Stars

Temperatures of Stars

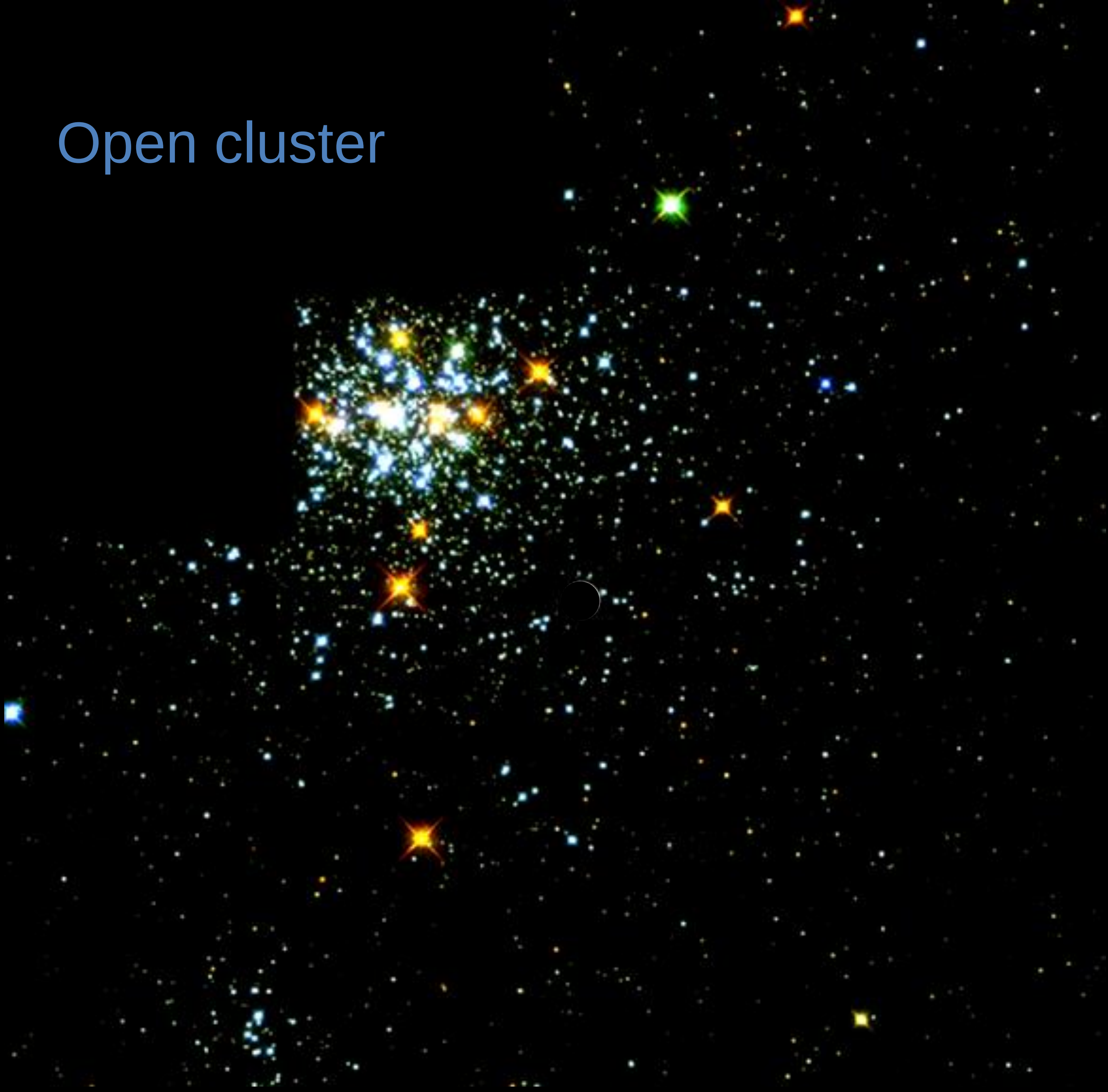
Grouping in the Galaxy

- free stars
- open clusters
- globular clusters

Luminosity vs Brightness

Stellar Classification: Temperature and Luminosity

Open cluster



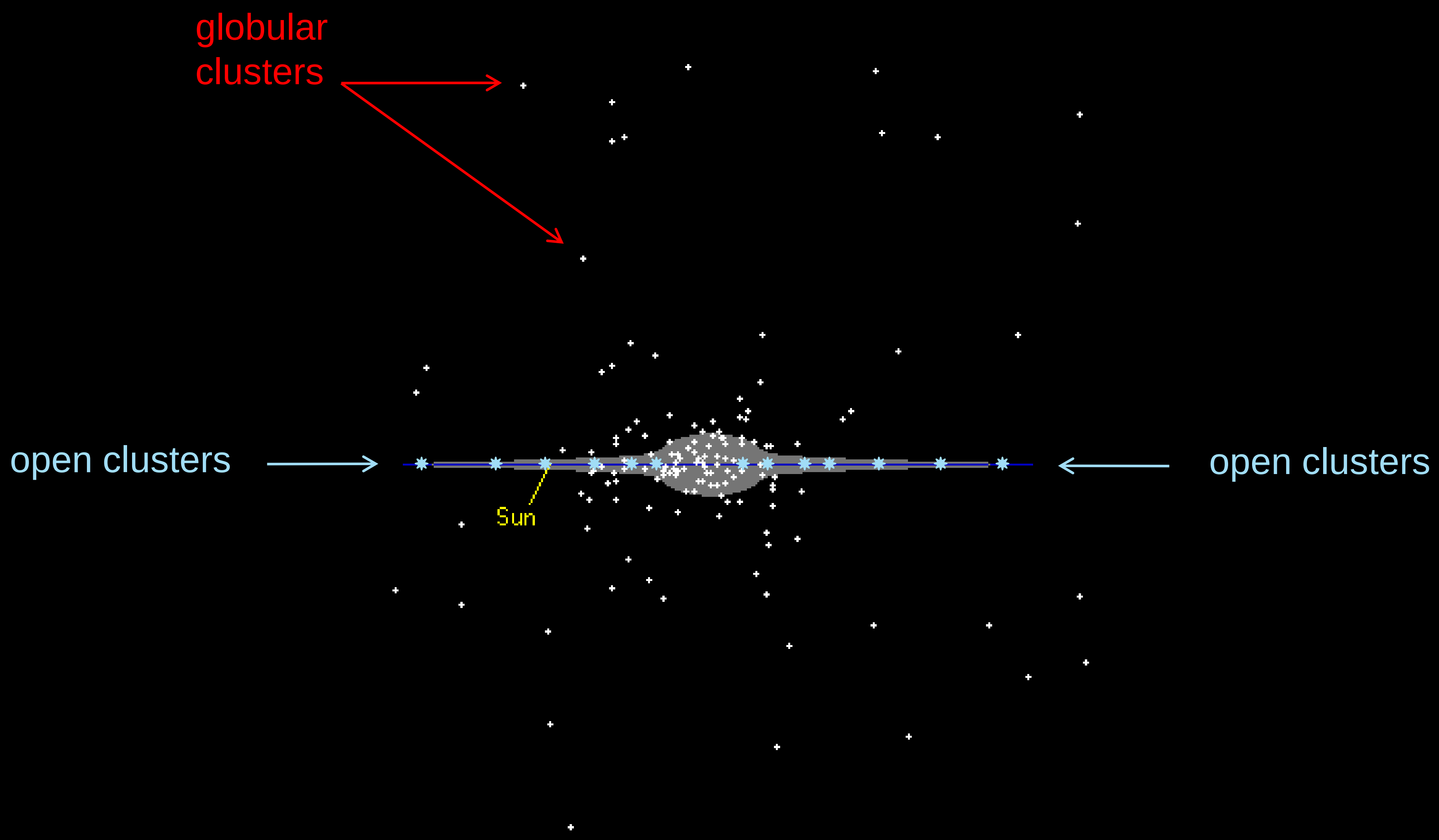
Stars are classified by their TEMPERATURE (color)
SPECTRAL TYPE

O	30,000 — 60,000 K	hottest
B	10,000 — 30,000 K	
A	7,500 — 10,000 K	
F	6,000 — 7,500 K	
G	5,000 — 6,000 K	
K	3,000 — 5,000 K	
M	1,800 — 3,000 K	coolest

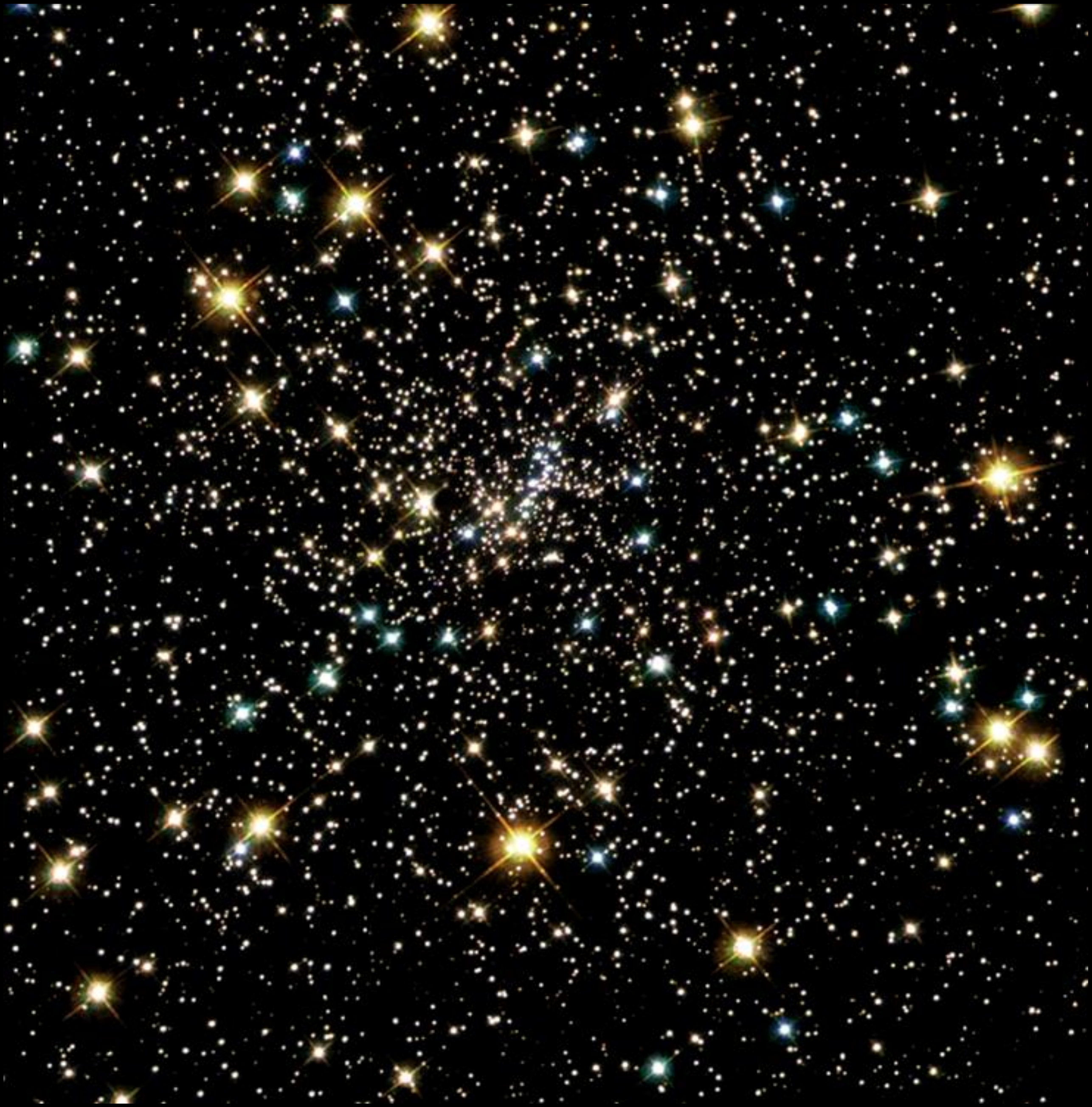
Stars are classified by their TEMPERATURE (color) with sub-classification from 0 to 9

A0	is	10,000 K	hotter
A9	is	7,500 K	cooler

G2 5,800 K our Sun



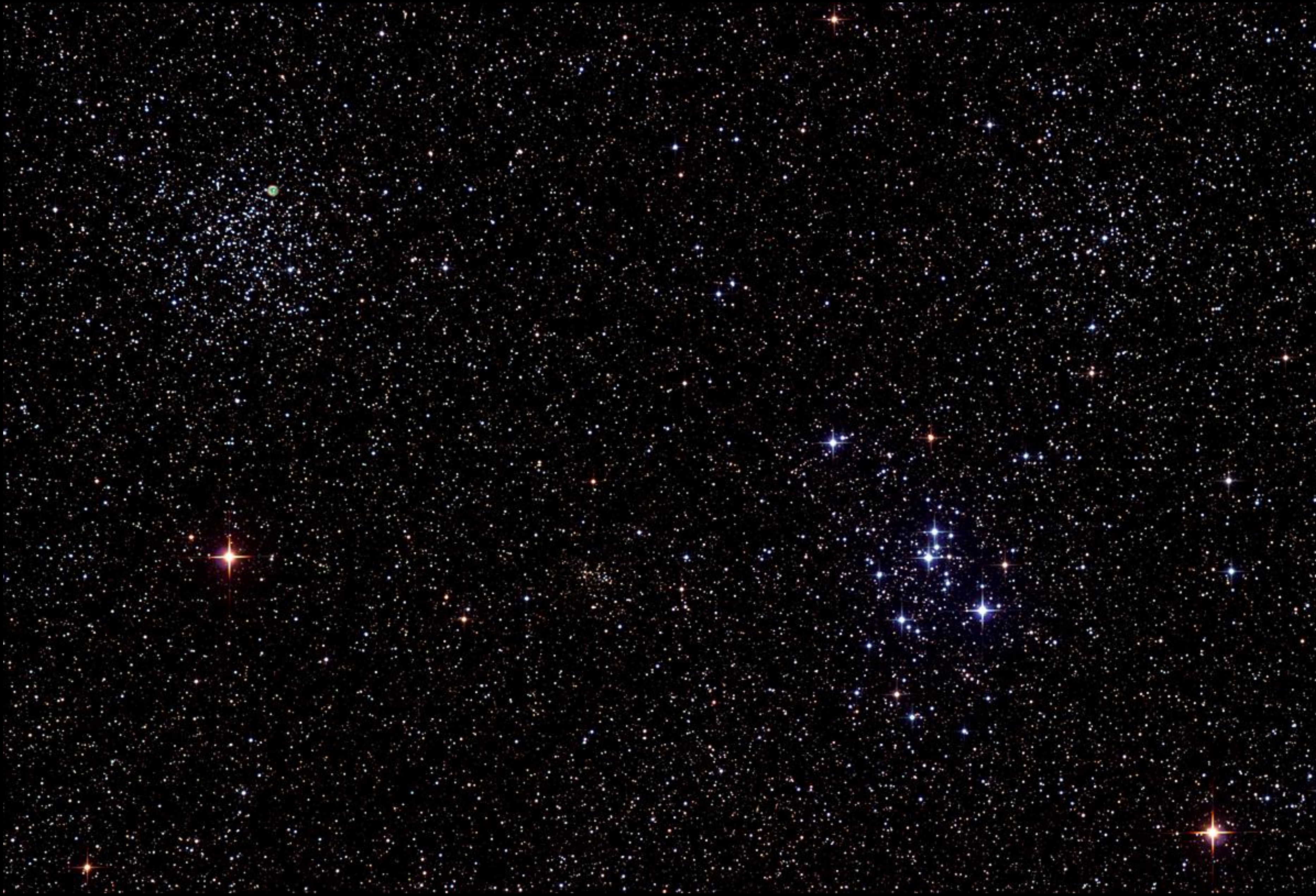
Open clusters are in the disk of Galaxy and continue to form to this day. Globular clusters formed when the MW was young



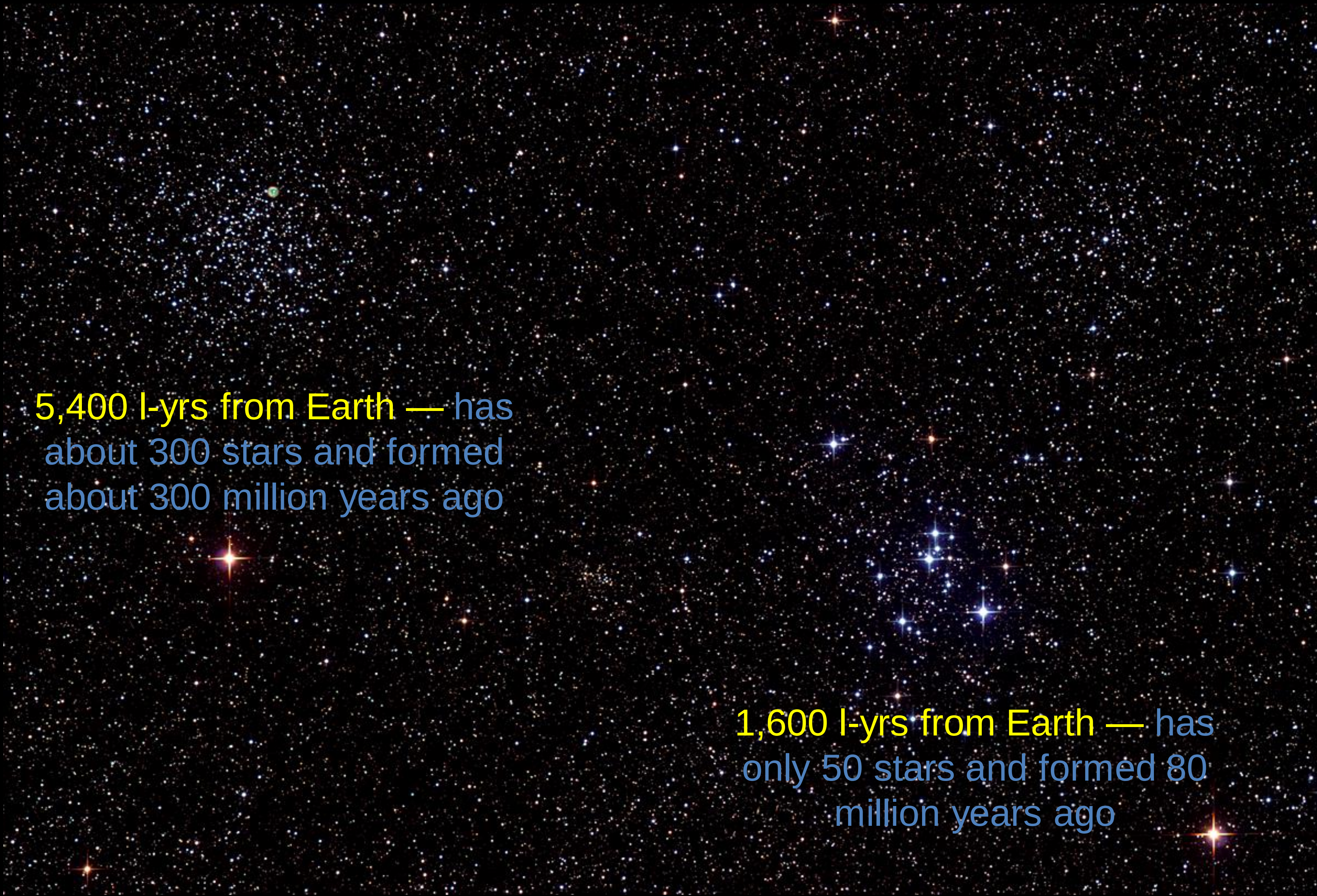
Open cluster

Open cluster

Double Open Cluster — 7,000 l-yrs from Earth but only a few hundred l-yrs apart!



Two Open Clusters near each other on the sky



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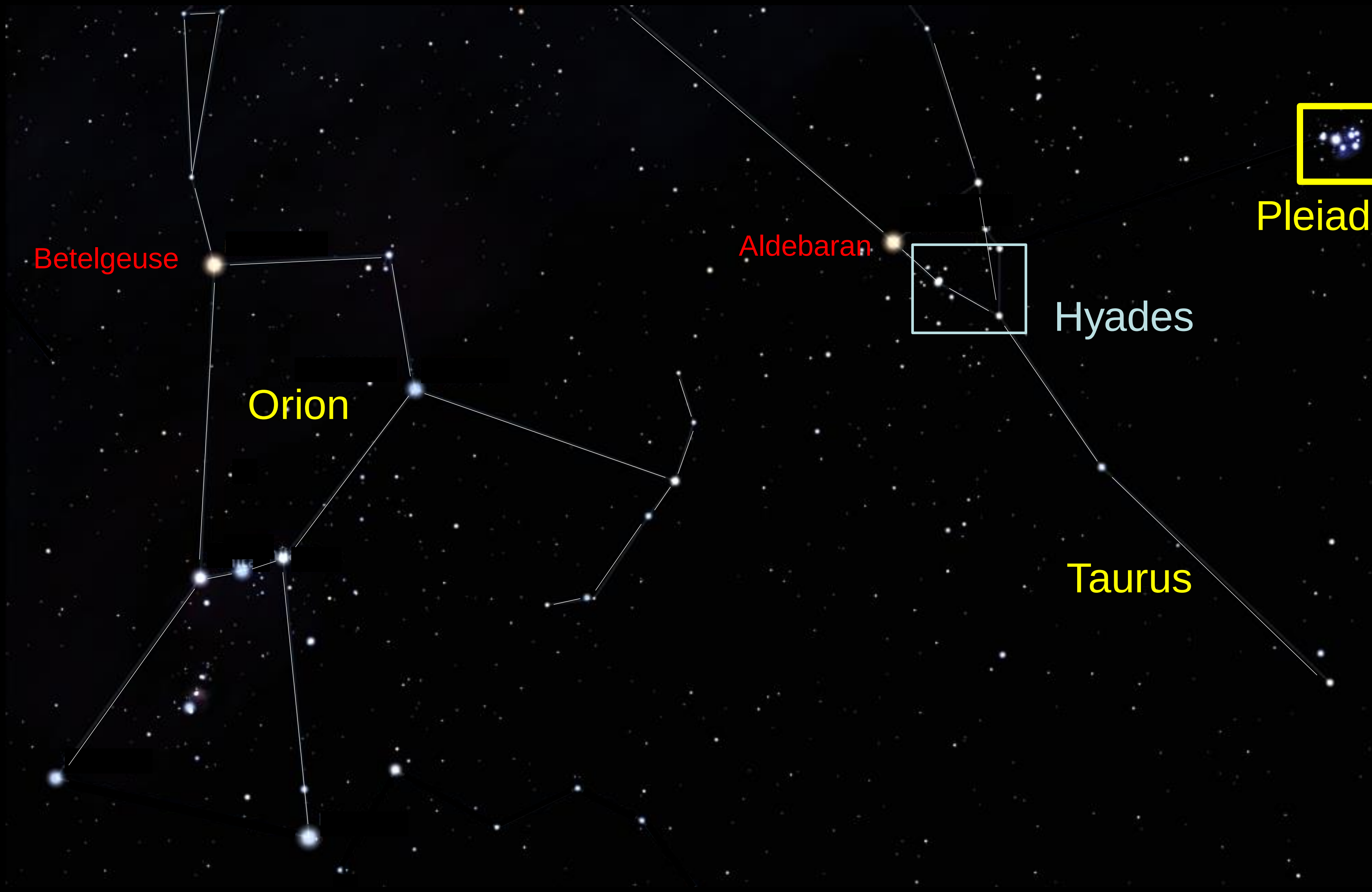
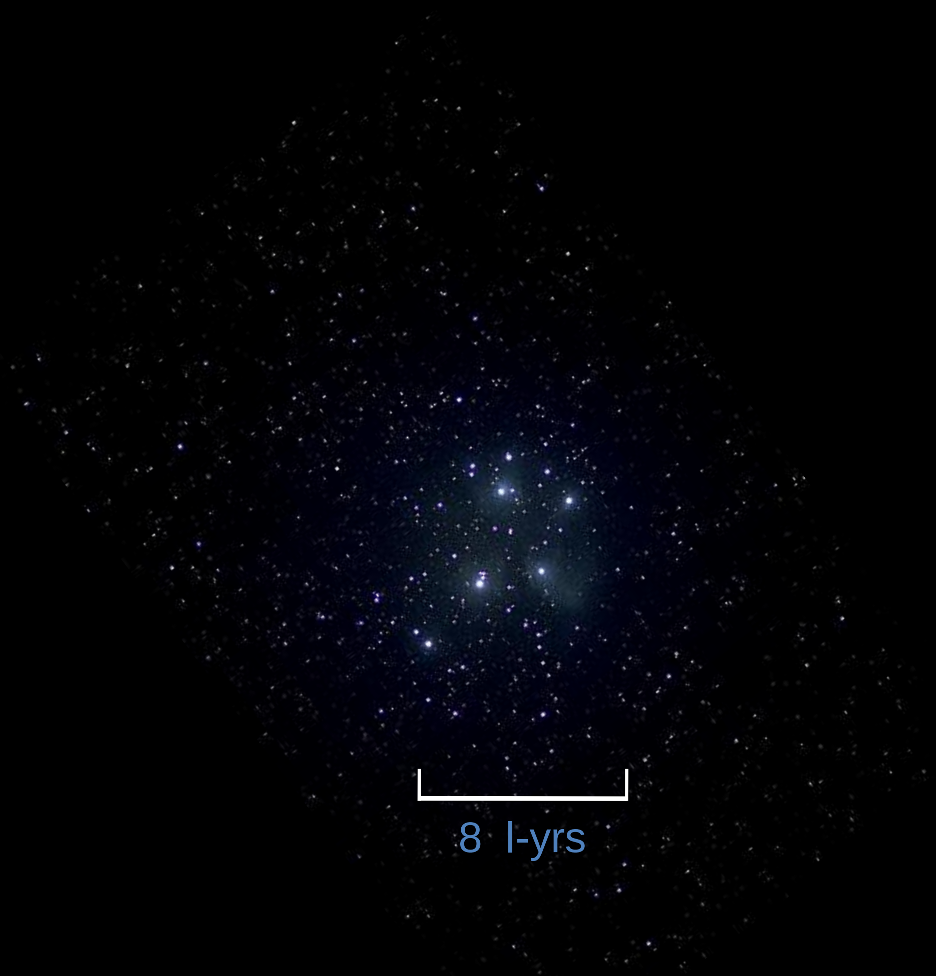


Two Open Clusters relatively near Earth — Pleiades and Hyades

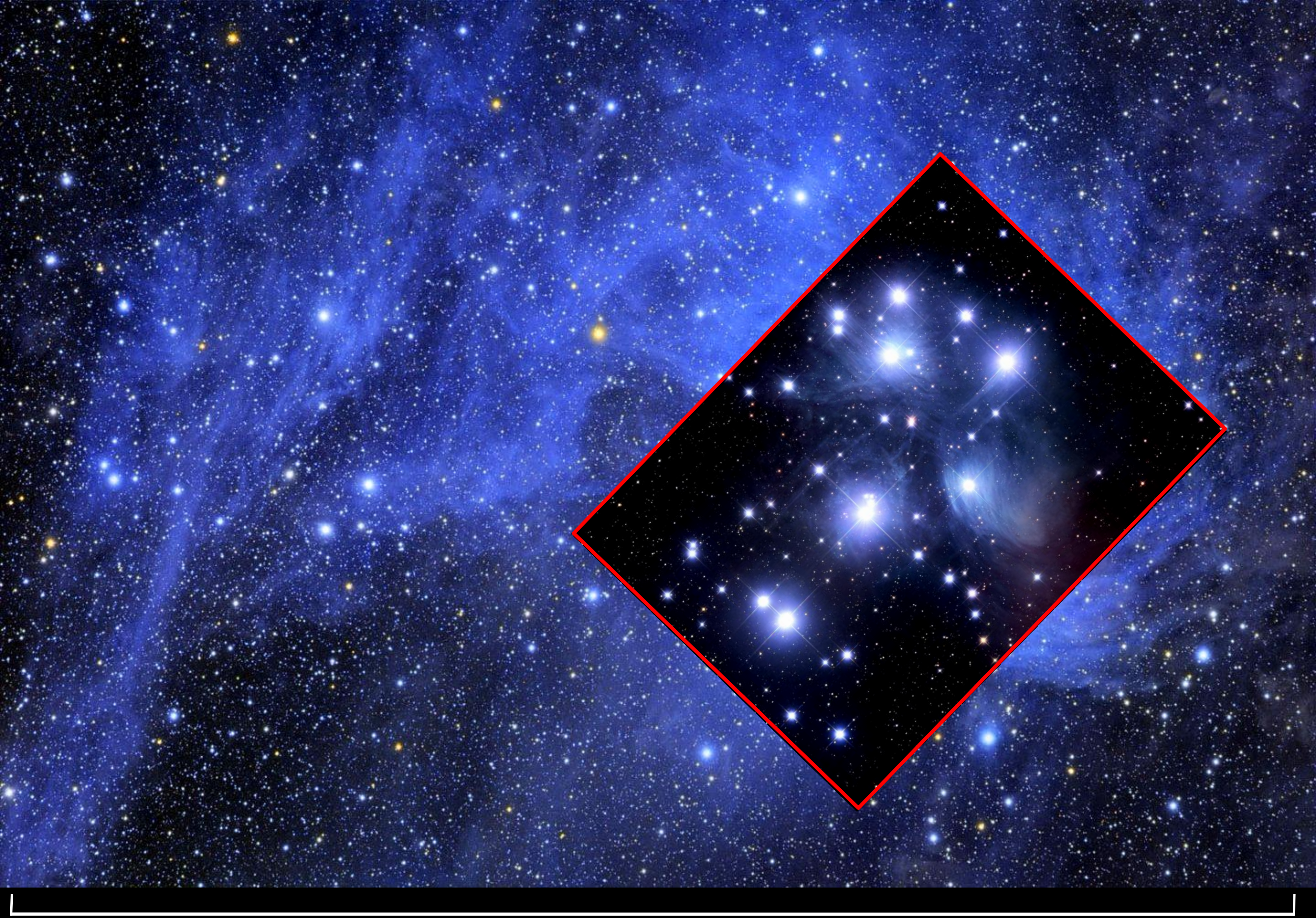


Pleiades Open Cluster — The 7 Sisters

390 l-yr away

To be accepted in the ancient Spartan army, all 7 stars had to be seen

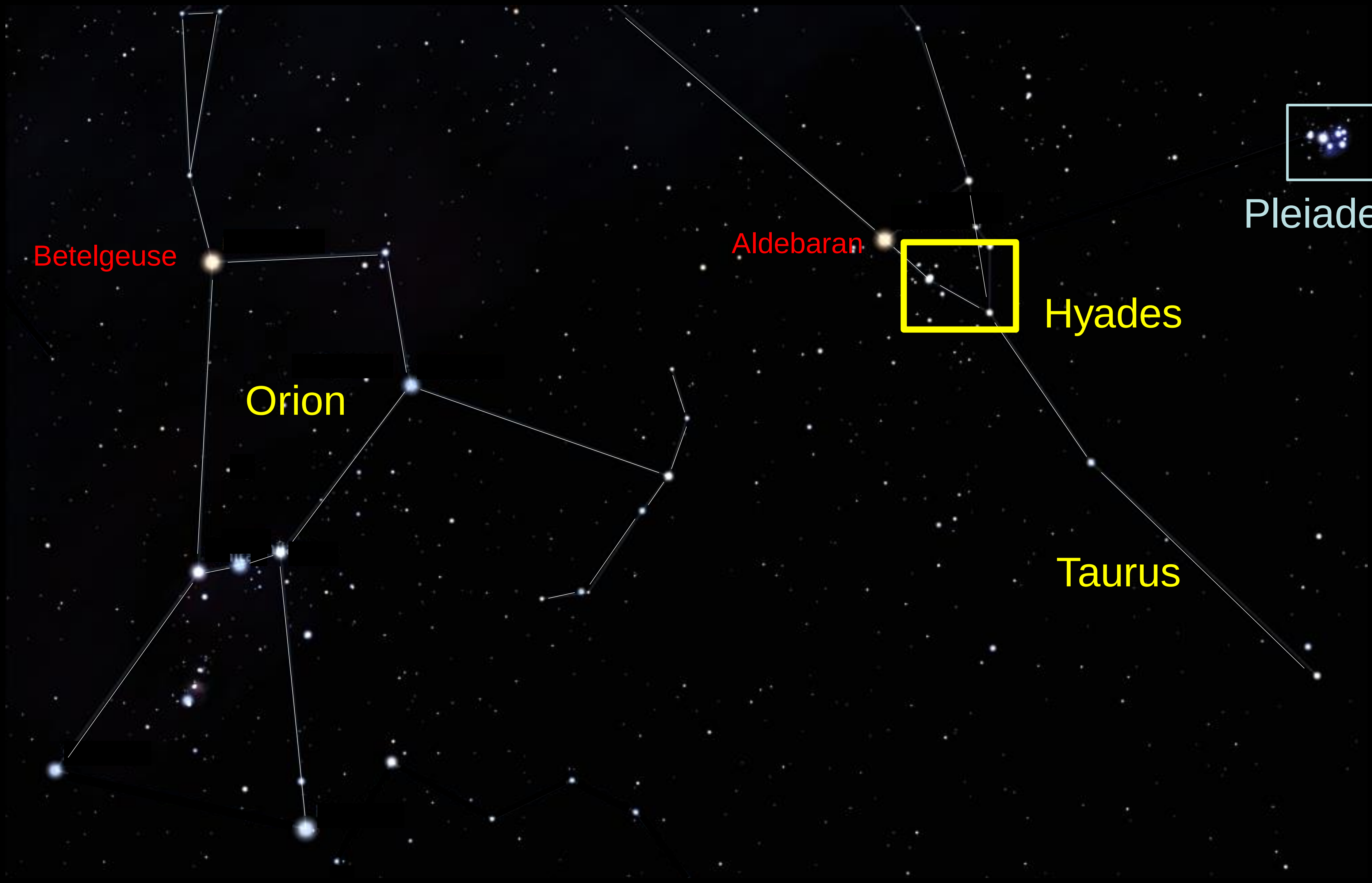
longer exposure shows dust reflecting the light of the stars



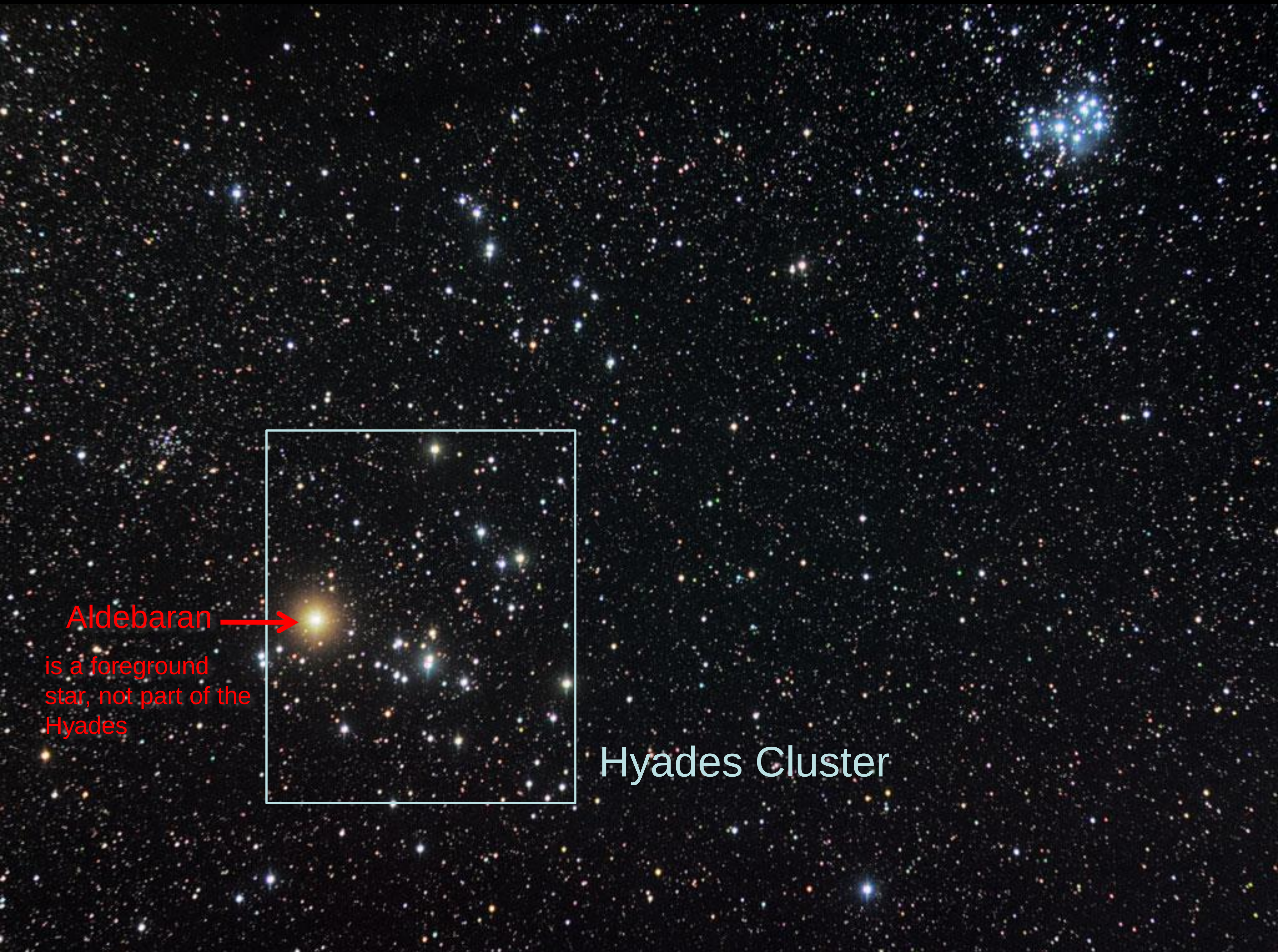
43 l-yrs

even wider view and longer exposure

even wider view and longer exposure

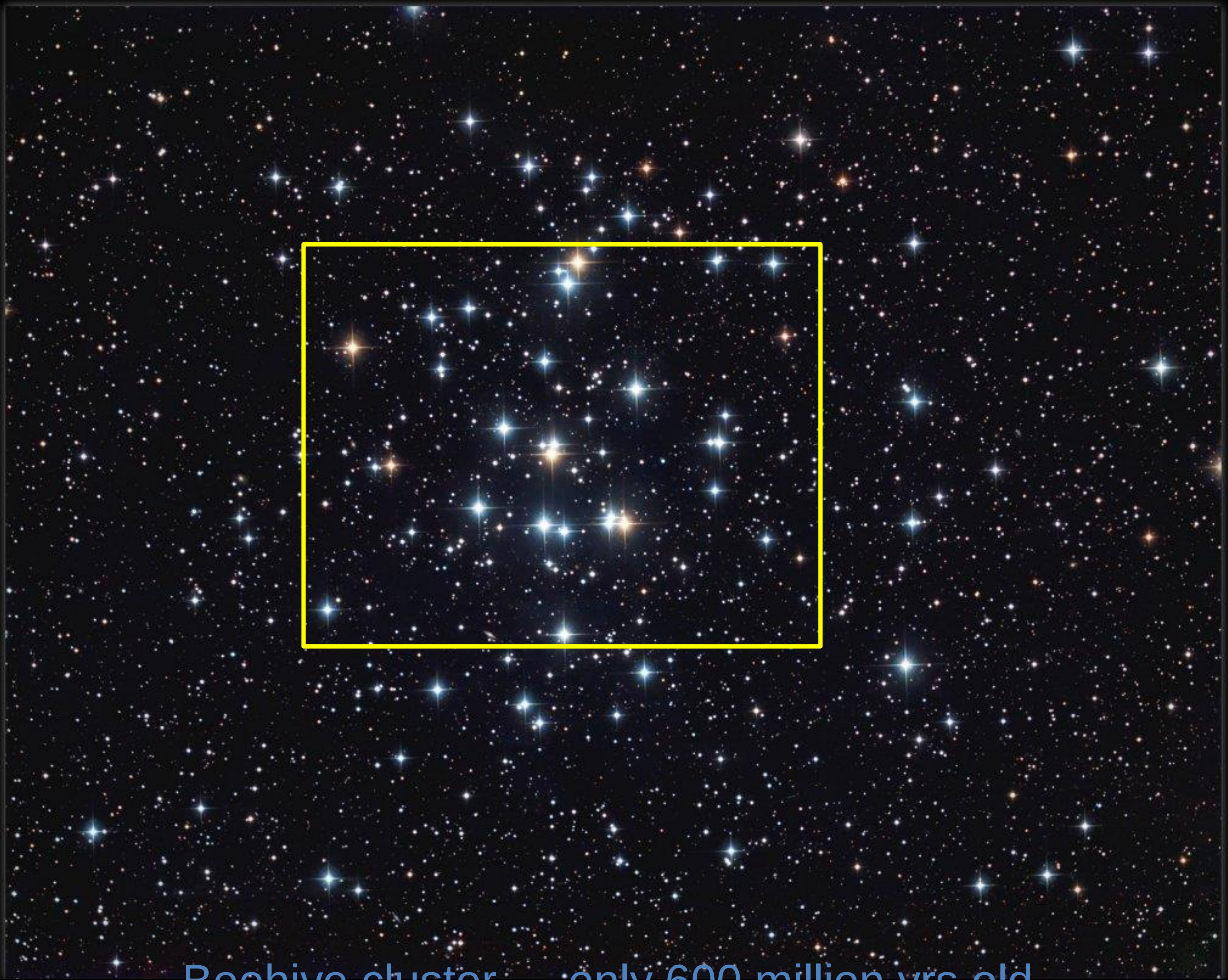


Two Open Clusters relatively near Earth — Pleiades and **Hyades**


Aldebaran
is a foreground star, not part of the Hyades
Hyades Cluster

Hyades cluster — closest cluster to Earth 153 l-yrs away

Beehive cluster — only 600 million yrs old



Beehive cluster — only 600 million yrs old

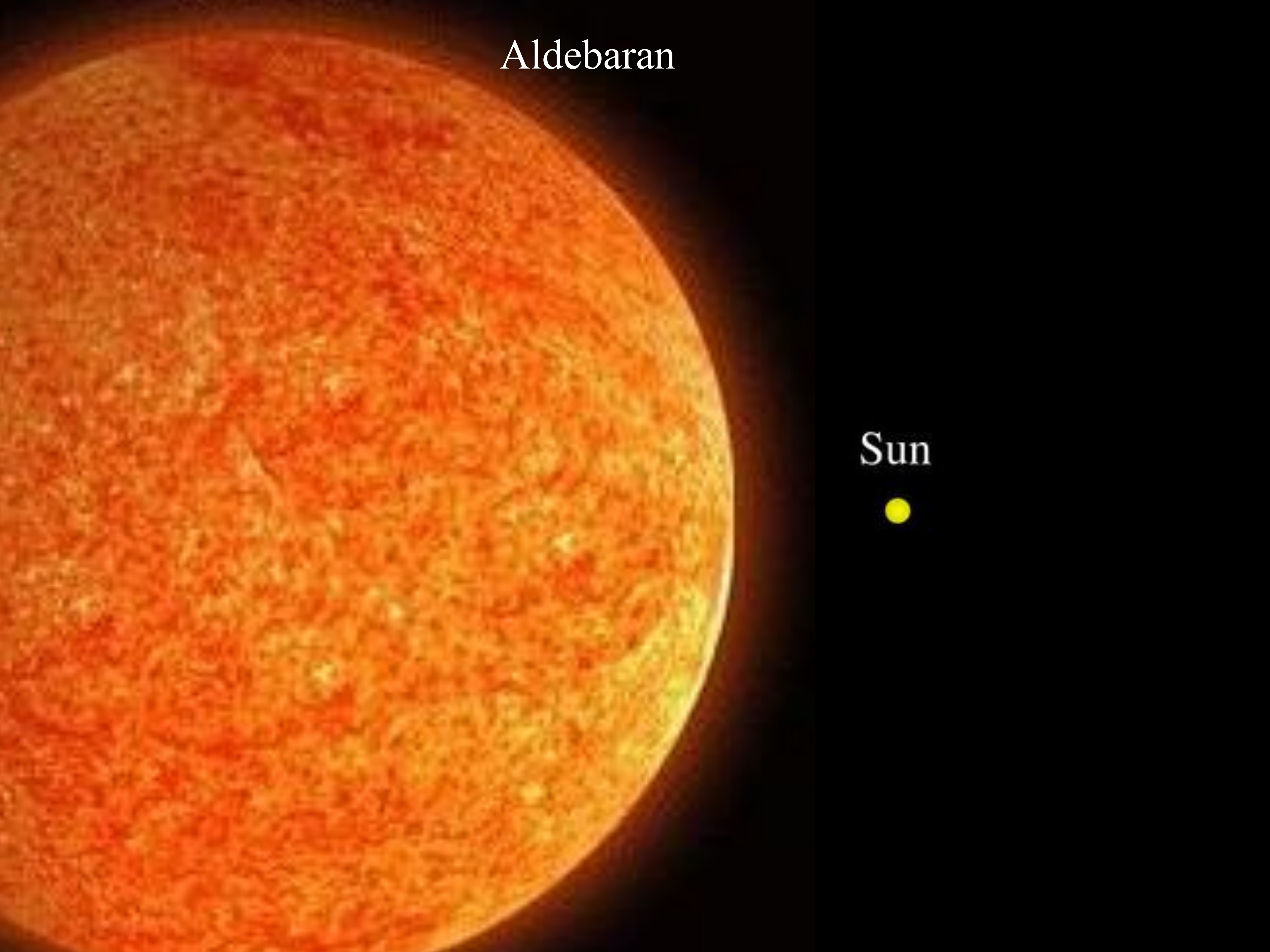
Beehive cluster — only 600 million yrs old

380 l-yr from earth — Triple star system Albireo — 5 M_{sun}.

75,000 yrs to orbit once around each other puts them at more than 1 ly-ry apart, and the yellow star is also a binary!

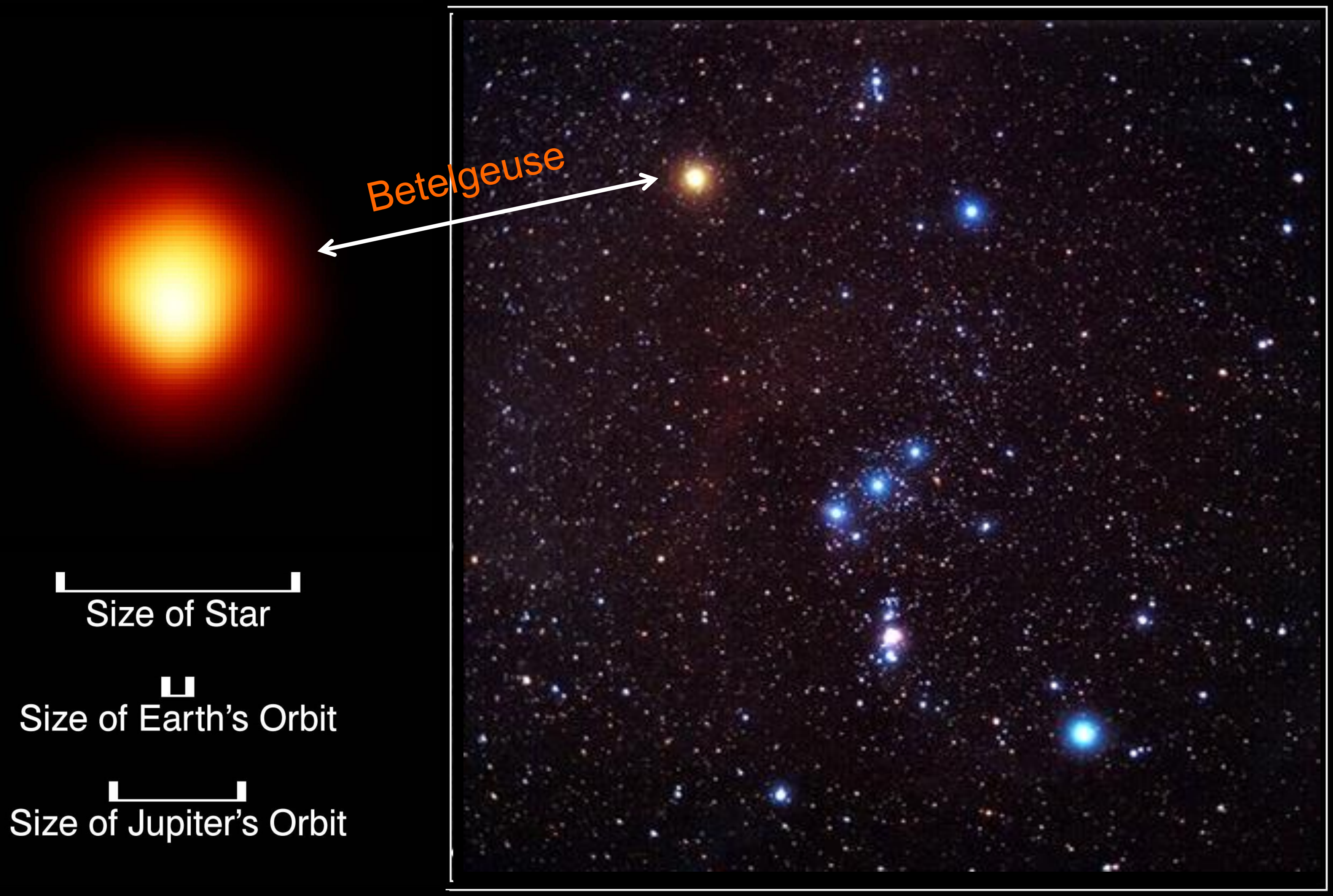
SS Cygni—Some double stars are so close, that mass is transferred — causing a NOVA flare up. These orbit each other every 49 days! 200,000 times closer than is Mercury from the Sun (0.01 l-min) and 370 l-yr from us.


Sun

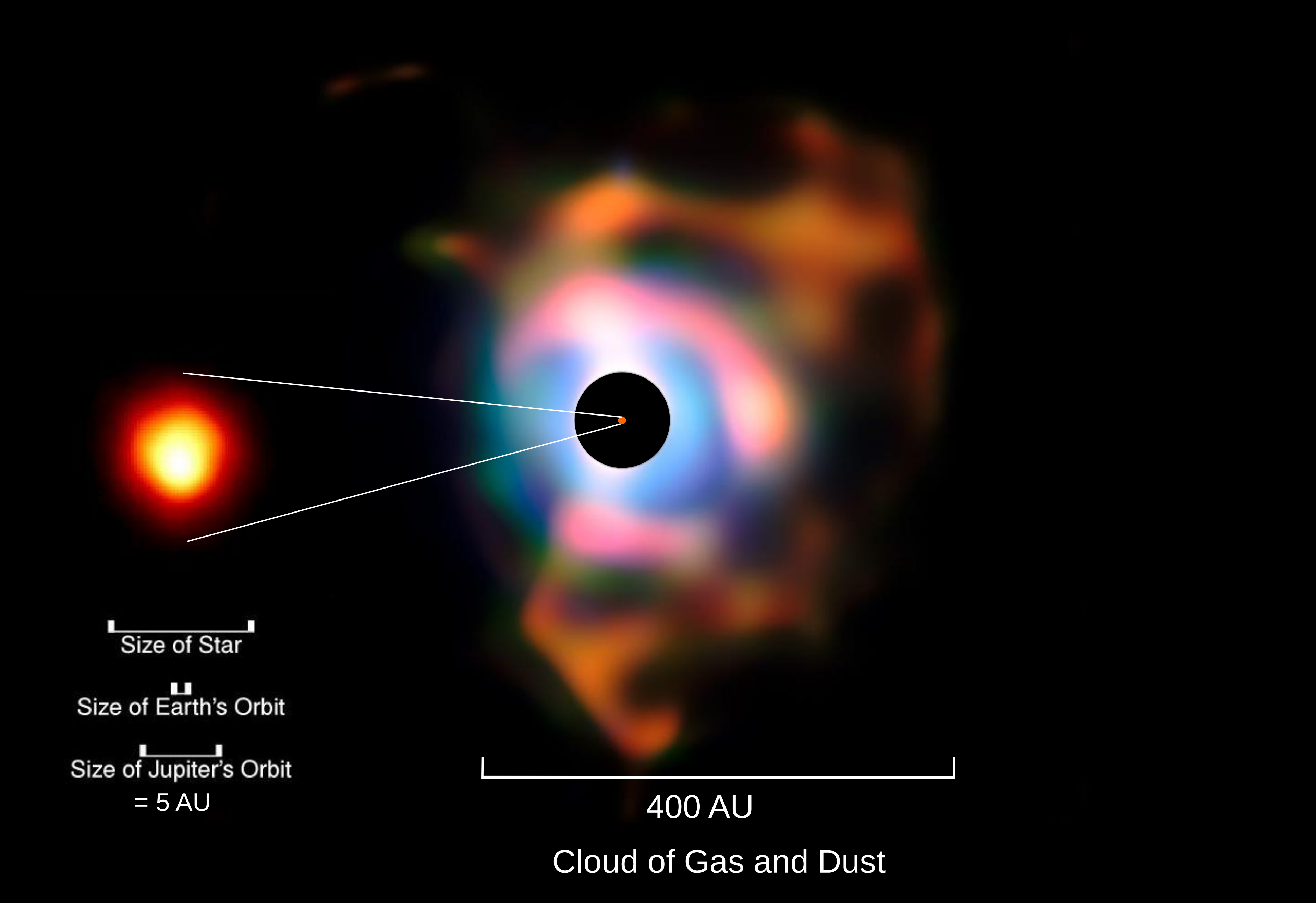

Aldebaran
Sun

Betelgeuse

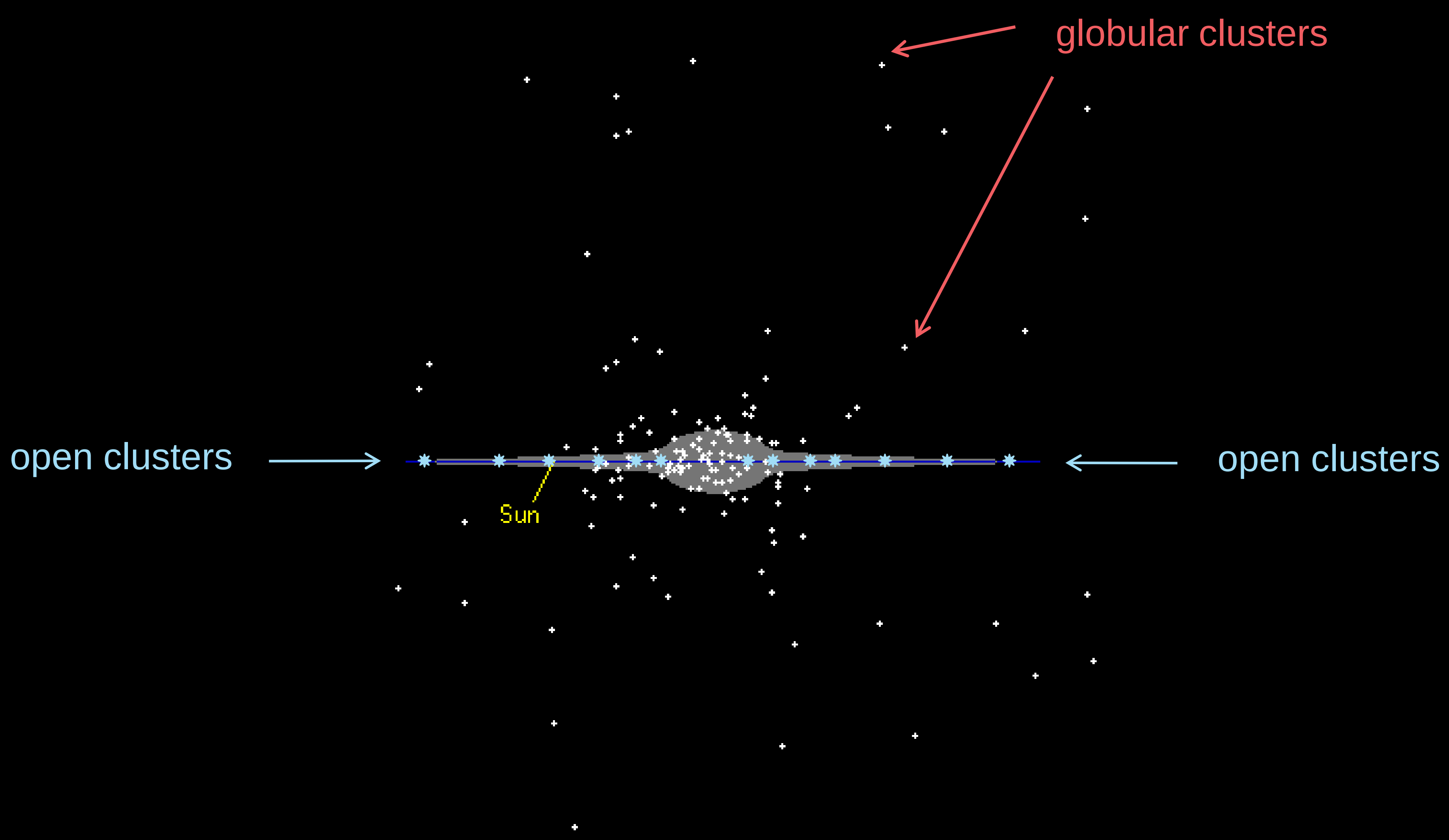
Aldeberan



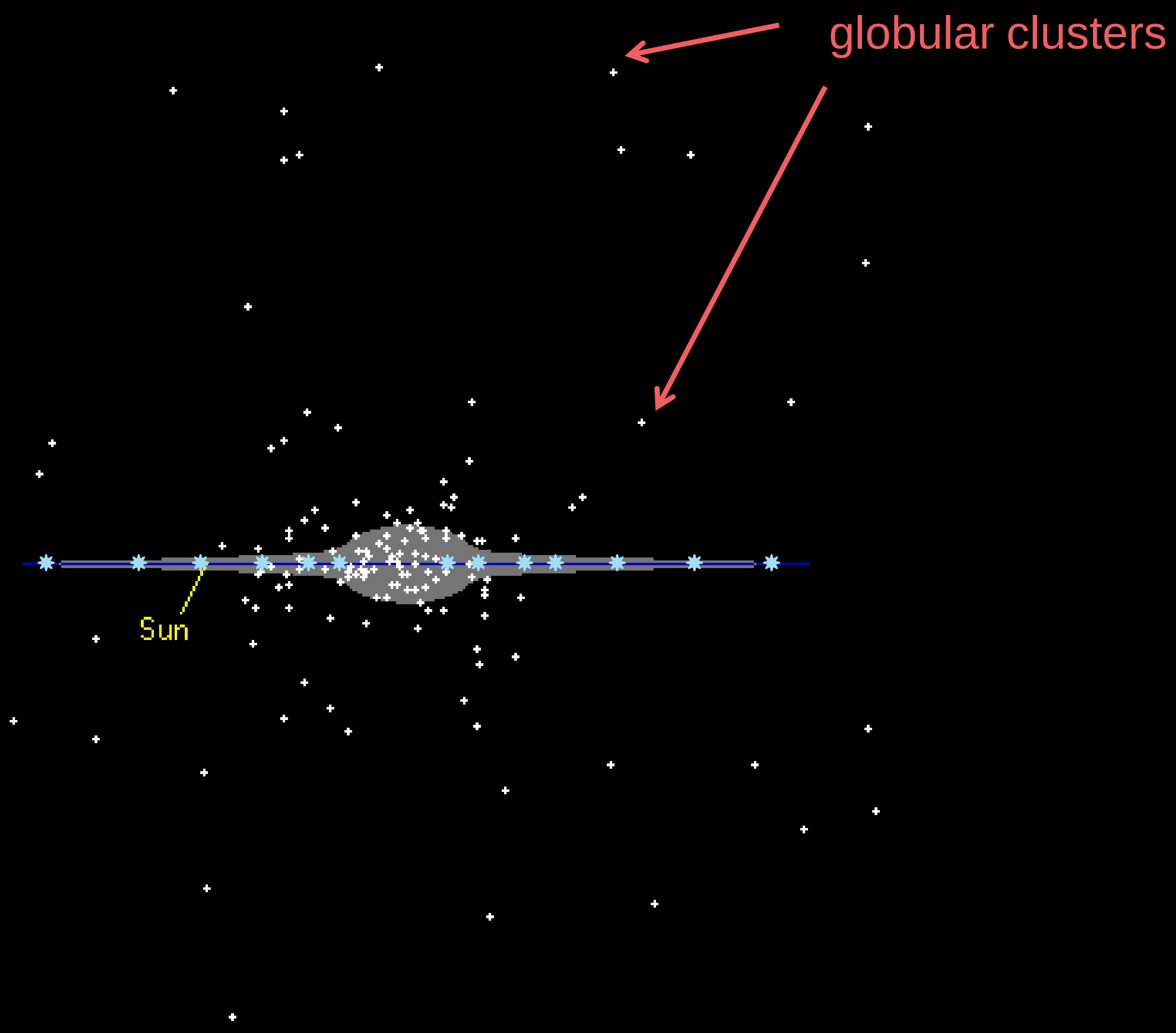
Orion Constellation



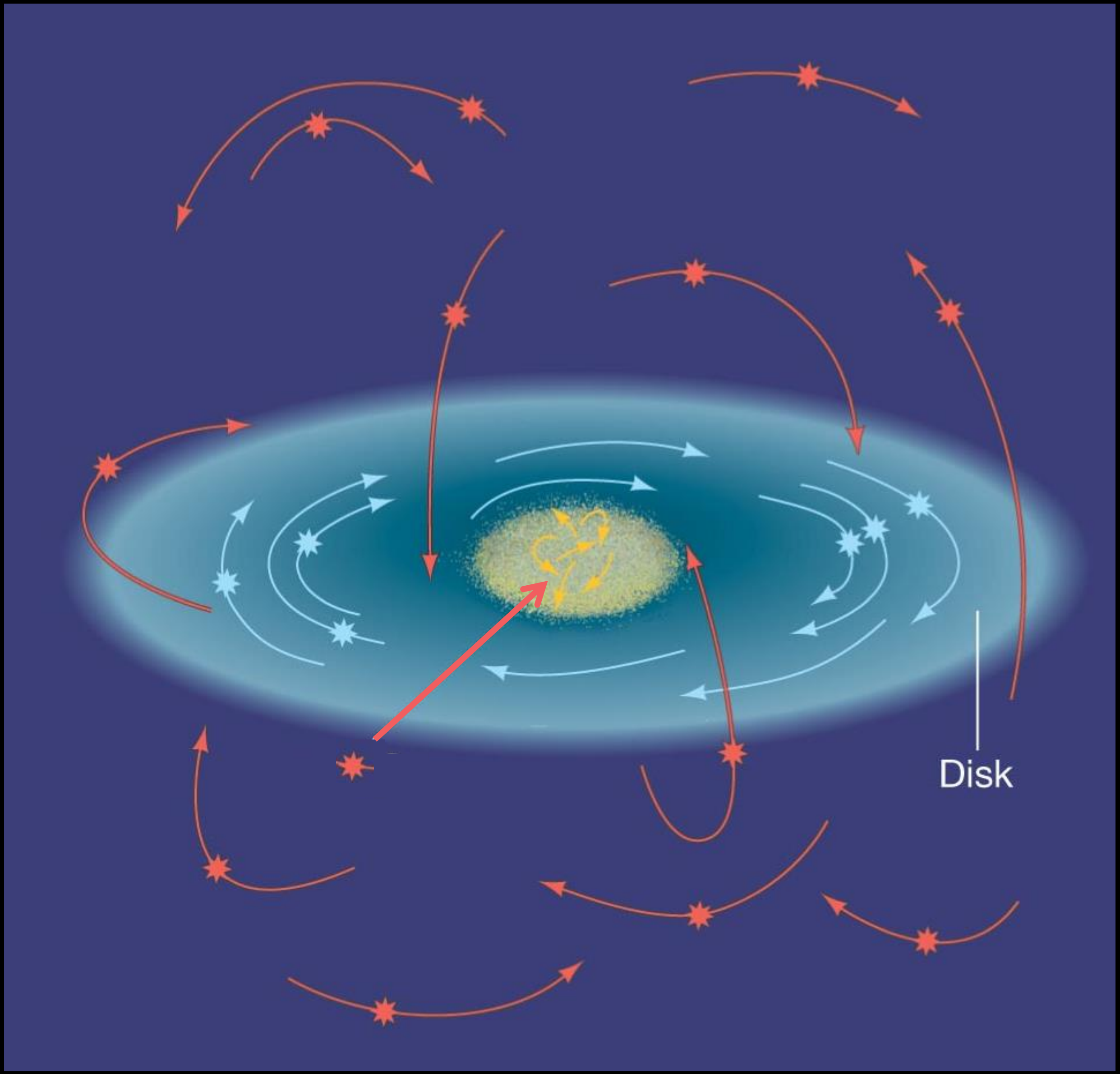
Betelgeuse is ready to go Supernova!



Open clusters are in the disk of Galaxy and continue to form to this day.



Globular clusters are distributed spherically in the Galaxy and were made in the early days of galaxy formation.



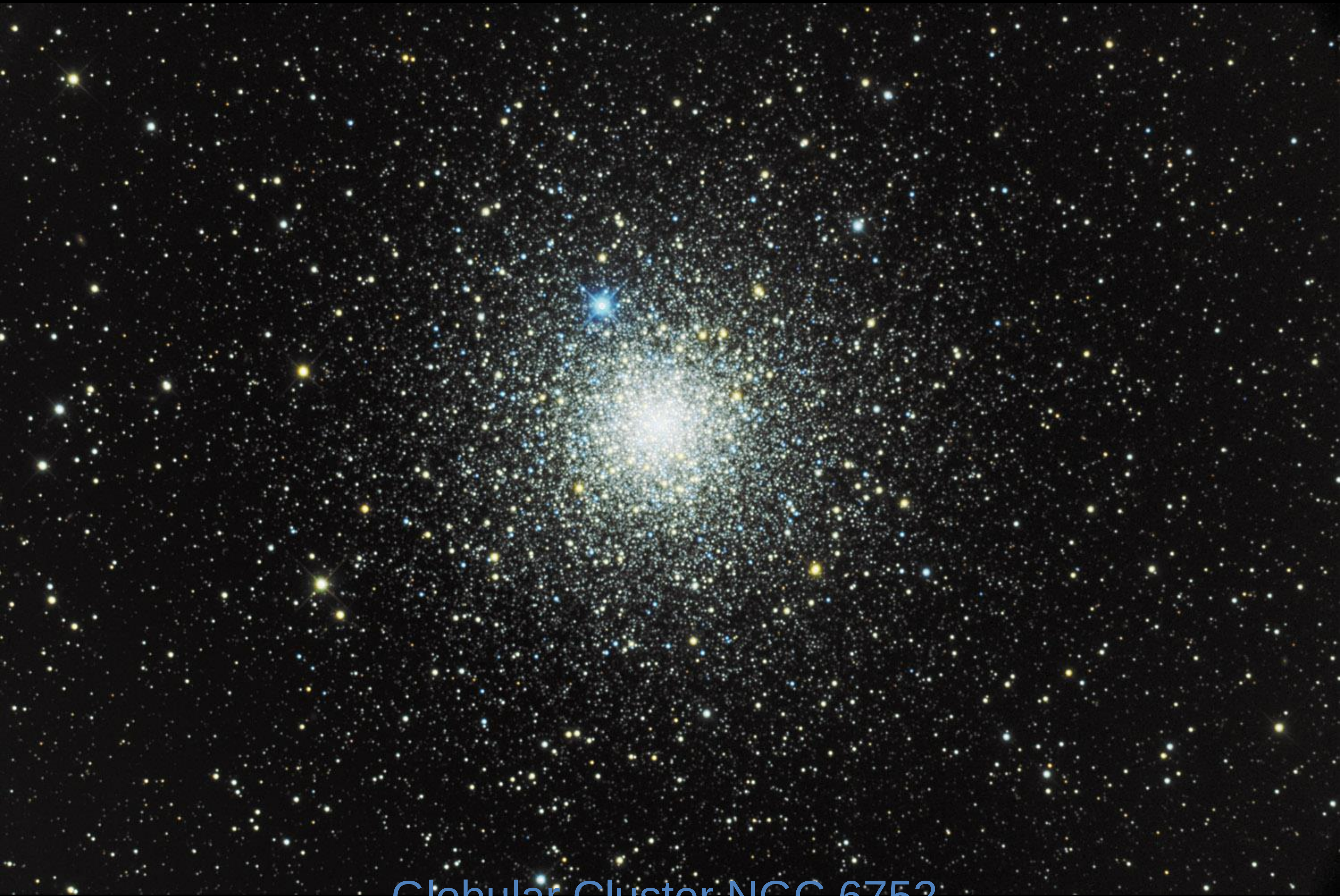
globular clusters swarm in all directions and are found above, below and within the disk

open clusters form in the flat disk and move around the Galaxy in the same direction

Globular Cluster Omega Centauri

containing several million stars and is 15,800 l-yr from Earth

Globular Cluster Omega Centauri — central region



Globular Cluster NGC 6752

containing several thousand stars and is 13,000 l-yr from Earth

Globular Cluster in Hercules

containing 300,000 stars and is 25,000 l-yr from Earth

Globular Cluster in Hercules — central region

There are two ways to classify stars:

Temperature Type (O, B, A, F, G, K, M)

they put out (POWER) = LUMINOSITY

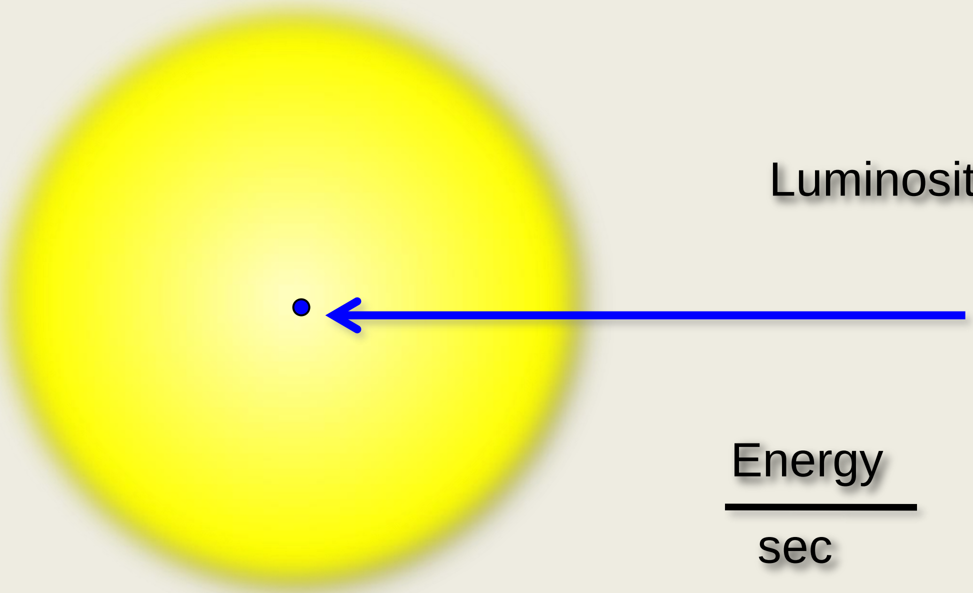
Power = Energy / Time

Temperature Type (O, B, A, F, G, K, M)

Is the Temperature of a star's

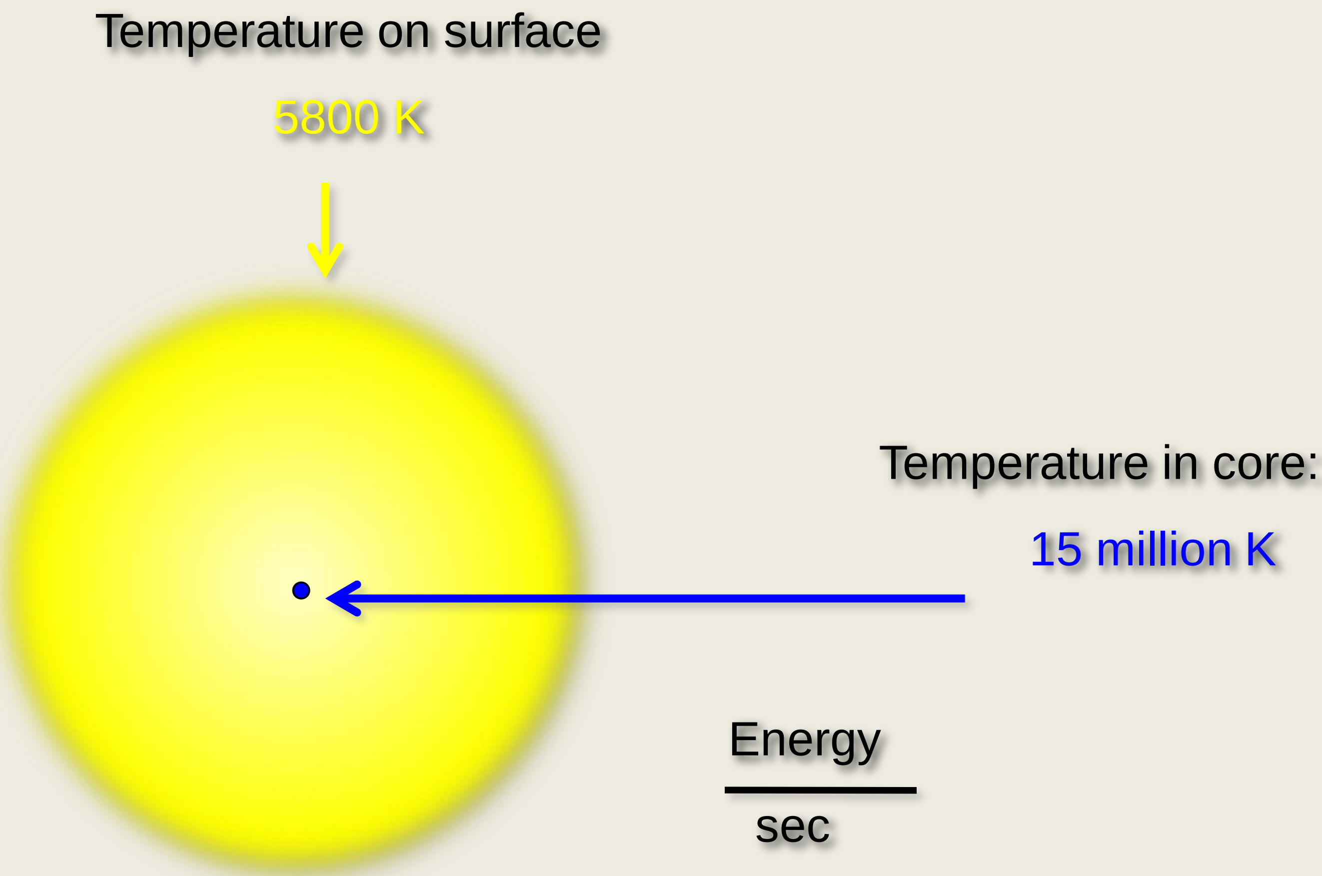
SURFACE

Luminosity Classification



Luminosity is due to the T's in the CORE

$$\frac{\text{Energy}}{\text{sec}}$$

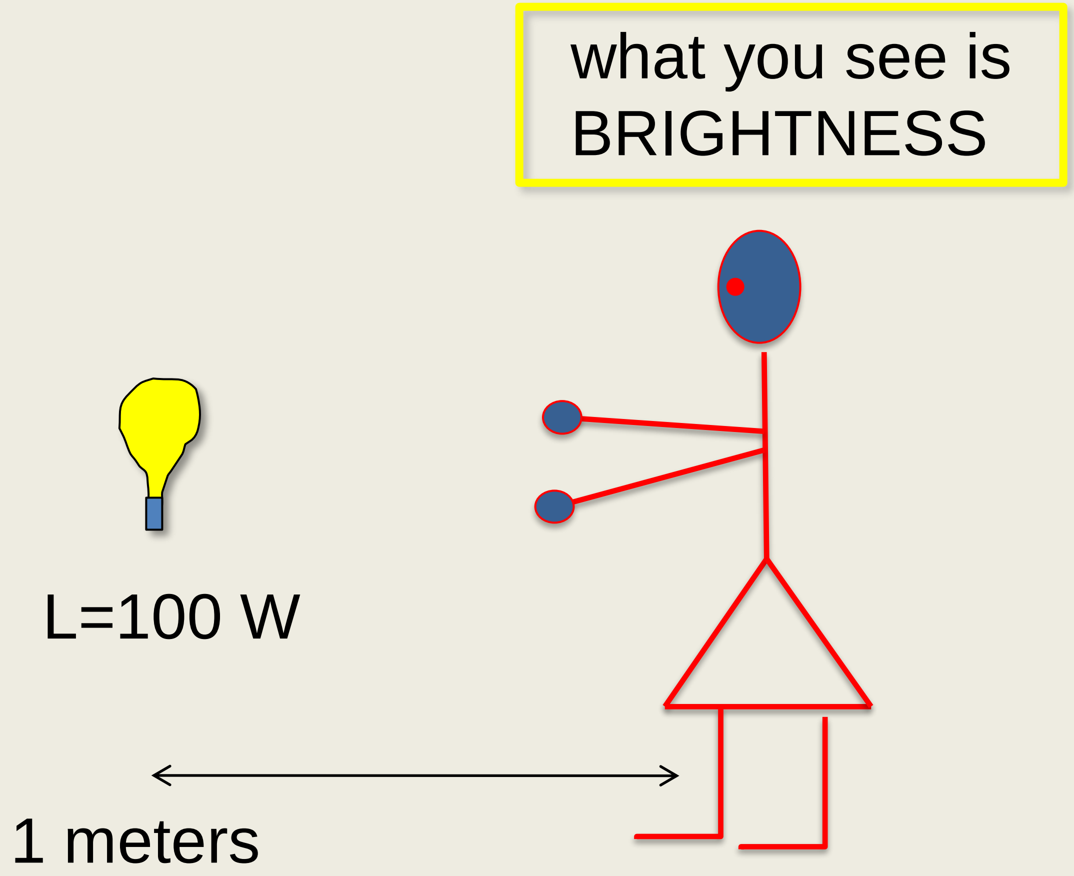

Temperature on surface
5800 K
Temperature in core:
15 million K
Energy
sec

$$\text{LUMINOSITY} = \text{Power} = \frac{\text{Energy}}{\text{sec}}$$

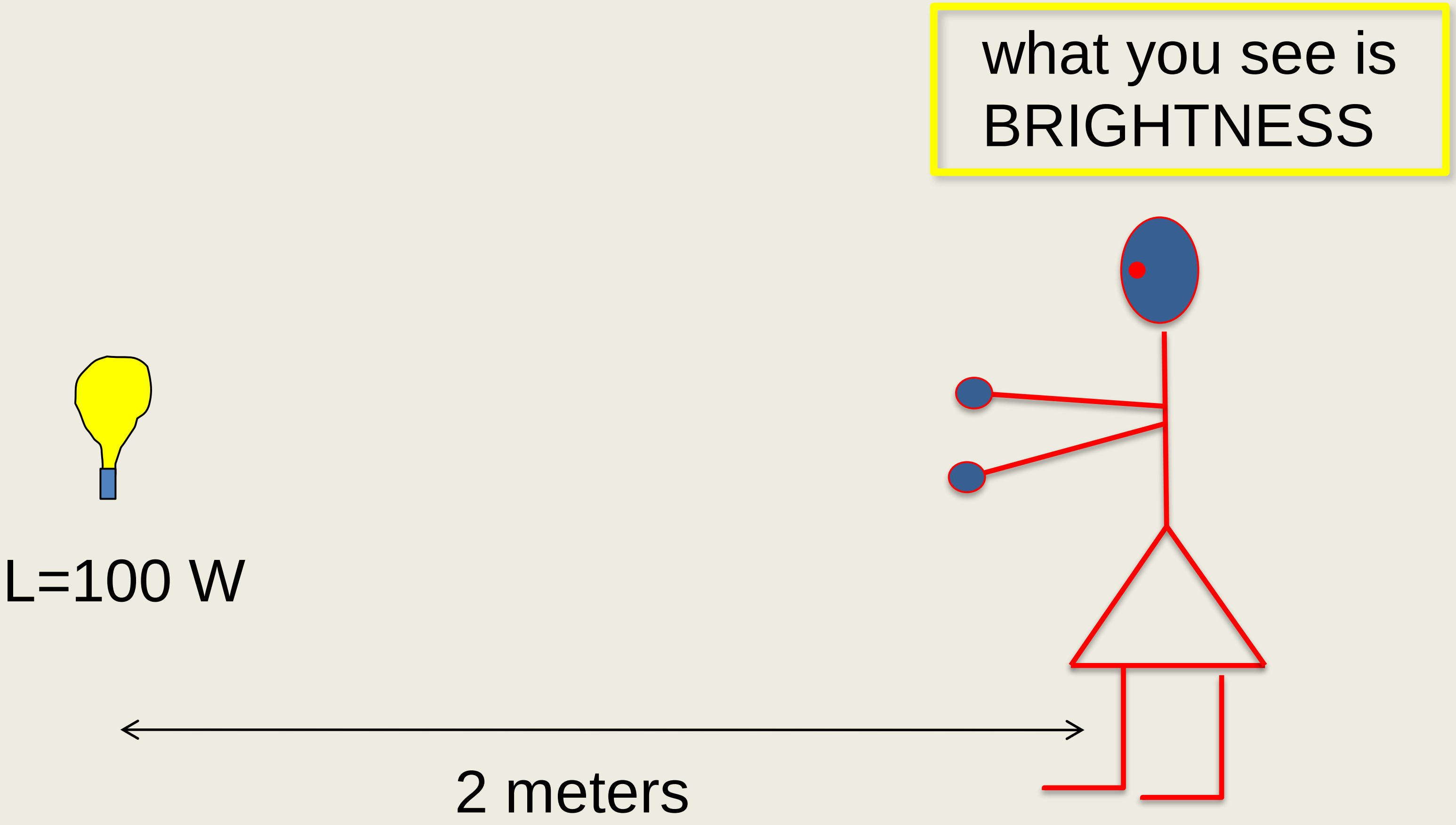
Notice that LUMINOSITY does not have a DISTANCE unit. LUMINOSITY is INTRINSIC to the star, just as is its mass.

$$\text{BRIGHTNESS} \propto \frac{\text{Luminosity}}{\text{Distance}^2}$$

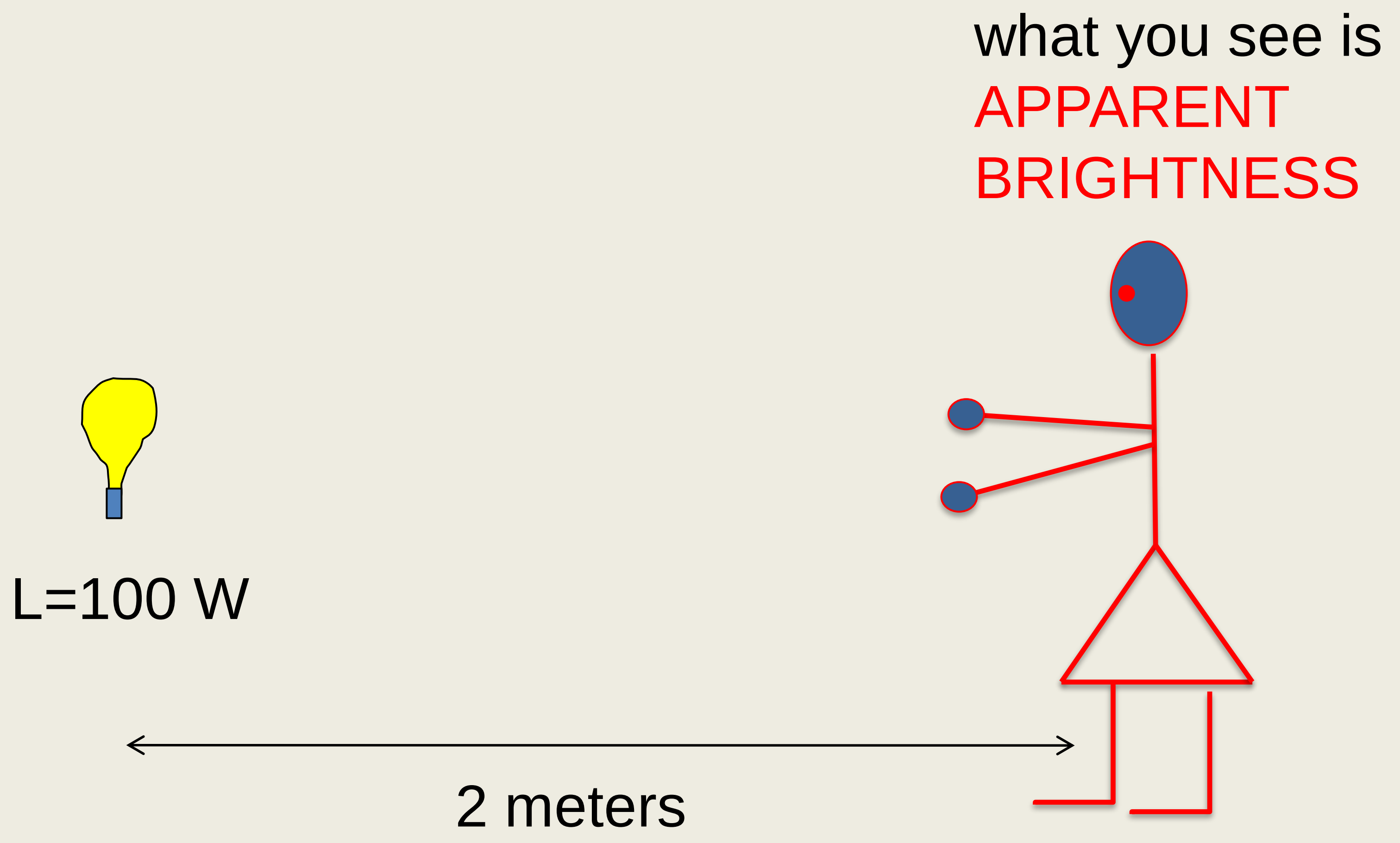
BRIGHTNESS relies on distance.


what you see is BRIGHTNESS
L=100 W
1 meters

How bright would the bulb appear now?



Since Brightness goes as 1 over the distance squared, it would appear 4 times dimmer.



To know how REALLY (ABSOLUTELY) BRIGHT a star is, you MUST

know its DISTANCE

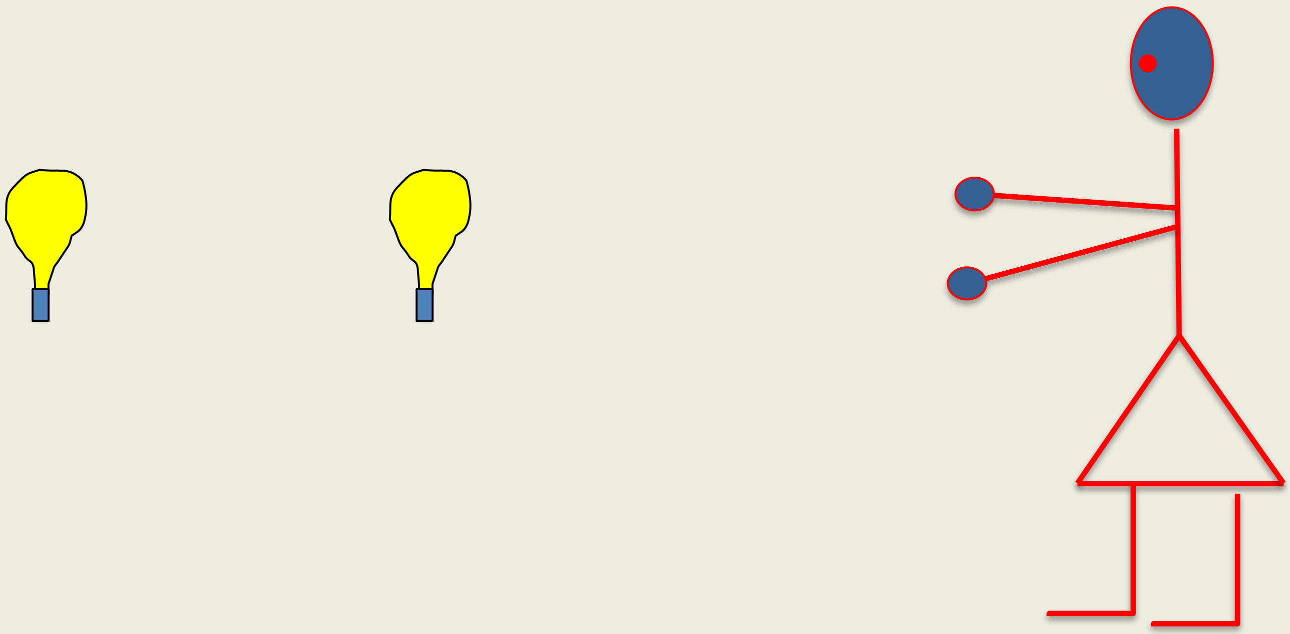
Stars appear to be the same distance, but they are not

For ex., if they are luminous but far, they will appear bright...

but if they are not very luminous but close, they will **appear** to be bright

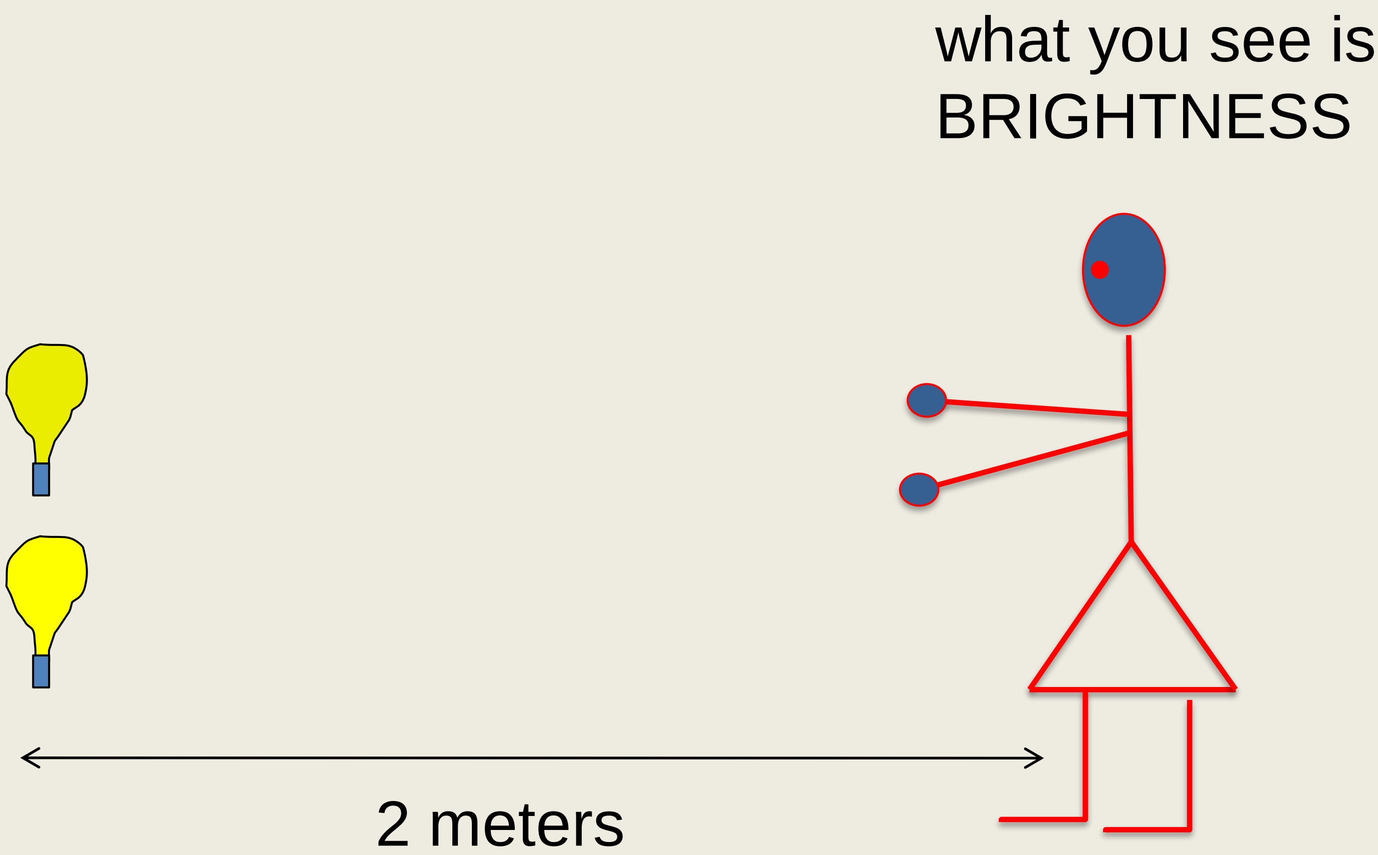
If you had two light bulbs whose luminosity was unknown, how would you tell which bulb was the more luminous?

what you see is BRIGHTNESS



The brightness of stars you measure is called their APPARENT BRIGHTNESS.

You would put them at the same distance from you and see which APPEARED brighter



The brightness of stars at a STANDARD DISTANCE is called their ABSOLUTE BRIGHTNESS.

There are 2 "kinds" of BRIGHTNESS:

APPARENT brightness

and

ABSOLUTE brightness

APPARENT brightness → how bright it APPEARS to you at its distance from you

ABSOLUTE brightness → how it WOULD appear at a STANDARD DISTANCE

Once you know the distance to the stars, you can calculate their their ABSOLUTE BRIGHTNESS.

The standard distance is 10 parsecs. A parsec is 3.26 l-yrs.

Why in the heck would anyone use a weird unit like

10 parsecs (32.6 l-yr) for the standard distance?

It goes back to parallax as the first distance measurement to the stars.

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The shift of a star is measured in angles,

and one degree is split up into 3,600 arcseconds,

that is,

1 degree = 3600 ”

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The shift of a star is measured in angles,

and one degree is split up into 3,600 arcseconds,

that is,

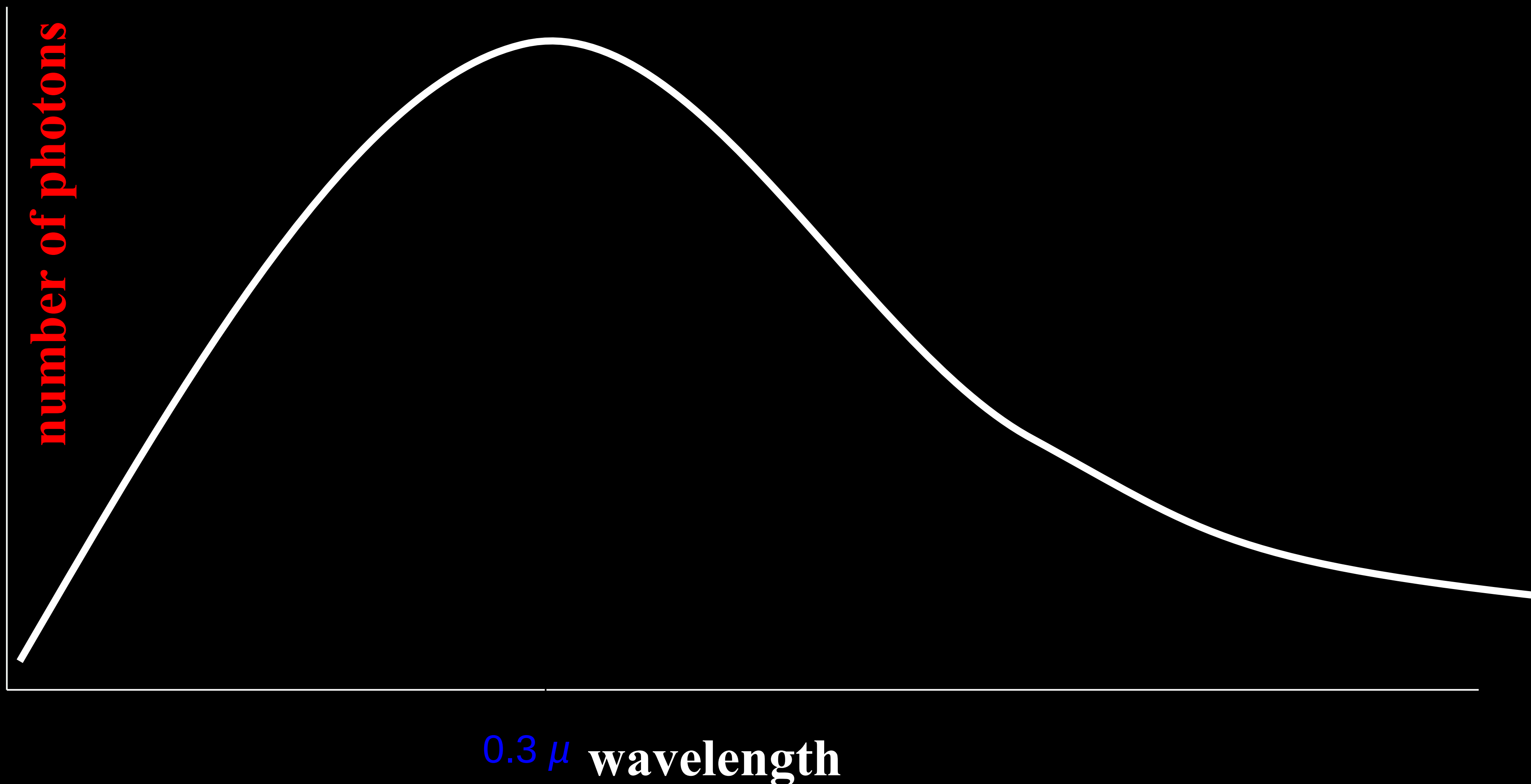
1 degree = 3600 ”

If a star’s parallactic shift is 1 arcsecond, the star is 1 parsec distant.

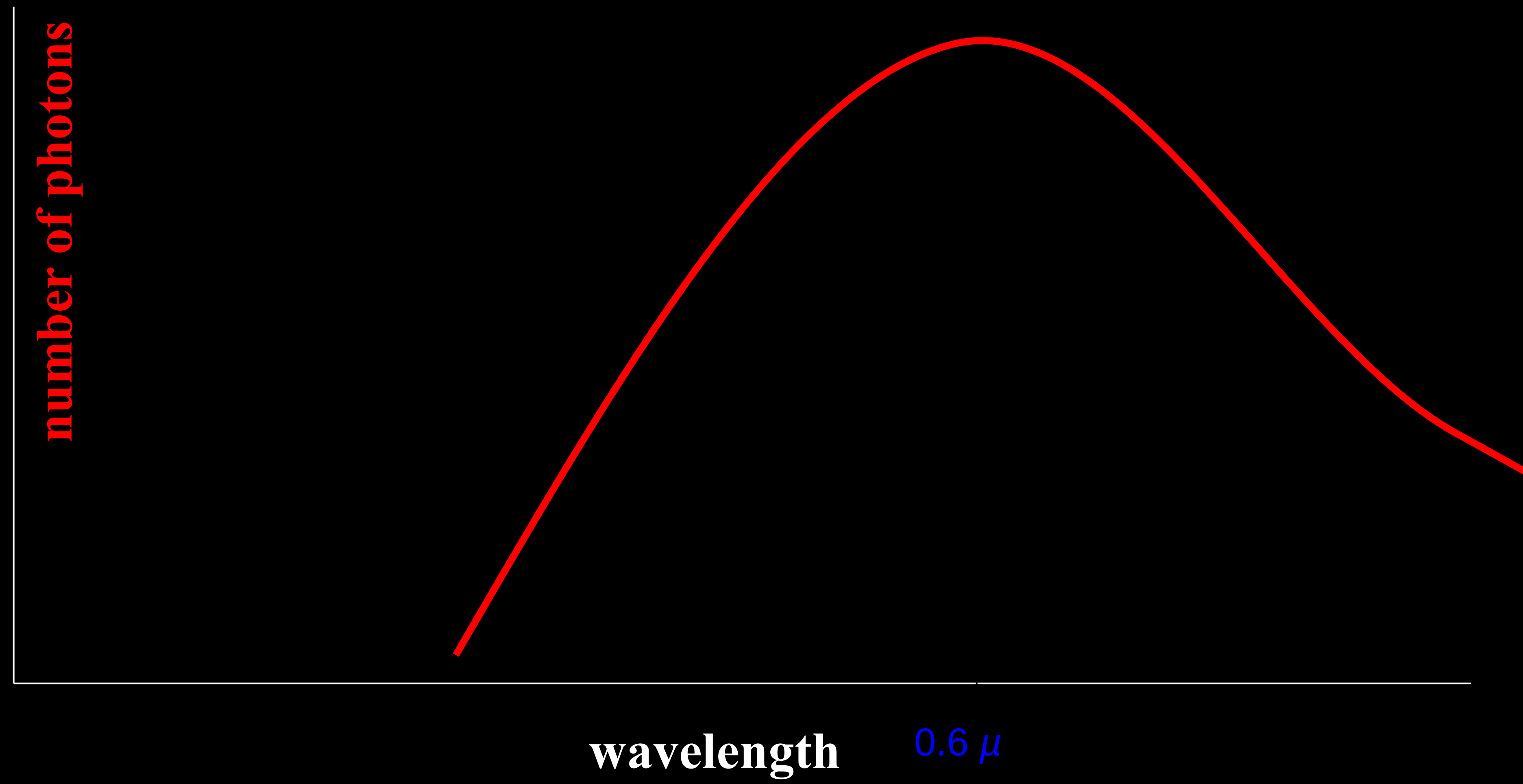
There are other ways to find the distances to stars which we will discuss in the next session.

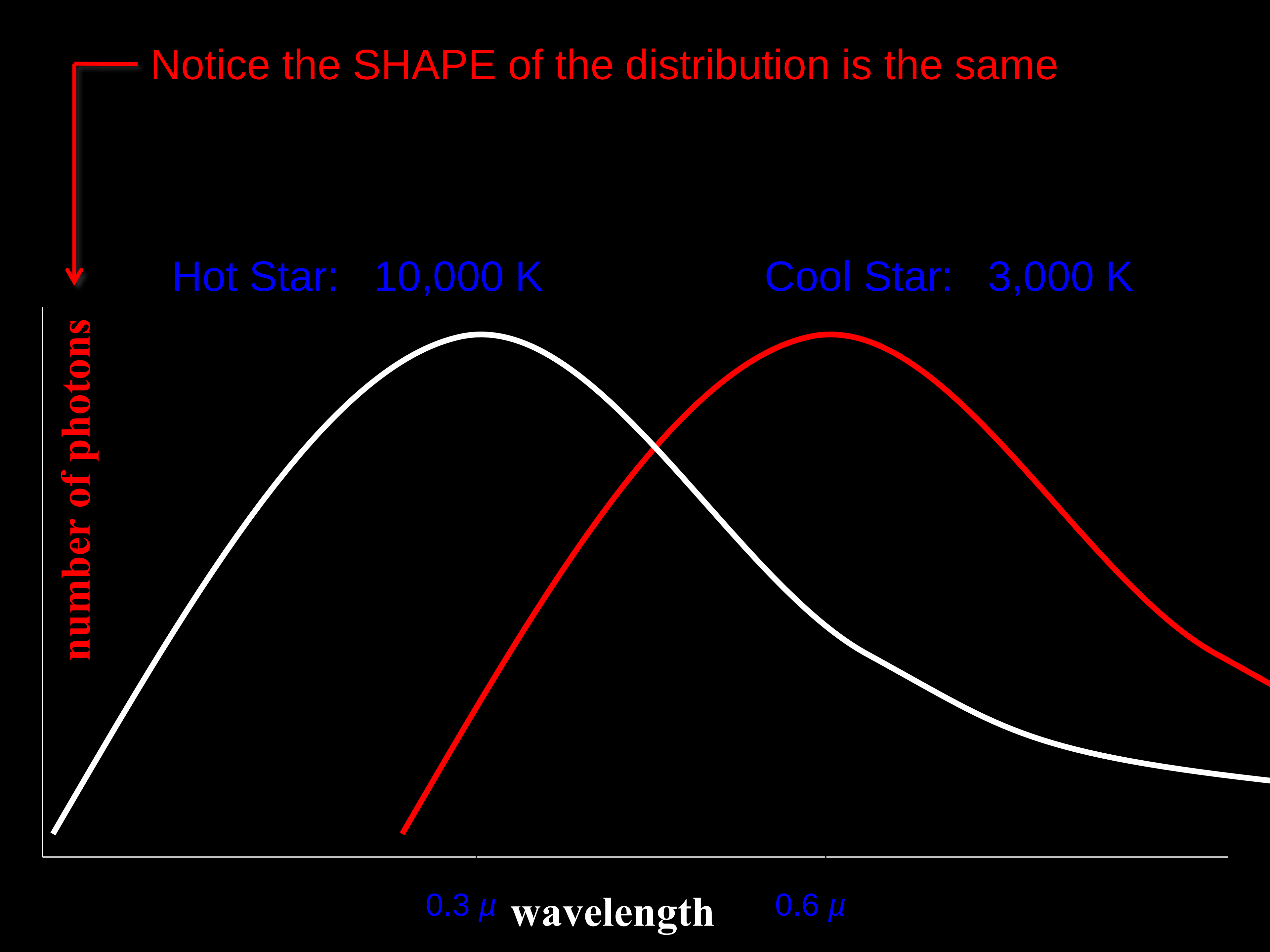
Stellar Classification: TEMPERATURE

Hot Star: 10,000 K

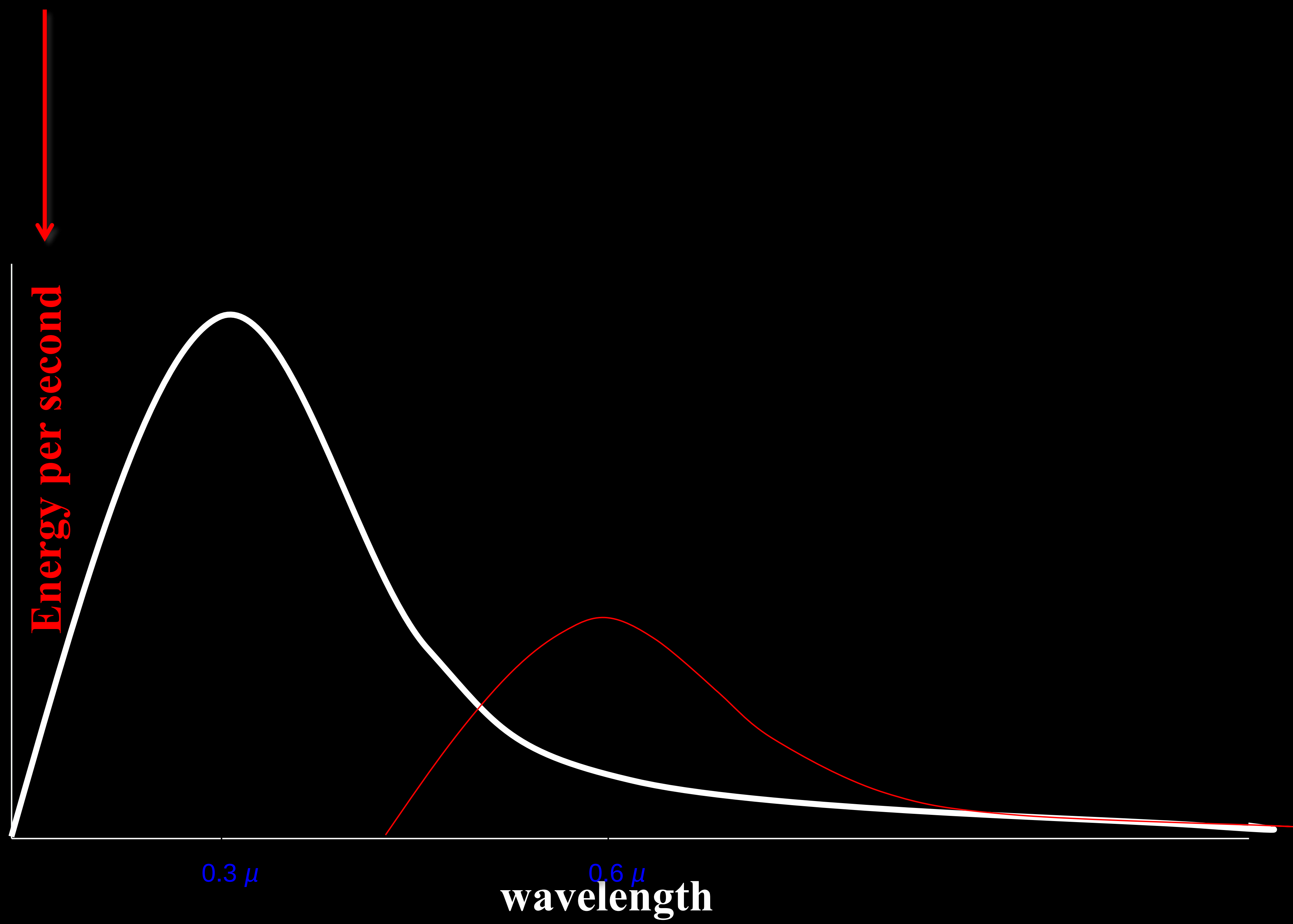


Cool Star: 3,000 K

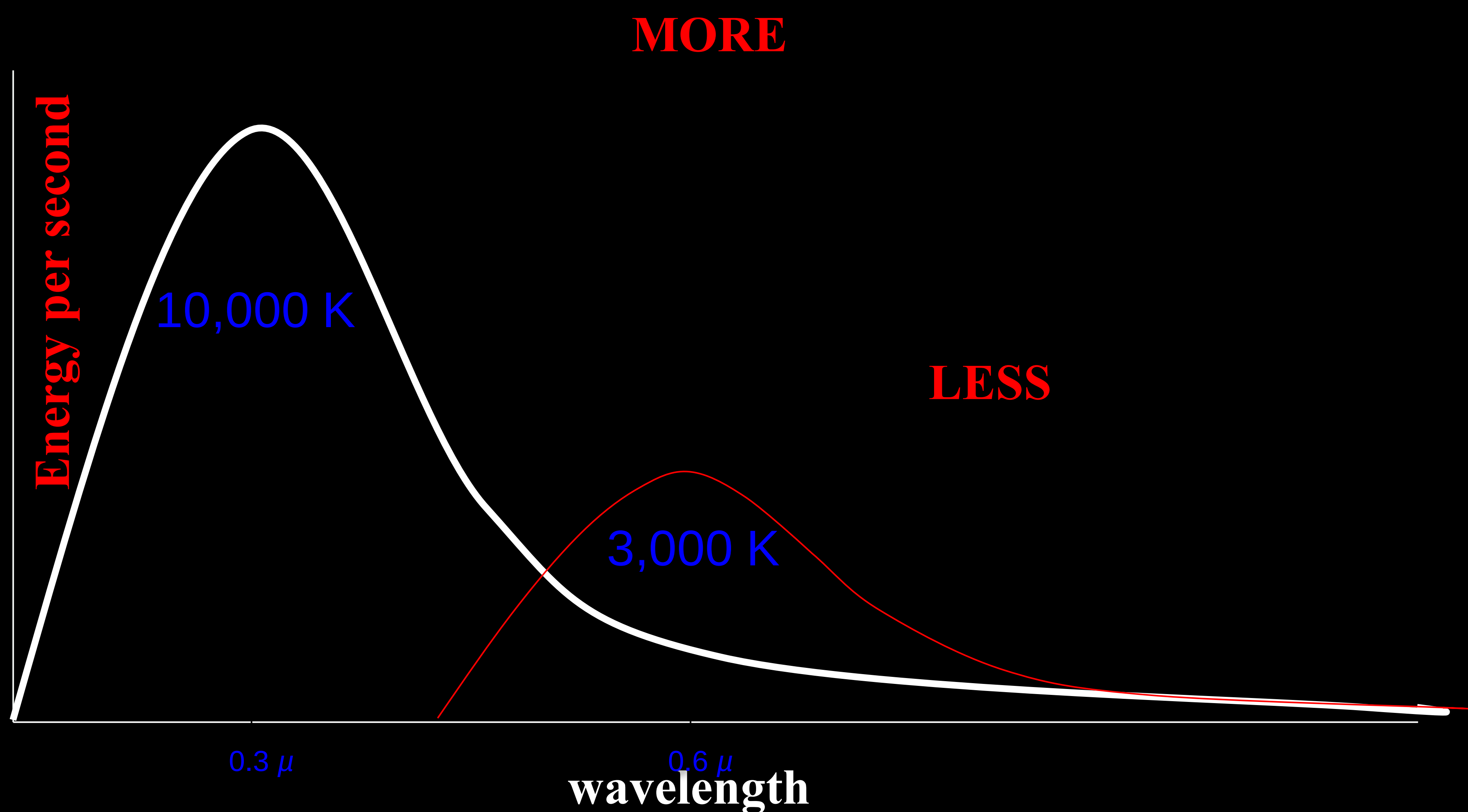


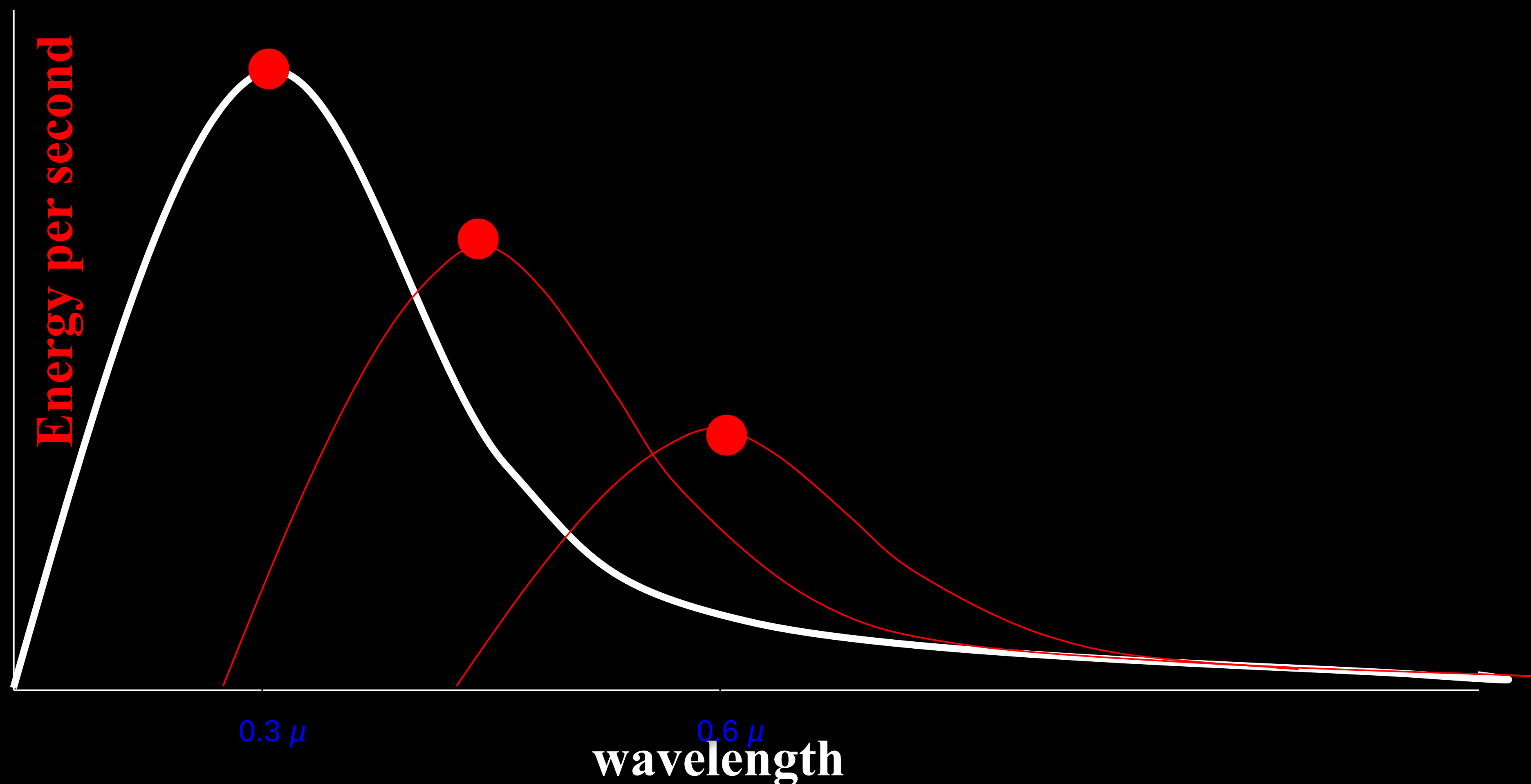


Notice the SHAPE of the distribution is the same
Hot Star: 10,000 K
Cool Star: 3,000 K
number of photons
0.3 μ
wavelength
0.6 μ

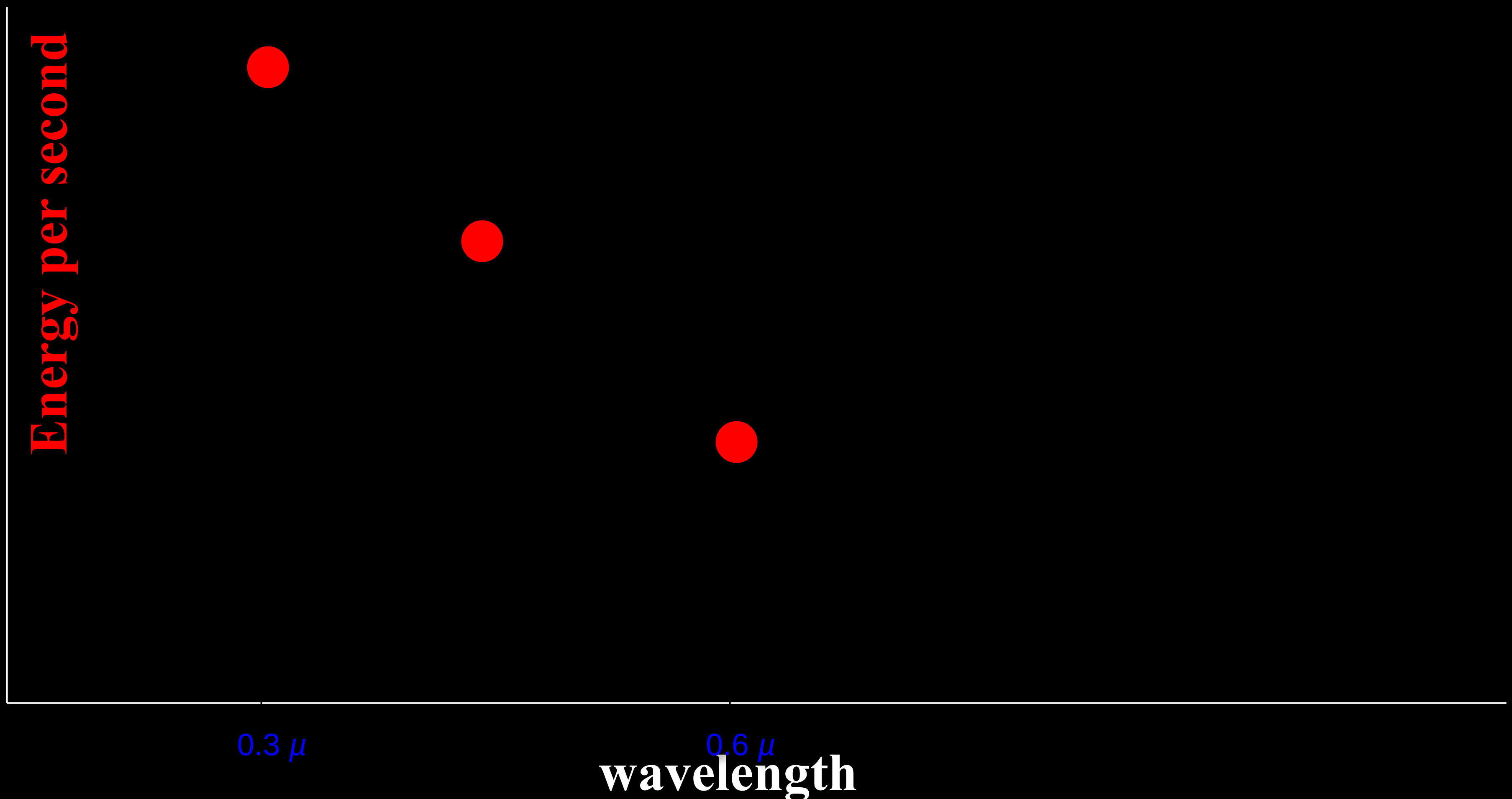


Energy per second
0.3 μ
0.6 μ
wavelength


MORE
Energy per second
10,000 K
LESS
3,000 K
0.3 μ
0.6 μ
wavelength



Energy per second
0.3 μ
0.6 μ
wavelength

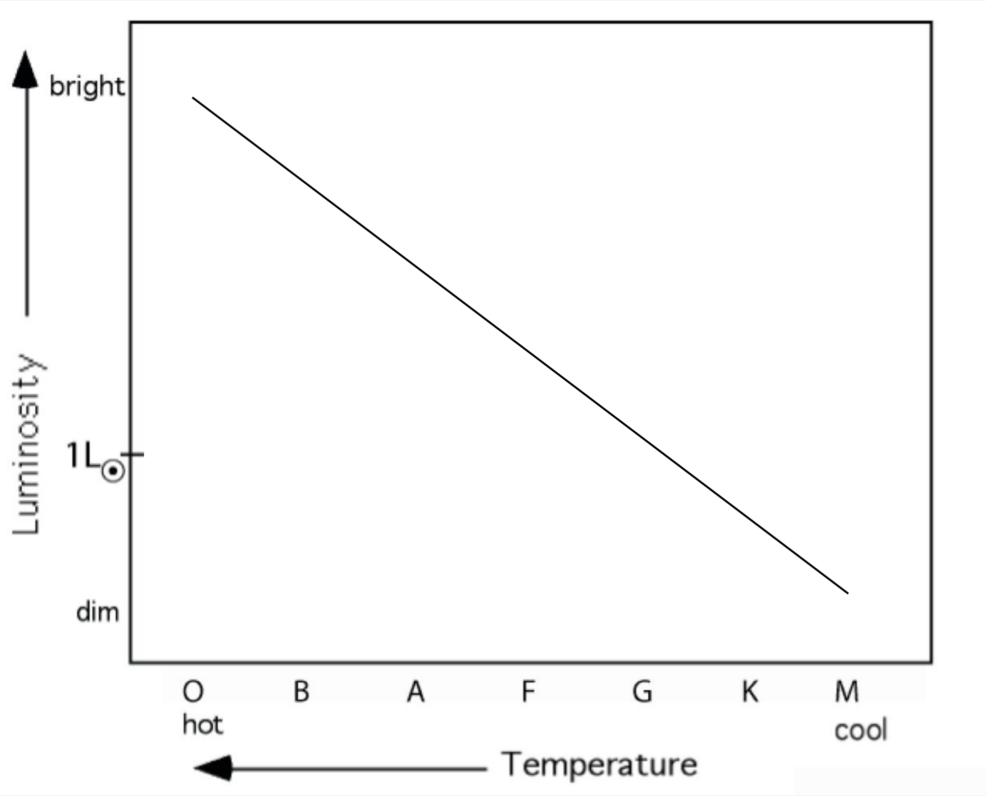

Energy per second
0.3 μ
0.6 μ
wavelength

$$\text{LUMINOSITY} = \text{Power} = \frac{\text{Energy}}{\text{sec}}$$

The hotter the star, the more short wavelengths it emits.

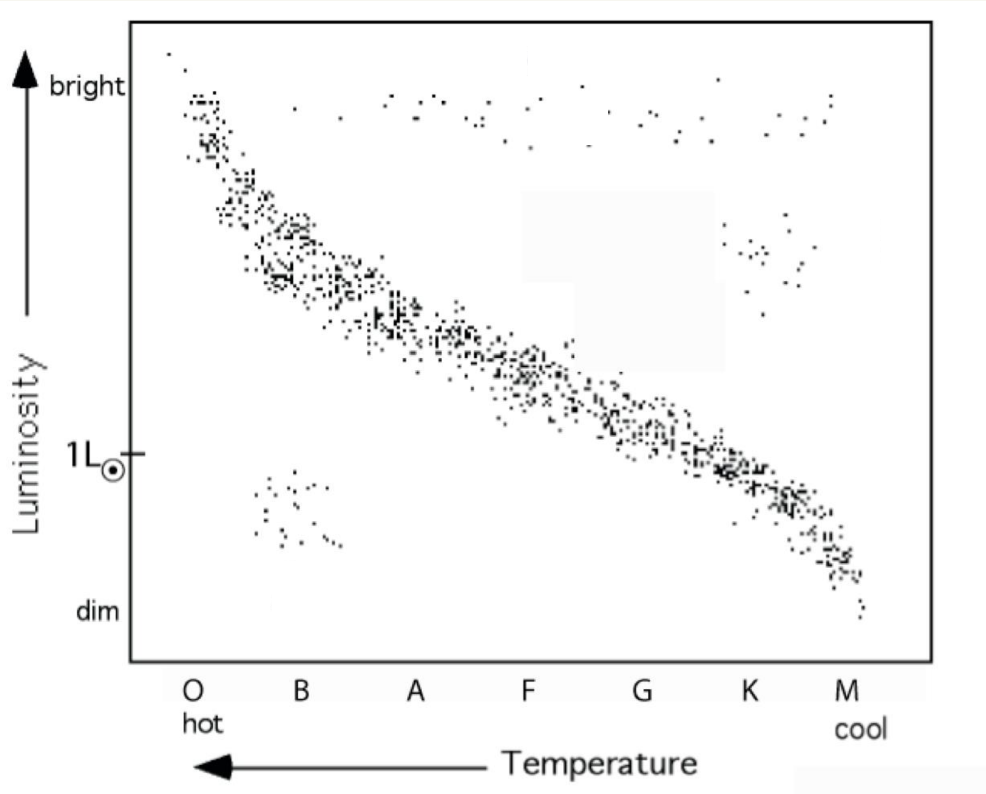
Then we would expect luminosity plotted against temperature to make a straight line…

The HOTTER the Star, the Greater its ABSOLUTE BRIGHTNESS



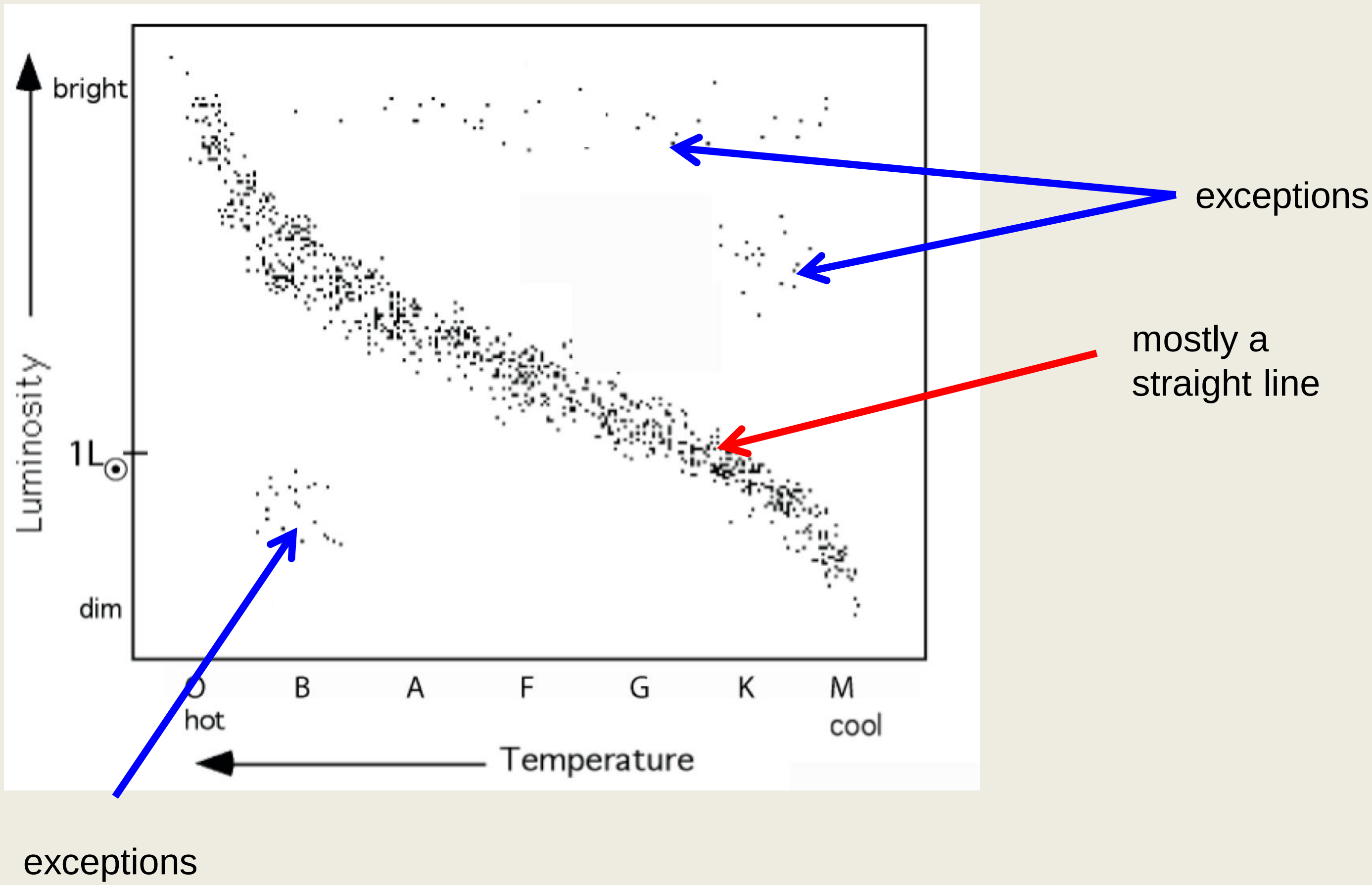
There should be a one-to-one correlation between luminosity and temperature

This is what Hertzsprung and Russell the absolute brightness and plotted the luminosity of 3,000 stars versus temperature.



It is a similar procedure to putting a box of light bulbs all at the same distance to be able to compare them directly.

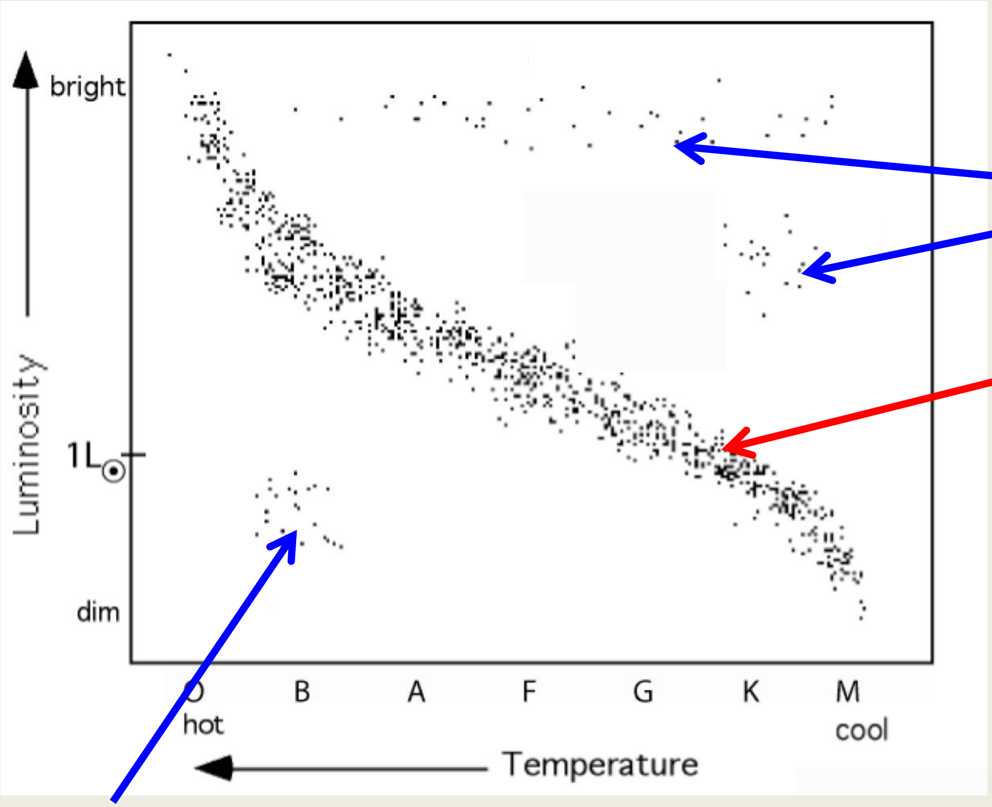
If you plot temperature against luminosity



Stars are classified on basis of TEMPERATURE and LUMINOSITY

The exceptions mean: Stars change with time.

➔ Stars evolve.



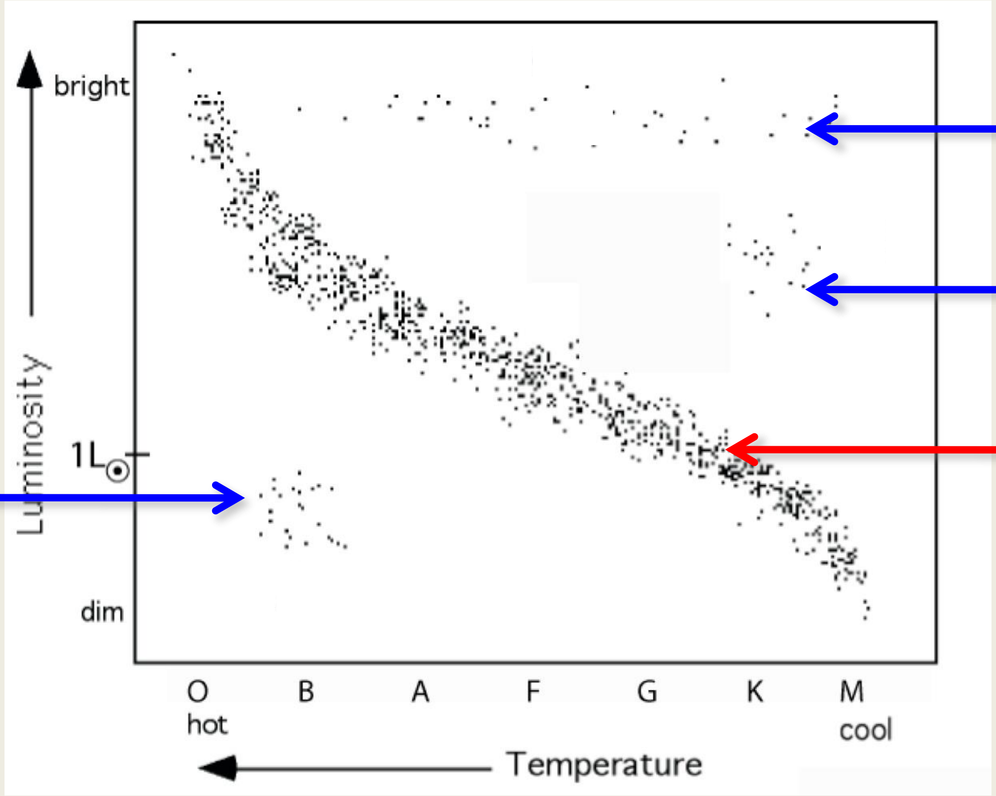
exceptions

mostly a straight line

exceptions

This is the Hertzsprung-Russell (HR) Diagram

White Dwarfs



Supergiants

Red Giants (He fusion)

Main Sequence (H fusion)

Luminosity Classifications

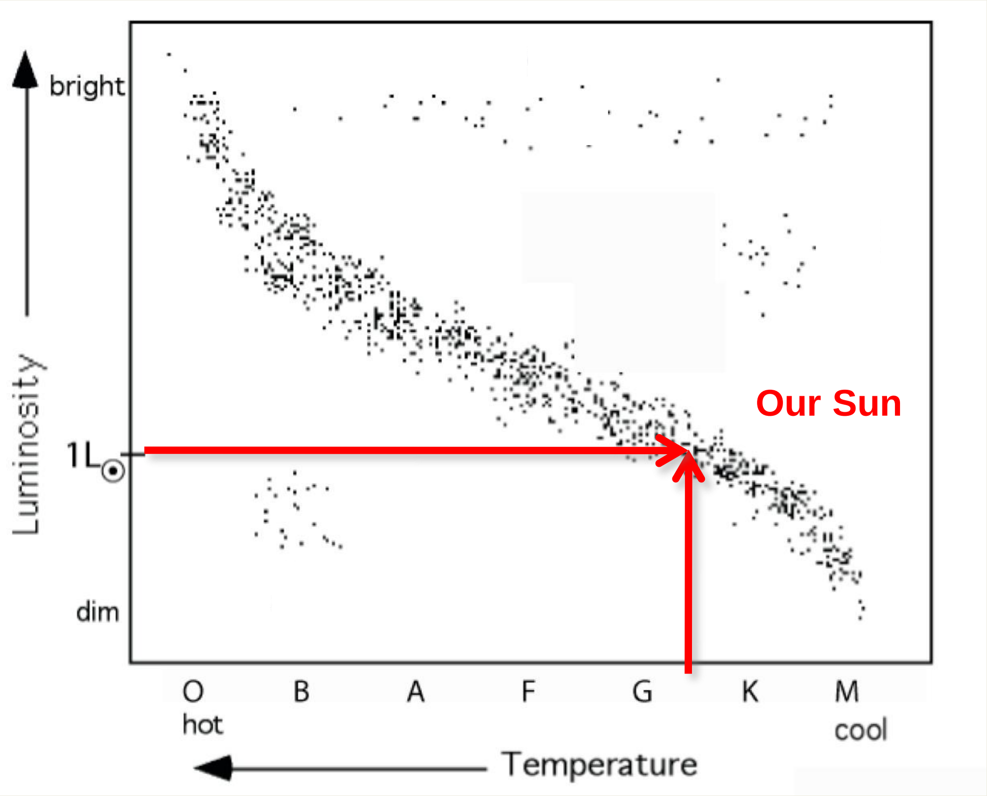
SO! Every Star has a first name: Temperature Type

and a last name: Luminosity Class

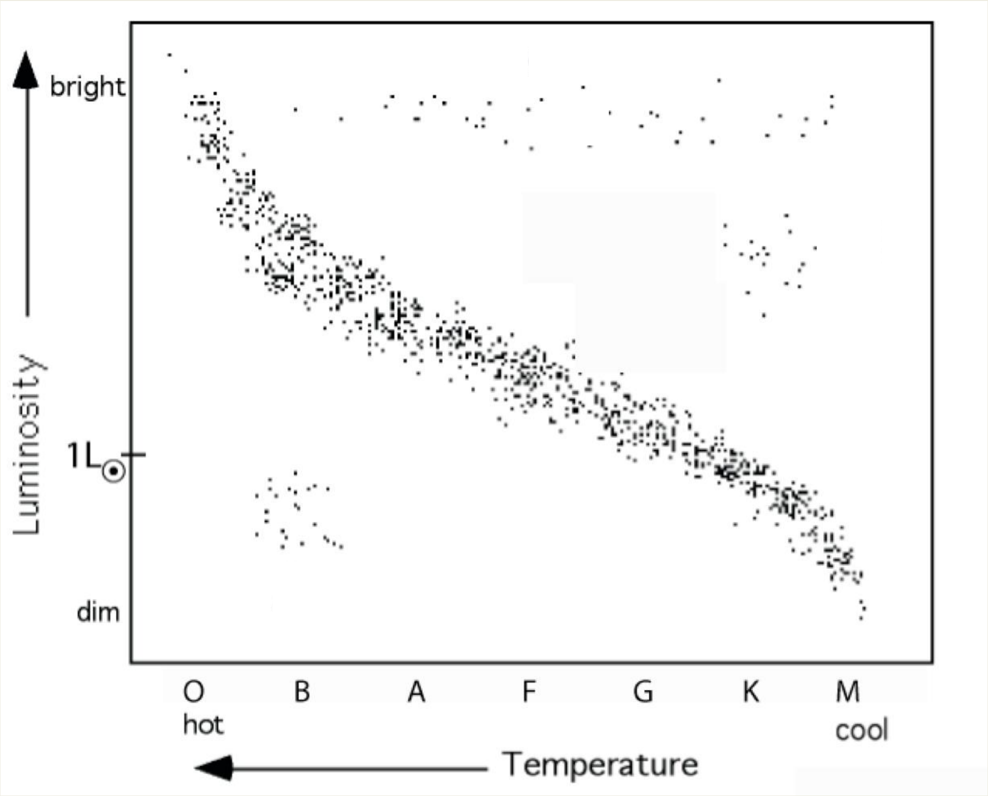
Temperature Type			Luminosity Class	
O	0 – 9	hottest	I	Supergiant
B	0 – 9		III	Red Giant
A	0 – 9		IV	White Dwarf
F	0 – 9		V	Main Sequence
G	0 – 9			
K	0 – 9			
M	0 – 9	coolest		

for ex., our Sun is a **G2 V star**

Our Sun is a G2 Main Sequence star



QUESTION: Which is more luminous, a K0 main sequence star or a K0 red giant?



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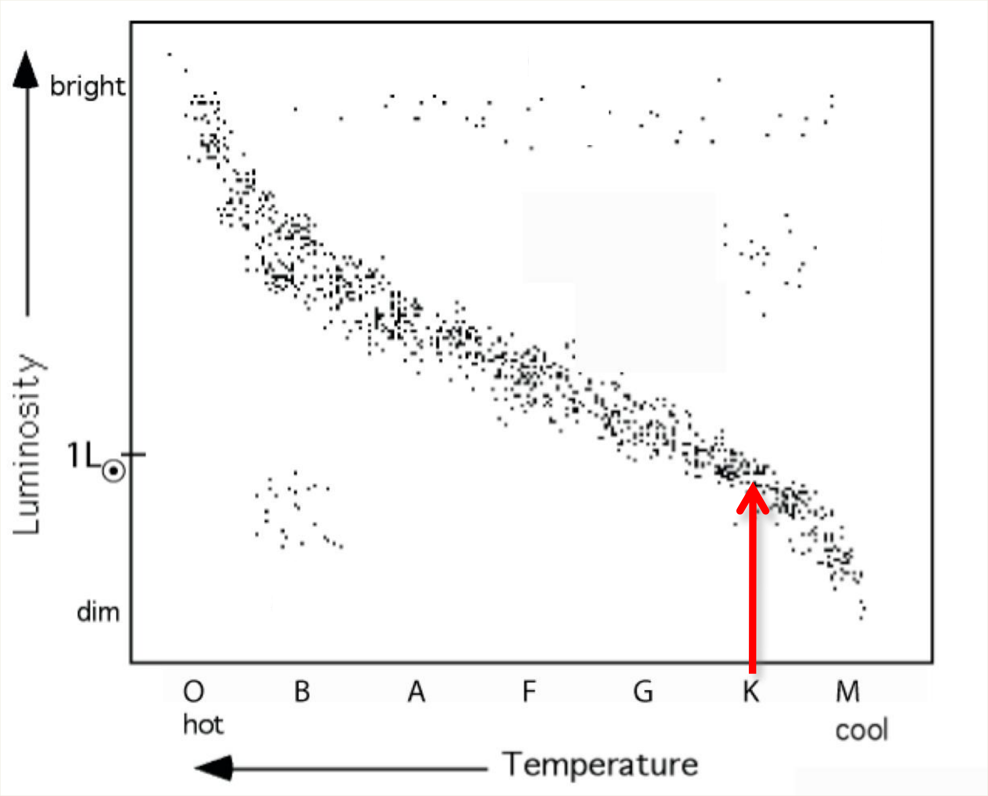

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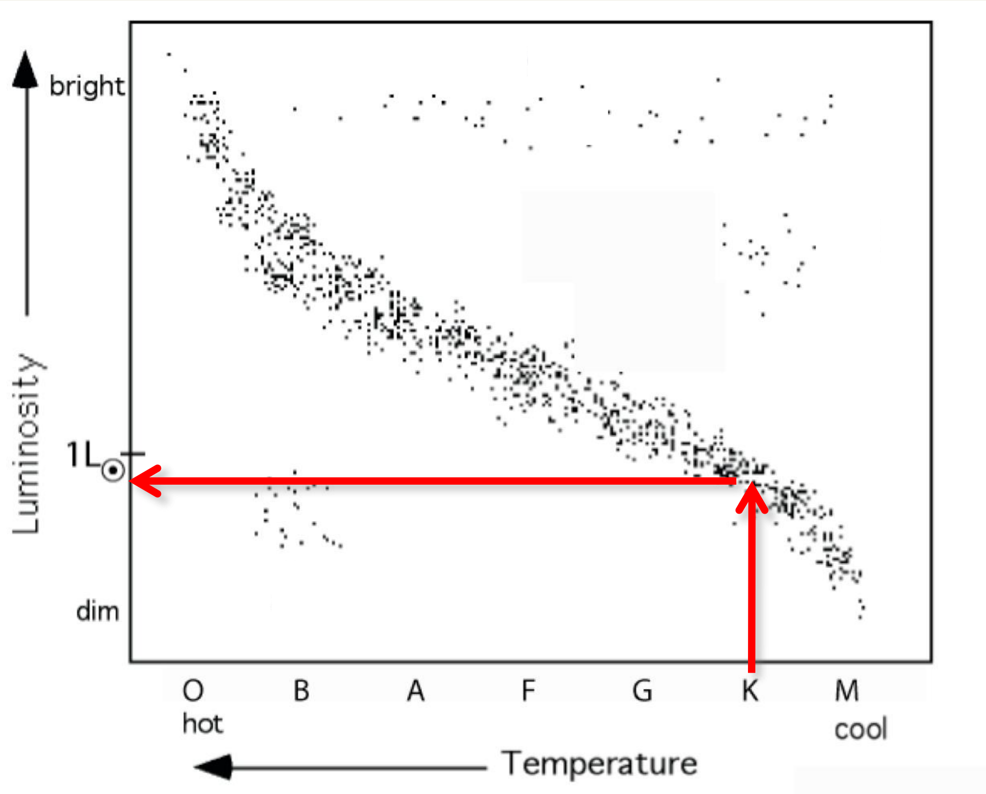

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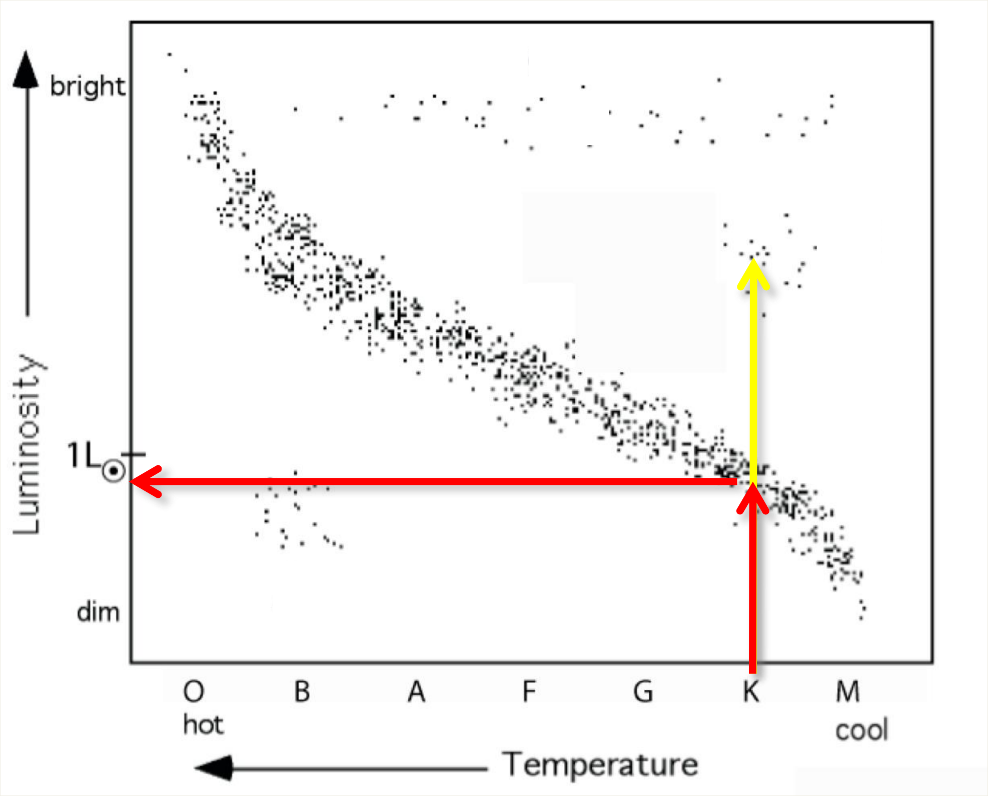
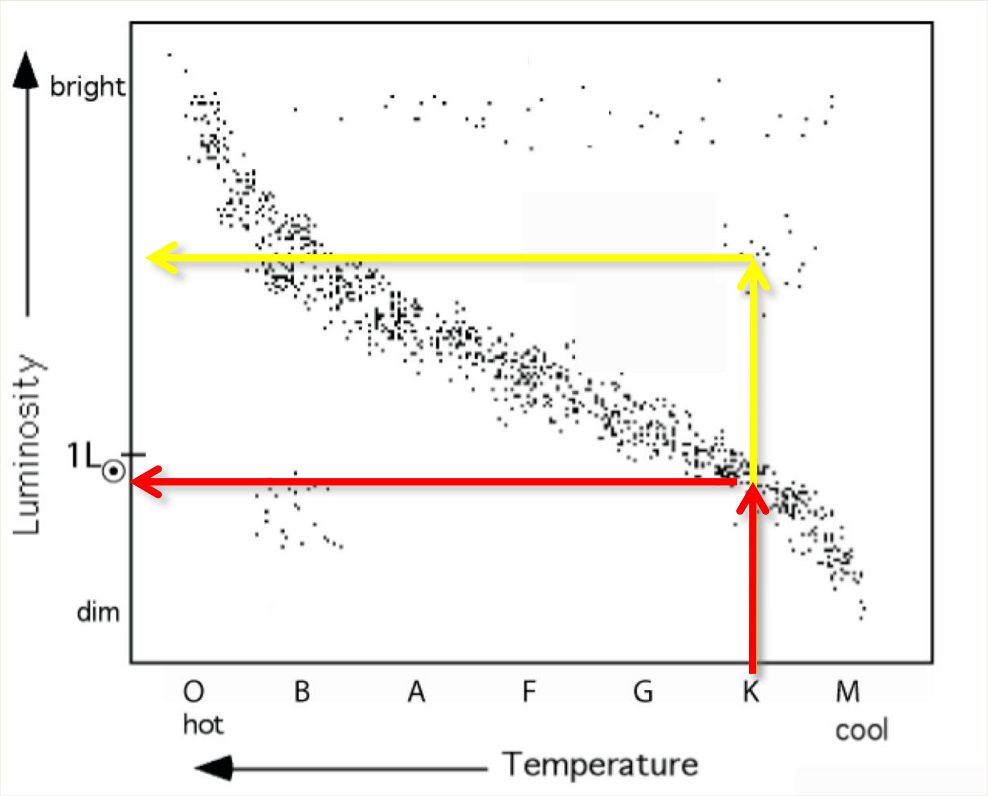


ANSWER: the K0 red giant is more luminous.



Knowing distance lets us calculate the LUMINOSITY and the ABSOLUTE BRIGHTNESS

With LUMINOSITY we can calculate how bright a star would be if it were 10 parsecs from us

Why not stick with LUMINOSITY?

Knowing distance lets us calculate the LUMINOSITY and the ABSOLUTE BRIGHTNESS

Why not stick with LUMINOSITY?

Because we want to compare

ABSOLUTE BRIGHTNESS

with

APPARENT BRIGHTNESS

to get the distance from Earth to the star.

Knowing DISTANCE is key in astronomy.

Distance to stars tells us the structure and size of

our Milky Way Galaxy

and

our Local Group of galaxies,

and ultimately, the structure of the Universe.

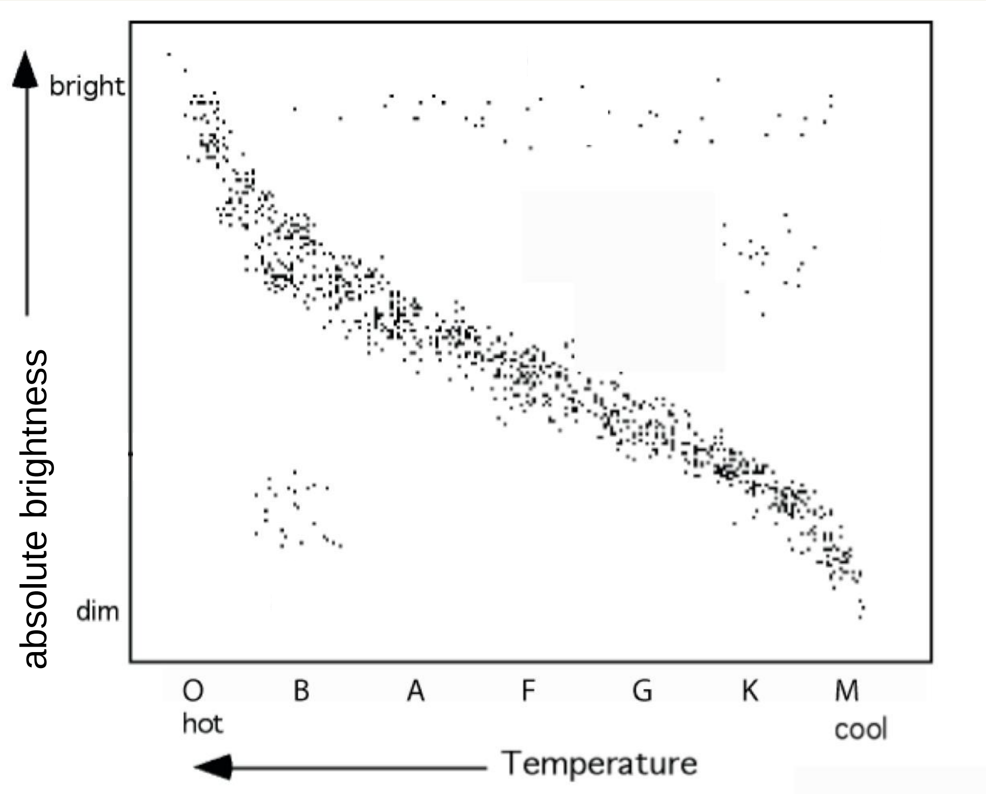
Parallax was the first distance measurement

method	observations	range
Parallax	2 pictures	200 l-yrs

Using spectra with the HR diagram came next

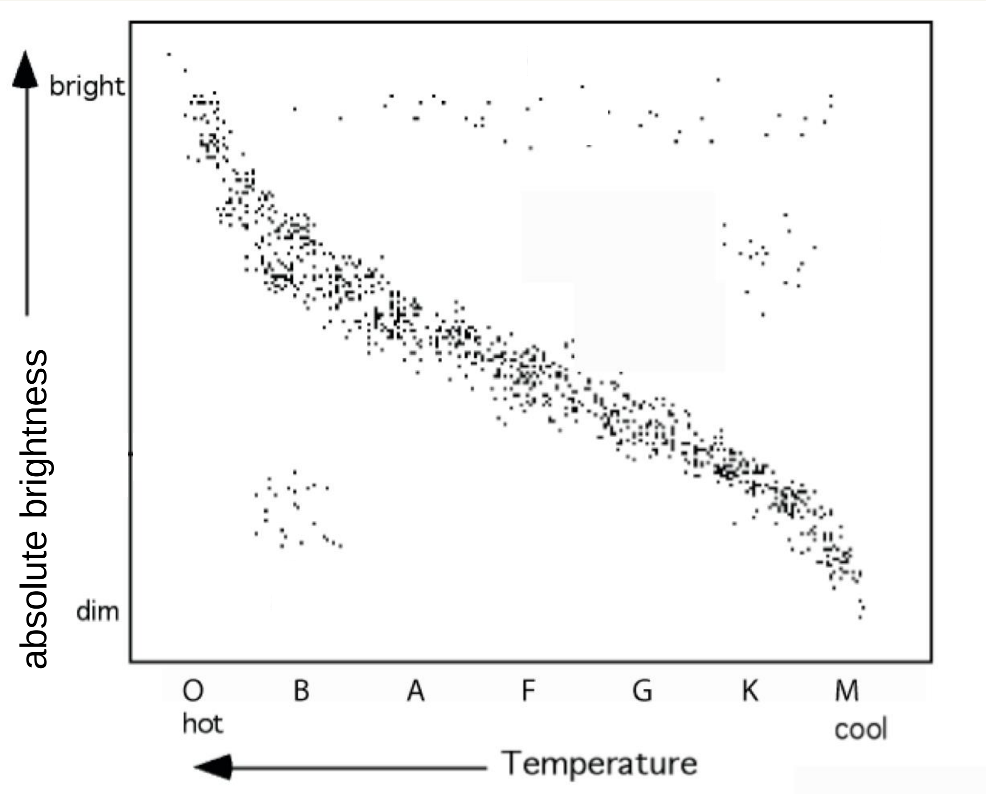
method	observations	range
Parallax	2 pictures	200 l-yrs
Spectroscopy with HR diag.	spectrum	30,000 l-yrs

Spectroscopy with HR diagram



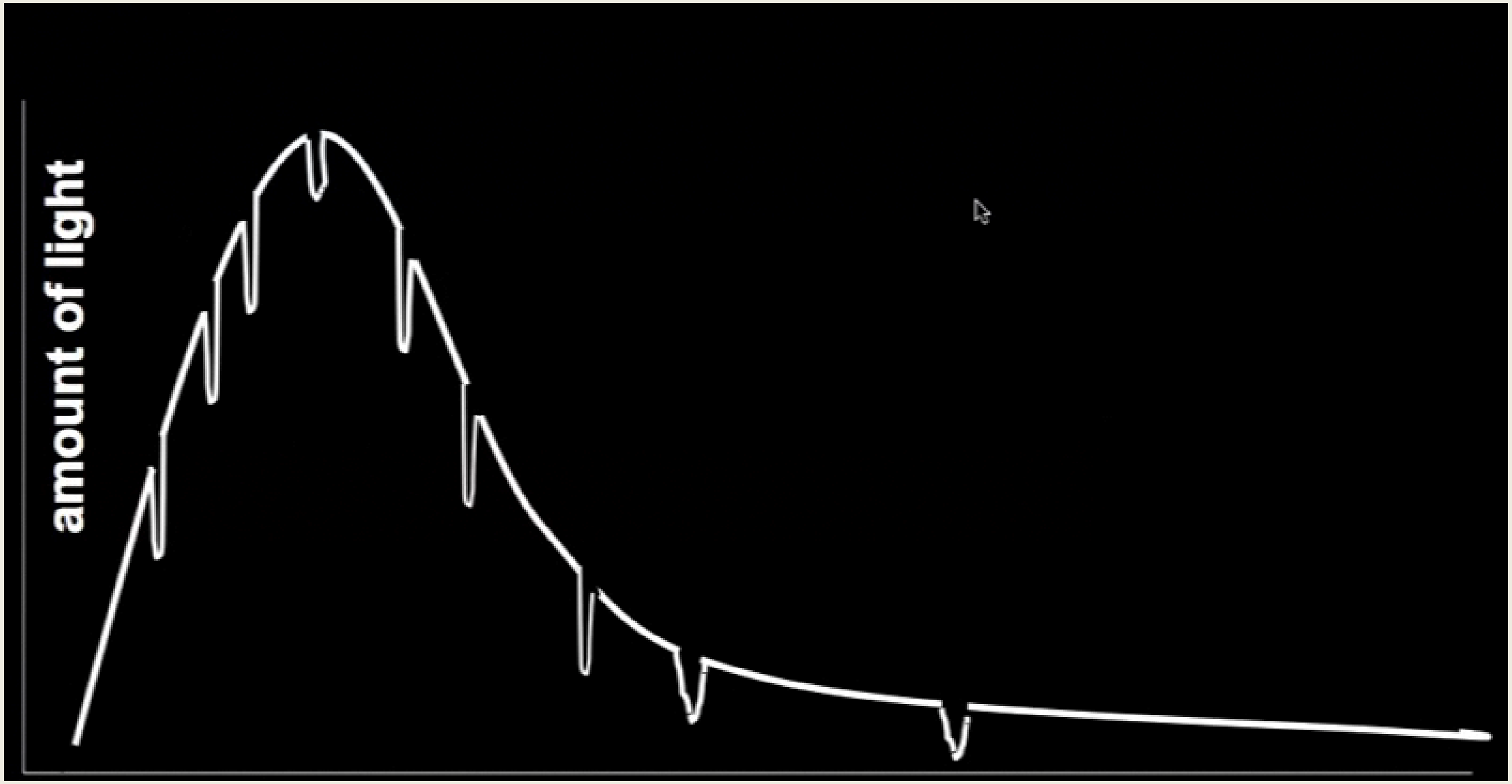
use the spectrum to get the TEMPERATURE
and the LUMINOSITY CLASS …..

Spectroscopy with HR diagram



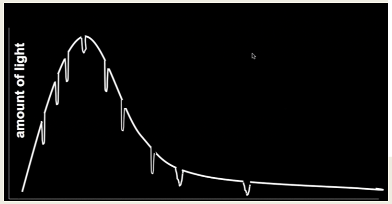
and use the HR diagram to get the absolute brightness. Compare the absolute and apparent brightness, and then you can calculate the distance.

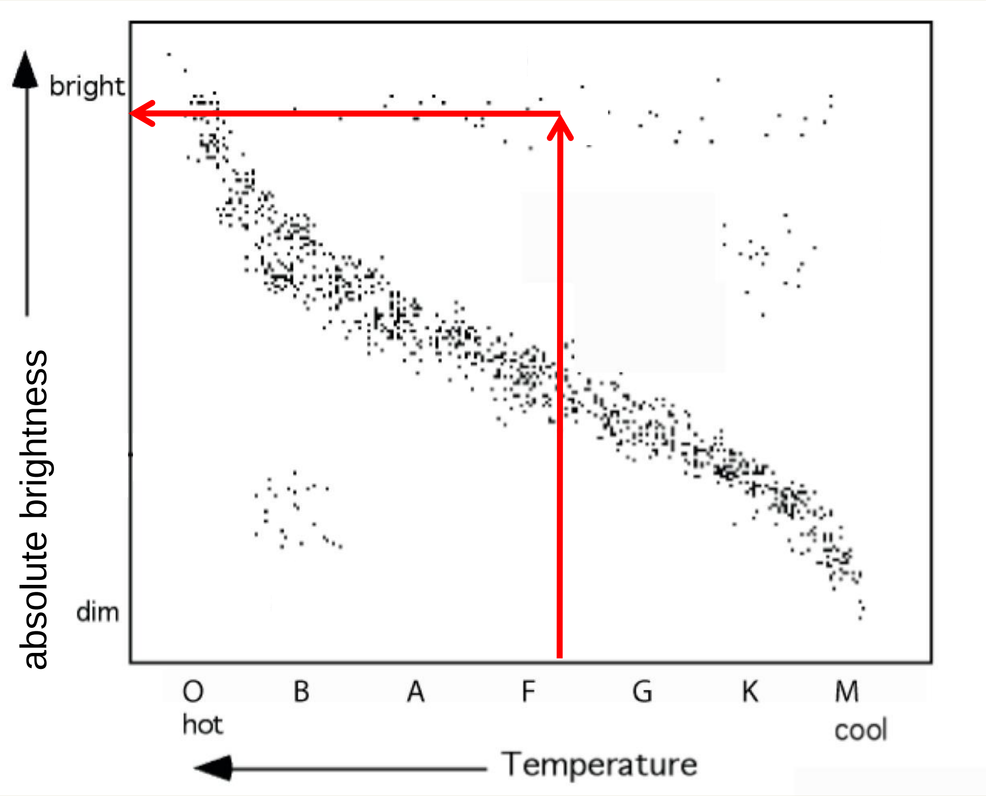
Spectroscopy with HR diagram



For example, consider this spectrum. You figure out that it tells you it is from an F3 supergiant star and you also measure its apparent brightness. Take the spectral information to the HR diagram….

Spectroscopy with HR diagram





and use the HR diagram to get the **absolute** brightness. From this diagram and your measurement of the apparent brightness, you are ready to calculate the distance.

so your calculation would look like this:

$$\text{distance} = 10\ \text{pc} \times \sqrt{\frac{\text{absolute brightness}}{\text{apparent brightness}}}$$

from the HR diag

from what you measured

so your calculation would look like this:

$$\text{distance} = 10\ \text{pc} \times \sqrt{\frac{\text{absolute brightness}}{\textbf{apparent}\ \text{brightness}}}$$

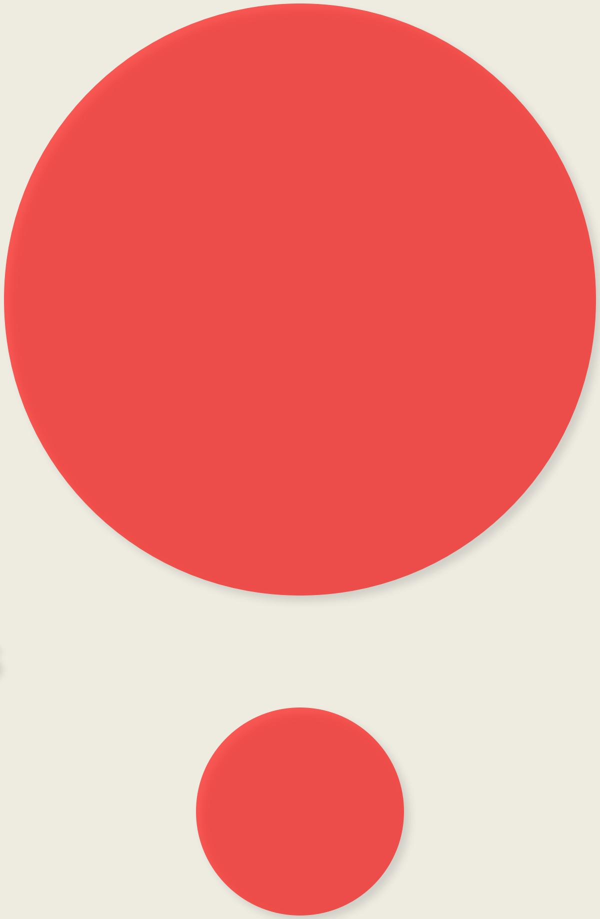
if you calculate that the ratio of absolute to apparent brightness is 400, then the star is 200 parsecs away!

$$10\ \text{pc} \times \sqrt{400} = 10\ \text{pc} \times 20 = 200\ \text{pc}$$

Method of Cepheid Variables expanded our reach

method	observations	range
Parallax	2 pictures	200 l-yrs
Spectroscopy with HR diag.	spectrum	30,000 l-yrs
Cepheid light curve		100,000,000 l-yrs

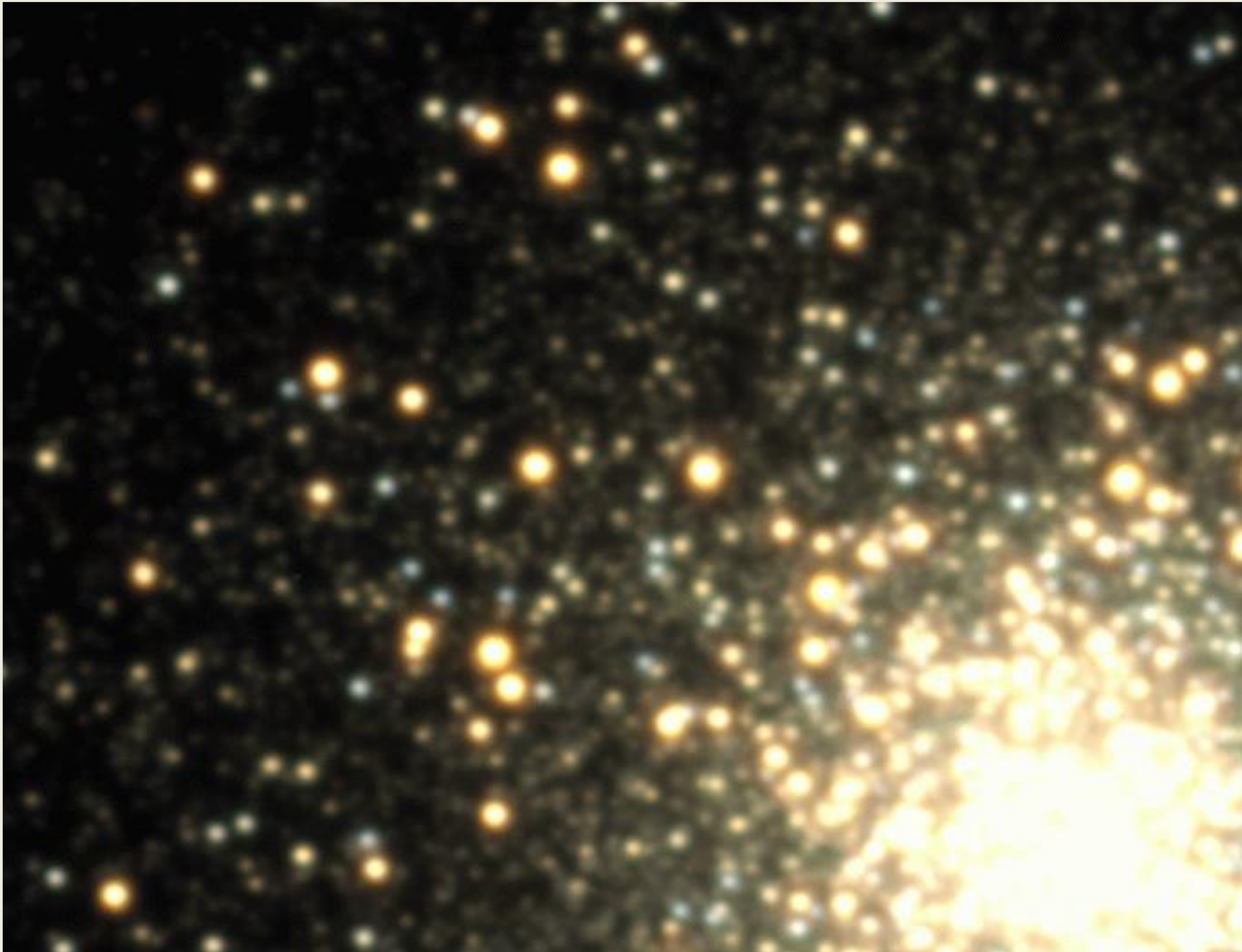
Cepheid Variables



— a type of pulsating Red Giant star

— their rate of pulsating is directly related to their absolute brightness

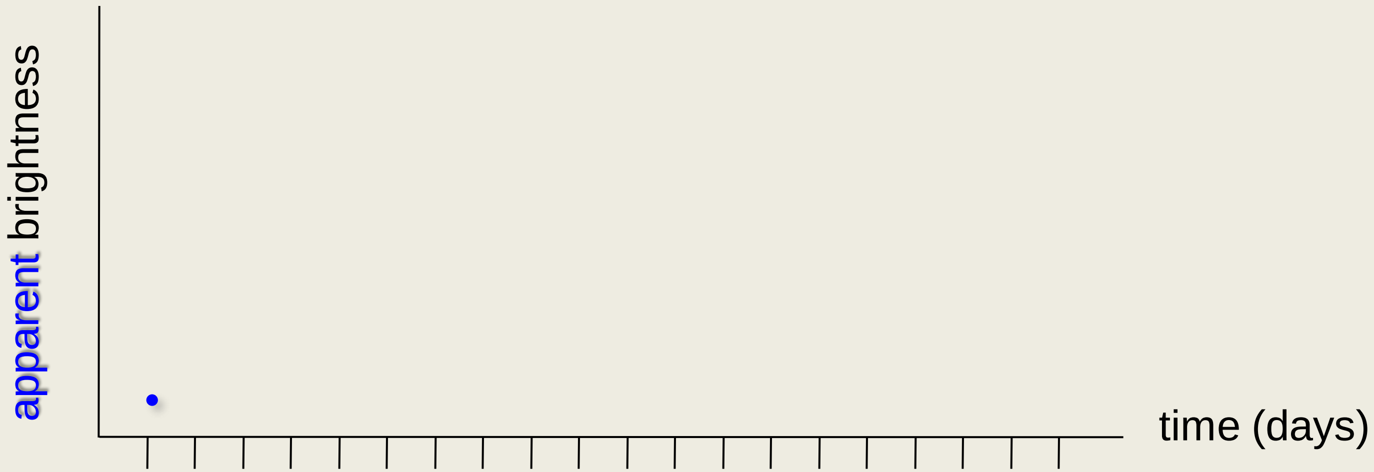
measure their pulsation rate, know their absolute brightness!



Cepheid Variables

How do you measure their pulsation rate?

You measure how bright they are over time. This is called a LIGHT CURVE



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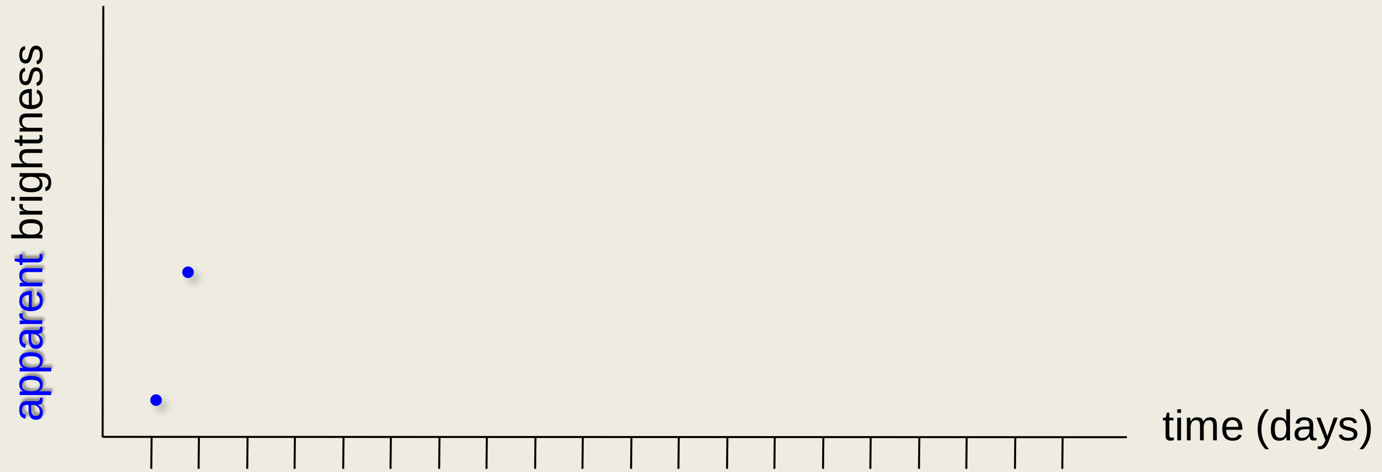

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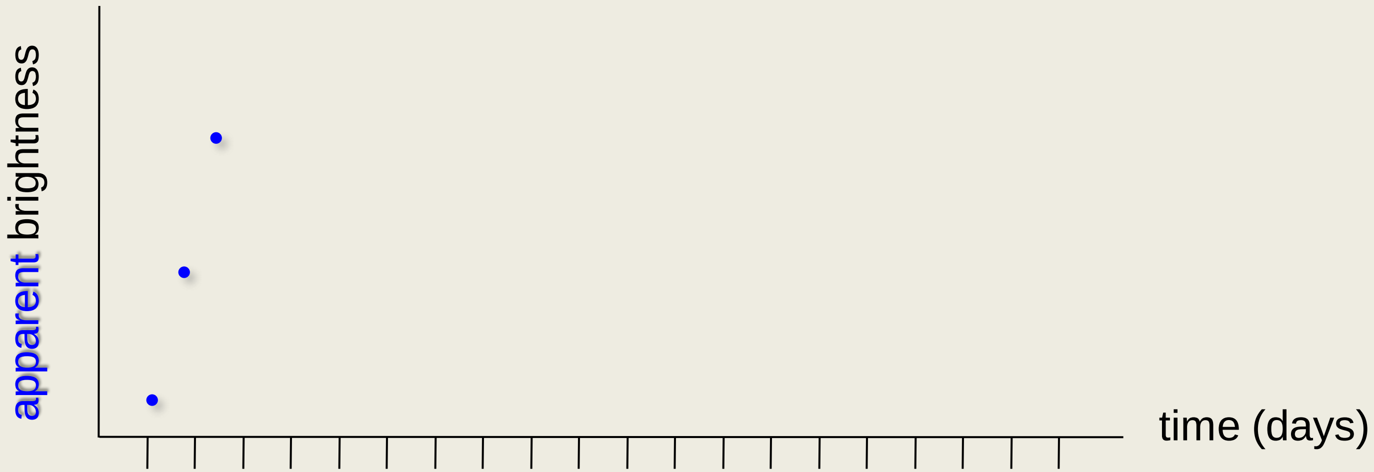

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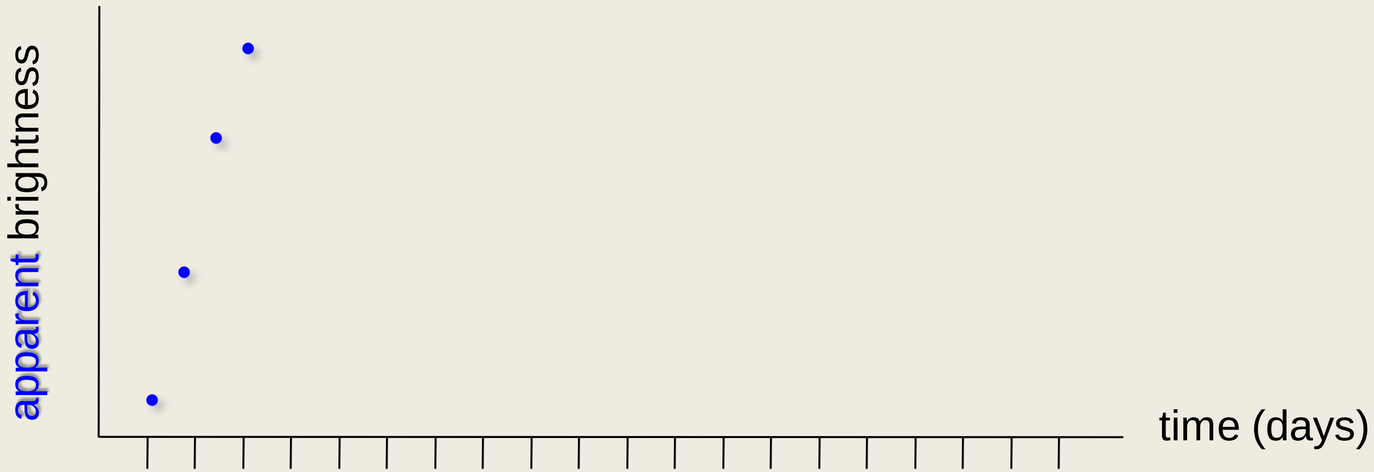

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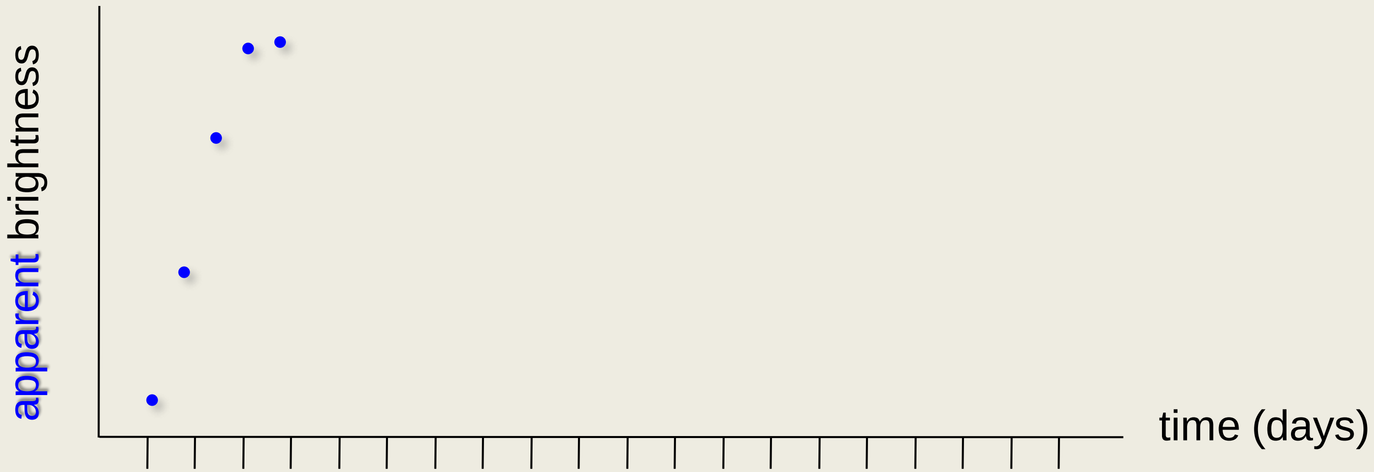

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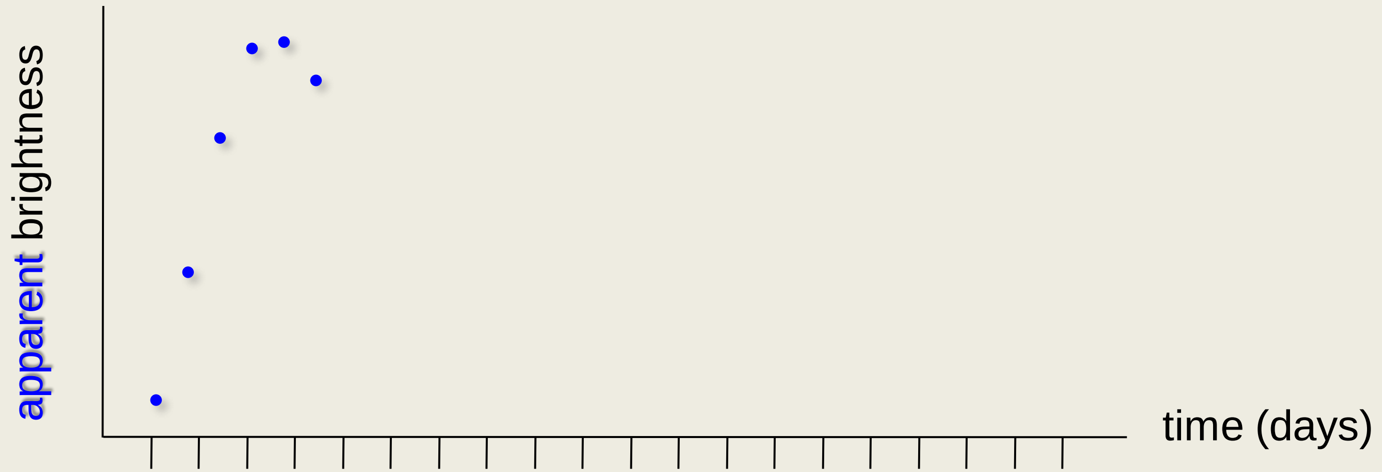

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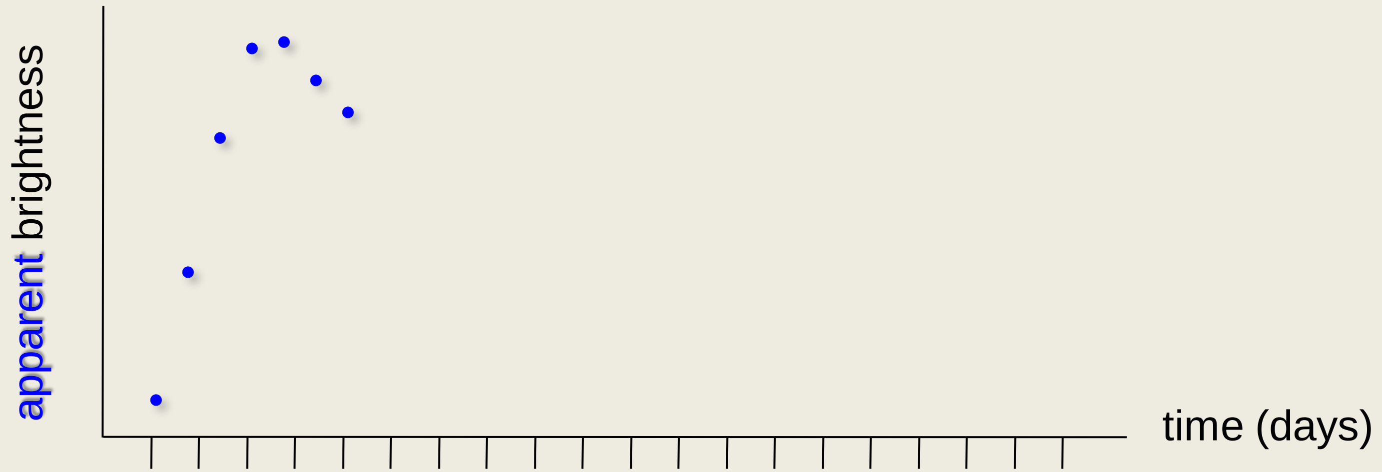

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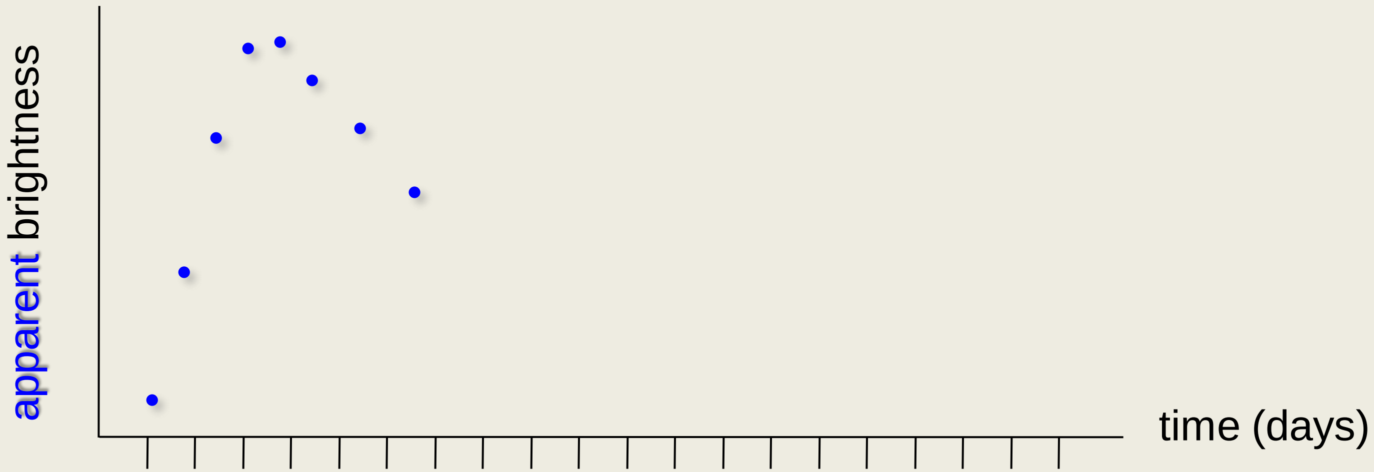

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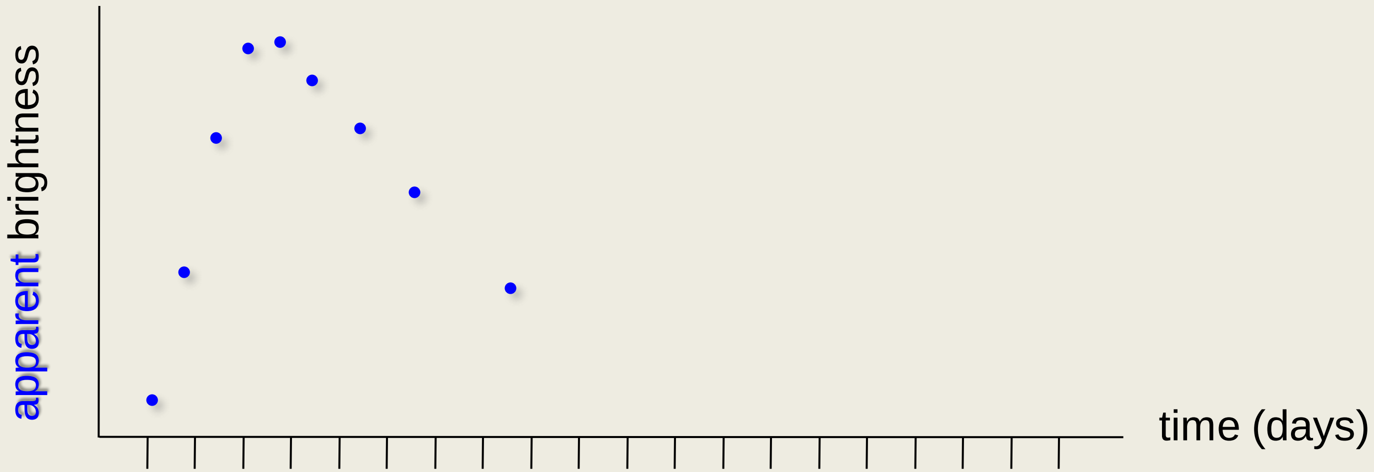

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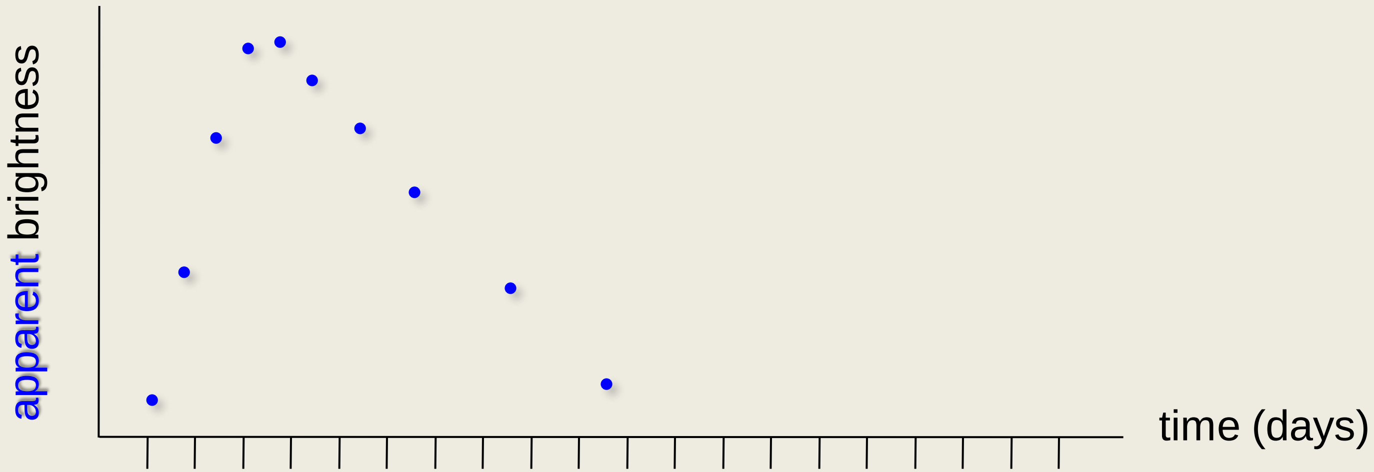

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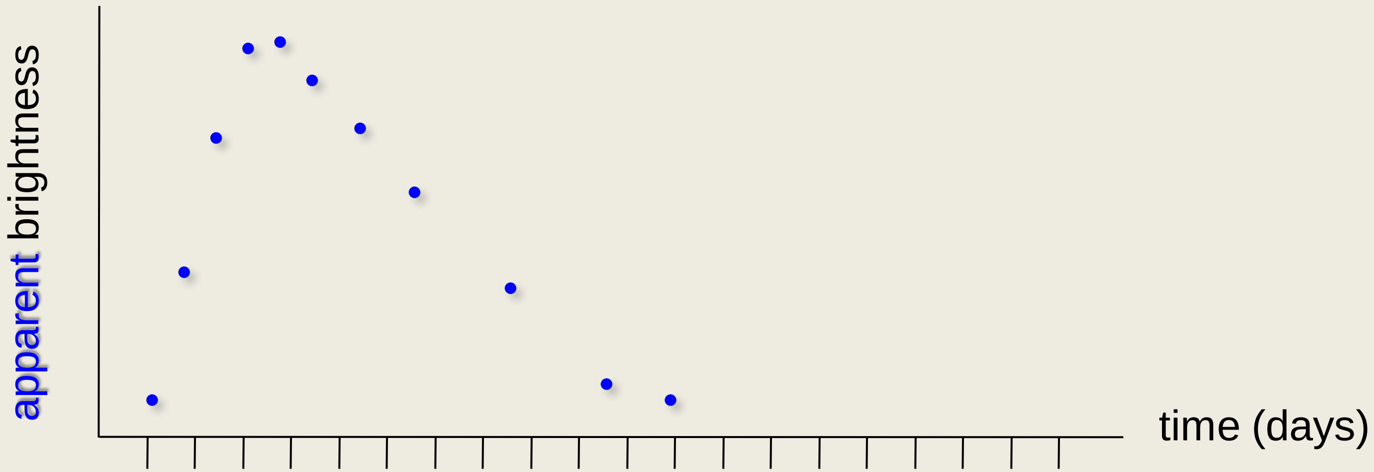

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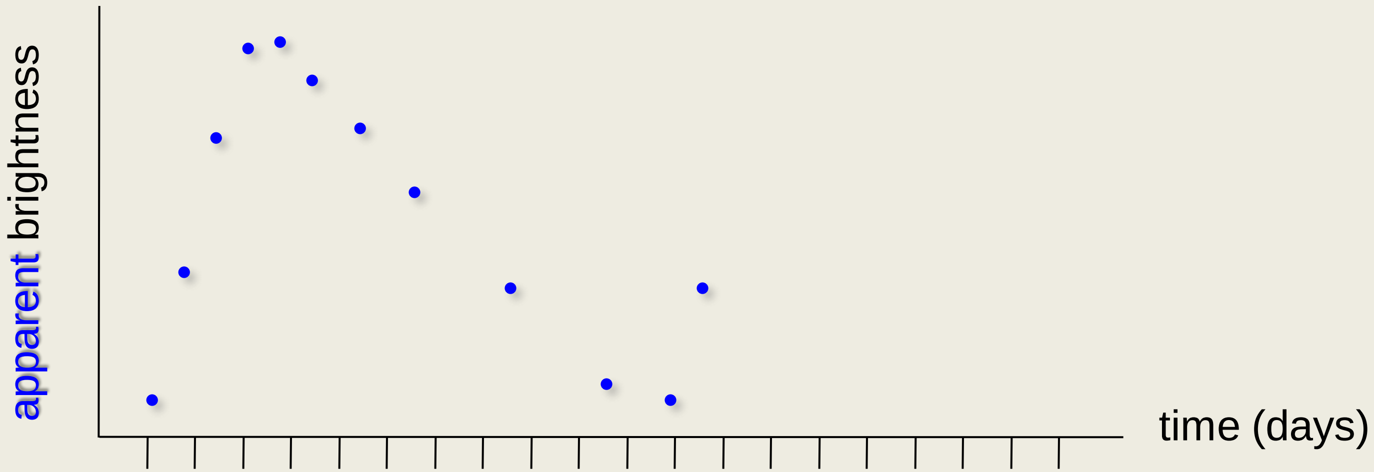

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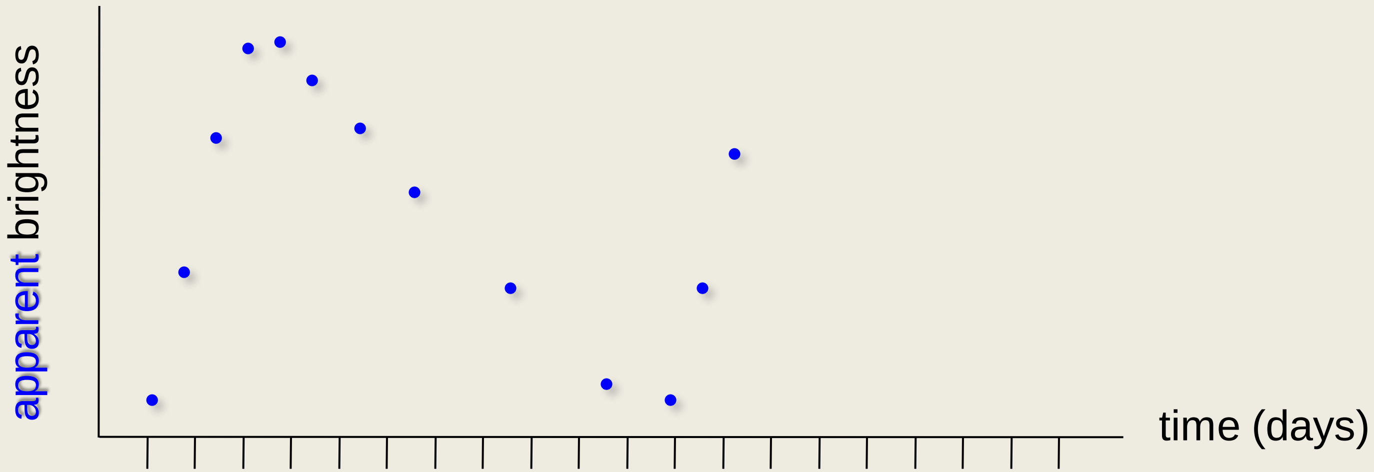

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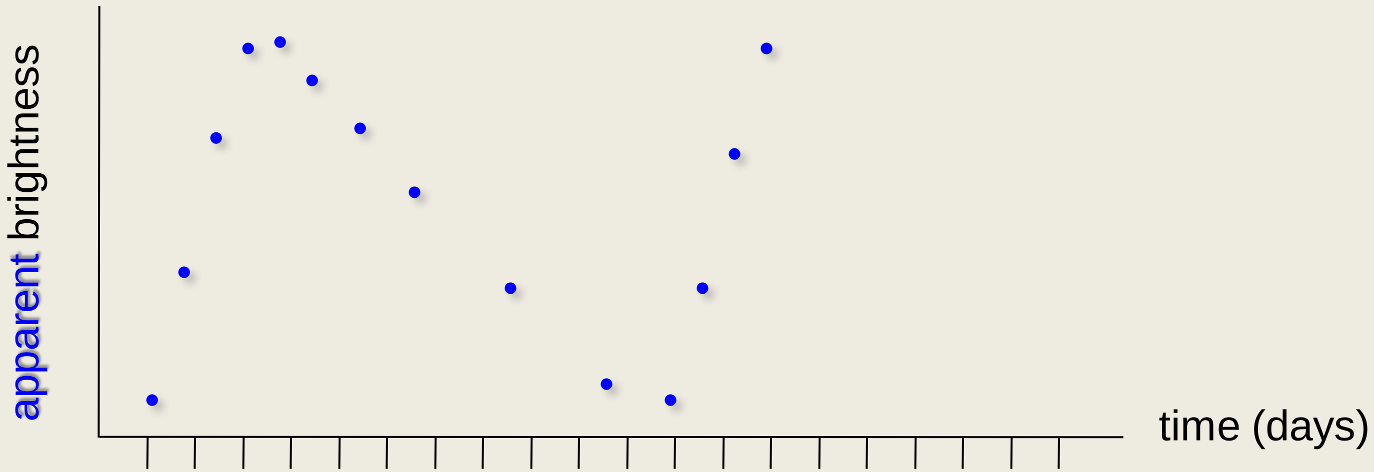

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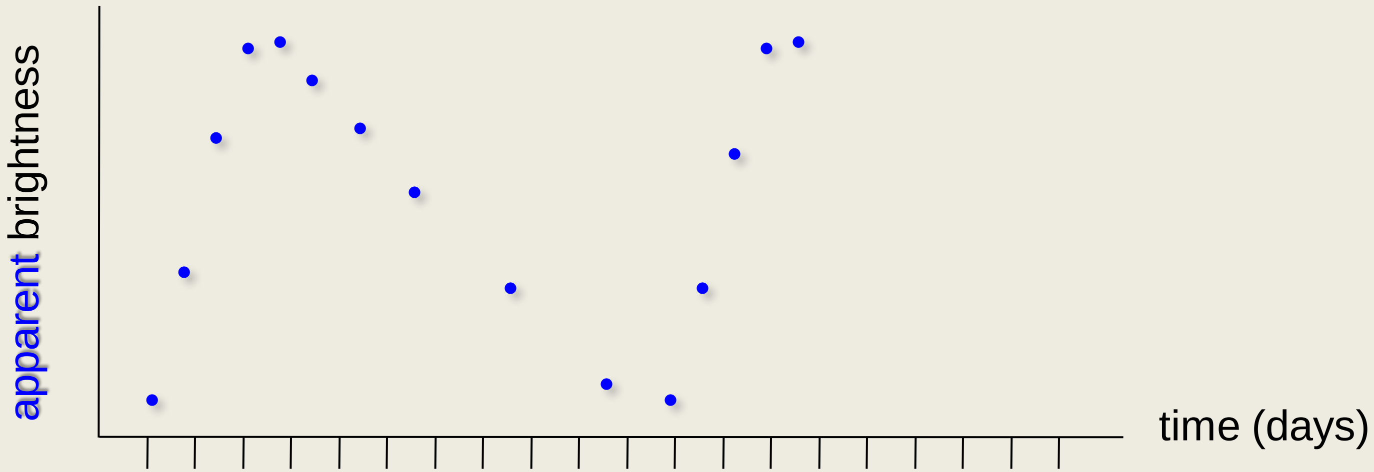

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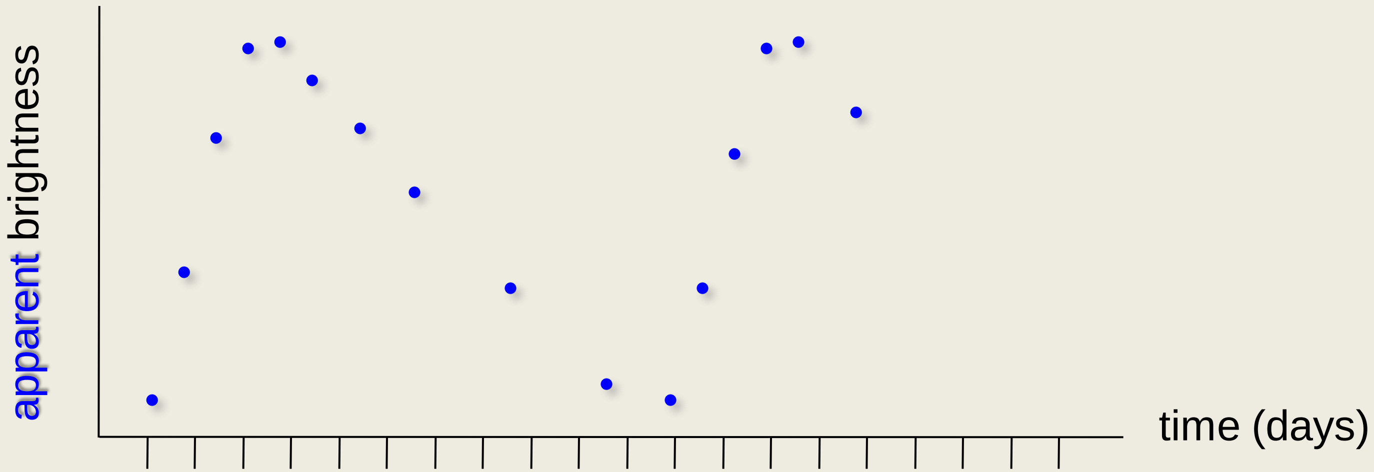

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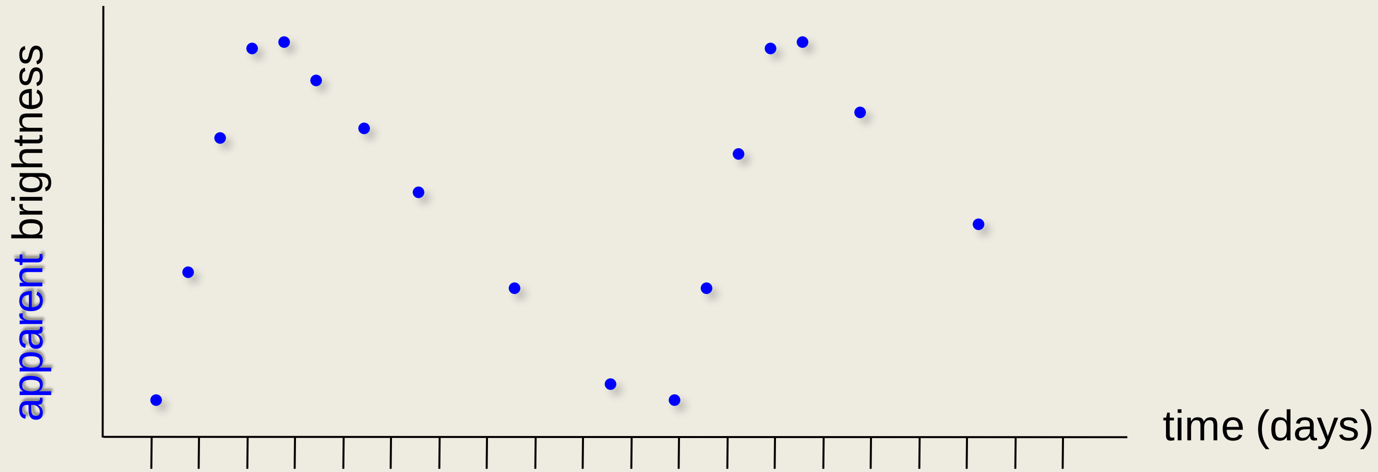

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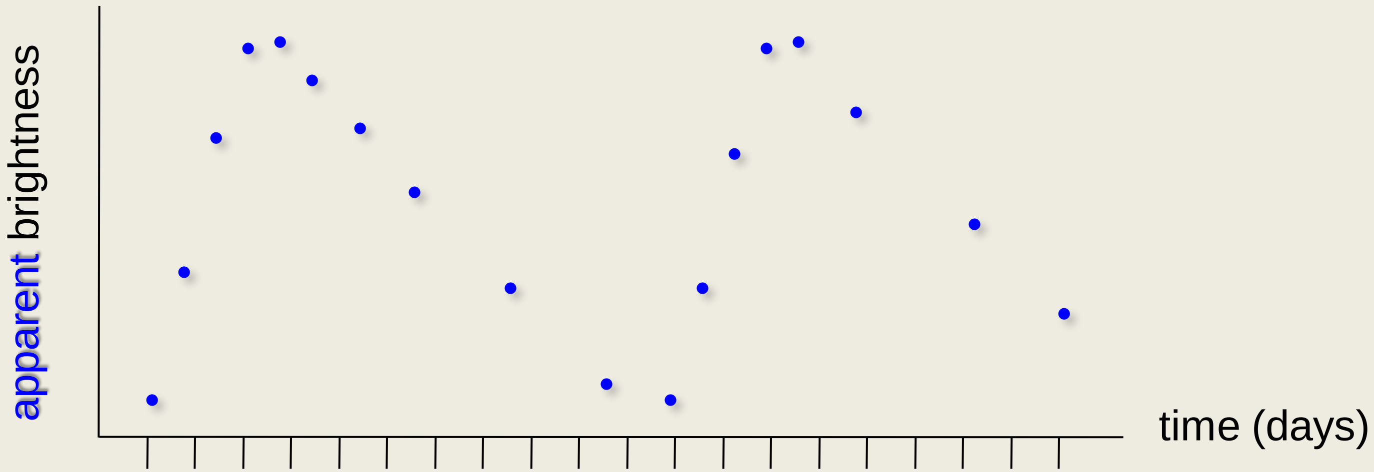

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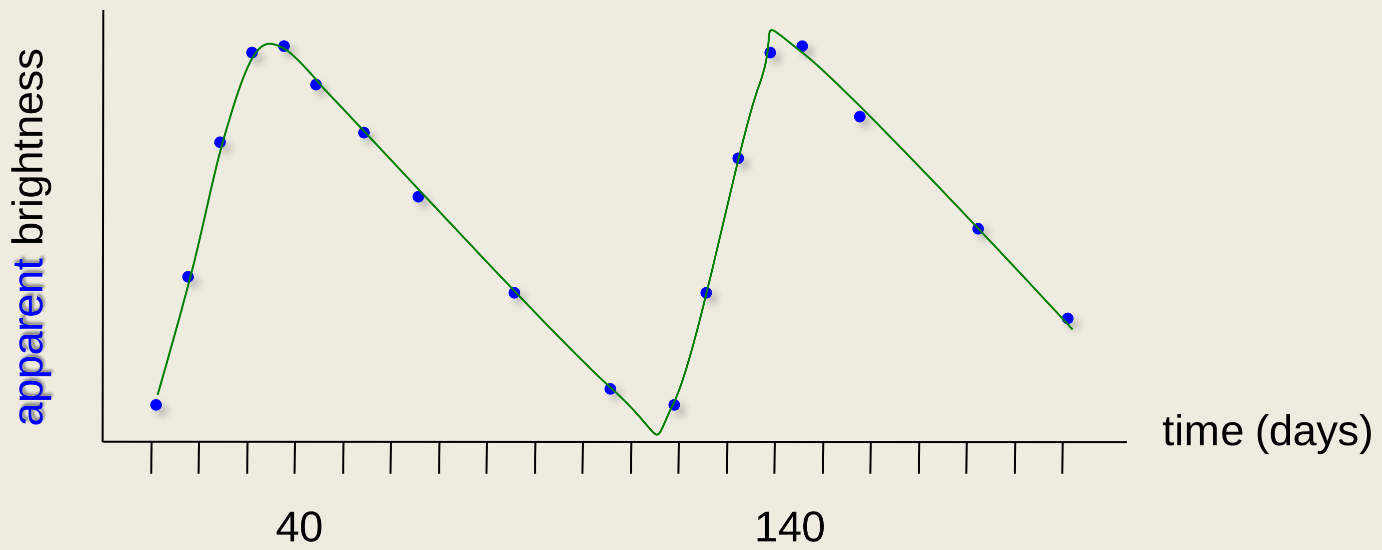
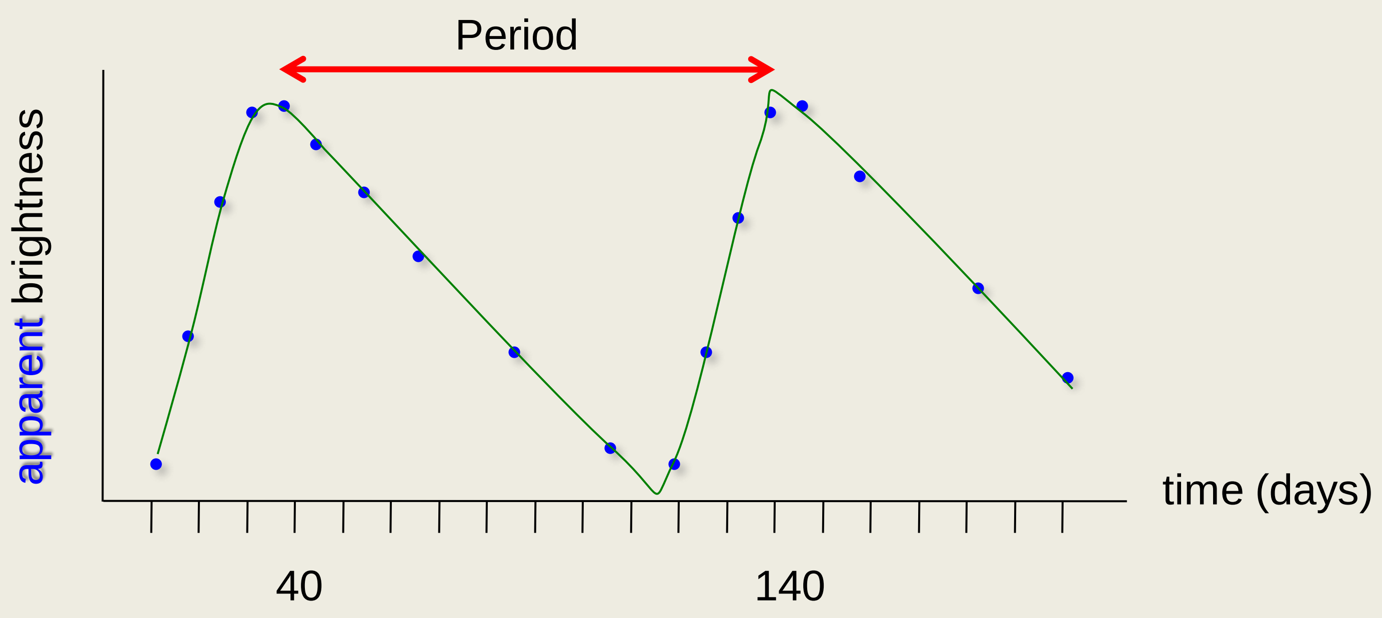


Cepheid Variables

How do you measure their pulsation rate?

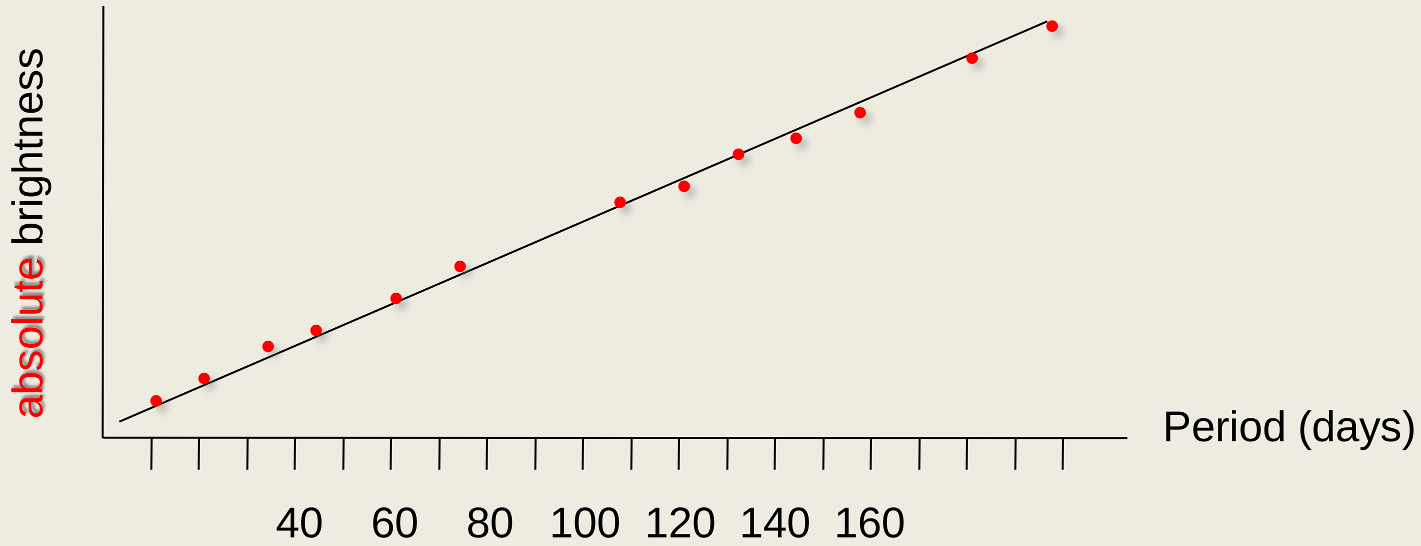
From the light curve, you measure the PERIOD



Cepheid Variables

You take the measured period to the standard Period–Luminosity Diagram and read off the ABSOLUTE BRIGHTNESS.

From the light curve, you measure the PERIOD



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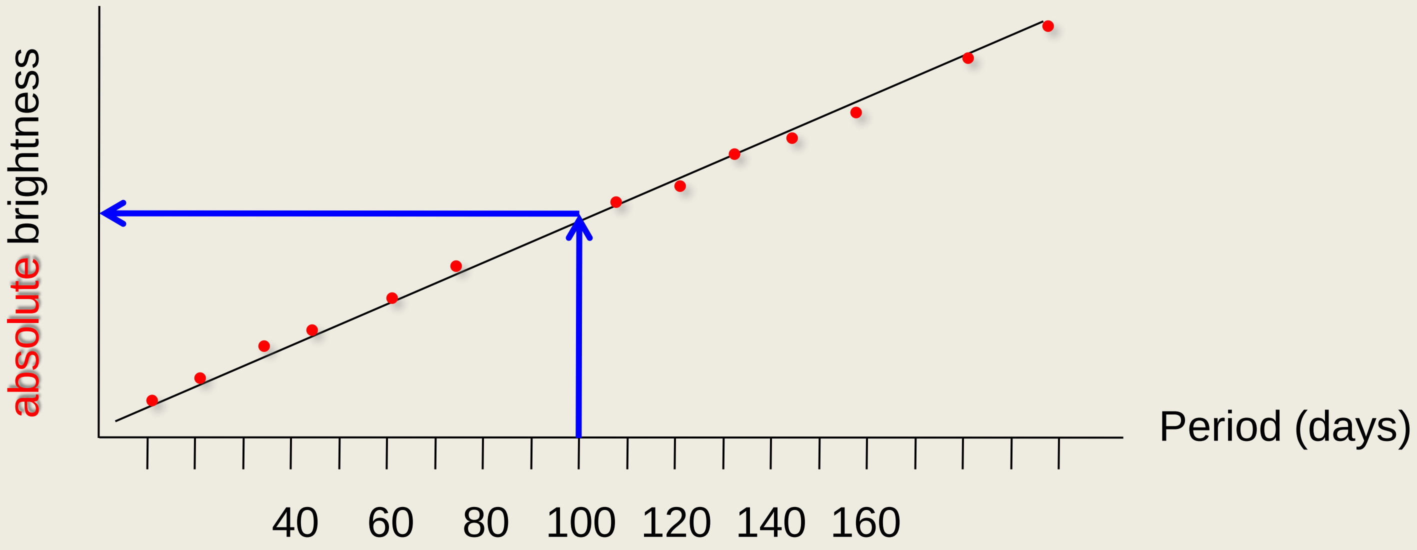
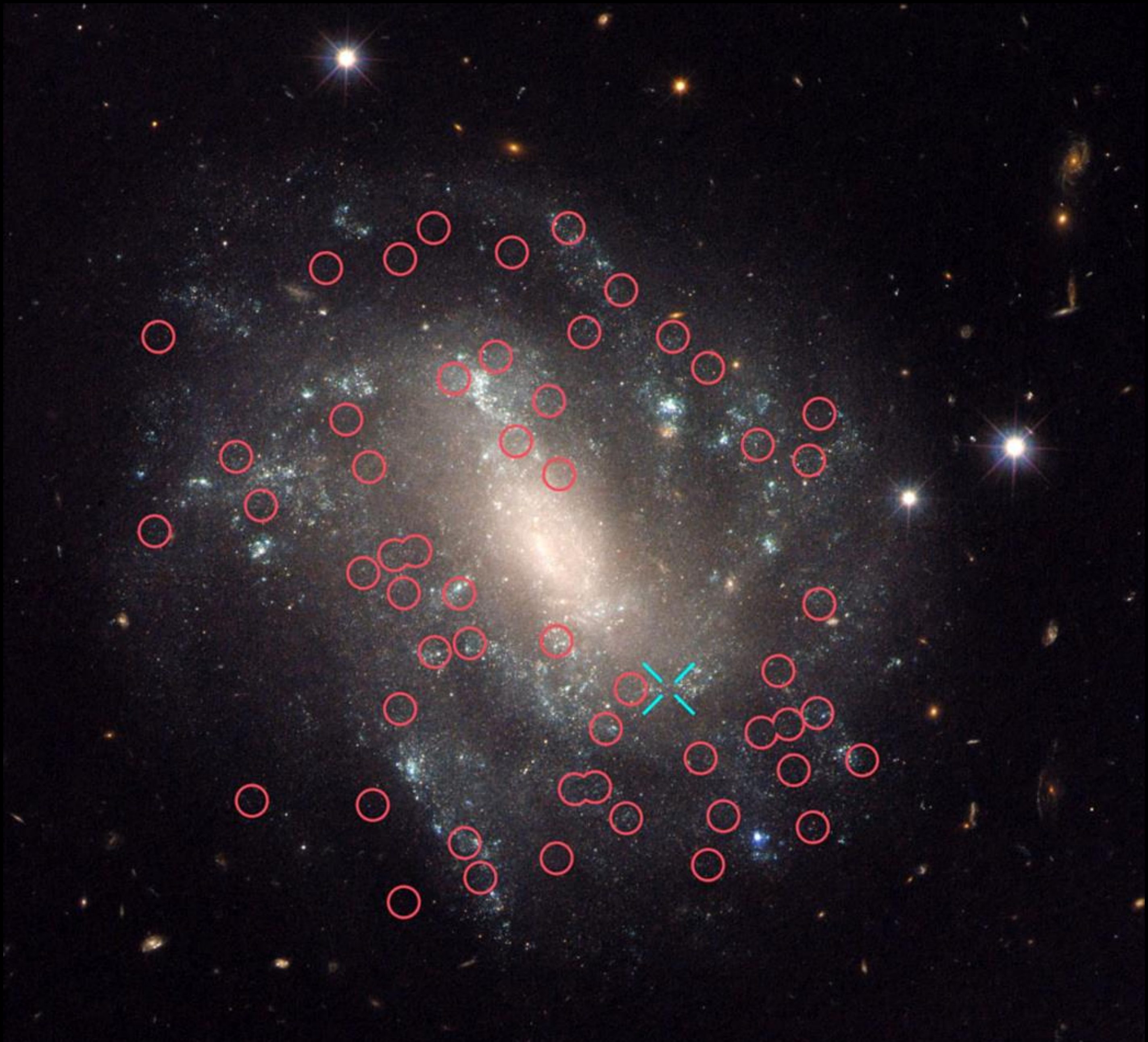


so your calculation would look like this:

from the P-L diag

$$\text{distance} = 10\text{ pc} \times \sqrt{\frac{\text{absolute brightness}}{\text{apparent brightness}}}$$

from what you measured



Cepheid Variables