

Beyond the Solar System...



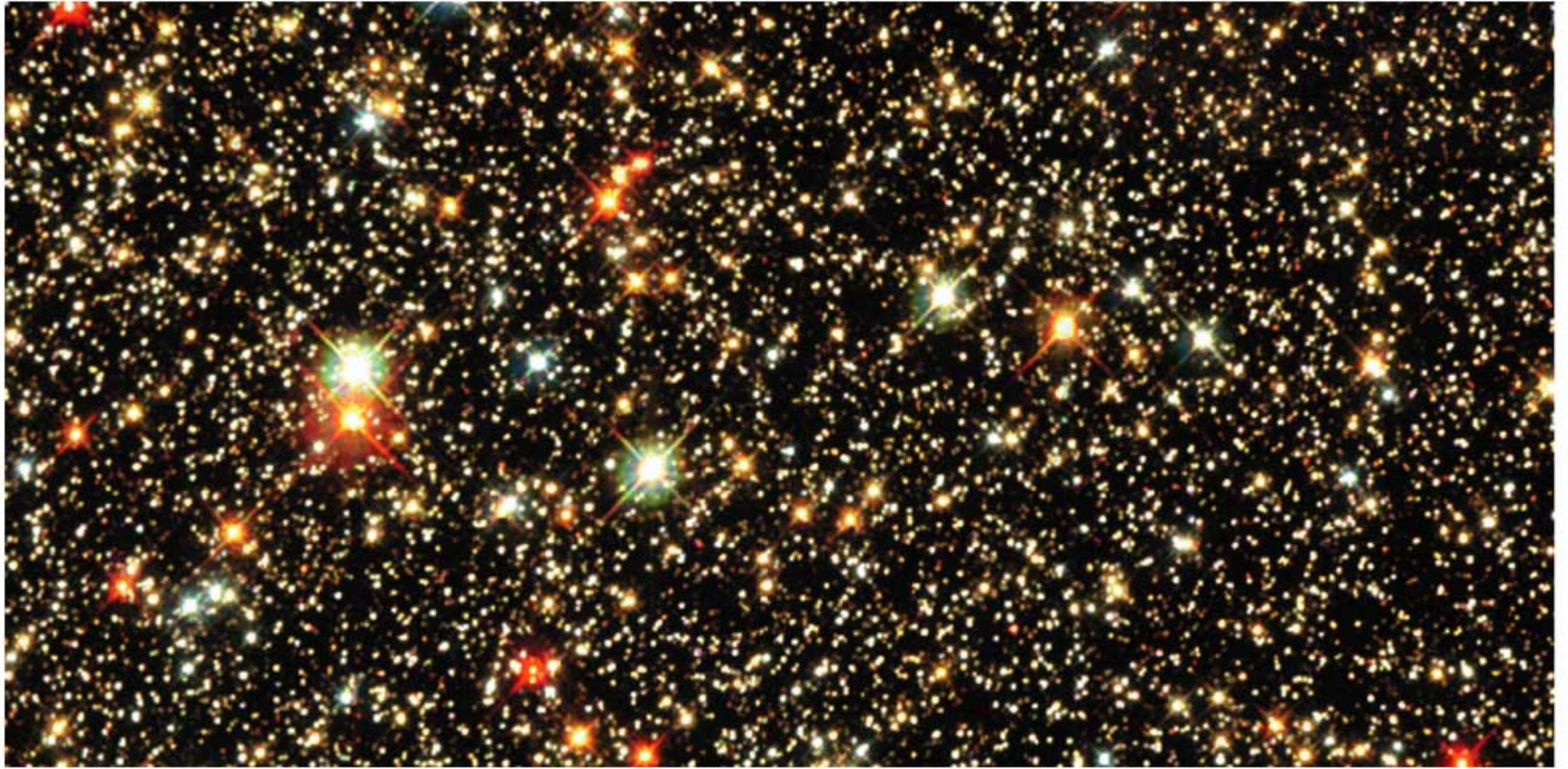
Reading: Chapter 6

Properties of Stars



What do you see ?

Properties of Stars



Stars have different brightness, colours and sizes. Why?

Properties of Stars

The brightness of a star depends on

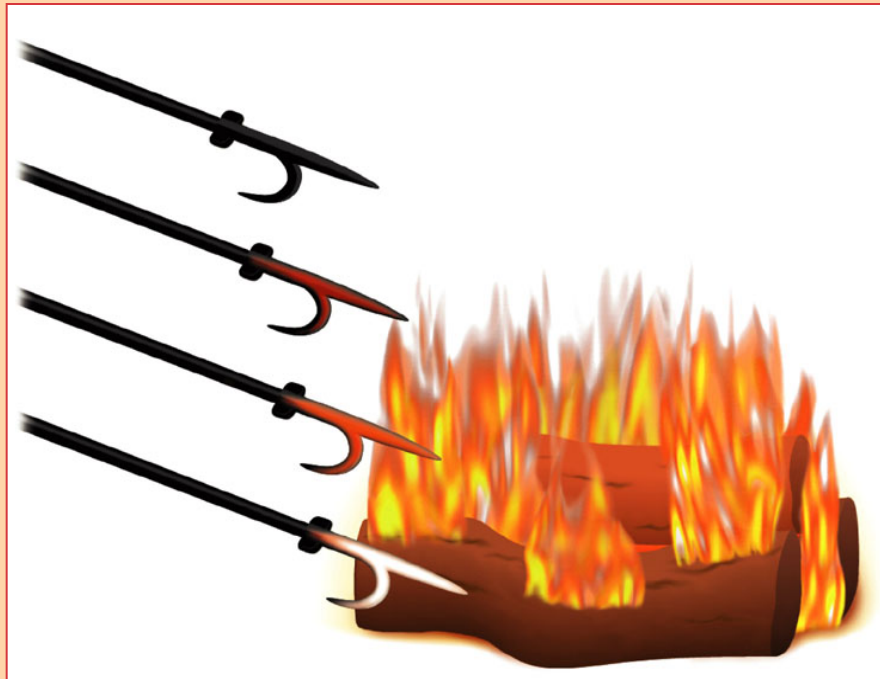
- Its luminosity (amount of energy it radiates per second)
- Its distance from us



Properties of Stars

The colour of a star depends on

- Its temperature



Properties of Stars

Questions

- How do we measure stellar distances?
- How do we measure stellar luminosity?
- How do we measure stellar temperatures?
- How do we measure stellar masses?

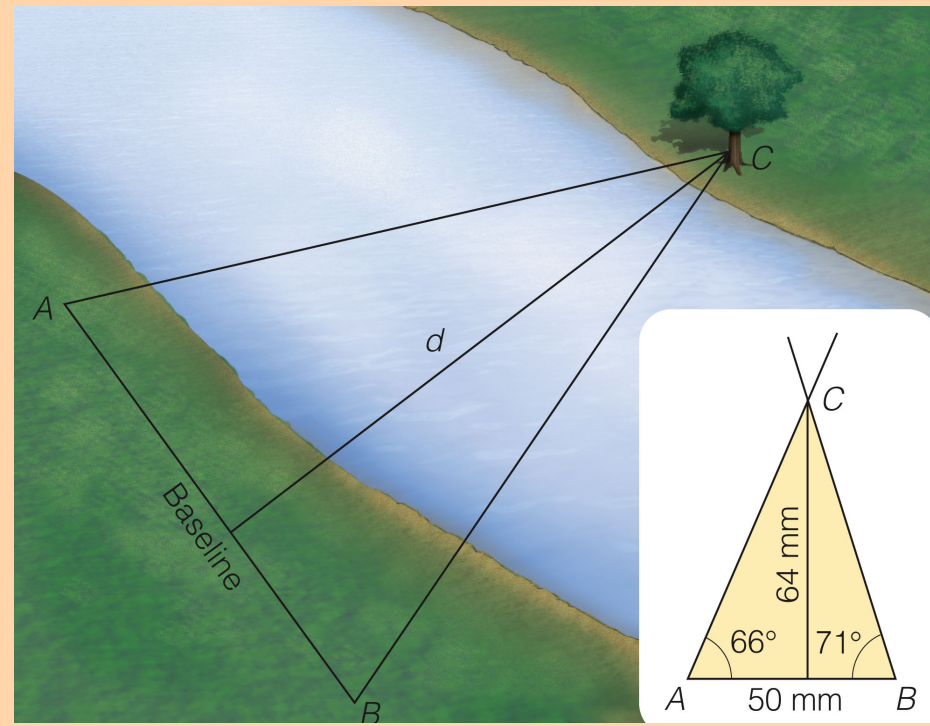
Stellar Distances



So how far are these stars?

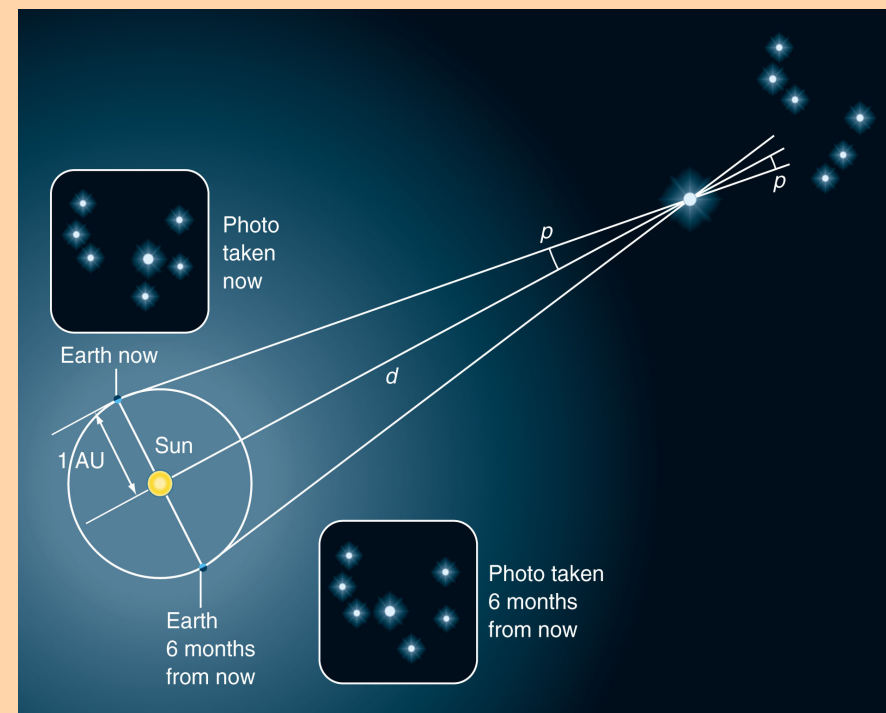
The Surveyor's Triangulation Method

- Surveyors measure the distance between A and B (baseline) and angles CAB and ABC.
- From this they can use trigonometry to work out the distance d

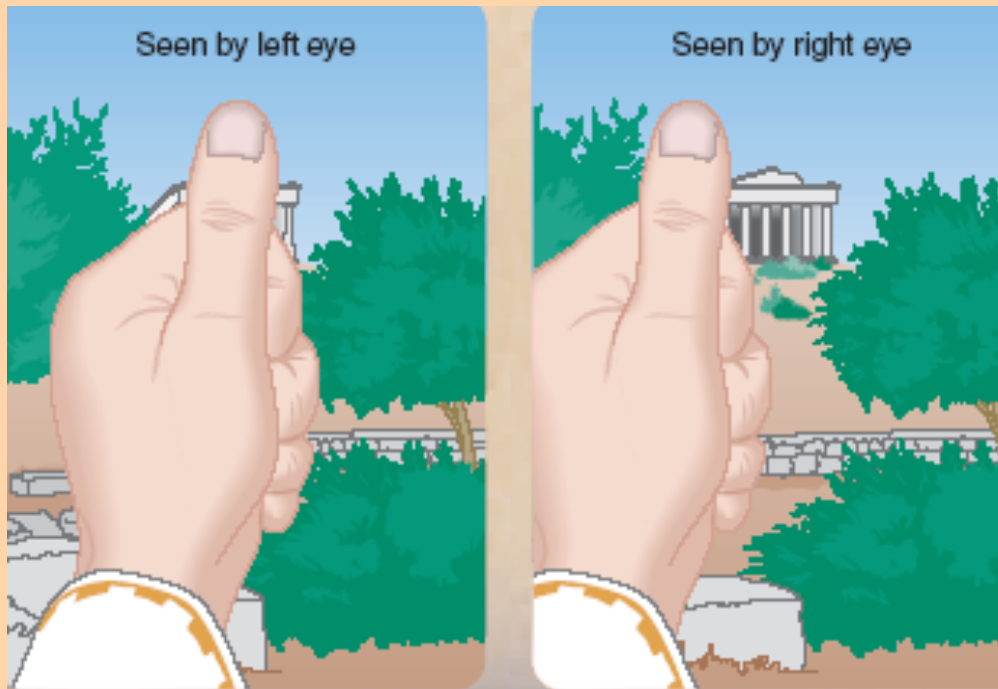


The Astronomer's Triangulation Method

- Baseline to measure stars is the diameter of the Earth's orbit.
- To measure angles to distant stars astronomers use the parallax effect



Measuring Stellar Distances



Baseline is the distance between your eyes
Nearby object: your thumb
Distant background: The building

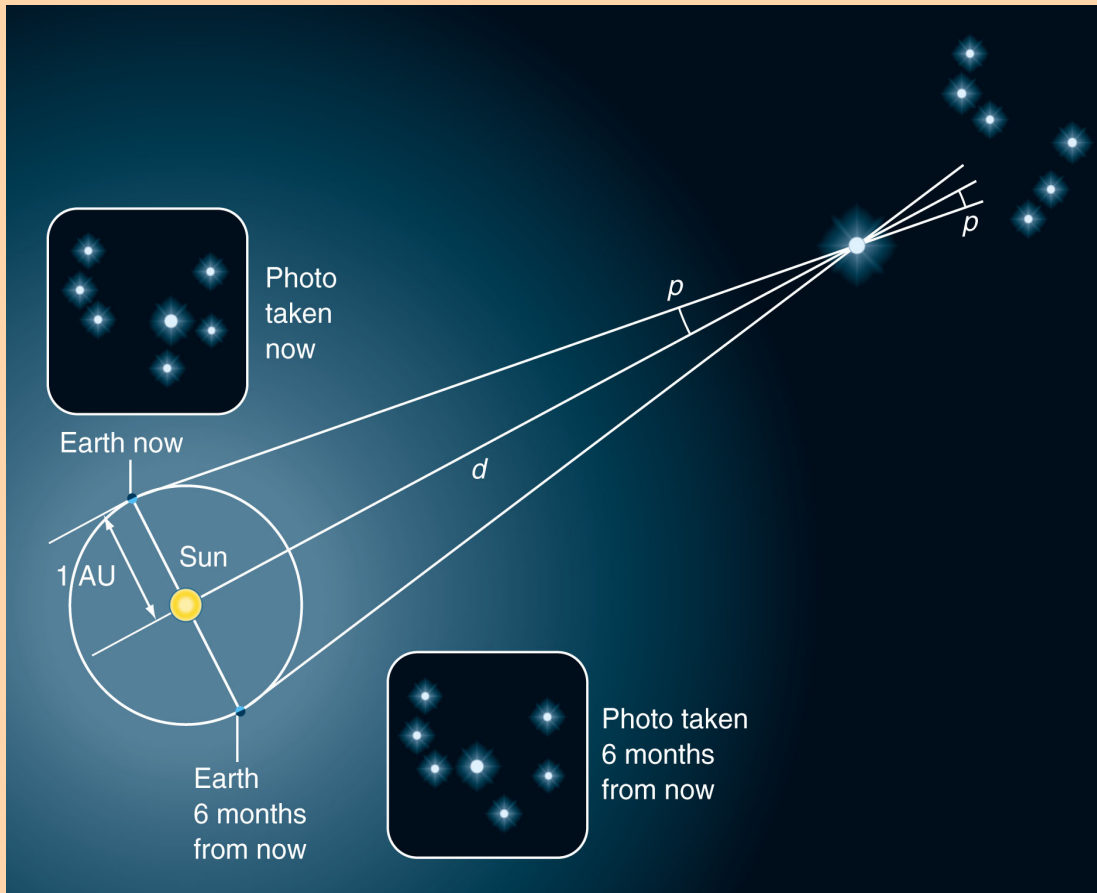
Parallax

is the apparent shift in position of a nearby object against a background of more distant objects

Parallax angle depends on distance

The **further** the object, the **smaller** the parallax angle

Measuring Stellar Distances



Apparent positions of nearest stars shift by about **an arcsecond** as Earth orbits Sun

An arcsecond is the angular size of a 10cent coin placed 3km away!

$$1 \text{ arcsecond} = 1\text{degree}/3600$$

Parallax and Distance

p = parallax angle

$$d \text{ (in parsecs)} = \frac{1}{p \text{ (in arcseconds)}}$$

$$d \text{ (in light-years)} = 3.26 \times \frac{1}{p \text{ (in arcseconds)}}$$

1 parsec = The distance to a star that has a parallax of 1 arc second.

A parsec is 206,265 AU—roughly 3.26 ly.

Stellar Catalogs

- Accurate measurements of parallaxes smaller than 0.006 arcseconds is not possible from Earth due to twinkling cause by Earth's atmosphere.
- ESA's Hipparcos space satellite gathered data used to catalog the distances to over 1 million stars.

Stellar Luminosities

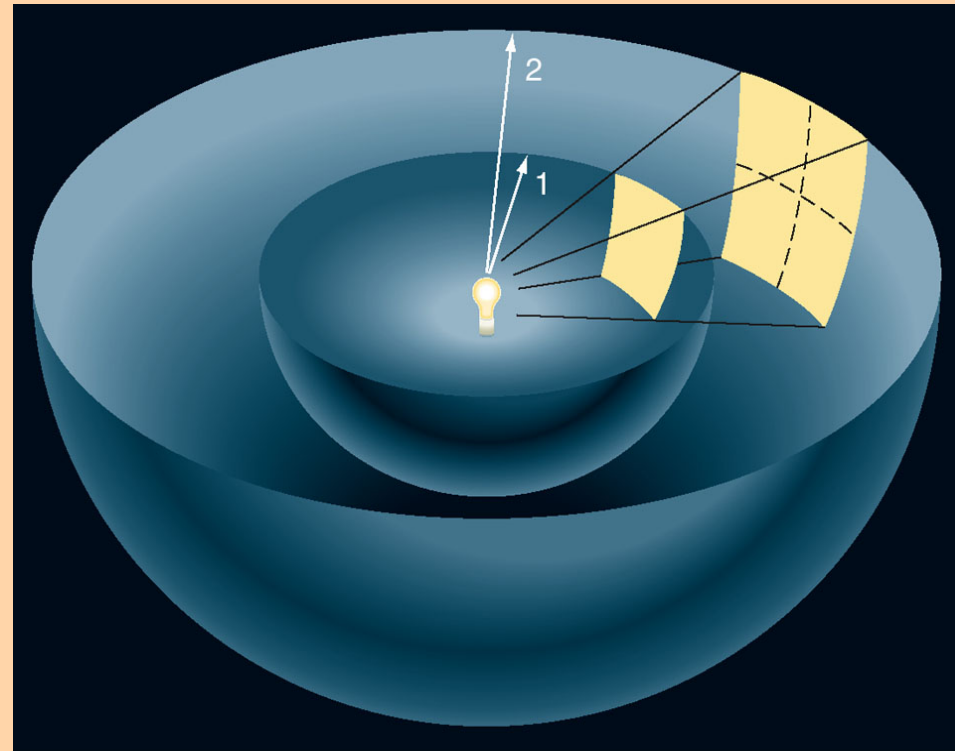


So how bright are these stars?

Apparent Brightness

The more distant a light source is, the fainter it appears.

The same amount of light falls onto a smaller area at distance 1 than at distance 2 => smaller apparent brightness.



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Area increases as square of distance => apparent brightness decreases as inverse of distance squared

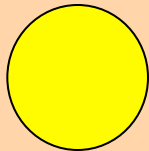
If a source is 2x farther away, it is 4x fainter

Intrinsic Brightness

This is a measure of the amount of energy the star emits.

The flux receive from the light is proportional to its intrinsic brightness or luminosity and inversely proportional to the square of the distance

Star A



Star B



Earth



Both stars may appear equally bright, although star A is intrinsically much brighter than star B.

Distance and Intrinsic Brightness

Rigel appears 1.28 times brighter than Betelgeuse,

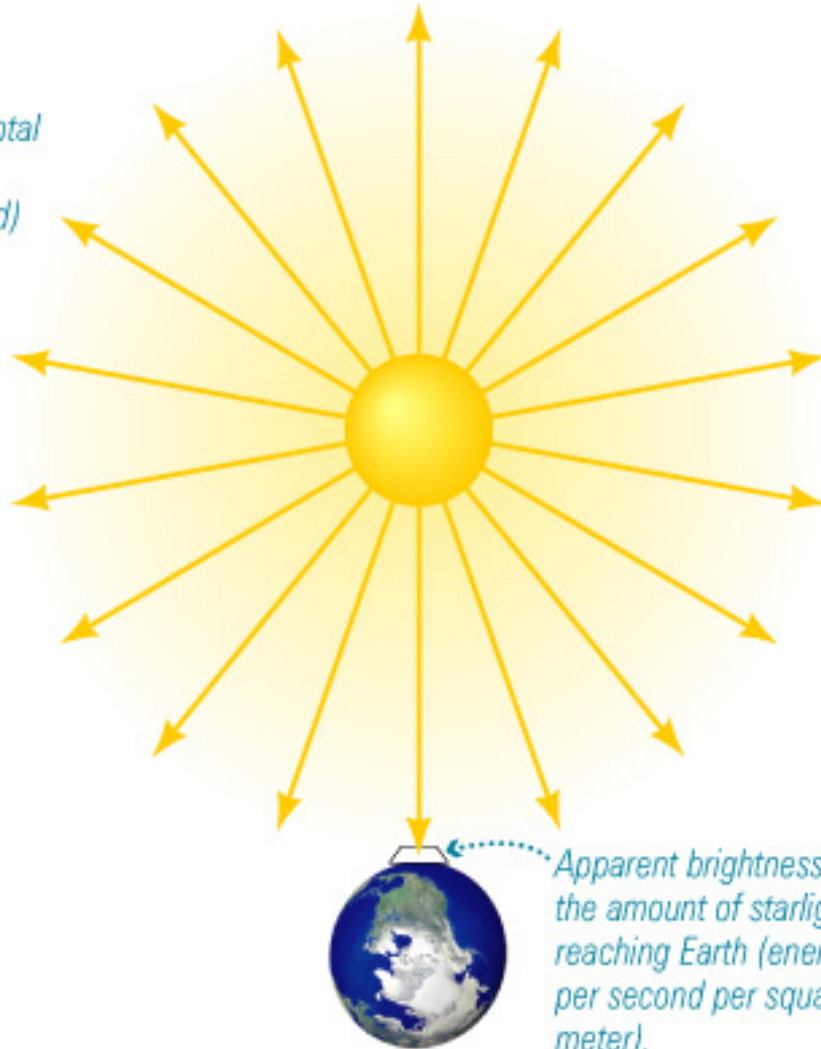
But Rigel is 1.6 times further away than Betelgeuse

Thus, Rigel is actually (intrinsically) $1.28 \times (1.6)^2 = 3.3$ times brighter than Betelgeuse.



Luminosity and Apparent Brightness

Luminosity is the total amount of power (energy per second) the star radiates into space.



Not to scale!

Apparent brightness is the amount of starlight reaching Earth (energy per second per square meter).

Luminosity:

Amount of power a star radiates

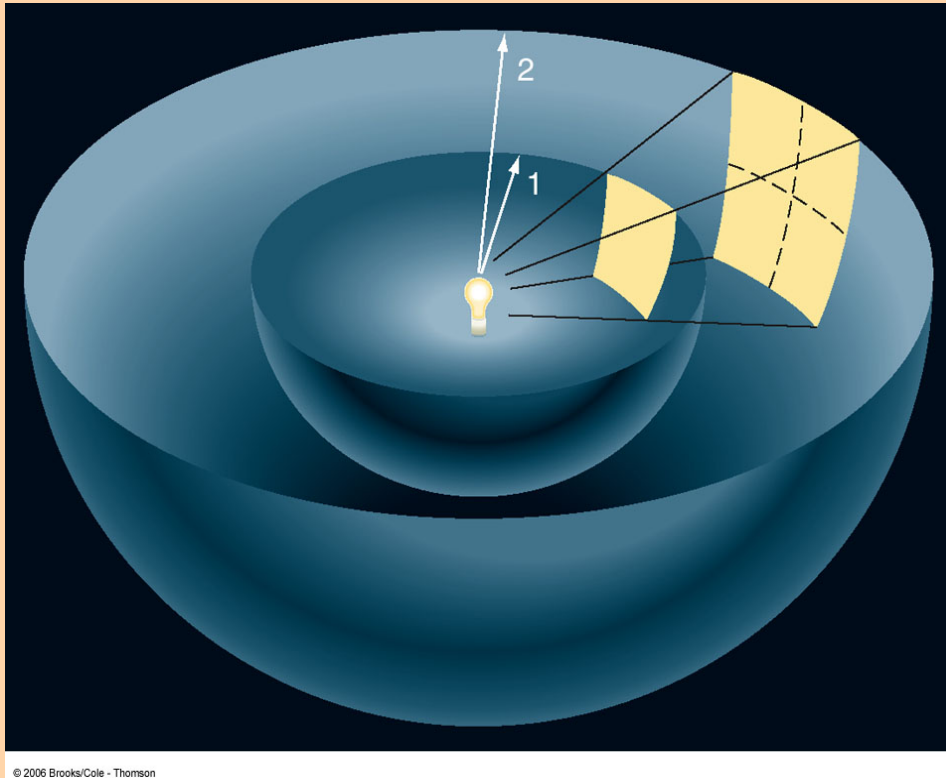
(energy per second = Watts)

Apparent brightness:

Amount of starlight that reaches Earth

(energy per second per square meter)

Luminosity and Apparent Brightness



Luminosity passing through each sphere is the **same**

Area of sphere:

$$4\pi (\text{radius})^2$$

Brightness is the luminosity divided by area

Luminosity and Apparent Brightness

The relationship between apparent brightness and luminosity depends on distance:

$$\text{Brightness} = \frac{\text{Luminosity}}{4\pi (\text{distance})^2}$$

We can determine a star's luminosity if we can measure its **distance** and **apparent brightness**:

$$\text{Luminosity} = 4\pi (\text{distance})^2 \times (\text{Brightness})$$

Thought Question

How would the apparent brightness of Alpha Centauri change if it were three times farther away?

- A. It would be only $1/3$ as bright
- B. It would be only $1/6$ as bright
- C. It would be only $1/9$ as bright
- D. It would be three times brighter

Thought Question

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Stellar Luminosities

We can determine a star's luminosity if we can measure its **distance** and **apparent brightness**:

$$\text{Luminosity} = 4\pi (\text{distance})^2 \times (\text{Brightness})$$

- We can measure brightness by dividing the energy collected per second by our telescope by the area of the telescope
- We can measure distance using the stellar parallax.

Putting the two together we can calculate the luminosity of different stars.

Stellar Luminosities

Example: The Sun

Apparent brightness: 1400 Watts/m²

Distance: 1 AU (150 million km)

$$\begin{aligned} \text{Luminosity} &= 4\pi (\text{distance})^2 \times (\text{Brightness}) \\ &= \mathbf{3.9 \times 10^{26} \text{ Watts}} \end{aligned}$$

This is the energy emitted by the sun in all directions every second!

Of this energy about 15MWatts is hitting this building right now!

This energy would cost \$1500/hr at current energy rates!

A human being emits about 100 Watts of infrared radiation

What is the Sun's luminosity at the distance of Mars?

Stellar Luminosities



Stars have a very wide range of luminosities:

Most luminous stars:

$$10^6 L_{\text{Sun}}$$

Least luminous stars:

$$10^{-4} L_{\text{Sun}}$$

(L_{Sun} is luminosity of Sun)