Clusters of Stars

Astronomy 101
Testing Stellar Evolution

• The Problem:
  – Stellar Evolution happens on billion-year time scales.
  – Astronomers only live for a few 10’s of years.

• The Solution:
  – Make H-R Diagrams of star clusters with a wide range of ages.
Star Clusters

• Groups of 100’s to 1000’s of stars.
• All stars in a cluster...
  – are at the same distance
    easy to measure relative Luminosity
    don’t need distances to individual stars
  – have the same age.
  – have the same chemical composition.
The Main-Sequence revisited

• The Main Sequence is a Mass Sequence:
  – High-mass stars are **hotter** and **brighter**.
  – Low-mass stars are **cooler** and **fainter**.

• Main Sequence Lifetime depends on Mass:
  – High-mass stars have **short** M-S lifetimes
  – Low-mass stars have **long** M-S lifetimes.

• Low-Mass stars take longer to form.
Progressive Evolution

• As a cluster ages:
  – High-mass stars reach the M-S first, with the low-mass stars still approaching.
  – High-mass stars run out of hydrogen in their cores first, evolving into supergiants.
  – As successively lower mass stars run out of hydrogen in their cores, they too evolve off.

• Peel off the Main-Sequence from the top.
Age: ~1 Myr

![Graph showing relationships between temperature and luminosity with a logarithmic scale. The graph includes a line representing the Zero Age Main Sequence.](image-url)
Age: ~10 Myr

B Stars

Temperature (K)

Luminosity ($L_{\text{sun}}$)
Age: ~100 Myr

A Stars
Age: ~1 Gyr

Temperature (K) vs. Luminosity ($L_{\text{sun}}$) for F Stars.
Age: ~10 Gyr

G Stars

Temperature (K)

Luminosity ($L_{\text{sun}}$)
Main-Sequence Turn-off

• Point where the Main-Sequence “turns off” towards giant stars.
  – As cluster ages, the stars at the turn-off are lower mass
  – Low mass stars have redder colors.

• Indicator of the cluster age:
  – Older Clusters have redder turn-off points.
Age: ~10 Myr

B Stars

Age: ~1 Gyr

F Stars

Blue T Red
Types of Clusters

• Open Clusters:
  – Sparse clusters (few 100–1000 stars)
  – few parsecs in diameter

• Globular Clusters:
  – Rich spherical clusters ($10^5$–$10^6$ stars)
  – 10–30 parsecs in diameter
Open Cluster

100’s of stars

Many blue M-S stars

Few giants

Young Ages (100’s of Myr)
Globular Clusters

- 100,000’s of stars
- Many giants
- No Blue M-S Stars
- Old Ages (~13 Gyr)
Open Clusters

• H-R Diagrams of Open Clusters show:
  – They are young to middle-aged
  – Have blue Main-Sequence stars
  – Few supergiants or giants
  – Older Open clusters have more red giants
  – Don’t see a horizontal branch
  – Youngest still have gas clouds associated
Globular Clusters

- H-R Diagrams of Globular Clusters show:
  - Very old: 10–15 Billion Years
  - Red turnoffs and no blue Main-Sequence stars
  - Lots of red giants
  - A prominent *Horizontal Branch*
  - Slightly *bluer* and *fainter* Main Sequence due to having *less metals* than nearby stars
Typical Globular Cluster H-R Diagram

- **Temperature (K)**
- **Luminosity** ($L_{\text{sun}}$)

- **Zero-Age Main Sequence**
- **Horizontal Branch**
Conclusions of the Tests

• Cluster H-R Diagrams give us a snapshot of stellar evolution.
• Observations of clusters with ages from a few Million to 15 Billion years confirms much of our picture of stellar evolution.
• Remaining challenges are in small details, but the big picture is secure.
Summary:

• H-R Diagrams of Star Clusters
• Ages from the Main-Sequence Turn-off
• Open Clusters
  – Young clusters of few 1000 stars
  – Blue Main-Sequence stars & few giants
• Globular Clusters
  – Old clusters of a few 100,000 stars
  – No blue Main-Sequence stars & many giants
Questions:

• Why are there two different types of clusters?
• What is the maximum age seen for clusters?
• Are there other cluster properties that scale with age?