CHAPTER 15

MULTIPLE STAR SYSTEMS AND VARIABLE STARS

15-1. Binary Stars

1. Eclipsing Binaries: Light curves shows variation in brightness due to eclipses. So eclipsing binaries are a type of variable star.

2. Spectroscopic Binaries: Doppler shifts of spectral lines indicate a pair of stars in orbital motion around a common barycenter, but light curve indicates no eclipses. This is because the orbital plane is tilted at a large angle to the line of sight to the system.

15-2. Star Clusters

There are 2 kinds of star clusters:

1. Open: Below is a photograph of the open cluster called the Pleiades (M45).

They can be any age and shape and contain a few to a few thousand stars.

Some are gravitationally bound while others are not.

They are found only in the disk of the galaxy, and they are usually associated with gas and dust clouds.

2. Globular:

Stars have a spherical distribution.

All are gravitationally bound systems, containing more than 100,000 stars.

They are all very old (>10 billion years old), and they contain no gas and dust.

They are found only in the halo of the galaxy and all are very far away (more than 5,000 LY).

It may be assumed that all the stars in a given star cluster are about the same age, that is, they all formed at about the same time out of the same cloud of gas and dust.

However, the stars in a given cluster have different masses.

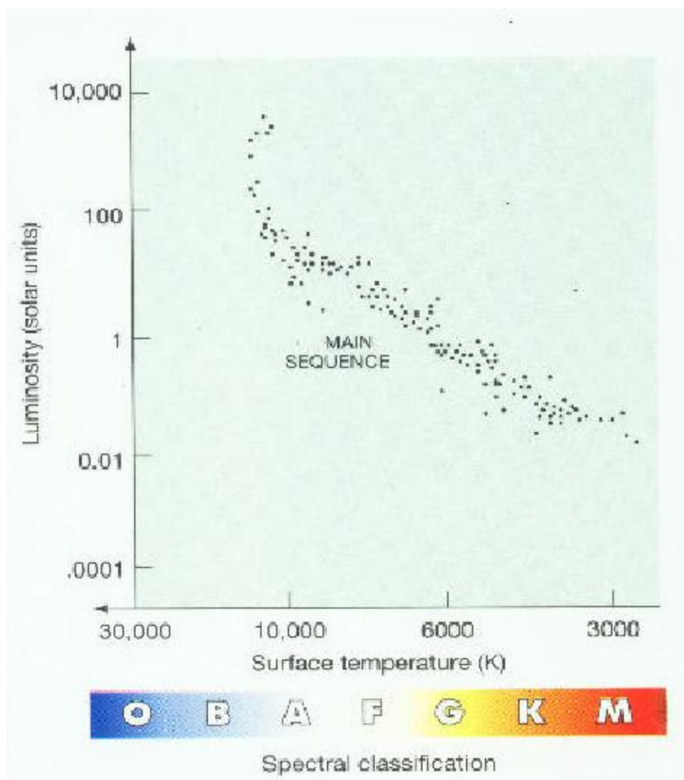
Since different mass stars evolve at different rates, the various stars in a given cluster will be in different stages of evolution.

Therefore, when one plots the spectral types and luminosities of the stars in a given cluster, the stars in a young cluster will lie along a different locus than the stars in an old cluster.

There are more than 250 stars in the Pleiades and they are all about the same age but different masses.

When the stars of the Pleiades are plotted in an H-R diagram, we get the stars defining a unique looking locus. This is shown in the above H-R diagram.

Notice how the upper end of the main sequence is missing. Instead the B and A stars are bent to the right of the main sequence.



This is because the massive stars in the cluster have already gone through the main sequence stage and have evolved to become white dwarfs. However, the latter stars are too faint to be detected at the distance of the cluster from us.

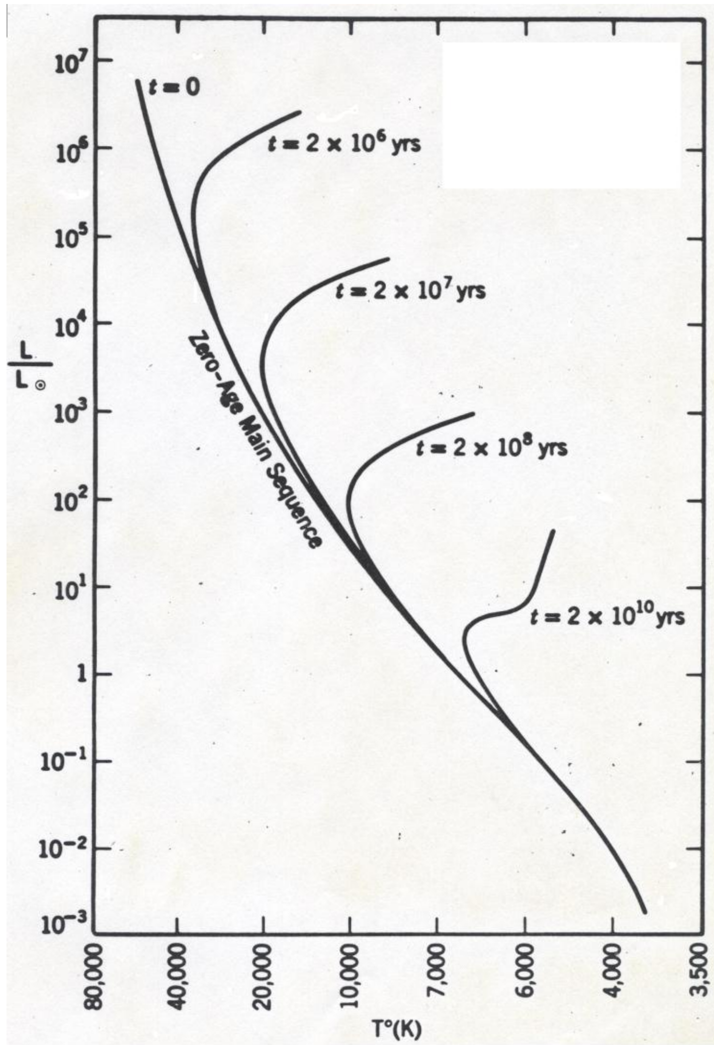
Less massive stars are evolving away from the main sequence and are on evolutionary tracks to the right of the main sequence.

Stars of less mass yet are still on the main sequence.

From theory, the main sequence lifetime for any mass is known. Therefore, if we look at the "turnoff point" from the main sequence for a star cluster, we can deduce the age of the cluster.

The most recent studies indicate that the Pleiades cluster is about 150 million years old.

Theoretical calculations have been done for hypothetical clusters of stars, showing the loci the stars in each cluster would define in an H-R Diagram at different times. The turnoff points for these hypothetical clusters is shown in the adjoining diagram. The turnoff point for each cluster indicates the age of the cluster.



15-3. Variable Stars

1. Eclipsing Binary Stars

2. Pulsating Stars
   a. RR Lyrae Stars. Periods are 1.5 hrs. to 24 hrs. They all have about the same absolute magnitude of about 0.0
   b. Delta Cepheids (Classical or type I Cepheids)
   c. W Virginis stars (Type II Cepheids)
   d. Mira or *o* (omicron) Ceti Stars. Pulsation is somewhat irregular and very long.

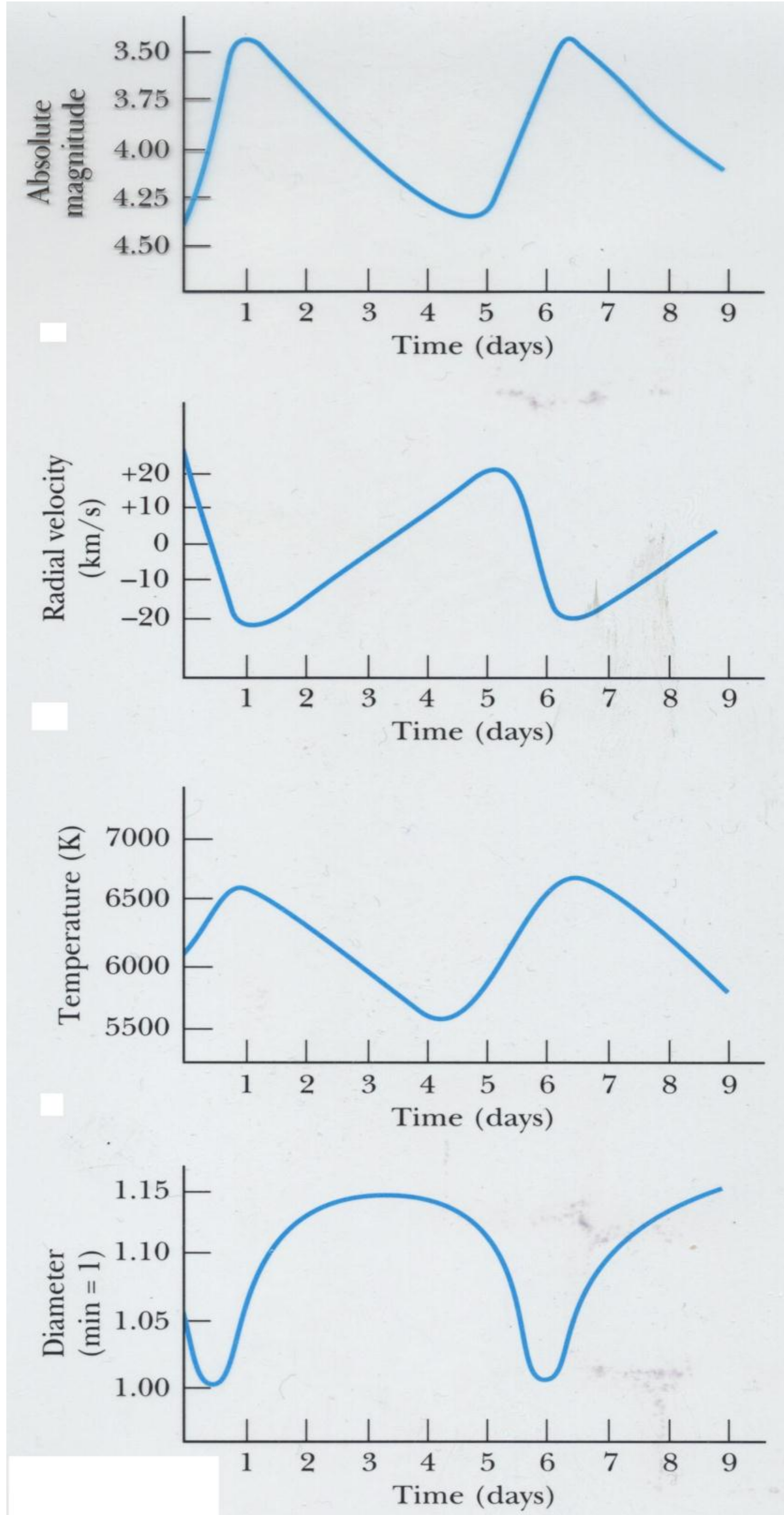
The adjoining figure schematically illustrates the changing parameters of a typical pulsating variable star. The top panel shows the light curve in terms of what is labeled as its absolute magnitude. But this is an error, since all pulsating variables are brighter than absolute magnitude 0.0. So it should be labeled as apparent magnitude. The period of pulsation is about 6.5 days.

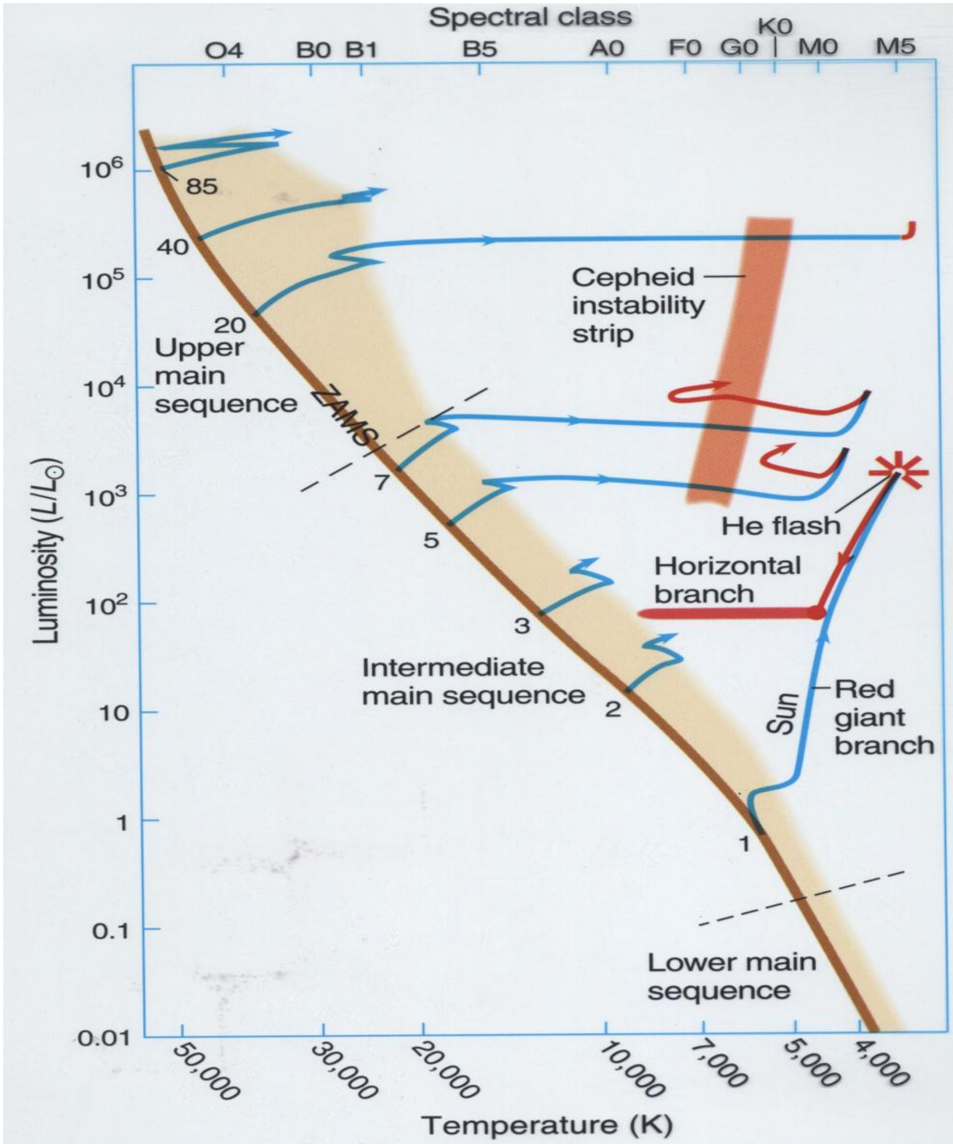
The next panel show velocity of the star's expansion, where positive radial velocities indicate the star is contracting.

The third panel shows how the surface temperature of the star changes as the star pulsated. Notice that the highest temperature coincides with the maximum in the light curve.

The forth panel depicts the changing diameter of the star. The minimum size of the star is out of phase some with maximum brightness and highest surface temperature.

Pulsating stars are stars that are passing through what is known as the instability strip in the temperature-luminosity or H-R Diagram. The instability strip is shown in the next diagram. Instability in the star is caused by changes in the degree of ionization of helium within a layer in the star. This is the result of the flow of radiation from deeper layers





3. Exploding or Cataclysmic Stars
   a. Novae: TN detonation of material on the surface of a white dwarf that is accreting material from its companion in binary systems.
   b. Supernovae
      Type I: carbon detonation in the interior of an accreting white dwarf
      or white dwarf coalescence.
      Type II: collapse of massive star
   c. Dwarf novae (U Geminorum Stars): Sudden changes in the rate of accretion of material to form an accretion disk.

4. T Tauri Stars: These stars vary irregularly due to clouds of gas and dust that are in orbit about these pre main sequence stars.

5. Flare Stars: Stars that have photospheric eruptions that last a few minutes to several hours. Our Sun is a flare star.

15-4. The Period-Luminosity Law

A study of the light curves for pulsating variable stars in a nearby dwarf galaxy called the Large Magellanic Cloud was carried out by H. Leavitt at the Harvard College Observatory early in the twentieth century.   Since all the stars in this system are the same distance from us, the different apparent magnitudes of the stars directly coded for absolute magnitudes or intrinsic brightness.

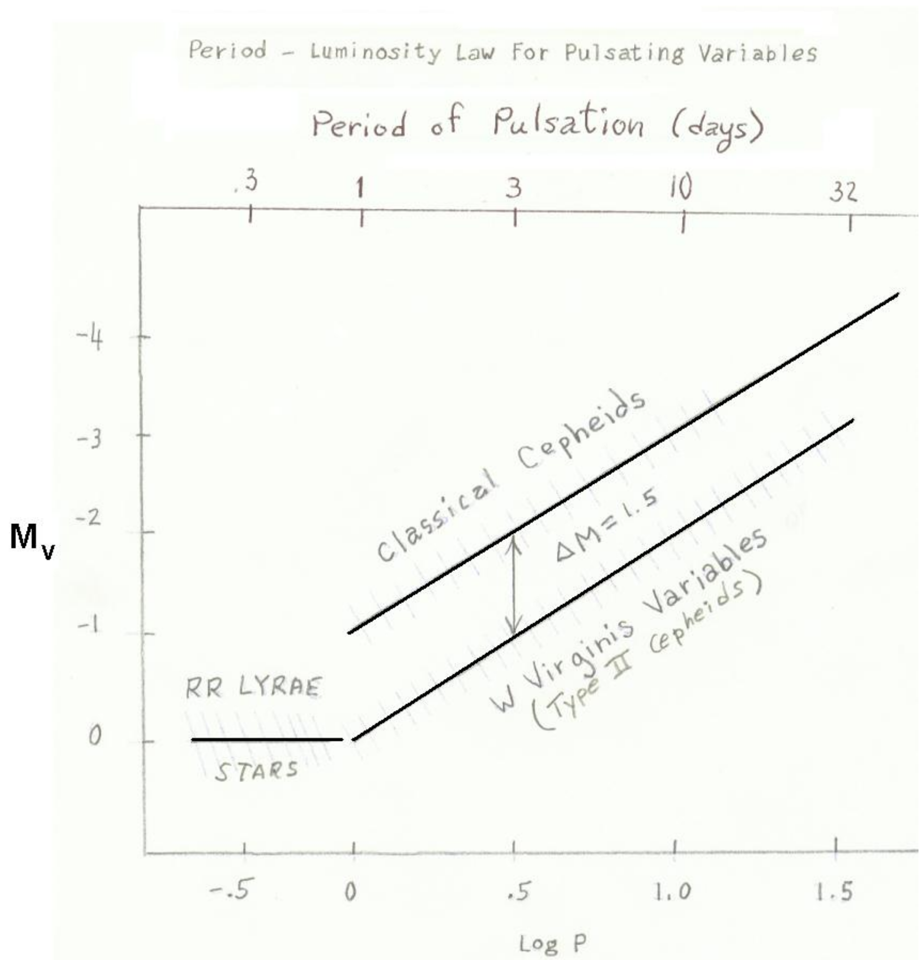
In 1912, she published a paper regarding a relationship between the magnitude or brightness of a pulsating star and its period of pulsation. In general she discovered that the brighter the star was, the longer its period of pulsation.

At that time, the distance of the LMC was not known and she presented the P-L Law in terms of relative brightness rather than absolute magnitude.

A few years later, H. Shapley was able to determine the distances of some RR Lyrae stars in our own galaxy and therefore their absolute magnitudes.

This permitted one to know the absolute magnitudes of the stars that Leavitt had used to define the P-L Law.

The calibration of the P-L Law then provided another way for determining the distances of stars and in particular the distances of star clusters and galaxies that contained pulsating variable stars.



To apply the P-L law, one first monitors the changing brightness of a variable and determines the period of pulsation. One then uses the P-L Diagram to determine the absolute visual magnitude of the star. Knowing the apparent and absolute magnitude of the star, the distance of the star may then be calculated