The Stars: A Census

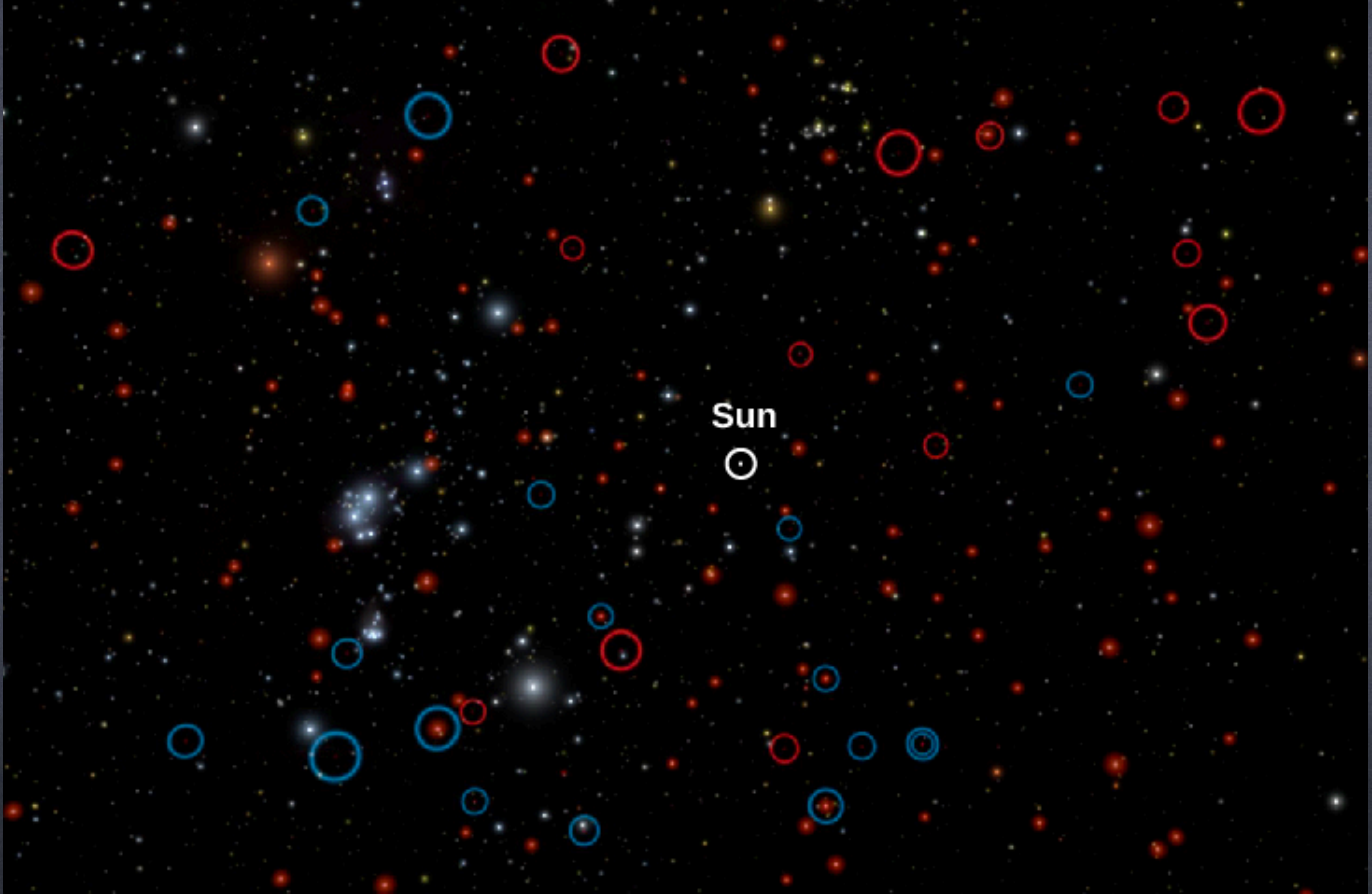
Chapter 18

Selection Effects

- If you look up at the night sky, or use a telescope you will see stars down to the faintest object you can see.
- The stars you see are limited by their brightness, but a bright star can be a close by star, or a luminous star that is far away. Because volume increases the farther away you go there are many more luminous stars that will be visible than nearby lowe luminosity starts.
- These kinds of biases are common in astronomy where everything is affected by what you can see.
- To get a 'fair' census of the stars we want all the stars in some volume and when we do that we find a lot of low luminosity stars.

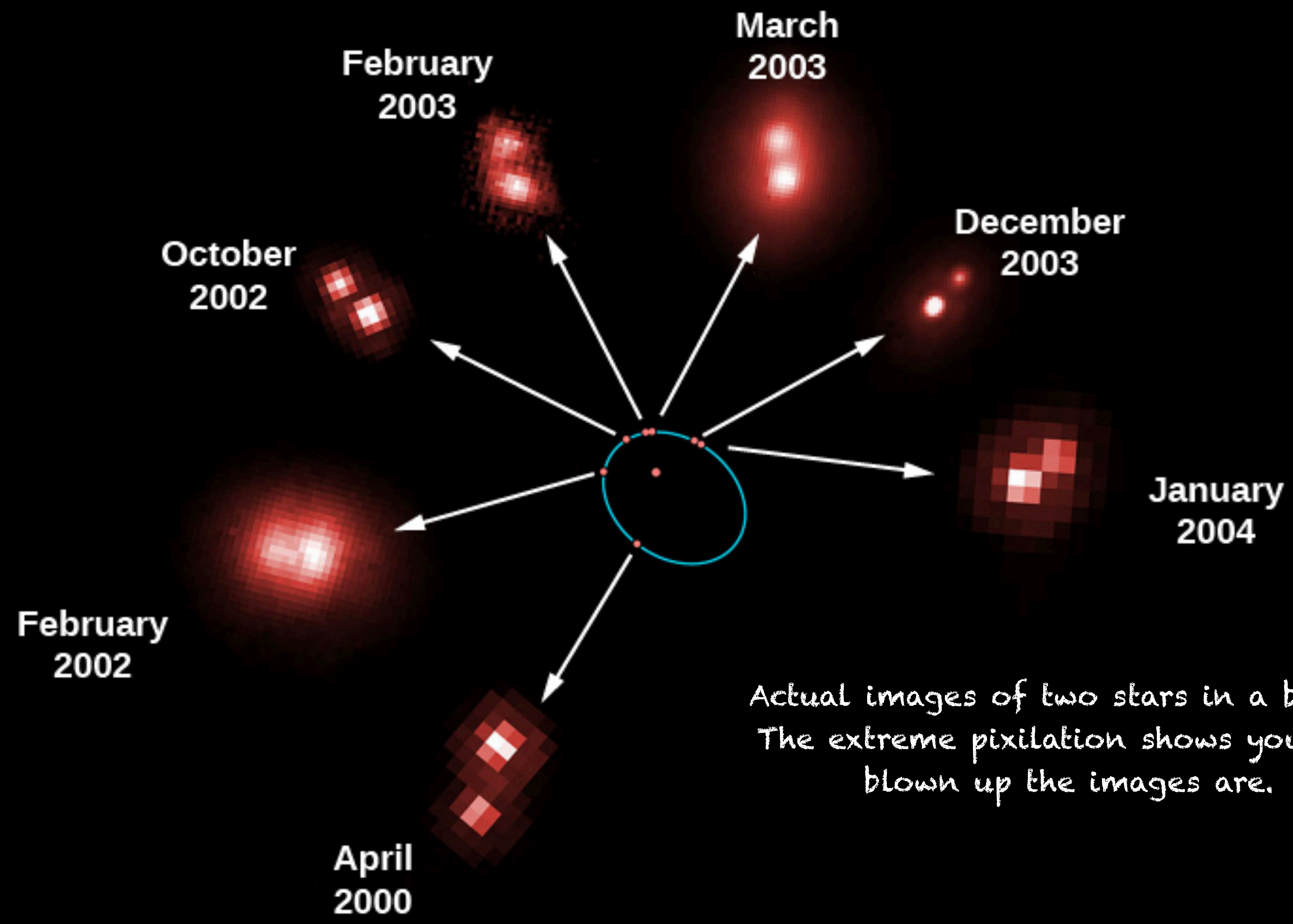
This image shows how the region around the sun looks from 30 light years away. The red and blue circles are brown dwarfs (that you cant really see).

Bright stars like the sun are very rare, most stars are red faint stars.



Measuring Stellar Mass

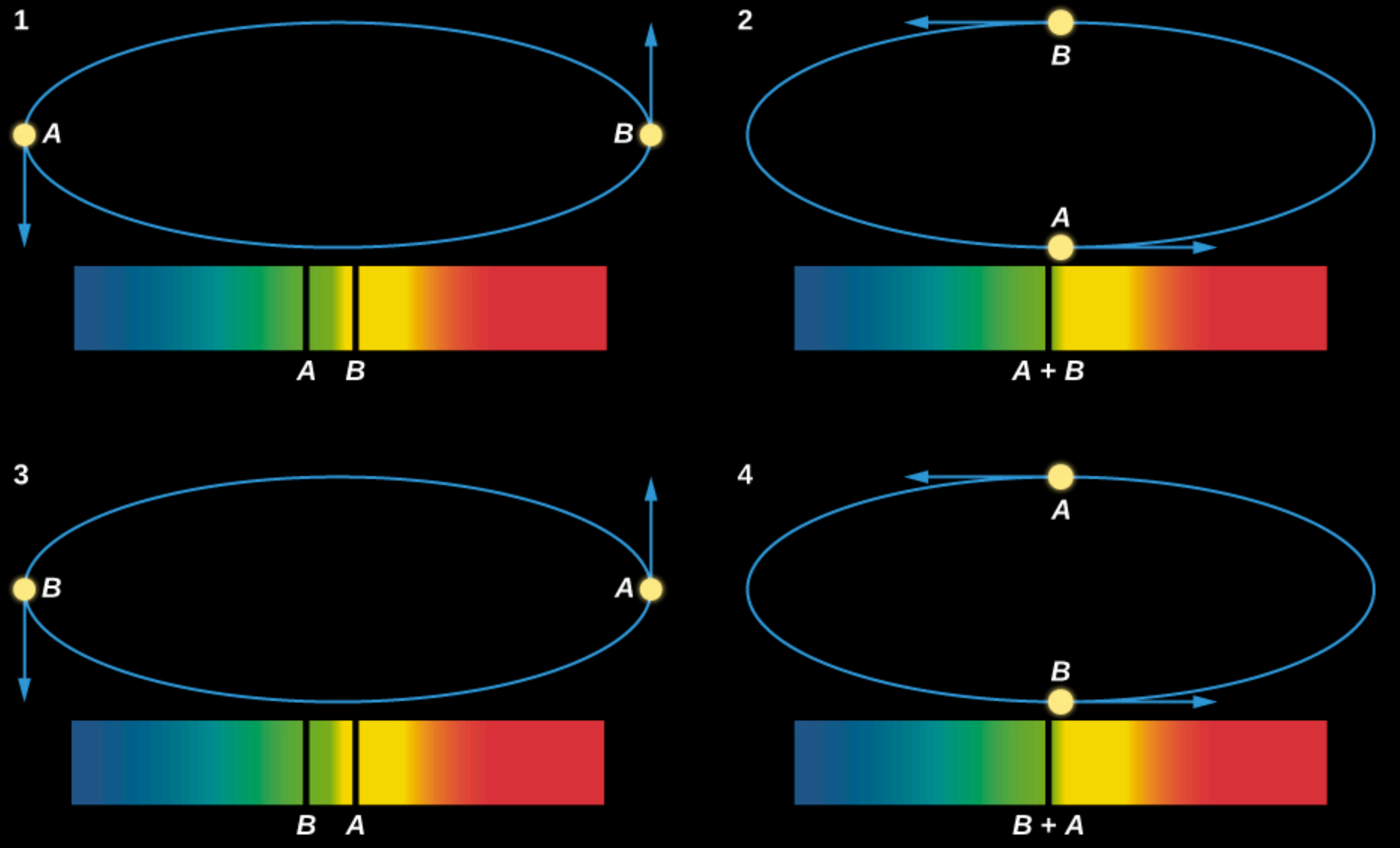
- Binary stars are stars that orbit around another star and they are actually very common. About half of all stars are in a solar system with other stars.
- These systems are how we can measure the mass of stars. If we can determine the orbit of at least one of the stars then we can figure out the mass of star it orbits.
- Rarely can we actually see the two stars orbit one another, instead we use the radial velocity technique to find binary stars (just like planets) and calculate their orbits.



Actual images of two stars in a binary.
The extreme pixilation shows you how
blown up the images are.

With Kepler's laws we learned that planets and satellites orbit the sun or a planet.

This is only true because one is so much more massive than the other. In general, two objects orbit around a common point called the barycenter or center of mass.



When we cant resolve the stars in a binary we see the combined light as coming from one object. Spectroscopic binaries can be identified by the splitting of spectral lines as the stars orbit.


1
2
3
4
A
B
A + B
B
A
B + A
+120
+80
+40
0
–40
Radial Velocity (km/s)
B
A
1
2
3
4
0
2
4
6
8
10
12
14
16
18
20
Time (days)

Measuring Stellar Masses

- If we measure the orbits we can use a modified version of Kepler's law to calculate the mass.

$$D^3 = (M_1 + M_2)P^2$$

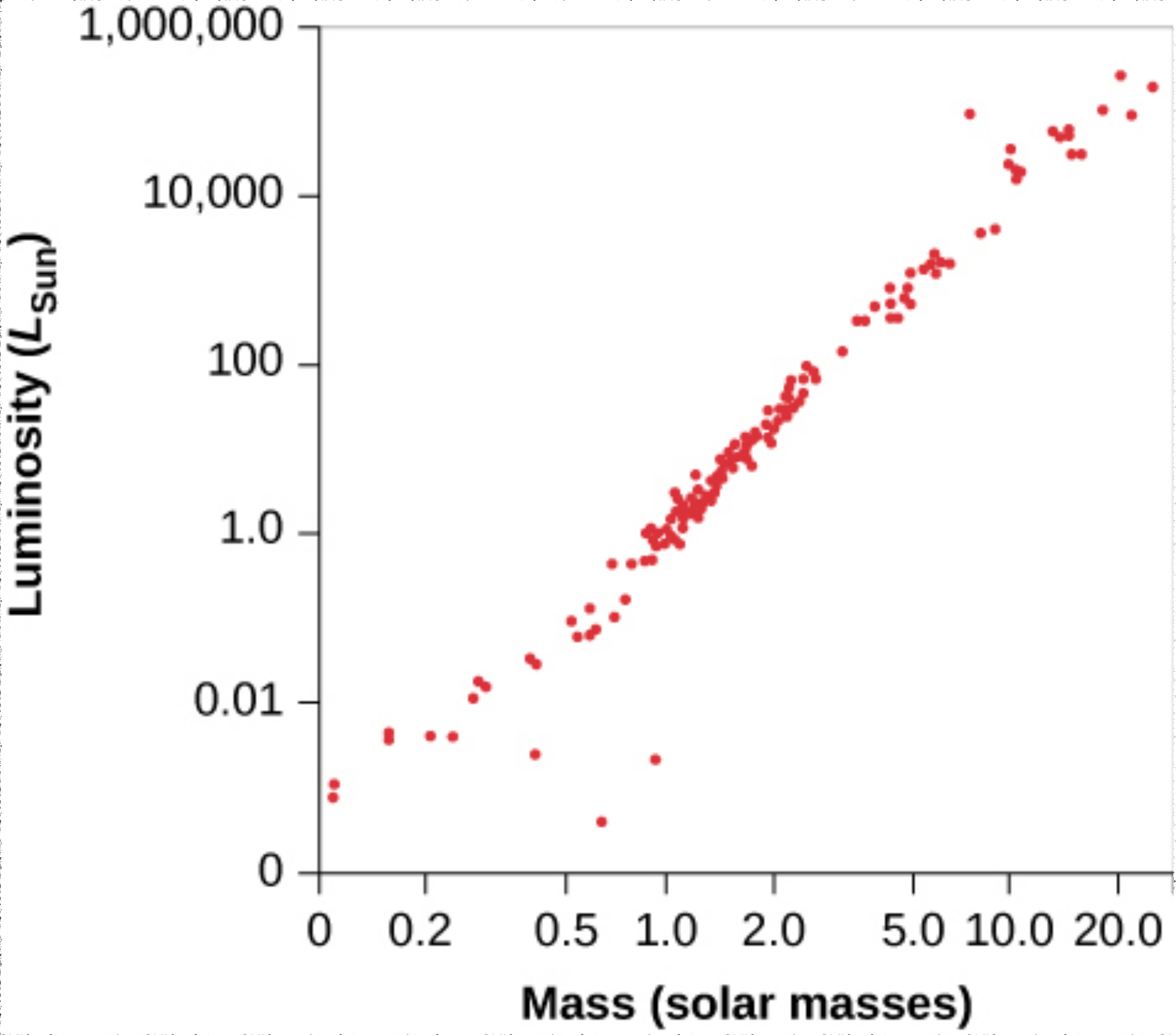
- From the radial velocity measurement we can determine the orbital period, P, and the star's velocity which we can use to get the size of the orbit, D.
- This only gives the sum of the masses, but because we know each stars velocity we can figure out the mass of each star.

The Masses of Stars

- From these measurements we can determine that most stars are less massive than our sun. The most common mass of a star is about 1/2 to 1/4 the mass of our sun.
- Within 30 light years of the sun the most massive star is 4 times the mass of our sun. The most massive stars are about 100 times the mass of the sun. There are a few stars with masses 250 times the mass of the sun, but they probably came about by unusual means.

The left image is taken in visible light and we only see some vary massive stars.
The right image taken in the infrared reveals many many low mass stars.

- There is a tight relationship between the luminosity of a star and its mass.
- It is not linear (the plot is a log plot), but goes as $L = M^4$.
- So a 2 times as massive star is about 16 times as luminous and a 10 times as massive star is 10,000 times as luminous.



Measuring the Sizes of Stars

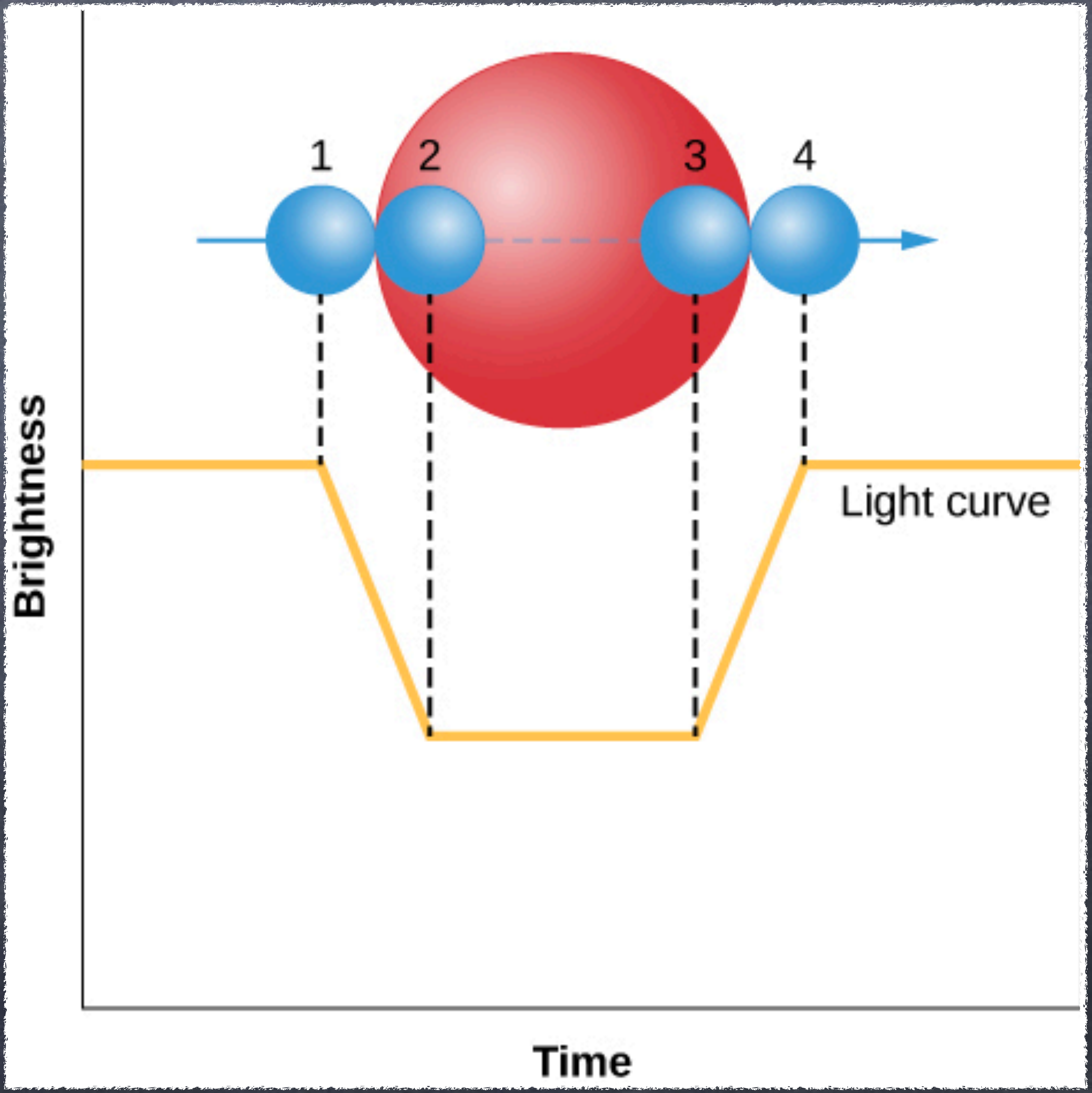
- In order to measure the sizes of stars we also make use of binaries, but know eclipsing binaries.
- Eclipsing binaries are stars that pass in front of each other. So this is the same as the transit technique we discussed for planets.
- From the transit we can determine the sizes of both stars.

Since both stars emit light there are two transits for eclipsing binaries. In general the smaller star will be 100% blocked, unlike the small decrease from a planet.

Measuring the Size of a Star

- The time it takes for the transit to reach the lowest flux depends on the size of the transiting star.
- The time that the transit stays at the lowest flux depends on the size of the background star.
- Thus we can determine the sizes of both stars. The same technique works for measuring the sizes of planets, though it is much harder to do.

https://www.youtube.com/watch?v=HEheh1BH34Q

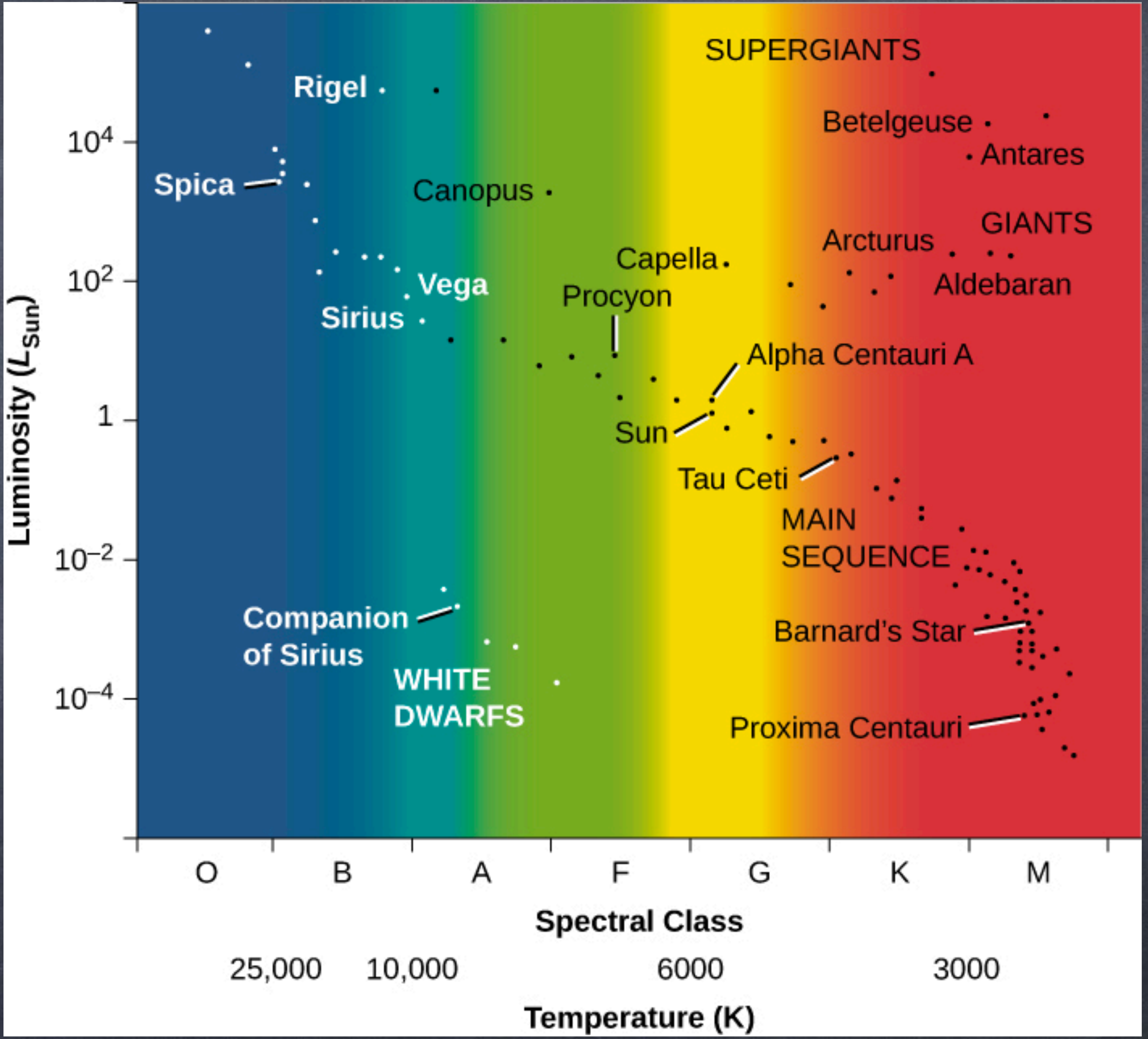


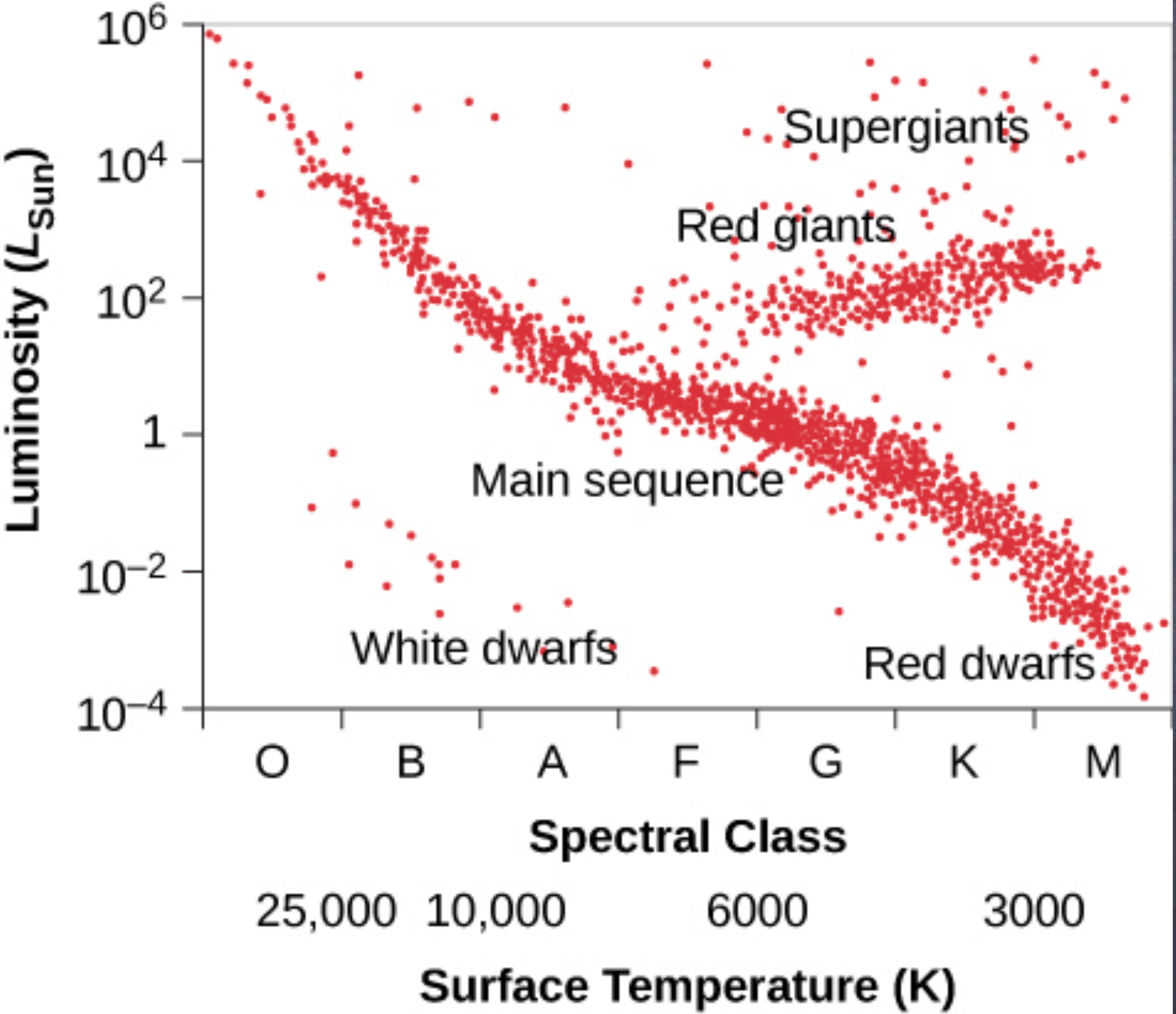
The HR Diagram

- With all this information about stars it is hard to make sense of them. Two astronomers Hertzburg and Russel came up with the clever idea of plotting a stars temperature versus its luminosity.
- This plot was so useful it is now called the HR diagram and will be our basis for understanding stars.

Placing stars on this diagram we begin to make sense of their properties.

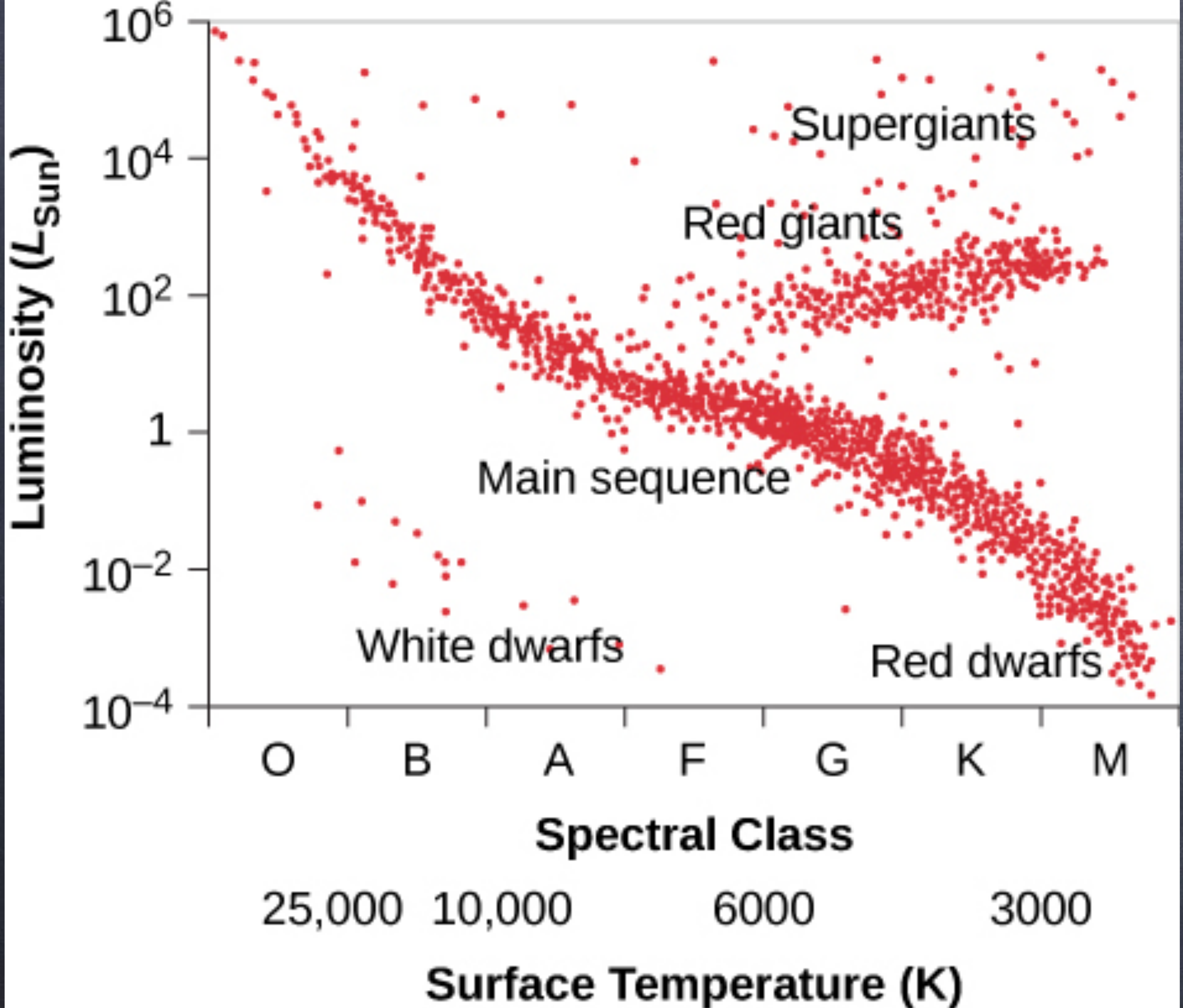
Some stars are hot and bright, while some are hot and faint. Some are cool and bright while some are cool and bright. Most seem to follow a trend from the upper left corner to the bottom right corner.





With many more stars it becomes clear that they are clustered into different groups.

90% of stars sit along the main sequence that goes from hot and luminous in one corner to cold and faint in the other.



Stars that are fainter then the main sequence are called white dwarfs.

Stars that are more luminous than the main sequence are called giants with super giants begin the brightest of them.

Understanding the HR Diagram

- Stars along the main sequence are fusing hydrogen to helium just like our sun. Stars do this for 90% of their lives, which is why 90% of stars are on the main sequence.
- Stars are spread out along the main sequence because of their mass. More massive stars are hotter and brighter, less massive stars are cooler and fainter. More massive stars are also bigger and cooler stars smaller.

Understanding the HR Diagram

- Once a star has burned up most of its hydrogen it can, if massive enough, begin to fuse other elements like helium, carbon, oxygen, etc.
- It then becomes bigger and cooler, moving into the red giants and super giants part of the diagram. Stars only spend a short time here and then run out of material to fuse.
- Some of these stars will expel their outer parts and just the core will remain. This is called a white dwarf. It is very hot and very small, so not that bright. White dwarfs are small and dense, 1% the size of the sun, with a density of 300,000 g/cm^3. A white dwarf will be the size of the Earth, but the mass of the sun.

Giant stars are way bigger than the sun which is why they are so luminous

Two images of the star Sirius one taken by Hubble in visible light (left) and the other taken in the x-ray. It's white dwarf companion is barely detectable in visible light, but clearly seen in x-ray.