How far to a Star ?

- Fundamental problem …..

- How far away is a point of light ?

. Is it a 100-watt light bulb ?
. A star as bright as the Sun ?
. A galaxy of 10^{11} stars ?

- Brightness alone is not enough.

- How to measure astronomical distances ?

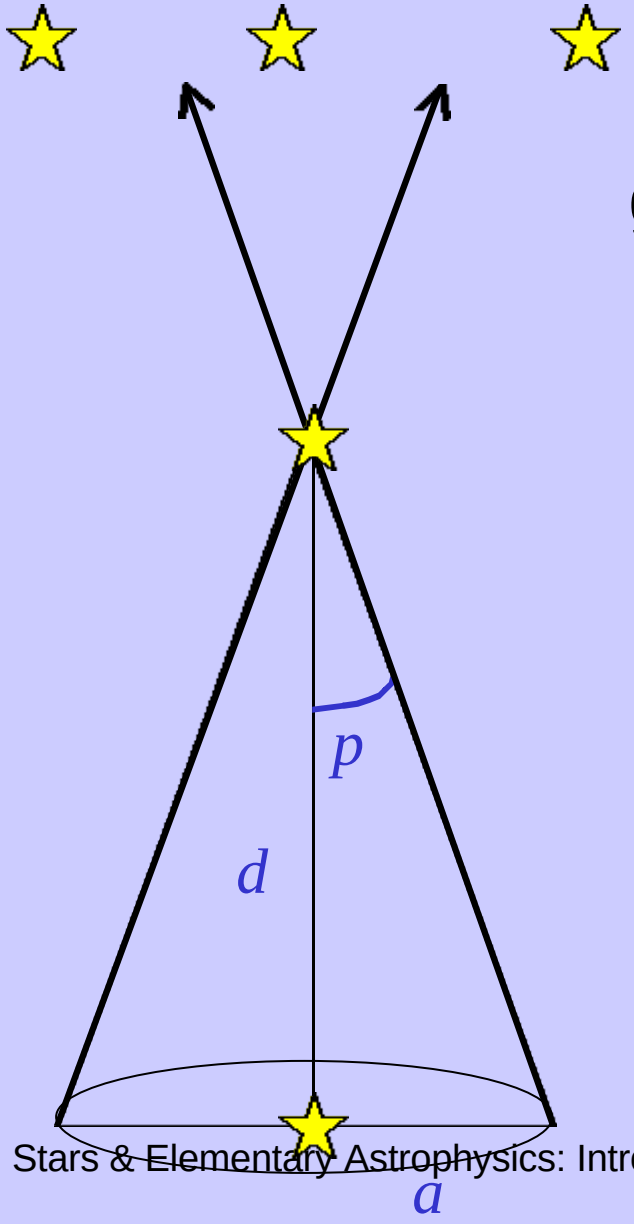
Astronomical Distances

- distance = speed x time
- light speed $c = 3 \times 10^{5}$ km/s
- 0.002 s Edinburgh-St.Andrews
- 0.1 s Earth circumference
- 1.2 s Earth-Moon distance
- 8 min Sun-Earth
- 40 min Jupiter
- 5 hr Pluto

Astronomical Distances

- 4.3 yr — nearest star (Proxima Centauri)
- 25,000 yr — centre of our Milky Way Galaxy
- 2×10^6 yr — nearest big galaxy (Andromeda, Messier 31, M31)
- 5×10^7 yr — nearest cluster of galaxies (Virgo cluster)
- $\approx 10^{10}$ yr — edge of visible part of Universe (The Big Bang)

Parallax



geometrical method

p = parallax angle

a = 1 Astronomical Unit (1 AU) = radius of Earth's orbit around the Sun.

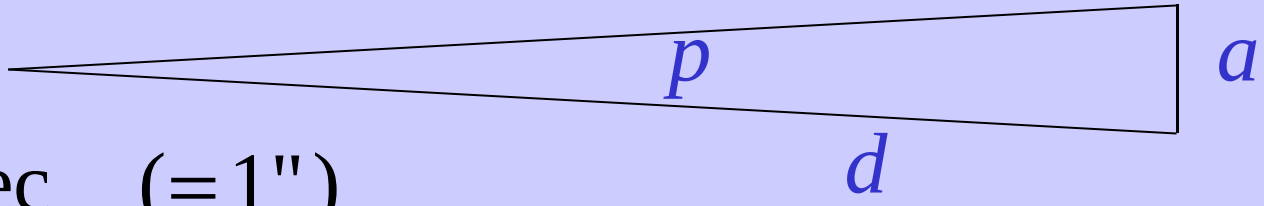
$$a = d \tan p$$

$$a \approx d\ p \quad \text{(small angle } p\text{)}$$

$$d \approx \frac{a}{p}$$

The Parsec -new distance unit

Example:



$$p = 1\ \text{arcsec} \quad (= 1'')$$

$$d = \frac{a}{p} = \frac{1\ \text{AU}}{1''} \times \frac{3600''}{1^\circ} \times \frac{180^\circ}{p\ \text{radian}}$$

$$= 206265\ \text{AU}$$

$$= 3.1 \times 10^{16}\ \text{m}$$

$$= 3.26\ \text{light yr}$$

= 1 parsec (1 pc)

Fast Method:

$d = 1/p$

For p in arcsec
and d in parsec

Stellar Parallaxes are tiny

- Bessel (1838) First parallax:
  61 Cygni p = 0.29 arcsec $\Rightarrow$
  d = 1/0.29 = 3.42 pc
- also in 1838: Henderson (á Centauri)
  . Struve (Vega)
- The nearest star (beyond the Sun)
  Proxima Centauri p = 0″.76 , d = 1.31 pc.

Limits of Parallax

- Ground-based CCDs 0.05” 20 pc
- Hubble Telescope 0.01” 100 pc
- Hipparcos (all sky) 0.005” 200 pc
  Today: *Nearby Stars Only*

- 2015: GAIA (whole galaxy) 10,000 pc

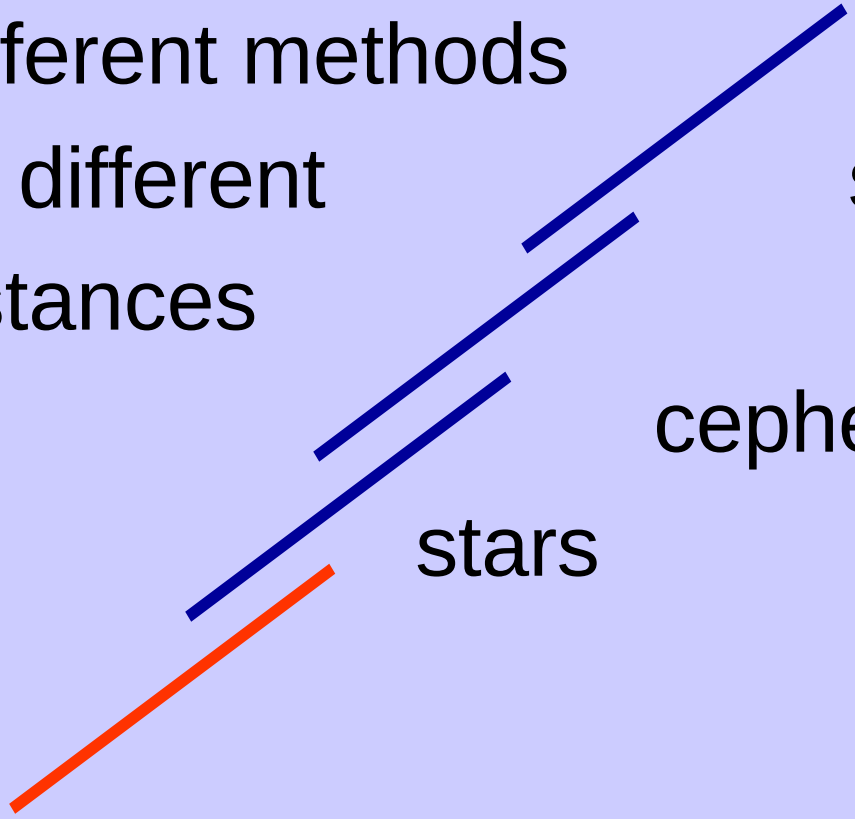
The Distance Ladder

- Different methods
- for different
- distances
-
-

supernovae

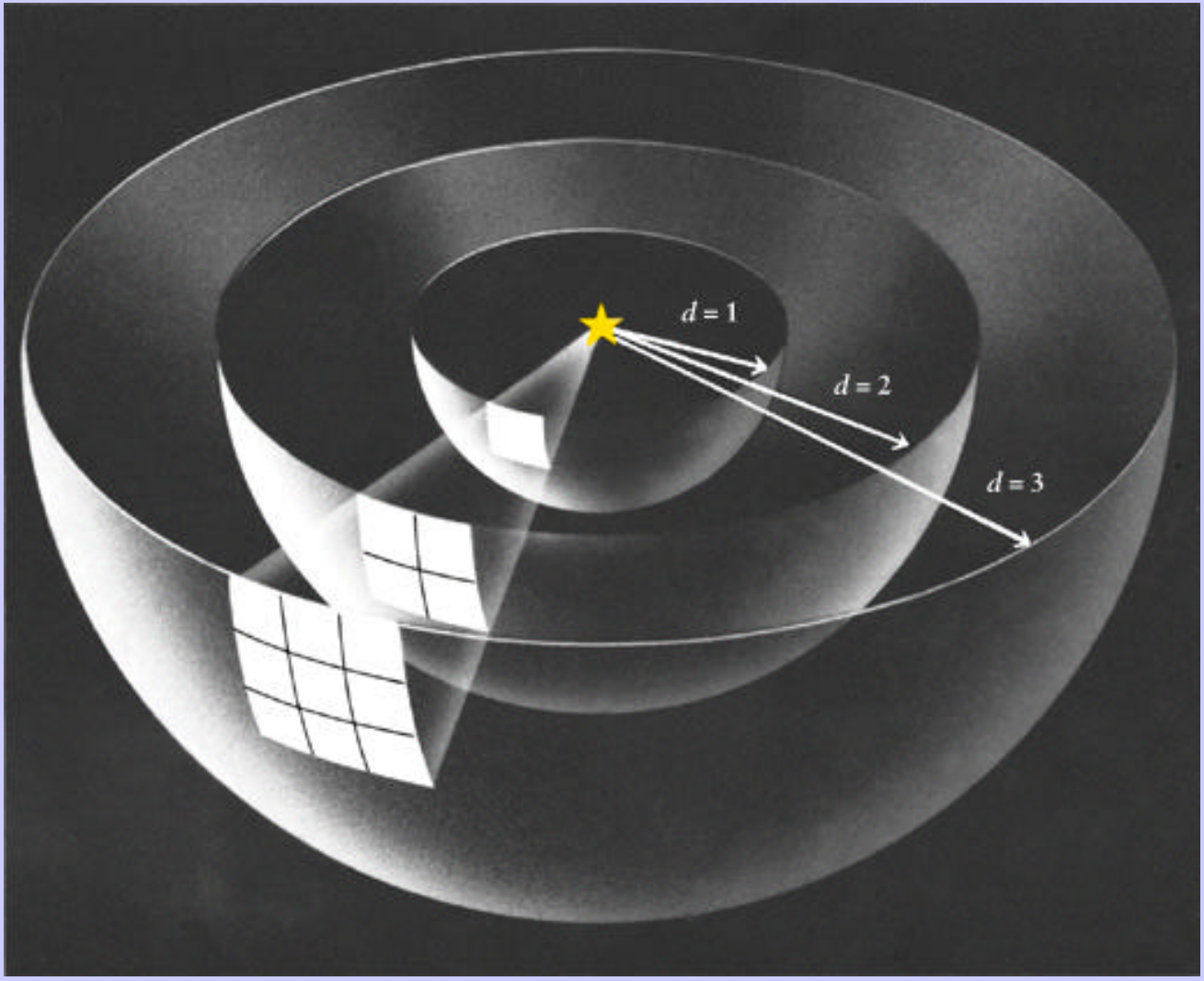
cepheid variables

stars



- ***PARALLAX IS THE FOUNDATION FOR ALL OTHER METHODS***

Inverse Square Law



Luminosity, Flux

Luminosity

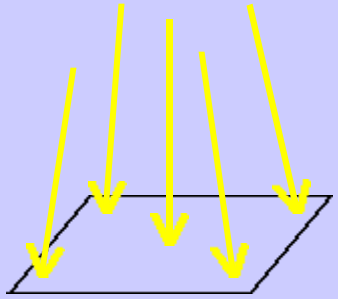
$$L = \frac{\text{energy}}{\text{time}}$$

Units: Joule / sec = Watt (e.g. 100 W light bulb)

Solar luminosity: $L_{sun} = 3.8 \times 10^{26}\ \text{W}$

Flux

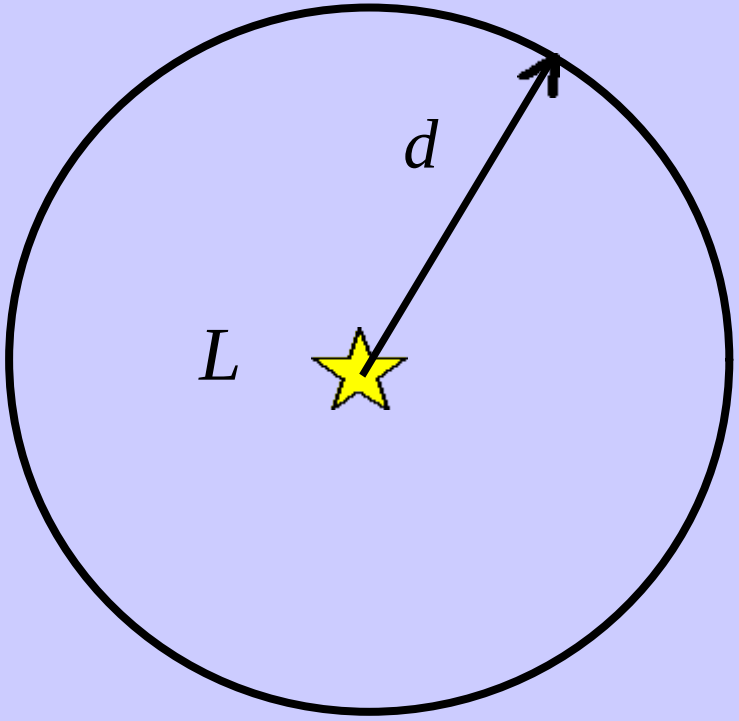
$$F = \frac{\text{energy}}{\text{time} \times \text{area}}$$



Units: Watts / square metre

Sun viewed from Earth: $F_{sun} = 1380\ \text{W/m}^2$

Inverse Square Law



$$\text{area of sphere} = 4\pi d^2$$

Flux viewed from distance d :

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