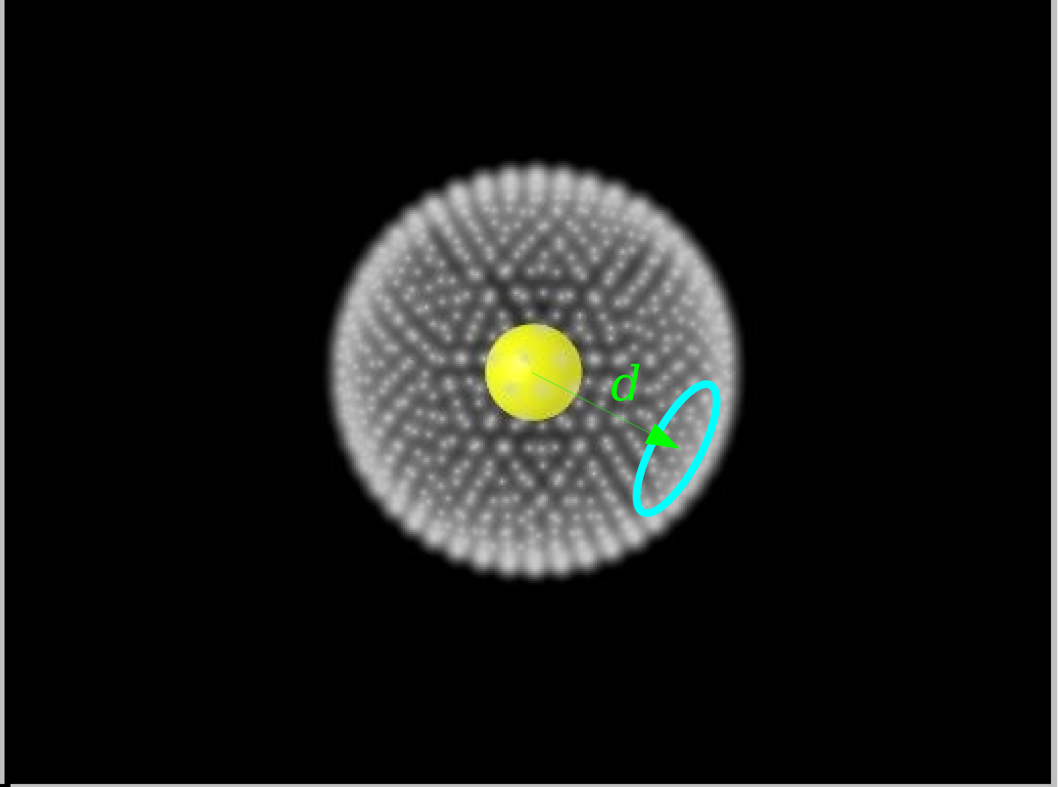
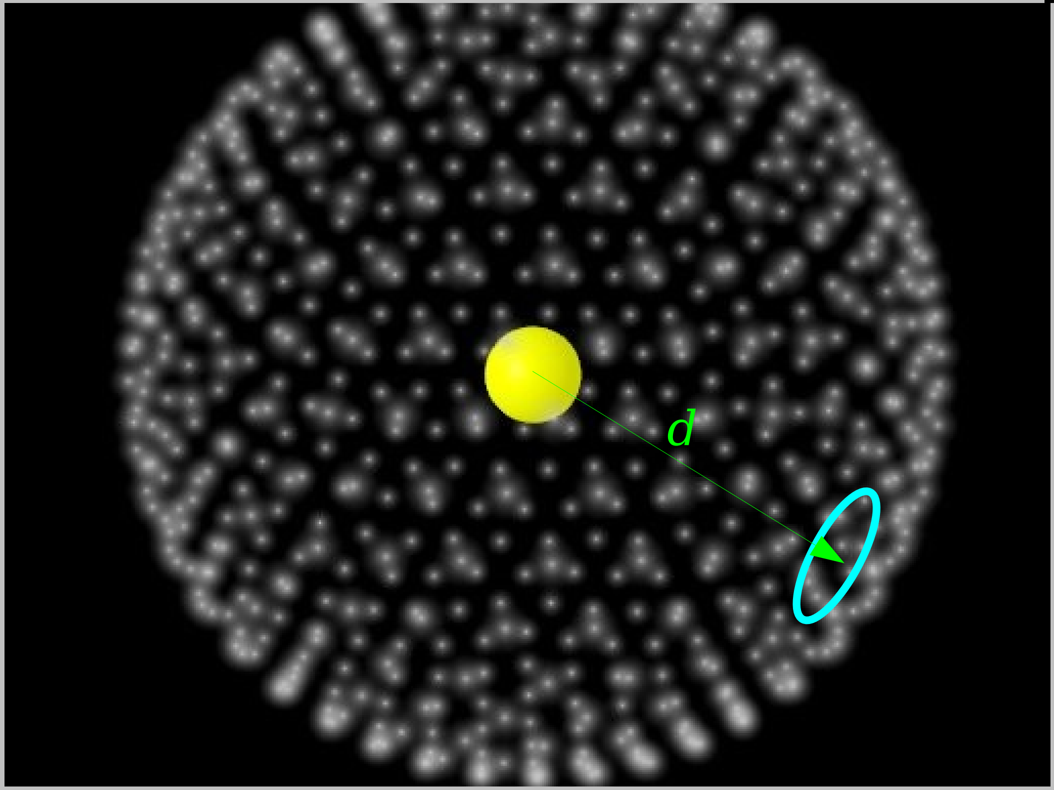
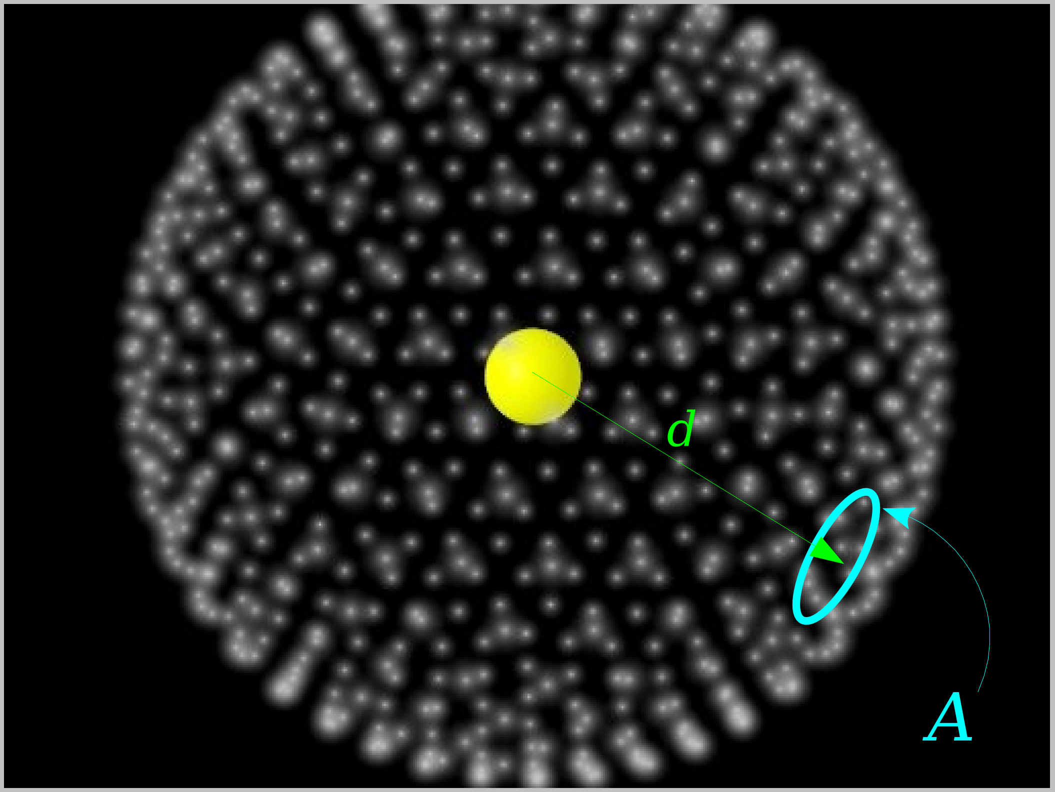
The amount of light seen by a given telescope (which is what we call *Brightness*) goes down as the distance from the source goes up:

$$B \propto \frac{1}{d^2}$$





An object that is twice as far away will appear ¼ as bright.

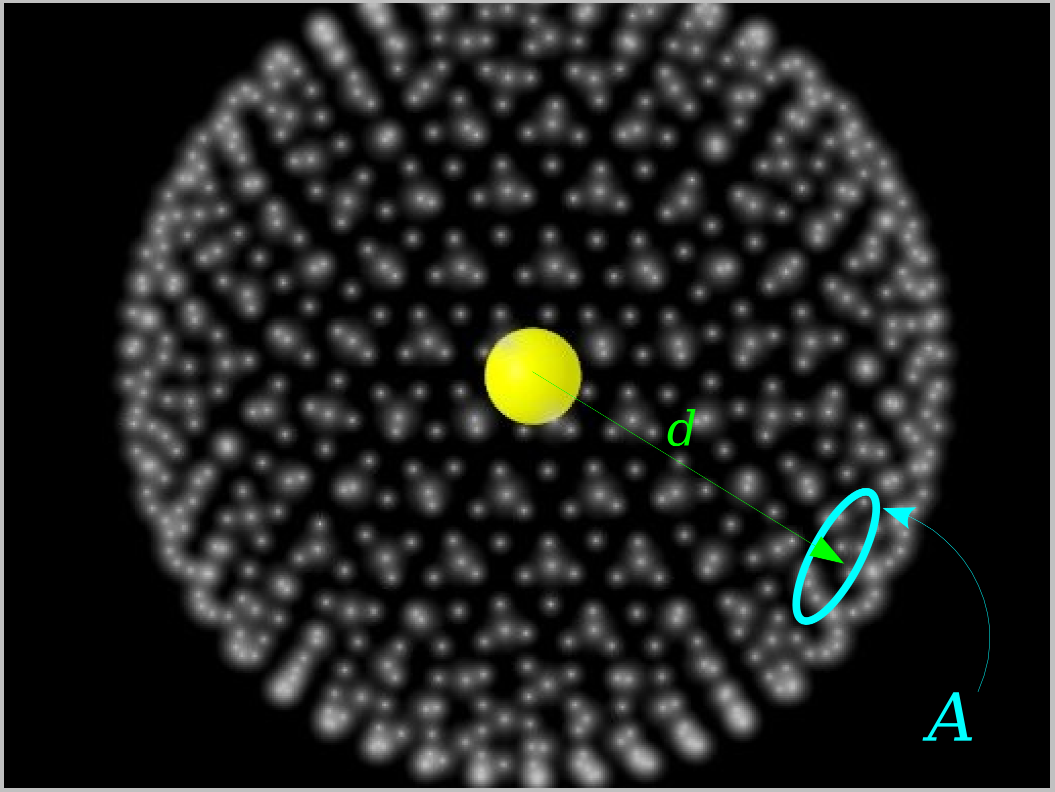


L = energy output from the source

d = distance from the source to the observer

A = area of observer's collecting instrument (telescope)

$4\pi d^2$ = area that light is spread over a distance d away from the source.



Light detected by the telescope per second:

$$\frac{E}{t} = L\left(\frac{A}{4\,\pi\,d^2}\right)$$

Note : energy detected depends on the size of the telescope.

Define *brightness* to be independent of telescope size.

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

B Observed brightness : how bright the star looks. (The rate that a telescope with area 1 m^2 collects energy, or the amount of energy it collects each second) Units: W/m^2

L Intrinsic luminosity. The rate at which a star (or other object) puts out energy. (Energy output per second.) Units: W

d Distance from you (the observer) to the star. Units: m (or any other distance unit, so long as you keep your other units consistent!)

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

When we use this equation, d is the distance from the object (e.g. a star) of luminosity L to the observer (usually us). How is this d defined?

- A The distance from the *surface* of the star to us.
- B The distance from the *center* of the star to us.
- C This distance to us from a point in the star between the surface and the center, depending on the temperature of the star.
- D The distance to us from a point in the star between the surface and the center, depending on whether this is a nearby or very distant star.
- E Any of A-D ; it doesn't matter.

An astronomer observes two stars in an open cluster. Star A is about twice as bright as Star B. Which one is more luminous?

A Star A is more luminous.

B Star B is more luminous.

C The two stars are the same luminosity.

D It is impossible to tell which star is more luminous from the information provided.

You observe a star of known luminosity, and use the measured brightness to estimate the distance. Unknown to you, an intervening dust cloud absorbs the light, making it 1/25 as bright as it would have been without the cloud. How much have you over or underestimated the distance to this star?

You will overestimate the distance between you and the star; it will appear dimmer than it would have had the gas cloud not been there, so your calculations will place it further away.

You know that you overestimated the distance by a factor of five. This is because the brightness is proportional to 1/(distance^2).

1/25 the brightness would be (1/25)(1/(distance^2)), which is 1/(25(distance^2)), which is 1/((5 x distance)^2).

$$B_1 = \frac{L_1}{4\pi d_1^{\,2}} \qquad B_2 = \frac{L_2}{4\pi d_2^{\,2}}$$

B_1 = brightness measured without dust

d_1 = real distance

B_2 = brightness actually measured

d_2 = (mis)estimated distance

$$\frac{B_1}{B_2} = \frac{\dfrac{L_1}{4\pi d_1^{\,2}}}{\dfrac{L_2}{4\pi d_2^{\,2}}}$$

$$\frac{B_1}{B_2} = \left(\frac{L_1}{L_2}\right)\left(\frac{d_2}{d_1}\right)^2 \qquad \frac{d_2}{d_1} = \sqrt{\frac{B_1}{B_2}} = \sqrt{25\,\frac{B_1}{B_1}} = 5$$

$$B_1 \propto \frac{1}{d_1^{\,2}} \qquad B_2 \propto \frac{1}{d_2^{\,2}}$$

$$\frac{B_1}{B_2} = \left(\frac{d_2}{d_1}\right)^2$$

Because we're talking the same star, our distance estimate is all that matters; L is the same in each case.

An astronomer sees two stars, Star A and Star B. Star A is brighter than Star B. Which star is closer?

A Star A is closer to us than Star B.

B Star B is closer to us than Star A.

C The two stars are at the same distance.

D It is impossible to tell which star is closer from the information provided.

We don't know the intrinsic luminosity of each star. E.g. Sirius, less luminous than Deneb, but brighter in our sky (much closer).

An astronomer sees two stars which appear the same brightness. One star is redder, one star is bluer.

A The red star is closer to us than the blue star.

B The blue star is closer to us than the red star.

C The two stars are at the same distance.

D It is impossible to tell which star is closer from the information provided.

When two objects are of the *same size*, the bluer (hotter) one emits more energy per second.

Later in the Sun's life (a few billion years from now), it will become what we call a *Red Giant*. It will be up to 100 times its current size, but it's temperature will drop from around 6,000K to around 4,000K (therefore making its color redder).

When this happens, from the Earth the Sun will appear:

- A Much brighter
- B Much fainter
- C About the same brightness
- D It is impossible to make a statement about how bright the Sun will appear given the information provided.

Consider two stars of the same temperature and same size. Star A is twice as far away as Star B.

What is the Luminosity of Star A compared to Star B?

- A L_A/L_B = 1 (they have the same luminosity)
- B L_A/L_B = 2 (A is twice as luminous as B)
- C L_A/L_B = ½ (A is half as luminous as B)
- D L_A/L_B = 4 (A is four times as luminous as B)
- E L_A/L_B = ¼ (A is one fourth as luminous as B)

Consider two telescopes; telescope A has an aperture of diameter 8 inches, telescope B has an aperture of diameter 16 inches. Both telescopes, side-by-side, look at the same star. Telescope A measures brightness B_A, telescope B measures brightness B_B. What is the relationship between the two brightnesses measured?

A $B_B = \frac{1}{4} B_A$

B $B_B = \frac{1}{2} B_A$

C $B_B = 2 B_A$

D $B_B = 4 B_A$

E $B_B = B_A$

Consider two telescopes; telescope A has an aperture of diameter 8 inches, telescope B has an aperture of diameter 16 inches. Both telescopes, side-by-side, look at the same star. In one second, telescope A collects energy E_A, and telescope B collects energy E_B. What is the relationship between the energy collected by each telescope?

A $E_B = ¼\, E_A$

B $E_B = ½\, E_A$

C $E_B = 2\, E_A$

D $E_B = 4\, E_A$

E $E_B = E_A$