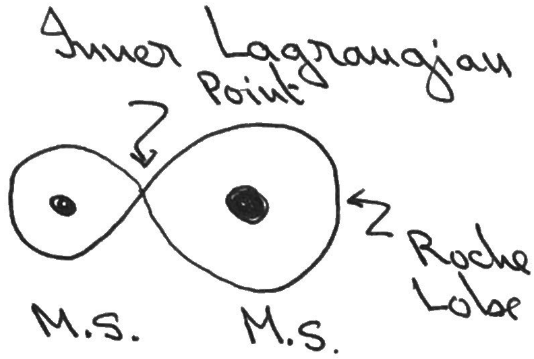
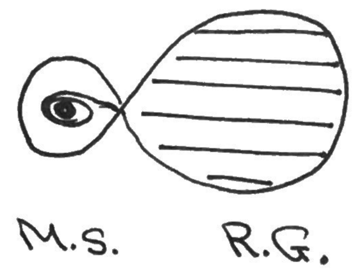
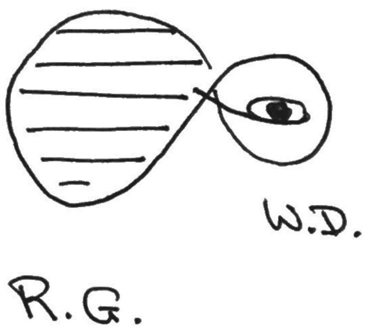
Evolution of Binary Stars







Matter from Red Giant circles around the white dwarf forming an accretion disk.

Two possibilities

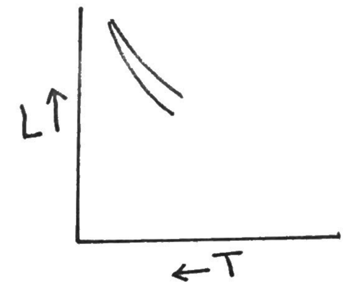
1: Small amount of matter is spewed onto the surface of the white dwarf - sudden burst of light - cataclysmic variable

2: Large amount of matter is spewed onto the white dwarf such that mass of white dwarf exceeds $1.4 M_{\odot}$ → Type I Supernova

Star Clusters

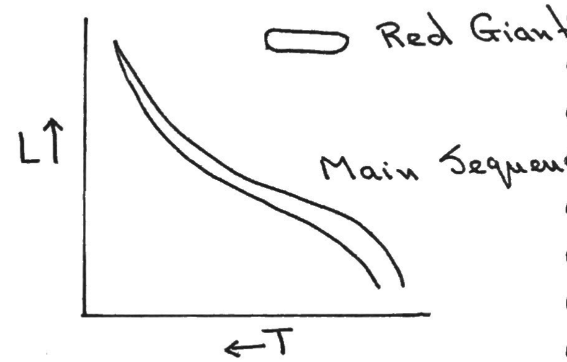
1) Associations :

   10 to 100 stars
   10 to 100 pc in diameter
   Young stars like (O, B stars) or (T Tauri stars)
   Extremely blue in color and metal rich
   Ill - defined structure
   Found in spiral arms of galaxies (they look like blue knots)



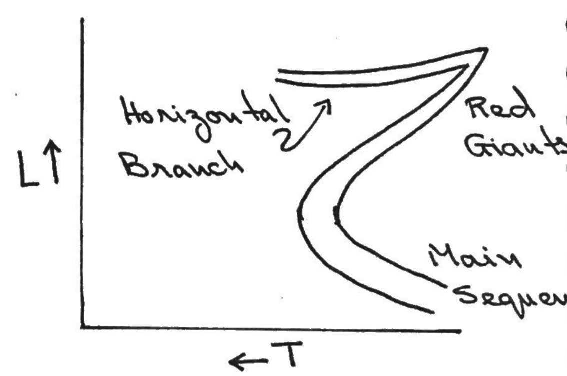
2) Open Clusters or Galactic Clusters :

   100 to 1000 stars
   4 to 20 pc in diameter
   Mostly young stars
   Blue in color and metal rich
   Loose structure
   Found in the plane of galaxies



3) Globular Clusters :

   10^4 to 10^6 stars
   5 to 25 pc in diameter
   Mostly old stars
   Red in color and metal poor
   Well defined spherical shape
   Found in the halo of galaxies



How to distinguish stars that belong to a cluster from foreground and background stars? - From proper motion studies. Stars in a cluster have approximately the same proper motion.

Assumptions about clusters :

1) Stars in a cluster are all at the same distance.
2) Stars in a cluster formed together at the same time.

Measuring the distance of a cluster by using main-sequence fitting technique.

0) Use the H-R diagram of a cluster (like the Hyades) whose distance is known.
1) Obtain the color-magnitude diagram of the cluster at unknown distance.
2) Choose a star on the main-sequence, from the unknown cluster, whose color (B-V) and apparent magnitude m is known.
3) Choose a star on the main-sequence of the known cluster having the same color (B-V). Find its absolute magnitude M.
4) The difference (m-M) is the distance modulus. Obtain distance from $m - M = 5 \log d - 5$.
5) Obtain distances for all main-sequence stars in the unknown cluster. The average gives the best distance to the unknown cluster.
6) Better still : Plot the color-magnitude diagram and the H-R diagram on the same scale on transparencies. Align the color (B-V) axis. Slide the unknown cluster along the y-axis (or magnitude axis) until its main-sequence coincides with the main-sequence of the known cluster. The amount you had to slide along the y or magnitude axis is the distance modulus (m-M) of the unknown cluster. Obtain distance from $m - M = 5 \log d - 5$.

Determination of the age of a cluster

Imagine all the stars in a cluster forming at the same time and lying on the Zero Age Main Sequence (ZAMS).

As the cluster ages the more massive stars evolve off the main-sequence.

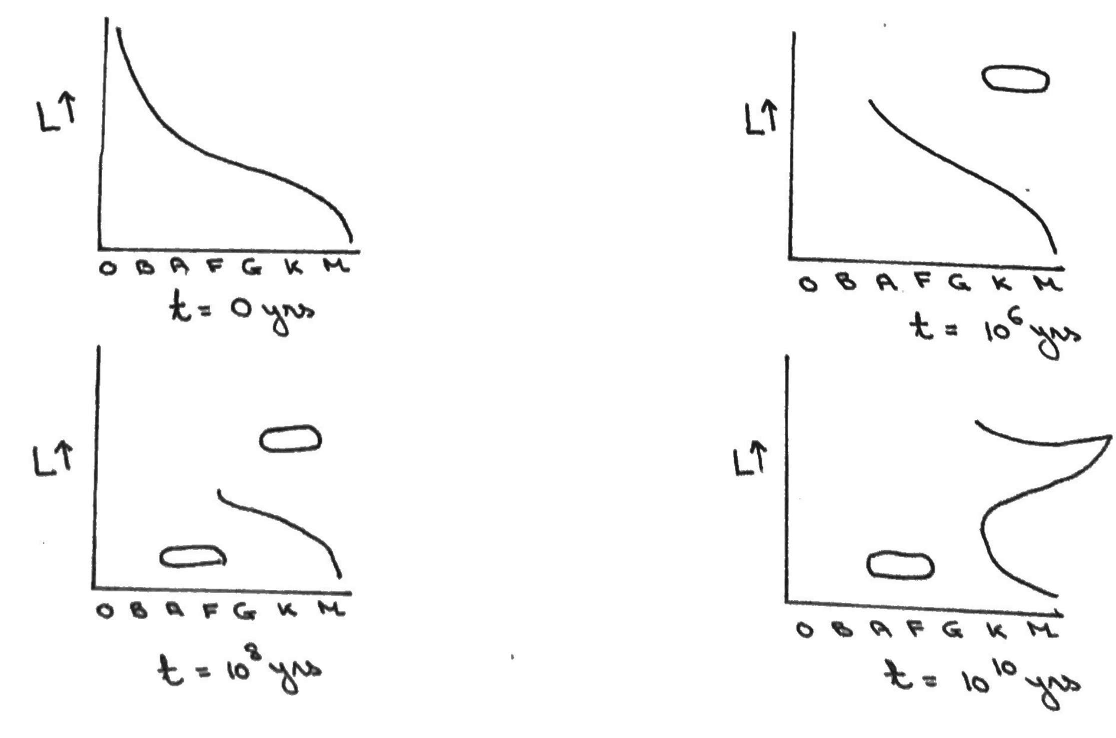
The turn-off point is a point on the main-sequence where stars are about to leave the main-sequence and become red giants.
Find the spectral type of the star at the turn-off point on the main-sequence.
Find the corresponding main-sequence mass of the stars of that spectral type.
The main-sequence lifetime of stars of that spectral type is the age of the cluster.

$$\tau = (1 / M^{2.5}) \times 10^{10} \text{ years}$$

Disruption of clusters

Even though theory would lead us to believe that most stars are formed in clusters a large fraction of stars that we see in the sky do not belong to any well defined cluster. These stars could very well have been members of clusters that have disrupted. Most clusters are expanding and / or losing members. There are several reasons for that :

1) High velocity stars exceed the escape velocity of the cluster and leave.
2) Stars on the near side of the galactic center move faster than the stars on the far side - stretching and shearing the cluster.
3) Tidal force due to the mass within the orbit of the cluster stretches the cluster.



Variable Stars

Stars whose light output varies with time are called variable stars. There are two broad classes of variable stars :

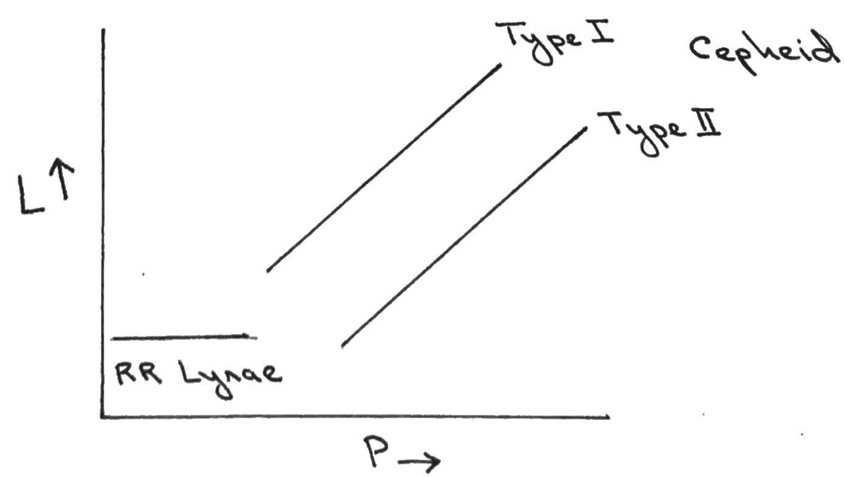
1) Geometric variables : These are binary stars whose light output varies because the stars are undergoing eclipses. Their absolute luminosity remains constant which means there is no change in either their radii or temperatures.

2) Intrinsic variables : These are stars whose absolute luminosity changes with time. Consequently their radii and temperatures also change with time. For some of the stars the changes in absolute luminosity are regular with a well determined period. Others vary irregularly with no determinable period or predictable behavior . Examples of intrinsic variables are - pulsating stars and cataclysmic variables.

Pulsating stars

1) Cepheid Variables (δ Cephei), $P \approx 5$ days
2) RR Lyrae stars, $P \leq 1$ day
3) Mira variables (o Ceti), $P \approx$ several months, irregular variables

Period - Luminosity (P-L) relation : Longer the period of a Cepheid variable the more intrinsically bright (or greater is the absolute luminosity) of the star. The absolute luminosity of an RR Lyrae star is constant with period.



Determination of distance using intrinsic variable stars

0) Obtain the light curve of the variable star i.e the variation of apparent luminosity with time.

1) From the light curve obtain the mean apparent luminosity (l) and the period P.

2) From the shape of the light curve and the period determine the type of variable star (whether Cepheid variable or RR Lyrae star).

3) Use the period - luminosity law to find the absolute luminosty (L).

4) Use the inverse square law to find the distance

$$l = L / (4 \pi d^2)$$