Lecture 10

Advanced Variable Star Stuff

March 18 2003
8:00 PM
BMPS 1420

This week's topics

- Types of Variables
  - Eclipsing binaries
  - Pulsating variables
    - Cepheid
    - RR Lyrae
    - δ Scuti
  - Cataclysmic variables

Eclipsing Binaries

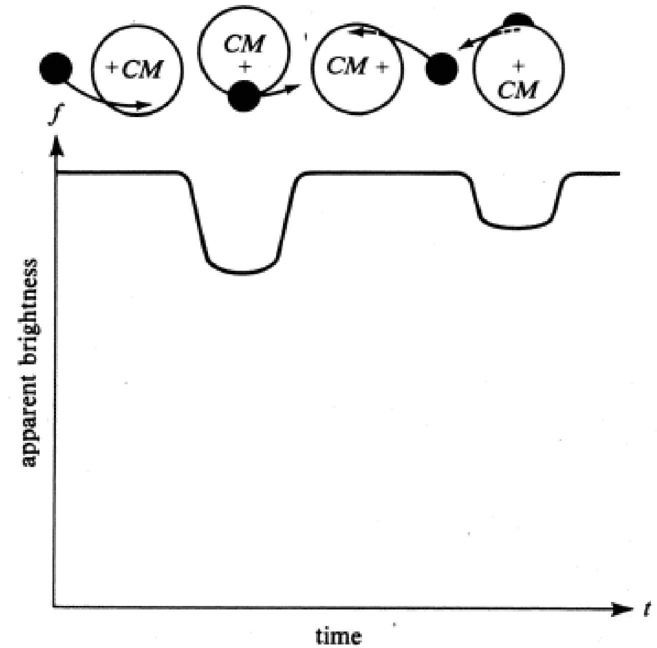
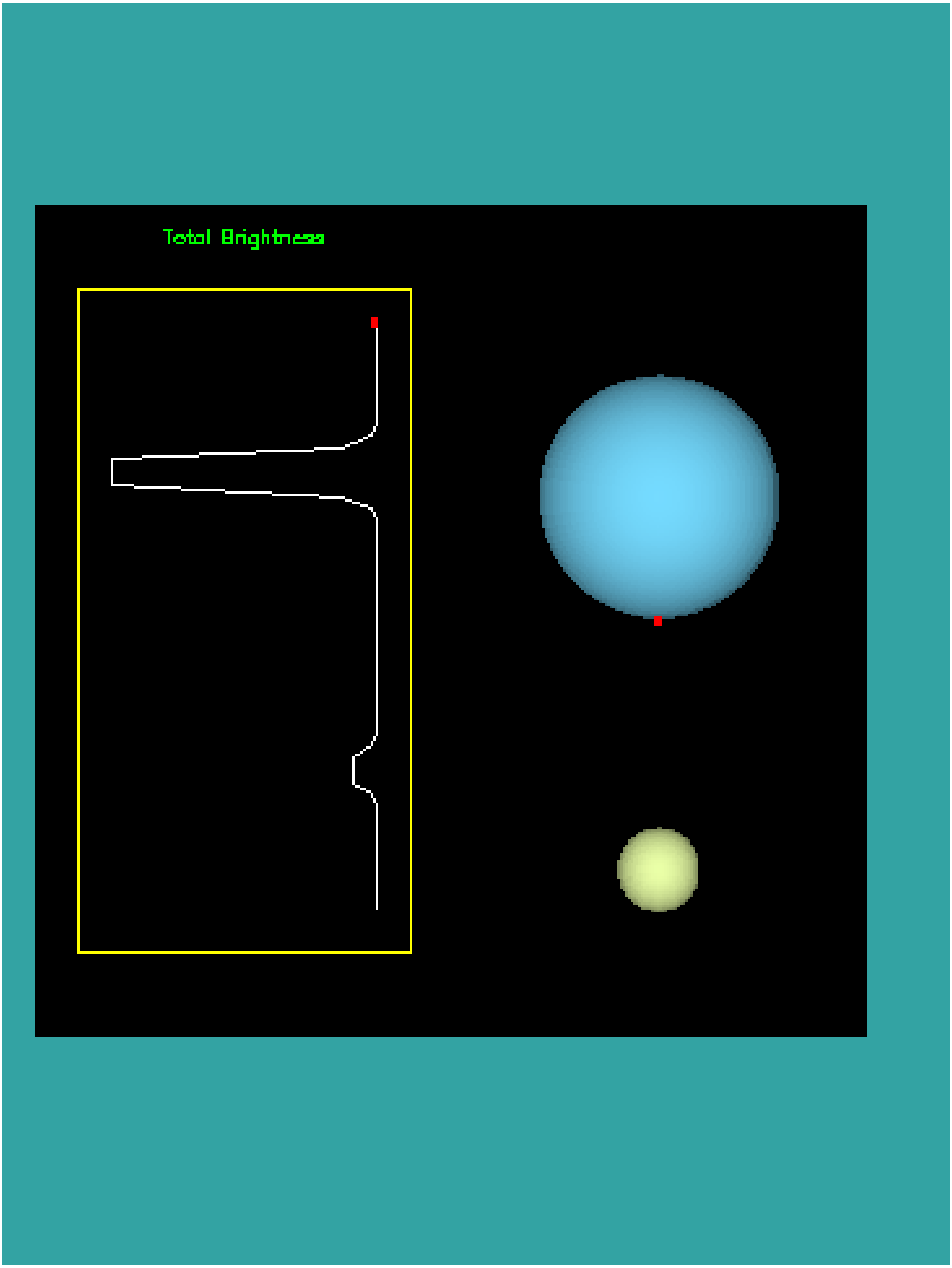


Figure 10.5. Schematic light curve of an eclipsing binary. Deeper eclipses result when the cooler star eclipses the hotter star than when the hotter star eclipses the cooler. The pattern of eclipses repeat once every binary period.

At least half of all "stars" in the sky are binary systems of some type. If their orbits are aligned with our line of sight, they may be eclipsing binaries.

Easiest variable to understand:

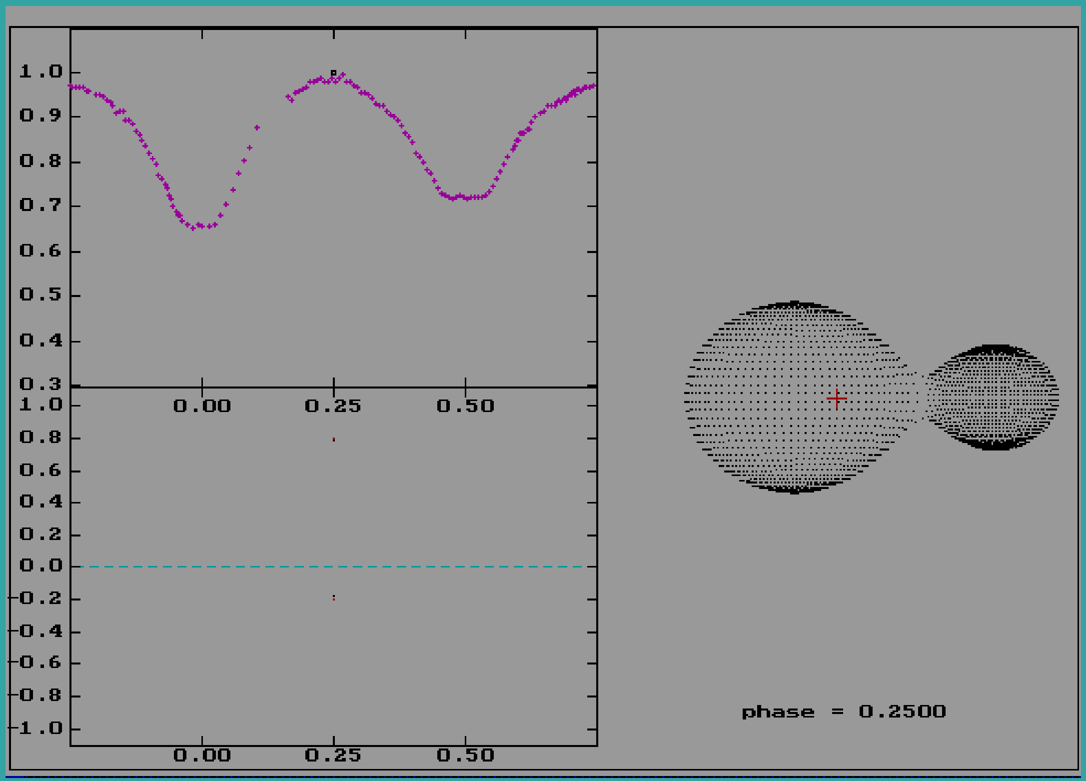
When both are visible, light is at maximum. When one is in front of the other, it blocks some of the light.


Total Brightness

Eclipsing Binaries

We don't usually see both stars, we see only the integrated light from the two star system.

The eclipsing nature of the system gives it a characteristic shape.



Uses for eclipsing binaries

If the system is set up well enough and we can get accurate spectroscopy of the stars, we can estimate their velocity. This can give us the radius!

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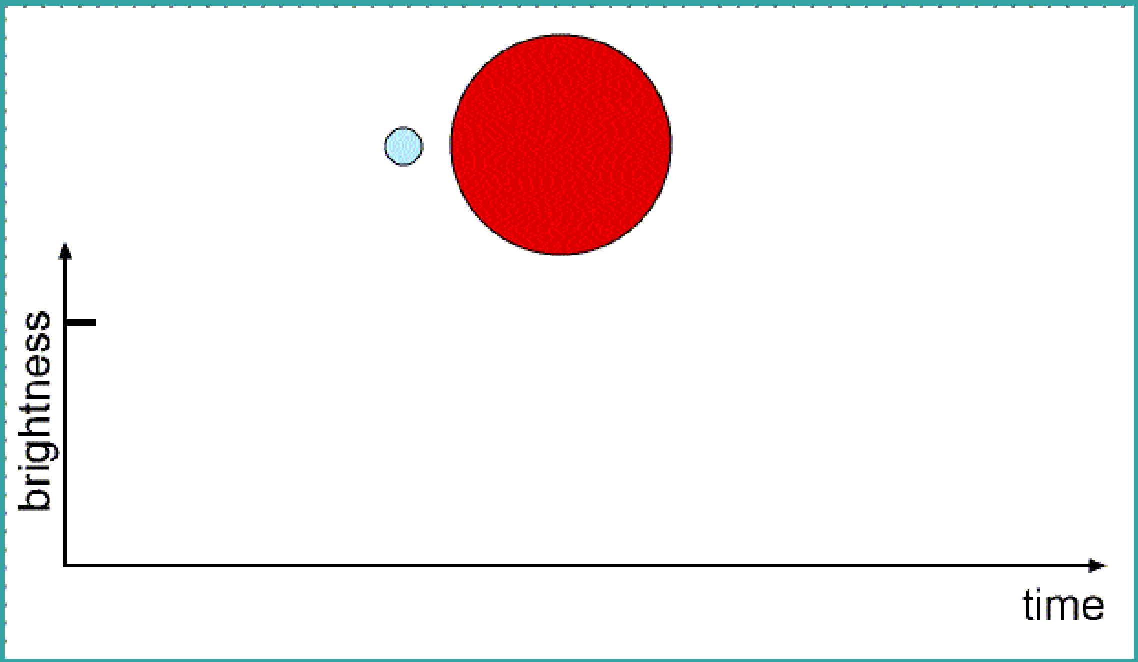

Above image from Nick Strobel's online astronomy notes at www.astronomynotes.com.

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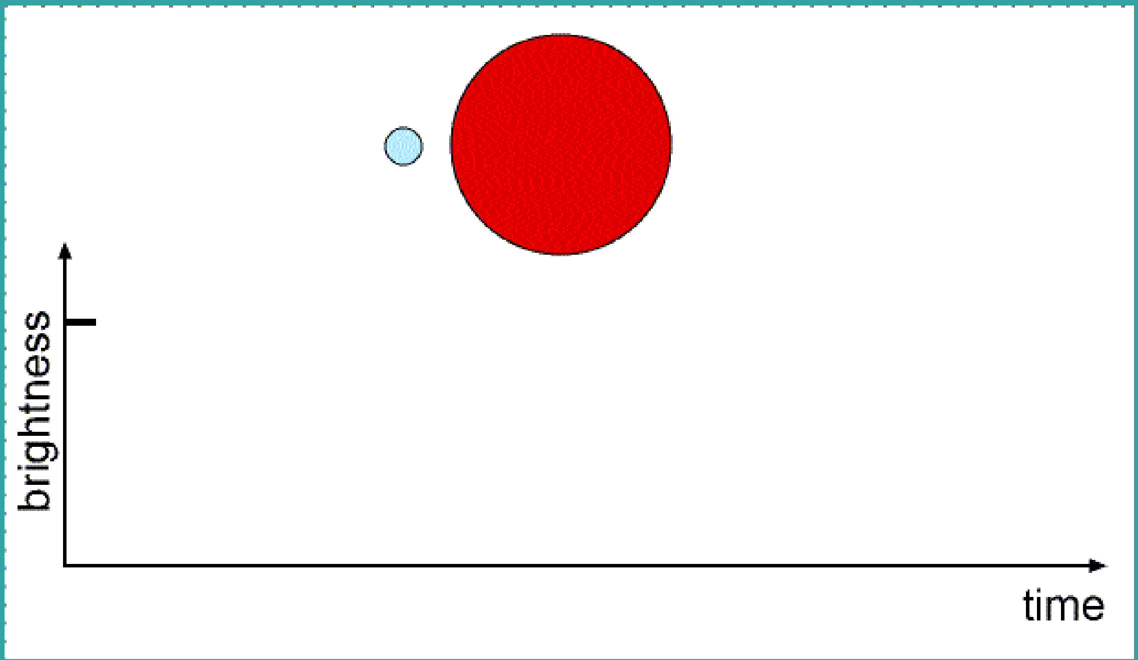
With information about the radius, velocity and Kepler's laws, we can calculate the masses of the two stars.

(More on this later?)



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Pulsating Variables

Unlike eclipsing binaries, some stars are variable not due to eclipse effects, but due to their very nature.

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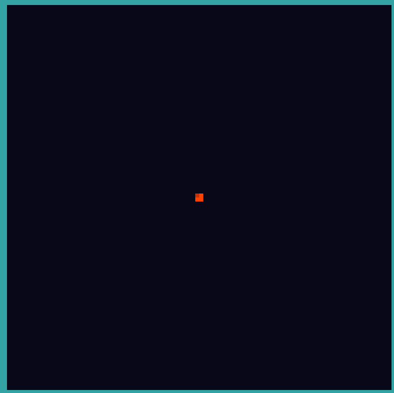

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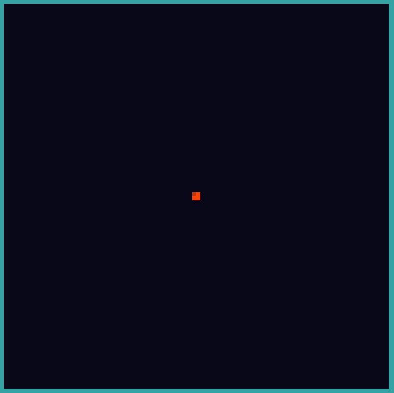

How did we come up with such a crazy idea?

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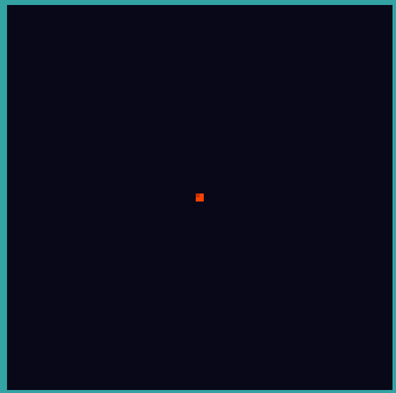

How did we come up with such a crazy idea?

What we actually observe is the luminosity of the star:

$$L = 4 \pi R^2 \sigma T^4$$

Pulsation

If we increase the radius but keep the temperature the same, which star is has the higher luminosity?

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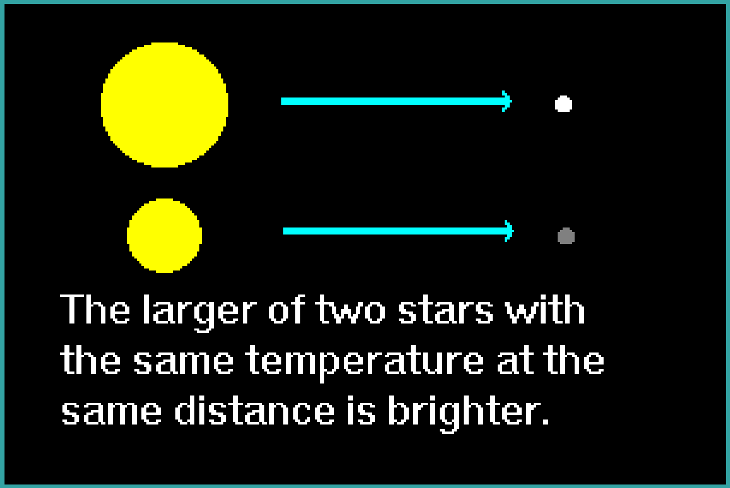

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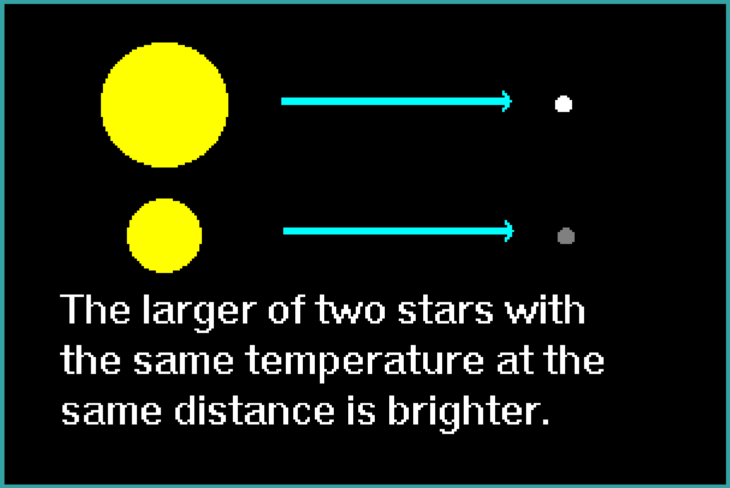

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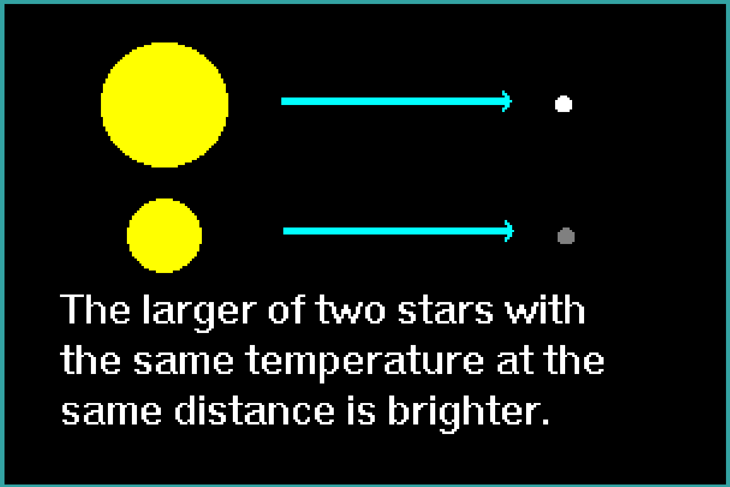

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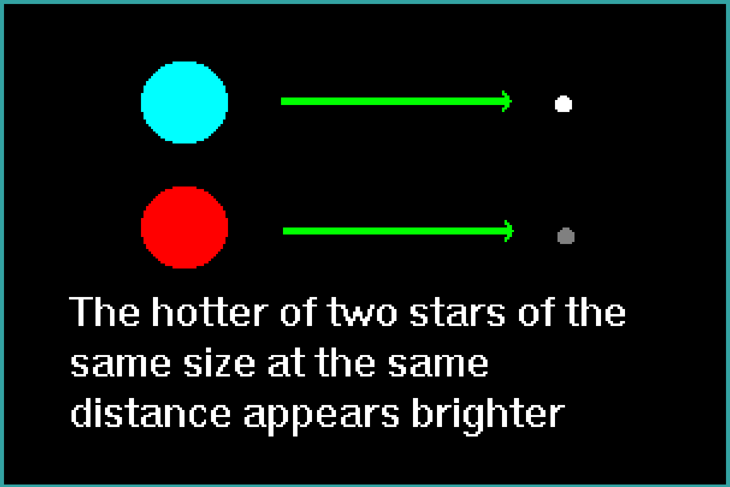

$$L = 4 \pi R^2 \sigma T^4$$

Pulsation

Turns out that both occur. What we have is a valve; as the valve "closes" it causes the interior to heat up. This increase in temperature eventually wins out over gravity and starts to push the outer atmosphere of the star outward. As the atmosphere pushes out, it cools off and falls back inward and the valve starts over.

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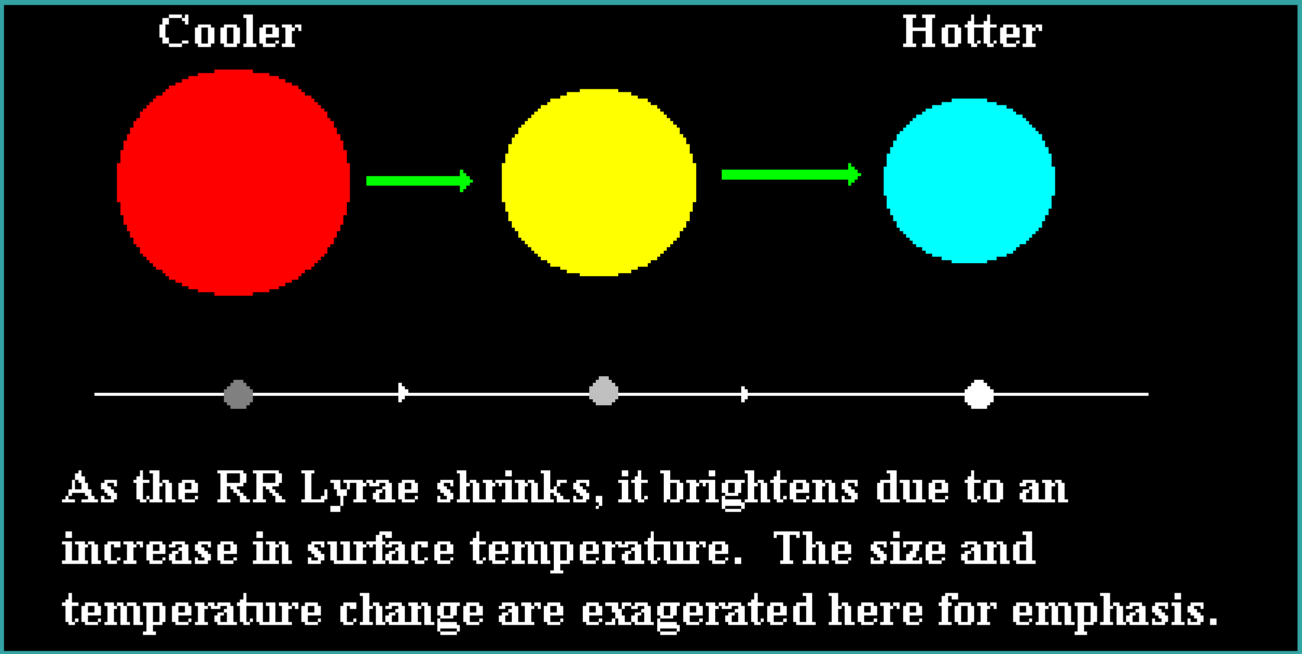

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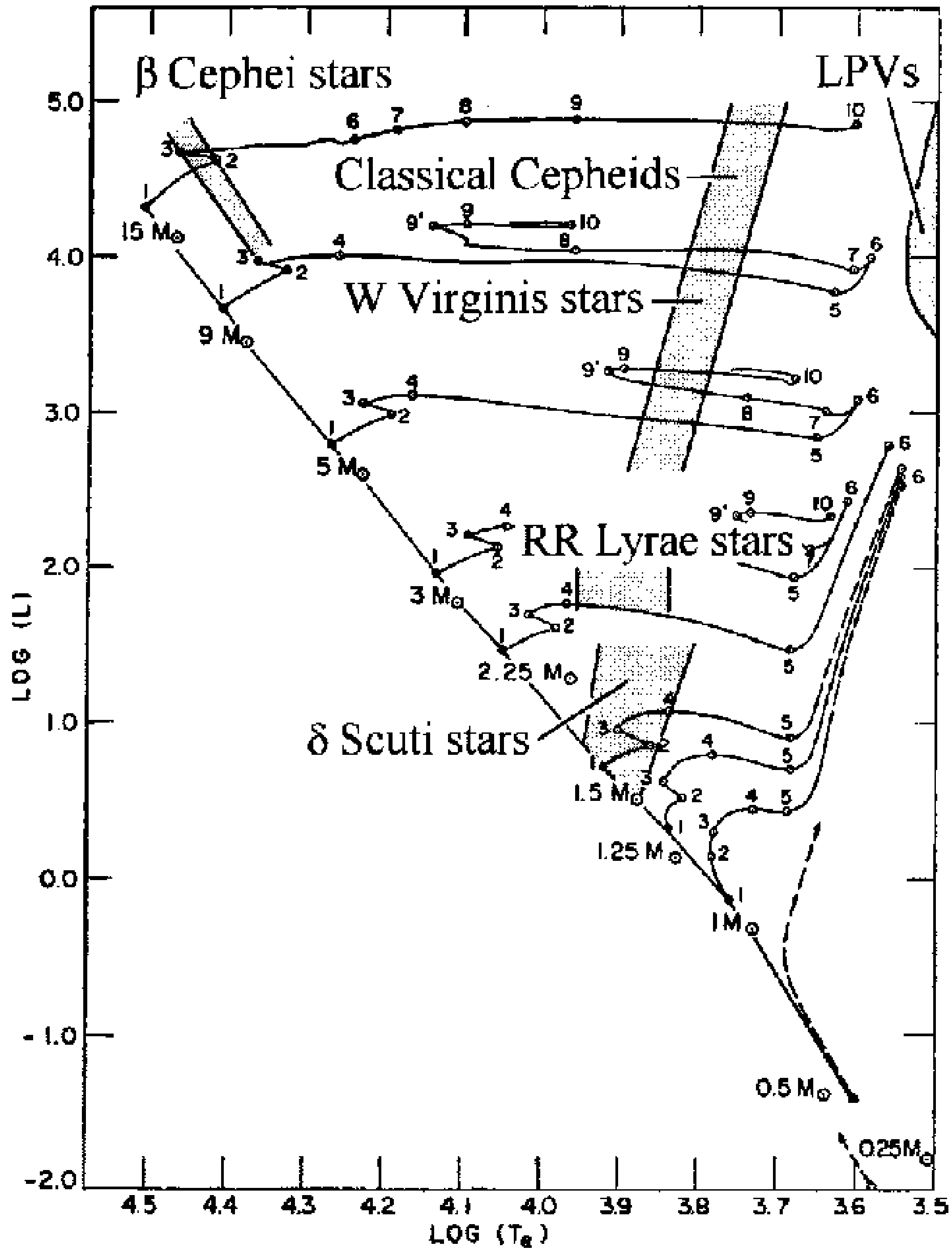

β Cephei stars
LPVs
Classical Cepheids
W Virginis stars
RR Lyrae stars
δ Scuti stars
15 M☉
9 M☉
5 M☉
3 M☉
2.25 M☉
1.5 M☉
1.25 M☉
1 M☉
0.5 M☉
0.25 M☉
LOG (L)
LOG (Te)

Cepheids

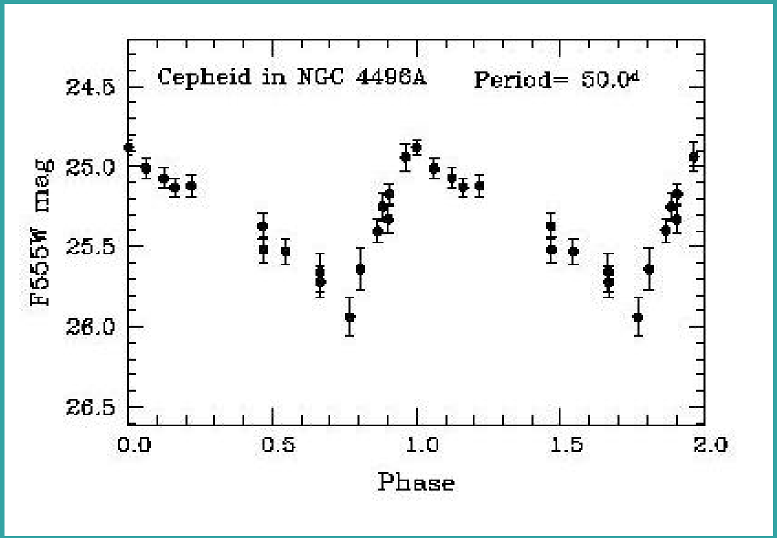
Description: Pulsating white to yellow giants (post main sequence)

Spectral Class: F G K

Period: a few days to 100 days

Distance:40 million pc (130 million ly)

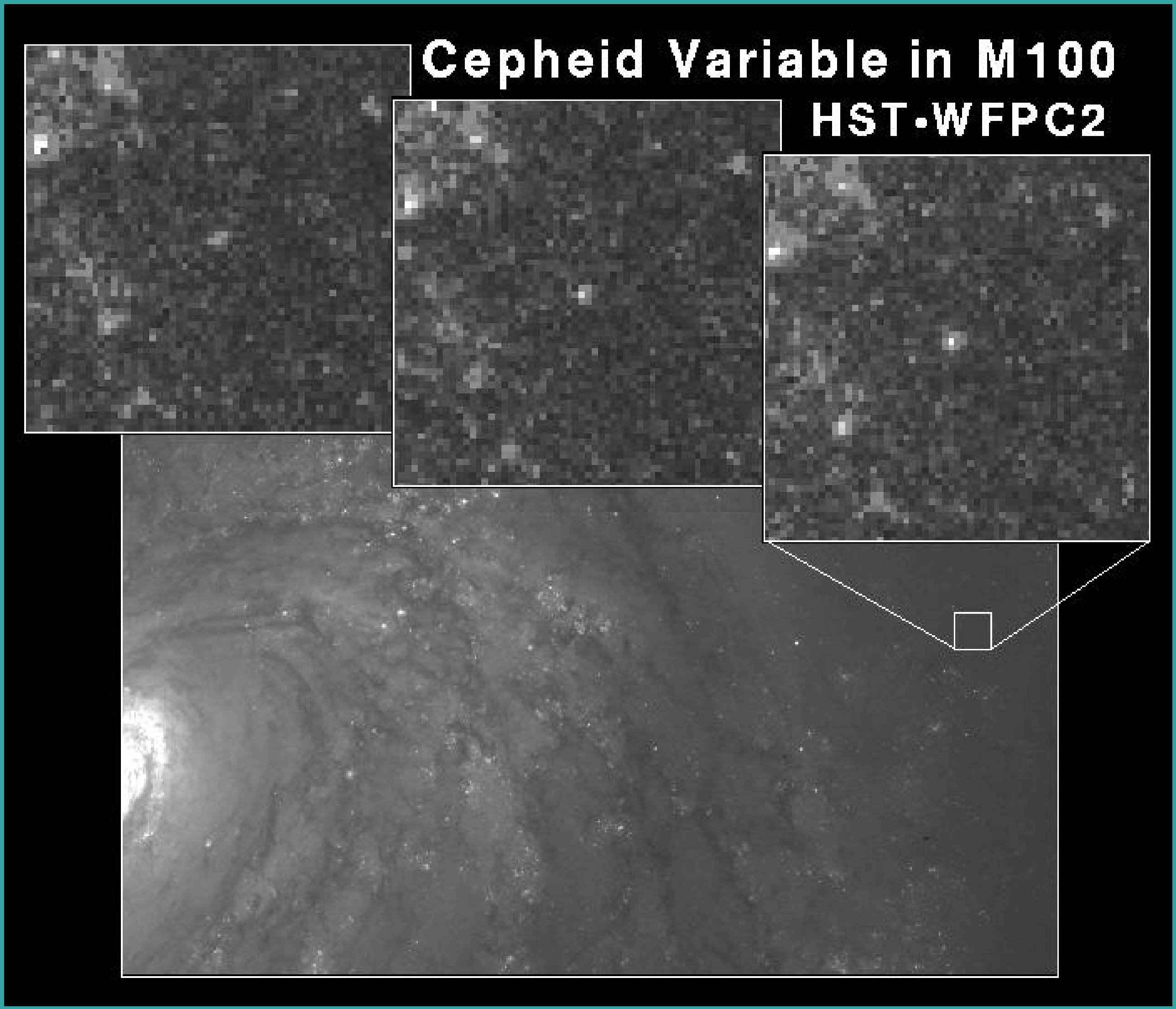
Started as: ~B main sequence



Regular period, shark-fin like light curve

Recall that the period luminosity relation is different for Pop I and Pop II.

Extragalactic Cepheid Variables



RR Lyrae

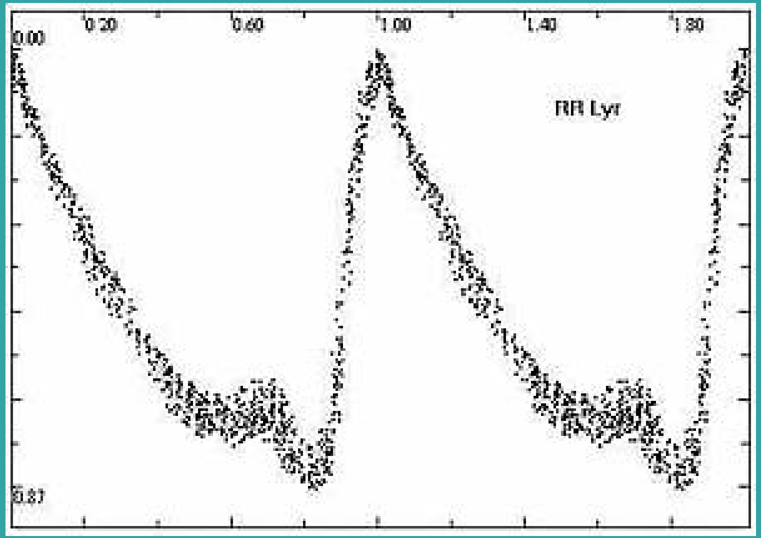
Description: Low mass horizontal branch stars in core He burning

Spectral Class: F G K

Period: hours to about a day

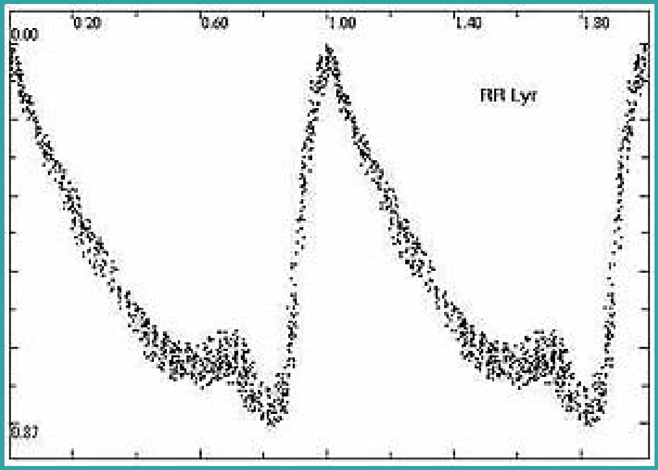
Distance:760,000 pc (2.5 million ly)

Started as: ~0.8 $M_{\odot}$ main sequence

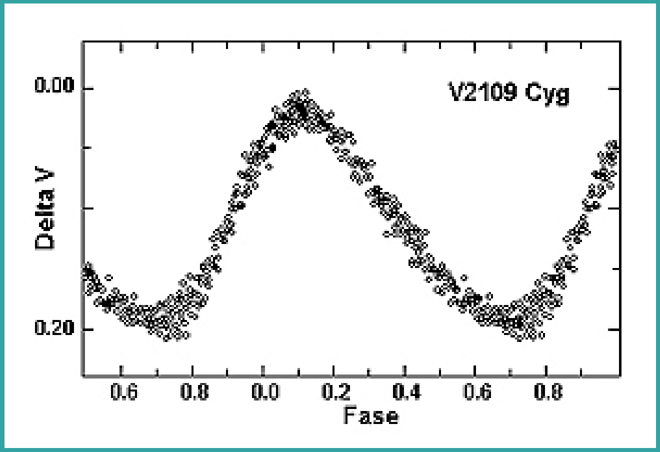


RR Lyrae types

RRab type



RRc type



Blazhko Effect

One more "wrinkle" in all this.

All pulsations we have discussed are radial. What if there are non-radial pulsations present?

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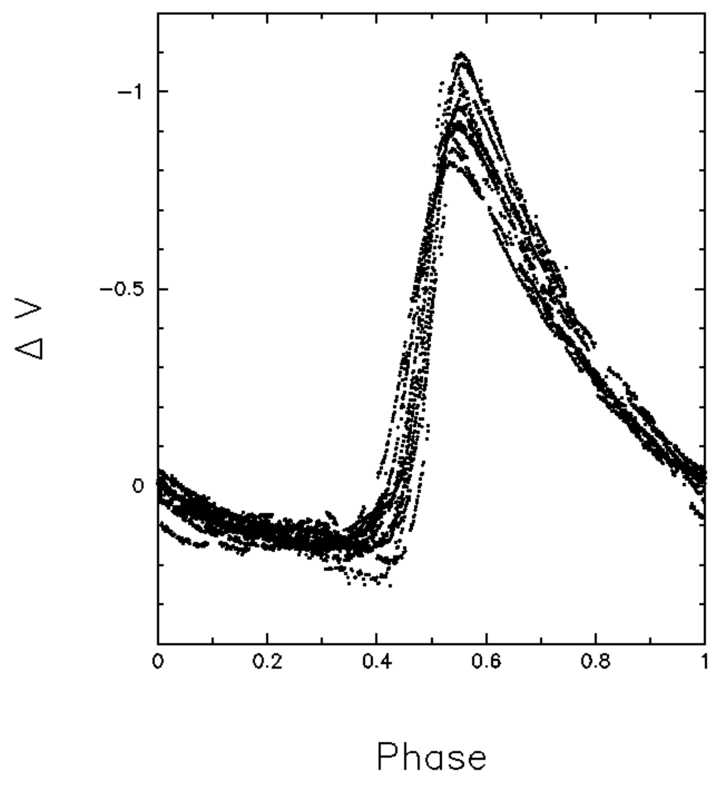
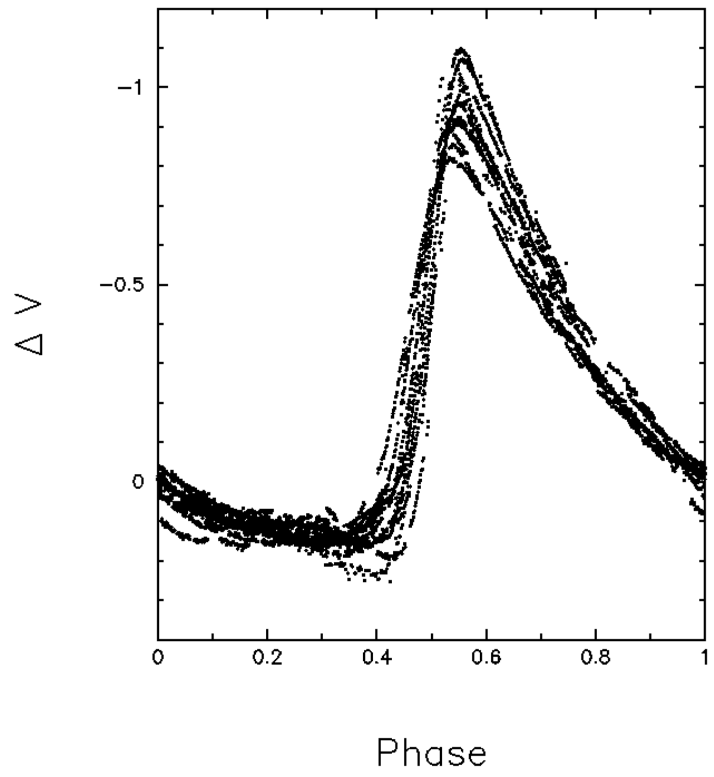


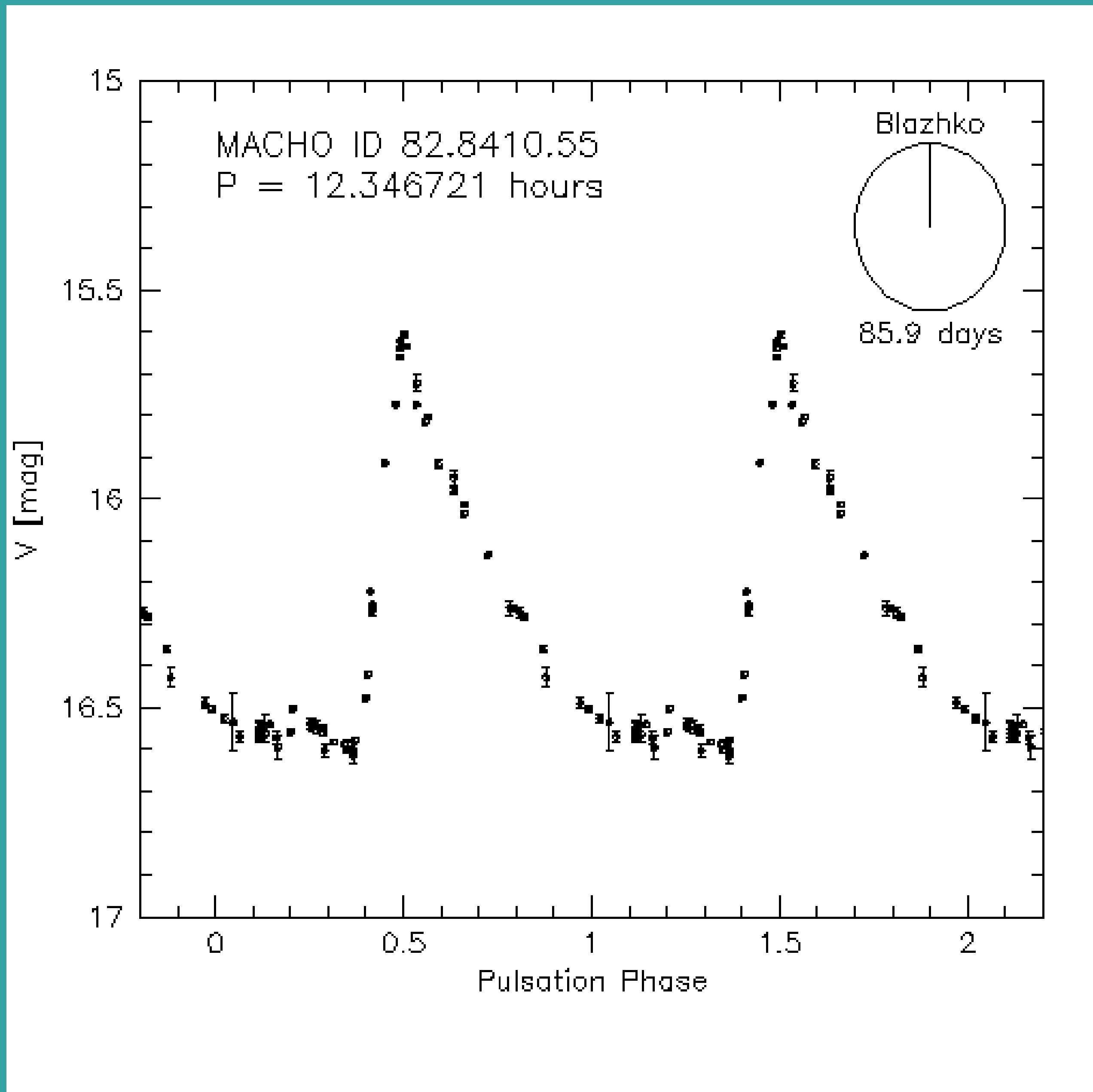
Blazhko Effect

One more "wrinkle" in all this.

All pulsations we have discussed are radial. What if there are non-radial pulsations present?

Two periods, one short (less than a day) one long (months) superimposed. It is just like adding sine waves of different frequency.




MACHO ID 82.8410.55
P = 12.346721 hours
Blazhko
85.9 days
V [mag]
Pulsation Phase
15
15.5
16
16.5
17
0
0.5
1
1.5
2

δ Scuti

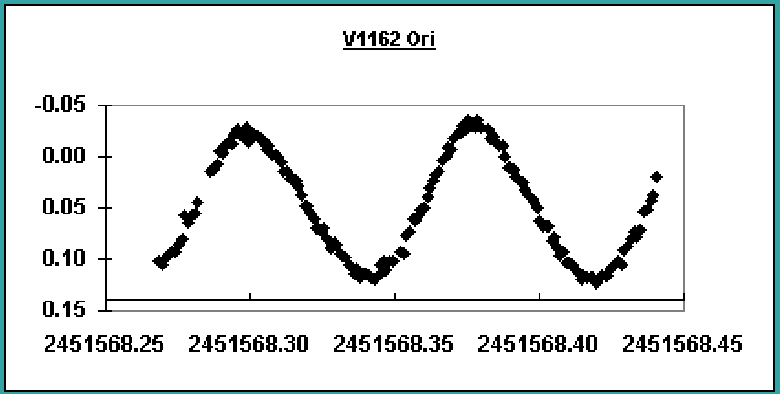
Description: MS to giant branch,
short period, low amplitude

Spectral Class: A F

Period: minutes to hours

Distance: local galaxy

Started as: ~2 $M_\odot$ main sequence



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We know that as a star ages, it tends to swell (moves up the giant branch). When this happens, the atmosphere can stray too close to the nearby companion star. This dumps fresh fuel onto the other star.

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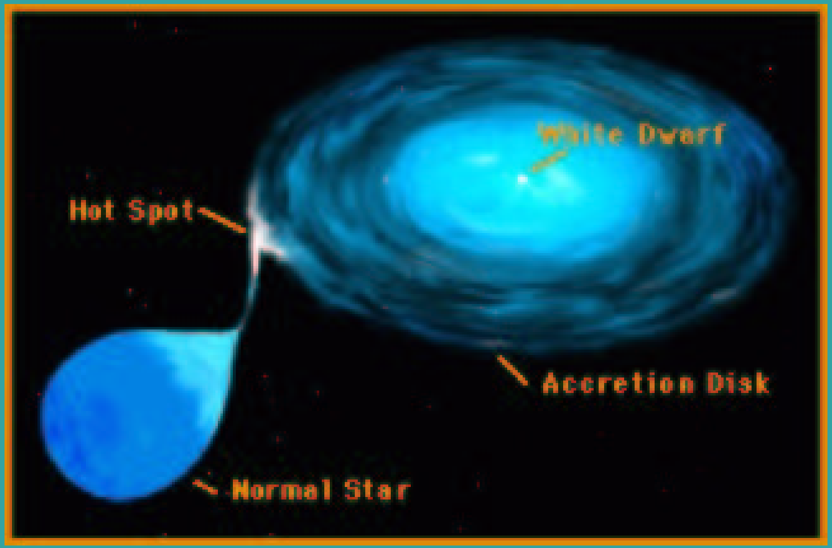

We know that as a star ages, it tends to swell (moves up the giant branch). When this happens, the atmosphere can stray too close to the nearby companion star. This dumps fresh fuel onto the other star.

This can have dire consequences.

Take a white dwarf for instance....

Cataclysmic variables

A white dwarf is the remnant that is left after a star similar to our Sun dies. It blows off all of its outer layers and leaves behind a hot dense core. There is no more fuel for nuclear fusion (the elements left are mainly things like carbon and iron, not easy to fuse).

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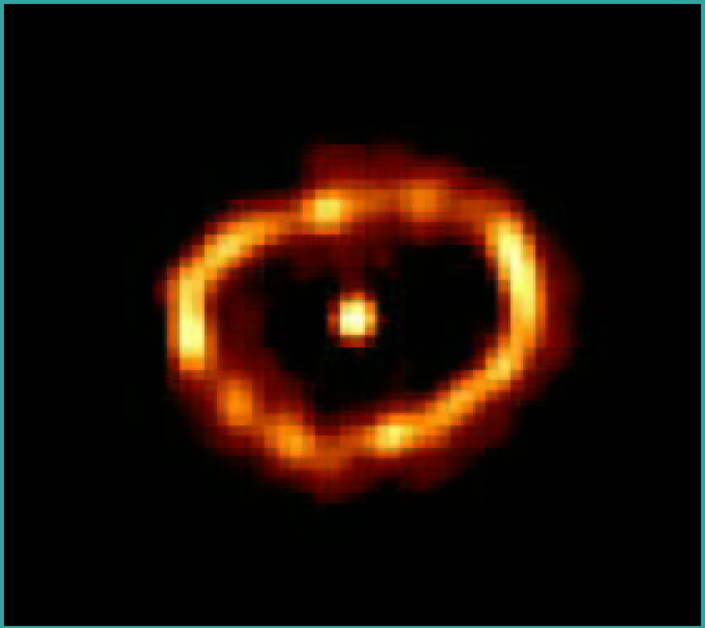
The envelope of fuel can start to fuse, and release a large amount of energy. This blows the envelope of fuel off.

Thus you get a nova.



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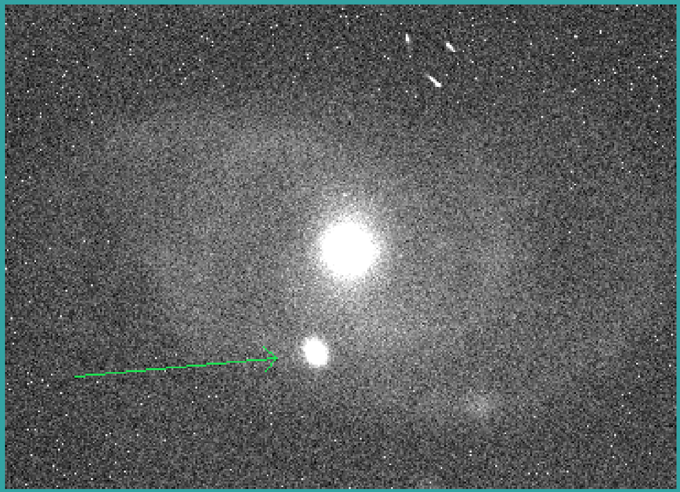

If you put too much fuel onto the white dwarf, you can push it over the edge so to speak. If you exceed the amount of matter that the WD can support, it will collapse and detonate as a supernova.

A similar fate awaits supermassive stars. They die as supernovae.