND
20 Hz
20 KHz
THAT HIGH-PITCHED NOISE IN EMPTY ROOMS
THE WAVE
SHOUTING CAR DEALERSHIP COMMERCIALS
CIA (SECRET)
HAM RADIO
KOSHER RADIO
CELL PHONE CANCER RAYS
SPACE RAYS CONTROLLING STEVE BALLMER
99.3 "THE FOX"
101.5 "THE BADGER"
106.3 "THE FRIGHTENED SQUIRREL"
24/7 NPR PLEDGE DRIVES
AM (US)
VHF
UHF
FHF
ALIENS
SETI
WIFI
GRAVITY
BRAIN WAVES
SOLANESK
SUPERMAN'S HEAT VISION
JACK BLACK'S HEAT VISION
SUNLIGHT
MAIN DEATH STAR LASER
CENSORED UNDER PATRIOT ACT
POTATO
BLOGORAYS
MAIL-ORDER X-RAY GLASSES
SINISTER GOOGLE PROJECTS
POWER & TELEPHONE
RADIO & TV
MICROWAVES
TOASTERS
IR
VISIBLE LIGHT
VISIBLE DARK
UV
MILLER LIGHT
X-RAYS
GAMMA/COSMIC RAYS
λ (m)
100Mm 10Mm 1Mm 100km 10km 1km 100m 10m 1m 10cm 1cm 1mm 100μm 10μm 1μm 100nm 10nm 1nm 100pm 10pm 1pm 100fm
f (Hz)
1Hz 10Hz 100Hz 1KHz 10KHz 100KHz 1MHz 10MHz 100MHz 1GHz 10GHz 100GHz 1THz 10THz 100THz
OTHER ENTERTAINING GREEK PREFIXES LIKE PETA- AND EXA- AND ZAPPA-
Q (Gal² / Coloumb)
17 117 π 17 42 Φ -2 12

Radio “Light”

What concepts about light are relevant to cellphones?

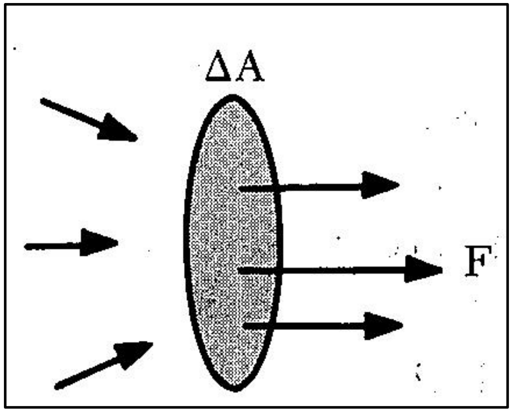
What happens when you change channels on your radio?

- Uses electromagnetic radiation
  - radio waves
- Signal travels at the speed of light
  - 3×10^8 m/sec
- Light travels in a straight line in a vacuum
  - need antennas to relay signal
- Signal strength decreases as inverse-square distance
  - need antennas to relay signal
  - some dead zones
- Light carries energy is transferred in differer forms:
  - sound to mechanical to light and back again

“Flux”

this quantity can be measured by detectors

The rate of energy passing through a differential area:



$$F = \text{Flux} = \frac{dE}{dA\,dt}$$

What are the units of Flux?

ergs cm^{-2} sec^{-1} = W m^{-2}

1 Watt = 10^7 erg/sec

“Luminosity”

L = flux integrated over the surface area of the object

$$L = \int_{surface} F \, dA$$

If F is constant and the surface is spherical (radius = R), then

$$L = 4\pi R^2 \cdot F$$

where F is flux at the surface and $4\pi R^2$ is surface area of the sphere

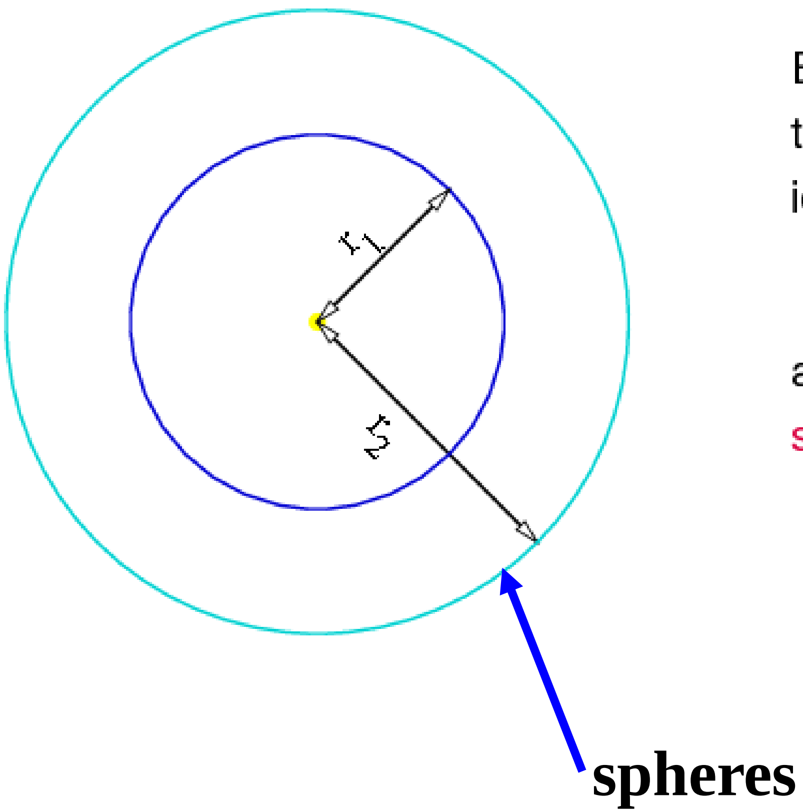
What do you see happening in this picture?

The bulb emits light in all directions. Its light carries energy.

200 Watts is a certain amount of energy per second.

How determine the total energy hitting a person's face in an hour?

Inverse-square "Law" of Energy Propagation



Because of energy conservation, flux through two shells around source is identical:

$$4\pi r_1^2 F(r_1) = 4\pi r_2^2 F(r_2) \qquad (2.46)$$

and therefore we obtain the inverse square law,

$$F(r) = \frac{\text{const.}}{r^2} \qquad (2.47)$$

The "inverse-square law"

apply energy conservation

For a star of radius (R_*) and luminosity (L_*):

$$L_* = 4\pi R_*^2 \cdot F_* = dE_*/dt$$

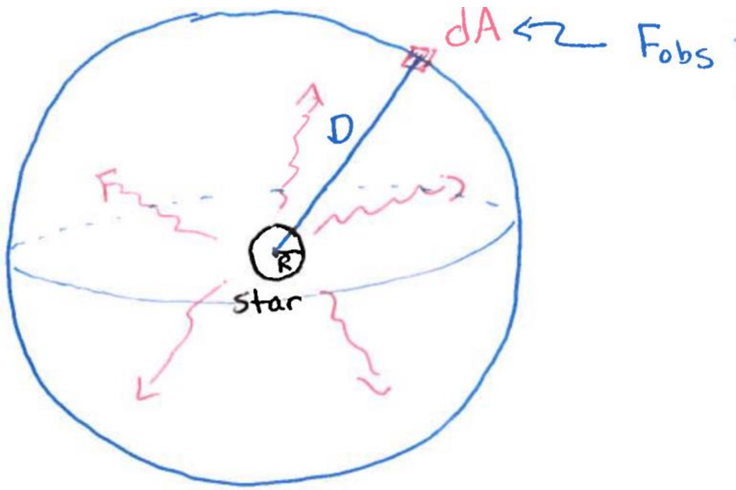
For an observer far away, the same rate of energy will expand outwards and flow through a larger sphere surrounding the star

$$L_* = dE_*/dt = 4\pi D^2 \cdot F_{obs} = 4\pi R_*^2 \cdot F_*$$

$$F_{obs} = F_* (R/D)^2$$

So, $F_{obs} \alpha\ 1/D^2$

i.e., "inverse-square" law



Problem

derive the "Solar Constant"

essential for designing solar panel systems

How many watts of sunlight reach a $1m^2$ surface on Earth?

$L_{Sun} = 4 \times 10^{26}$ W

Distance to Earth = 1 AU = 1.5×10^{11} m

$$F_{obs} = L_{Sun} / 4\pi D^2$$

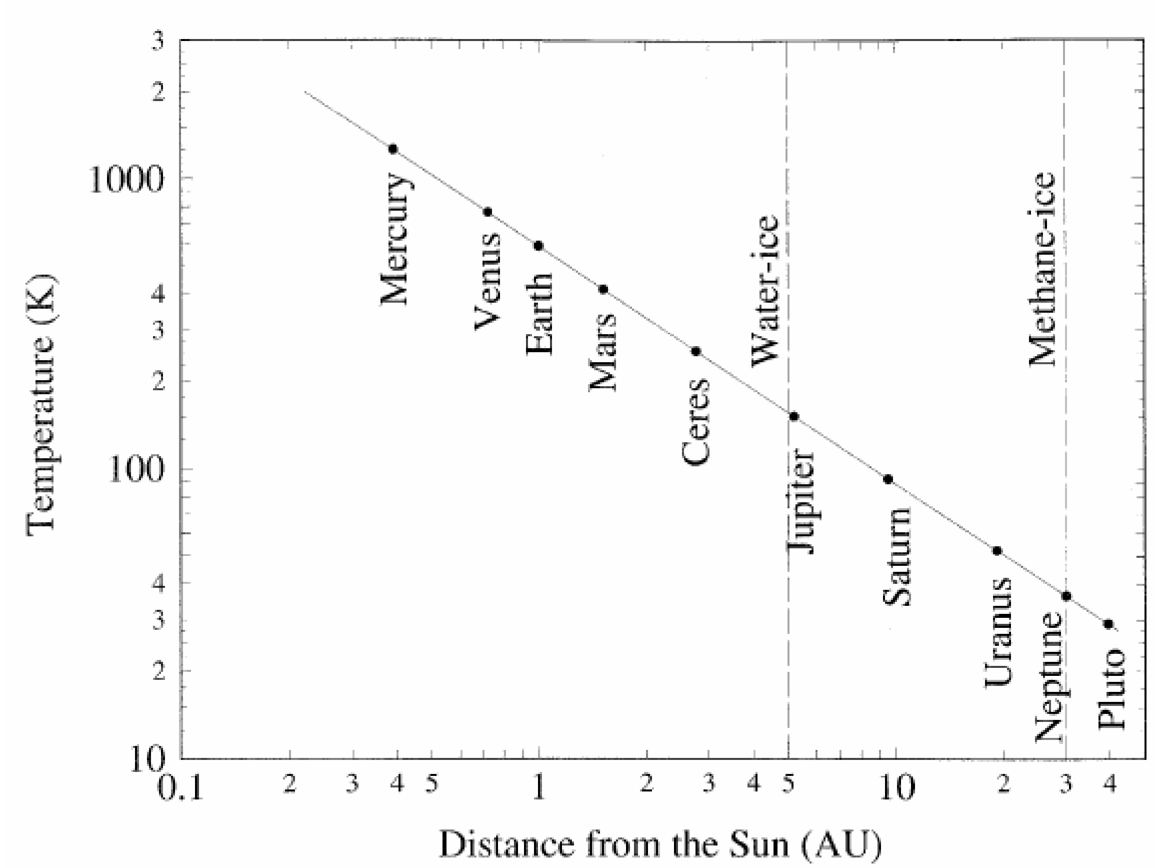
$$F_{obs} \approx 2000 \text{ W/m}^2 = 2 \text{ kW/m}^2$$

Problem

For a parent star of 3 L_{Sun}, how far away would a planet need to be to receive the same amount of energy as the Earth does from the Sun?

- **$L_{Sun} = 3.8 \times 10^{33}$ erg sec^{-1}**
- **$R_{Sun} = 7 \times 10^{10}$ cm**

Why Do Planets Become Colder with Distance From the Sun?



The graph uses a 'logarithmic' scale.

Review
logarithms

- **In the following:**
  - **$\log N \equiv \log_{10} N$**

- **Log scales in graphs**
  - **If every power of ten is an equal interval, then ...**
    - **half an interval is $0.5 = \log x$, or $x = 10^{0.5} = 3.16$**
  - **log 2 = ….**
  - **log 3 = 0.477**

- **<u>Examples</u>:**
  - **$\log 6 = \log (3*2) = \log 2 + \log 3 = 0.778$**
  - **$\log 8 = \log (2^3) = 3 \log 2 = 0.903$**
  - **$\log 9 = \log (3^2) = 2 \log 3 = 0.954$**

Interactive Problems

Pretend you are comparing three stars in the same constellation.

a. Your favorite star is 100 times more luminous than star #2 but both appear equally bright. How many times farther away is your favorite star?

b. Stars #2 and #3 have the same luminosity, yet star #2 appears 100 times fainter than star #3. How many times farther away is star #2?

c. The parallax of star #3 indicates its distance is 100 light-years. What are the distances to all three stars?

Make a Drawing

you

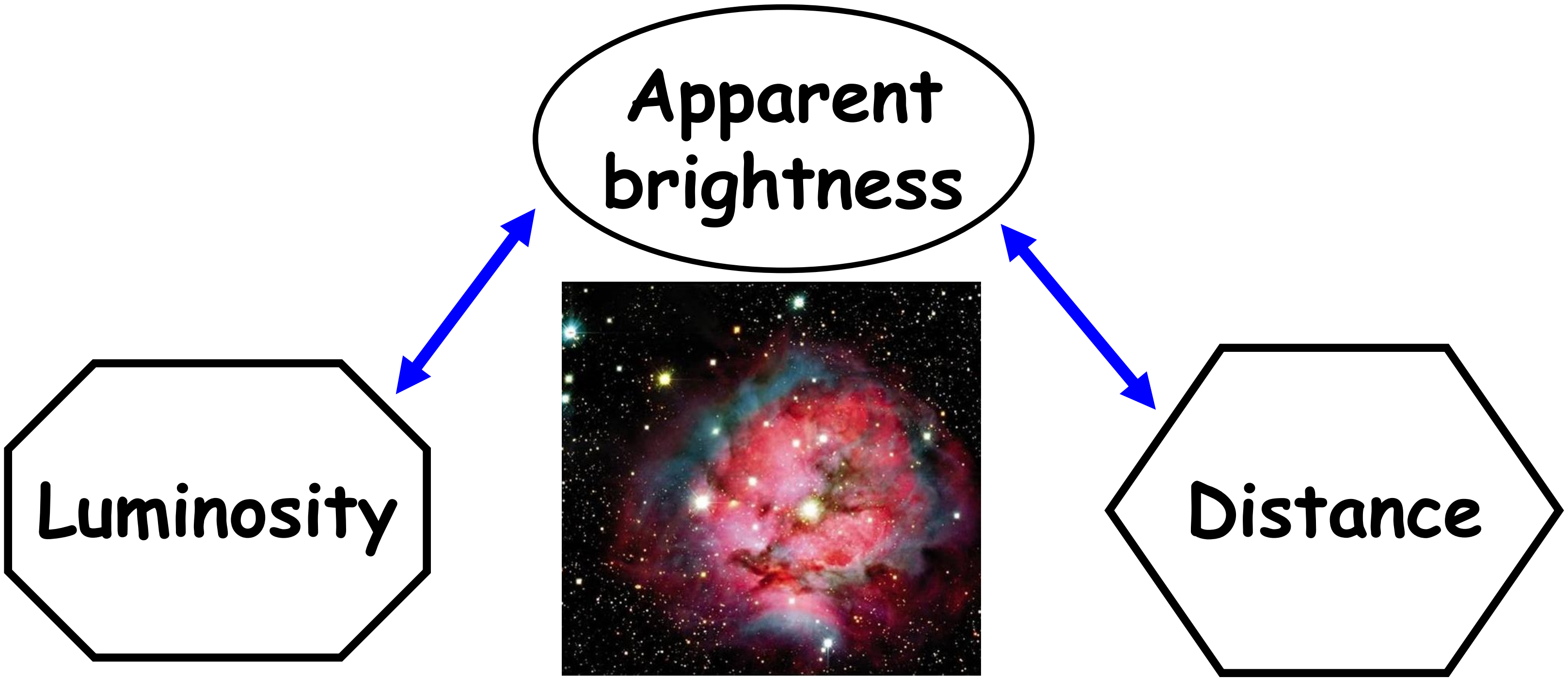
#1: 100 L
same brightness as #2

#2: L
100x fainter than #3

#3: L
100 light-years

"Standard Candles"

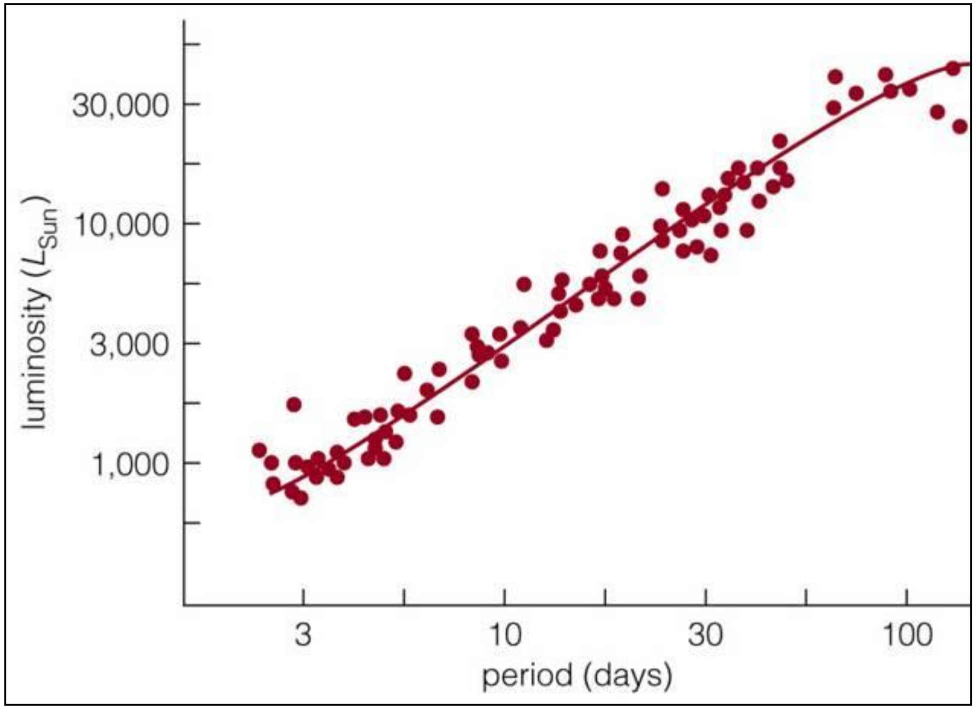
An object's brightness depends on its distance and how bright it really is.



If we know two of these characteristics, we can determine the third.

More Interactive Problems

The Sun-like star α Cen has ~1 L_{Sun}. If a Cepheid star of ~30 day period has the same brightness as α Cen, how far away is the Cepheid star? The Period-Luminosity Law for Cepheid variable stars is shown below.



“Monochromatic Flux”
“Flux Density”

The flux in a particular bandwidth of wavelength or frequency

$$\mathbf{F_{\lambda}} = dE / (dA\ dt\ d\lambda)$$

$$\mathbf{F_{\nu}} = dE / (dA\ dt\ d\nu)$$

What are the units of Flux Density?

<u>units</u>: ergs cm^{-2} sec^{-1} cm^{-1}

ergs cm^{-2} sec^{-1} Hz^{-1}

Total Flux Emitted by an Object

Integrate over all wavelengths or frequencies

$$\mathbf{F} = \int_0^\infty F_\nu \, d\nu = \int_0^\infty F_\lambda \, d\lambda$$

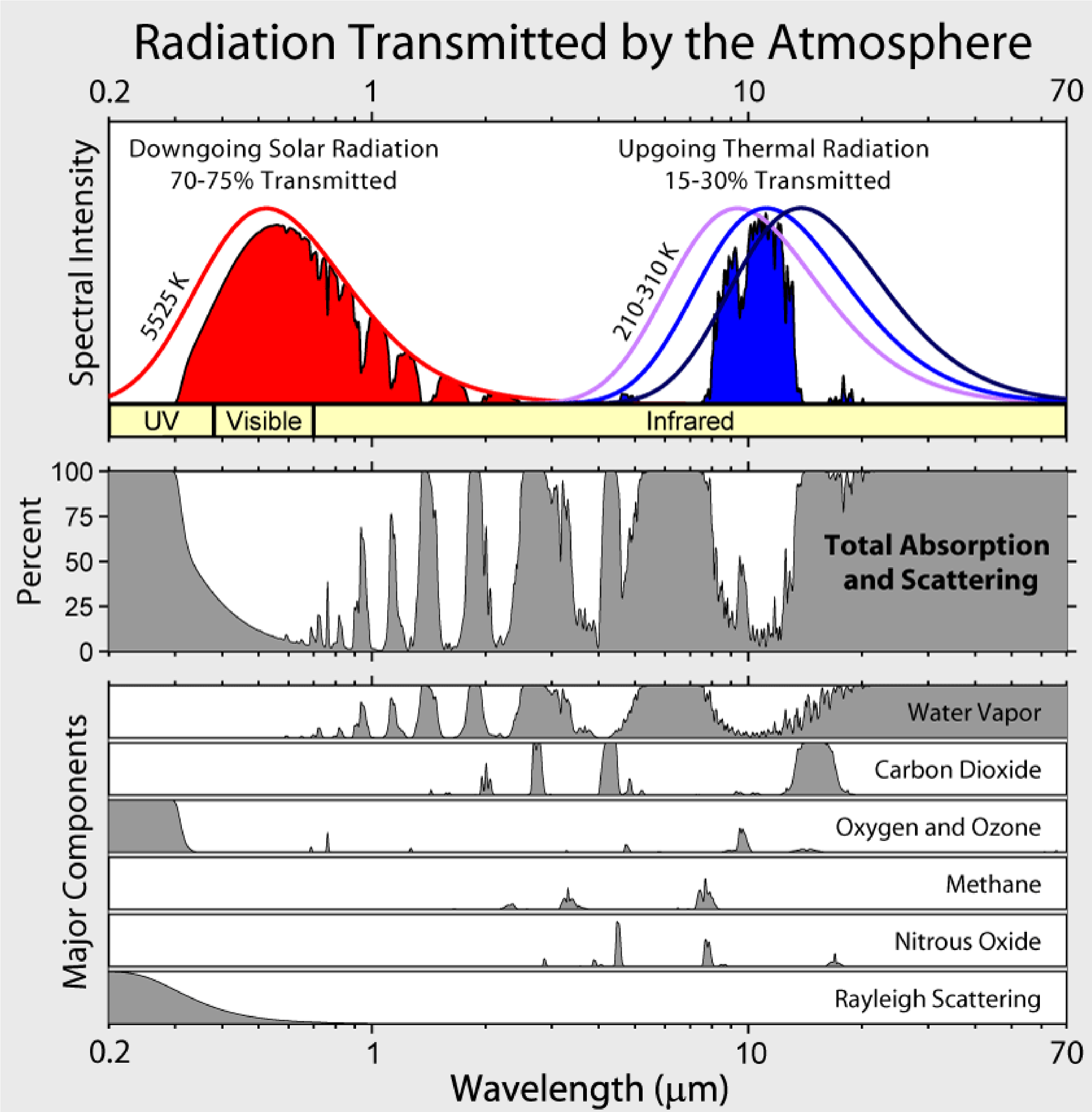
units: ergs cm^{-2} sec^{-1}

Note:

$d\lambda \neq d\nu$

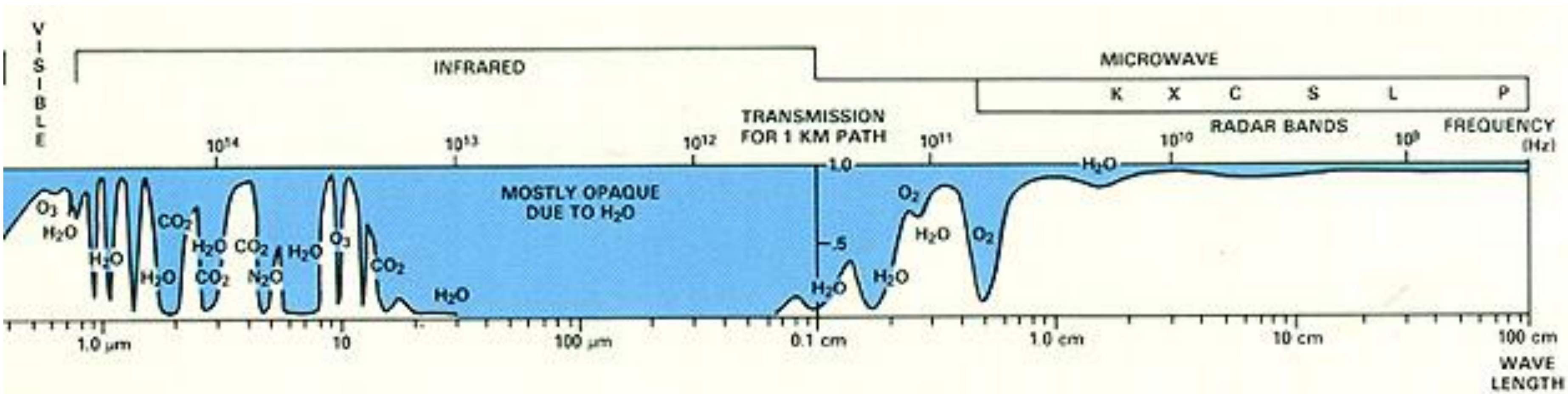
$F_\lambda \neq F_\nu$

[Solve problem #2 in Homework #5 to find the conversion.]

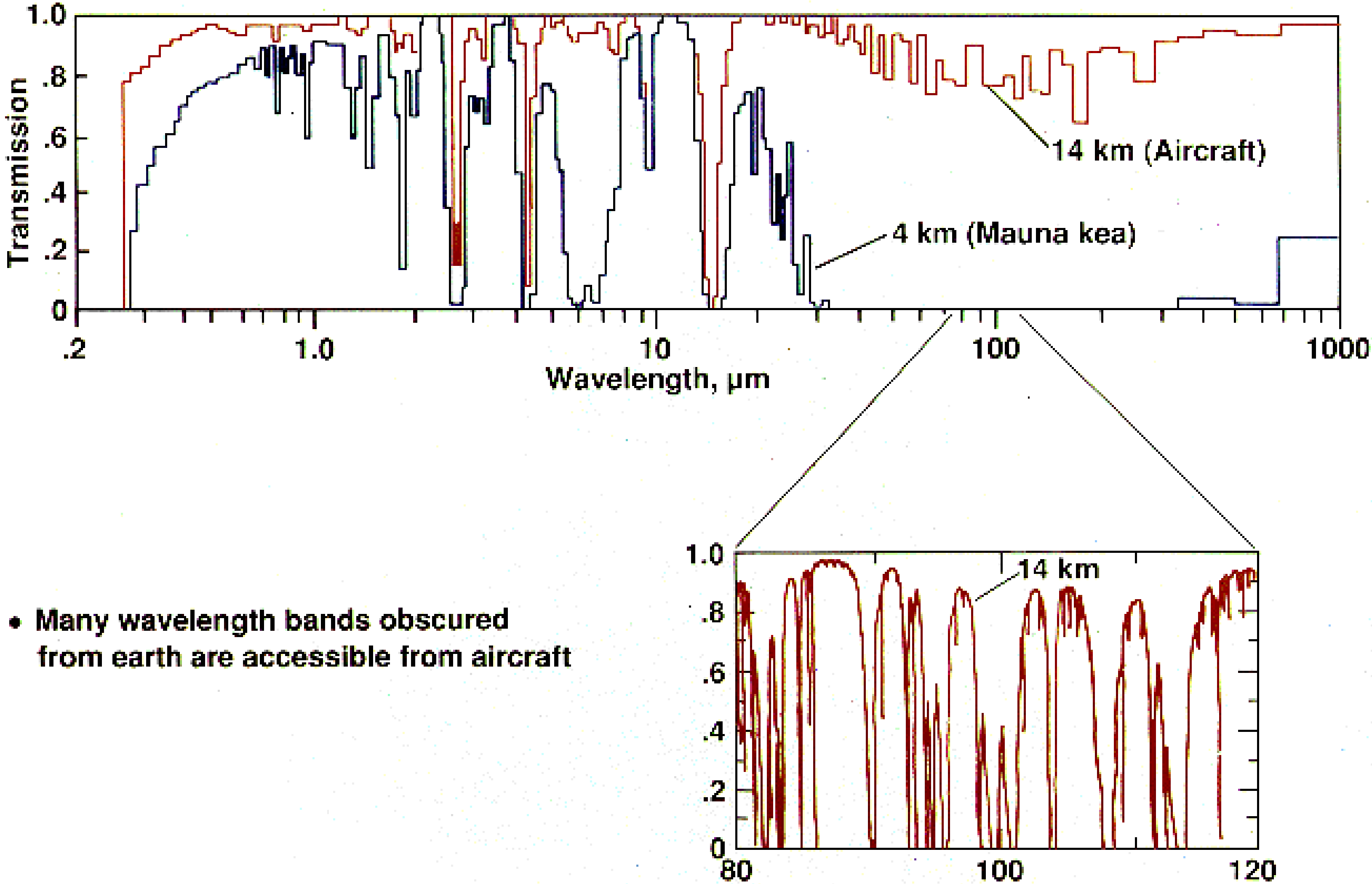


photometric “windows”

Atmospheric Transmission
"windows" of transparency

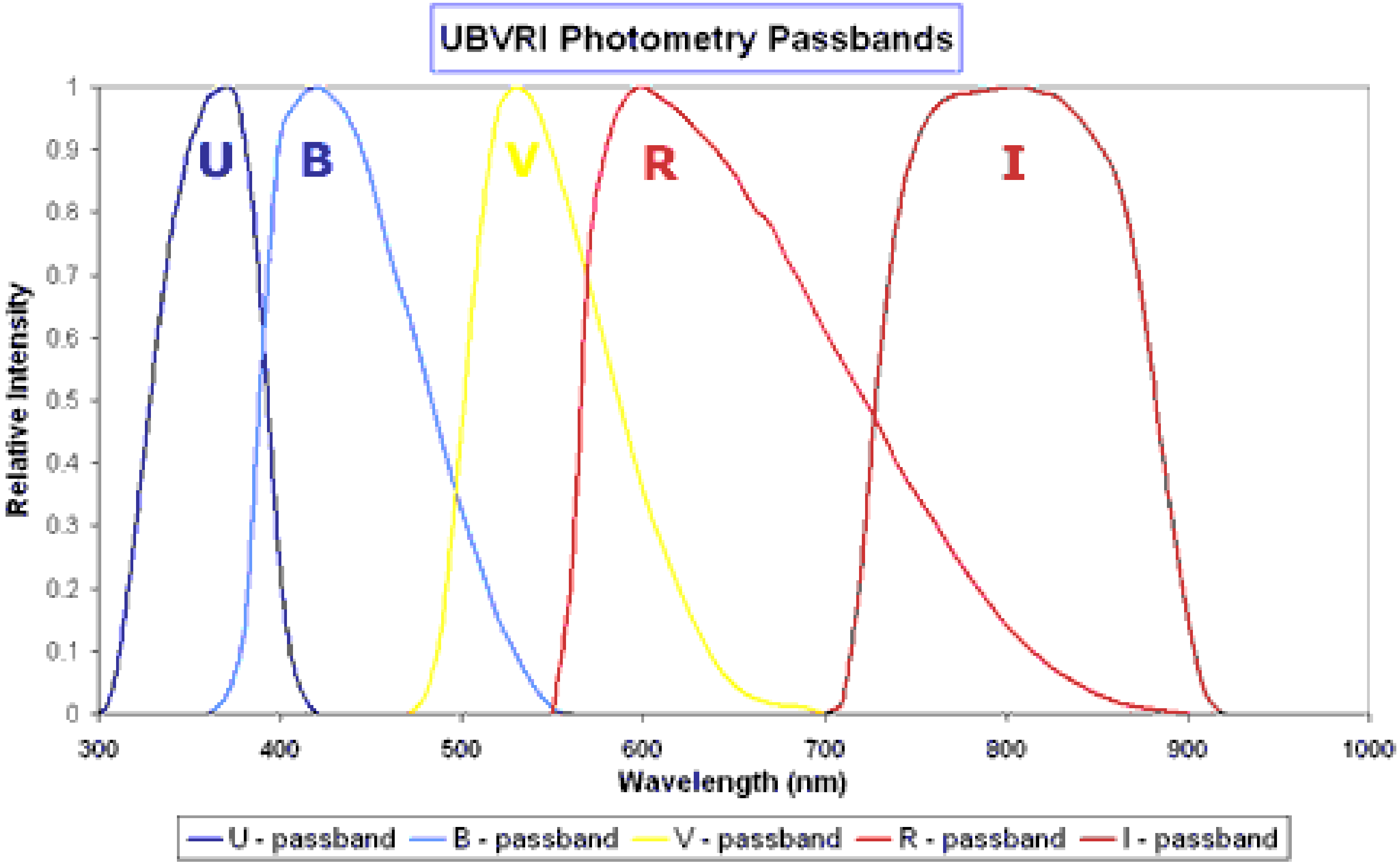


ATMOSPHERIC TRANSMISSION VERSUS WAVELENGTH

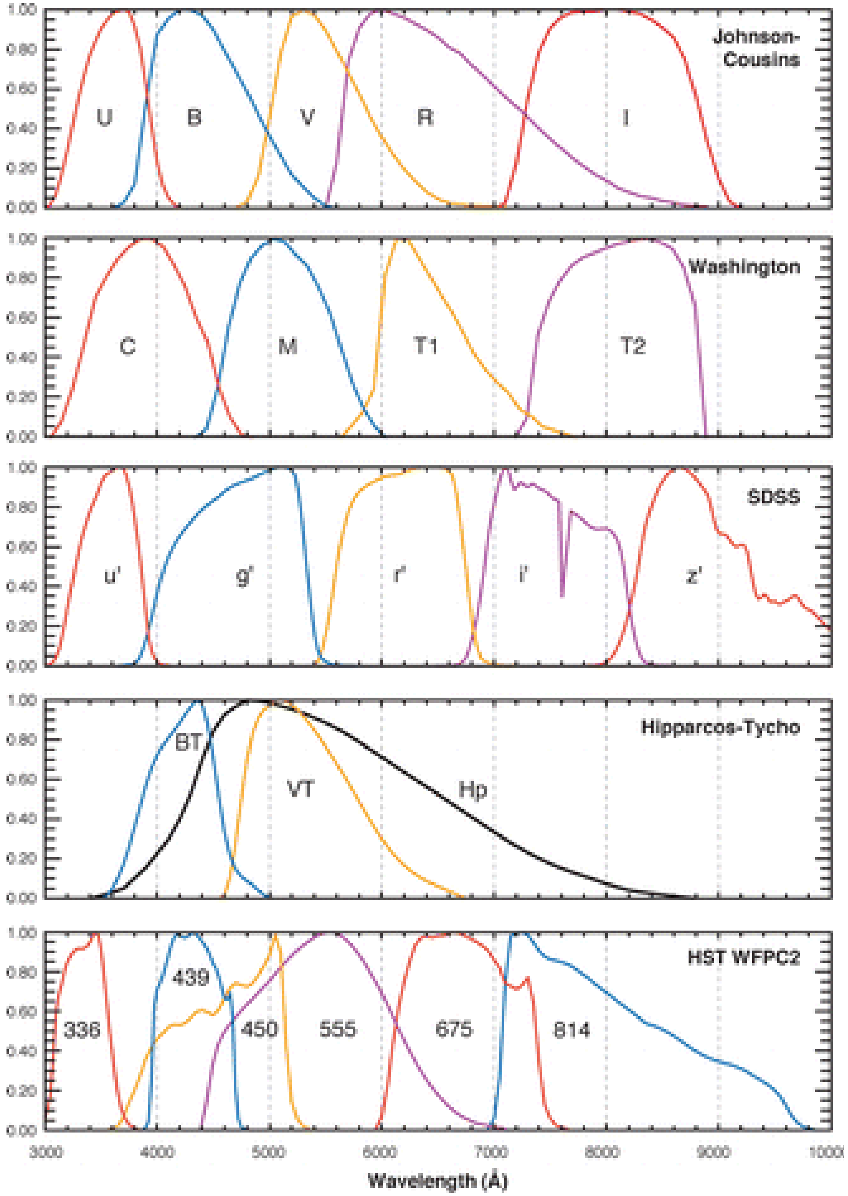


- Many wavelength bands obscured from earth are accessible from aircraft

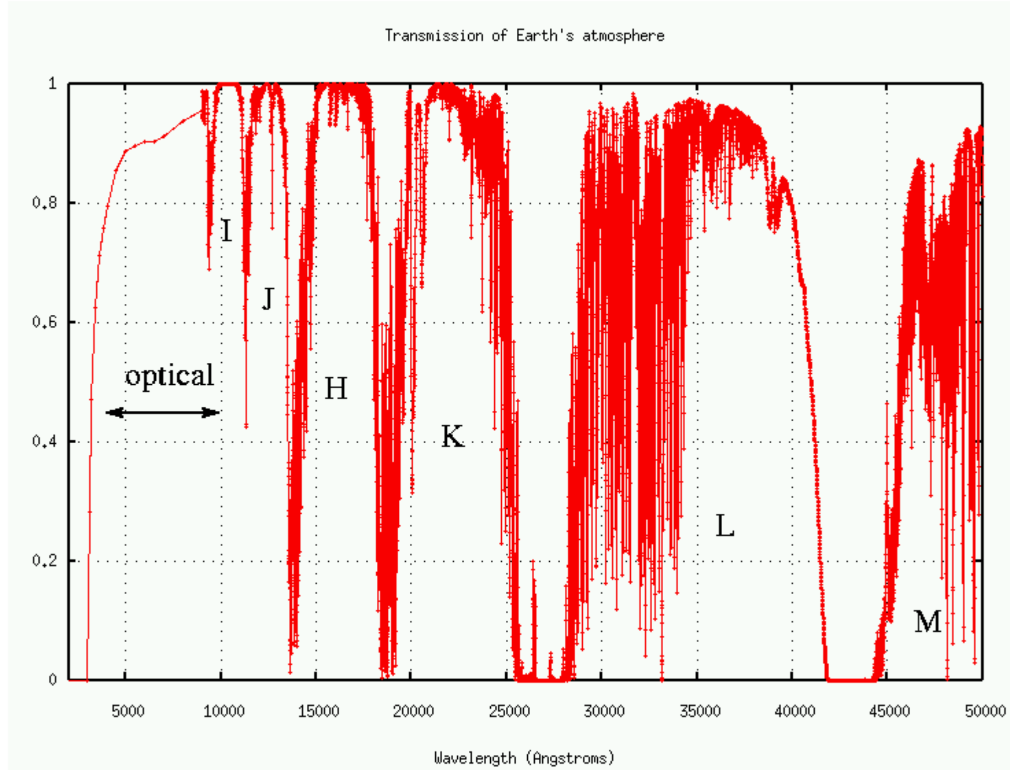
“Photometric” Filters



Photometric Systems



Bessell, MS. 2005
Annu. Rev. Astron. Astrophys. 43: 293–336



"Magnitudes"

- **Hipparchos (~150 BC):**
  - **Labelled stars according to "size" (i.e., apparent brightness = flux)**
  - **1st magnitude brighter than 6th**

- **Our senses are logarithmic, i.e., powers of ten.**

- **From modern electronic measurements:**
  - **A difference of one magnitude equals a flux ratio of**
    - $100^{1/5} = 2.5119$
    - **so 5 magnitudes =** $[100^{1/5}]^5$ **= 100x in flux (brightness)**
  - $F\ (\mathrm{mag} = 2)\ /\ F\ (\mathrm{mag} = 1) = 2.5119$
  - $F_2/F_1 = 2.5119^{(m1-m2)}$

Consider two stars of flux F_1 and F_2

$2.5119^{(m1-m2)} = F_2/F_1$

$(m_1-m_2) \log (2.5119) = \log (F_2/F_1)$

$\log (2.5119) = \log (100^{1/5}) = 1/5 * \log 100 = 0.4$

$0.4 (m_1-m_2) = \log (F_2/F_1)$

$\Delta m = (m_1-m_2) = 2.5 \log (F_2/F_1)$

<u>CHECK</u>: What if $m_1-m_2 = 5$. Then F_2/F_1 = ____?

Let one star have "zero magnitude"

magnitude difference = $\Delta m = (m_1 - m_2) = 2.5 \log (F_2/F_1)$

Let $m_1 \equiv 0$,

so $F_{m=0}$ is the flux from a zero-magnitude star

The star Vega is defined as zero-magnitude

Then $m_2 = -2.5 \log (F_2/F_{m=0})$

So, in general:

$m = -2.5 \log (F/F_{m=0})$

$m=m_v$ and $F=F_v$ are defined for some bandwidth, like visual ("v")