Recap

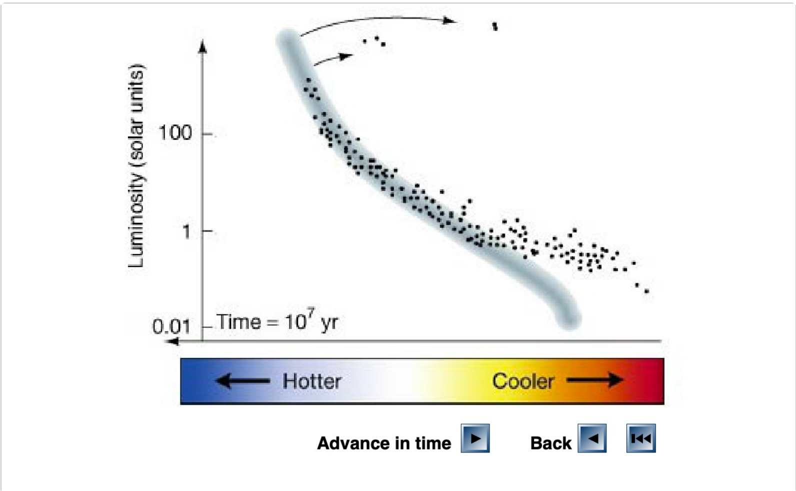
Open clusters:

- Found in the Galaxy
- Young (with hot, blue stars)
- Thousands of stars
- Irregular Shapes
- Nebulosity

Globular clusters:

- Found in the halo
- Old (no blue stars)
- Hundreds of thousands to millions of stars
- Spherical in shape
- No gas/dust

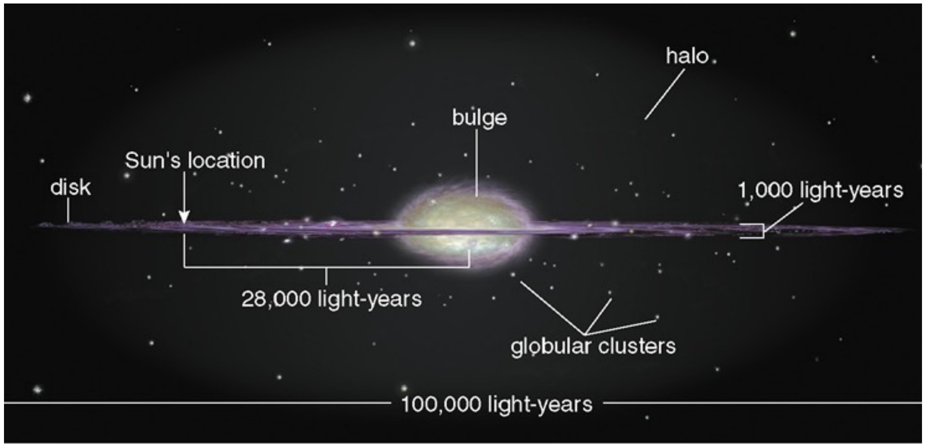
Recap



- We can tell that stars are part of the same cluster by looking at their **proper motion** (motion in the plane of the sky)
- We can create an **H-R diagram of a cluster with apparent magnitude** under the assumption that all cluster stars are at the same distance
- If we compare this Cluster H-R diagram to an H-R diagram with absolute magnitude, we can get the distance modulus (m - M) and consequently the distance.

Cluster Ages

- All stars in a single cluster **formed at about the same time**
- All the stars are (essentially) the **same age**
- If we can determine the age of any star in a cluster, we determine the age of **all stars in the cluster**.



Cluster Facts

In a single cluster

- All stars are the same age
- Not all stars are the same mass
- Stars of different masses have different main sequence lifetimes
- Some stars become red giants sooner than others

Which cluster stars become red giants first?

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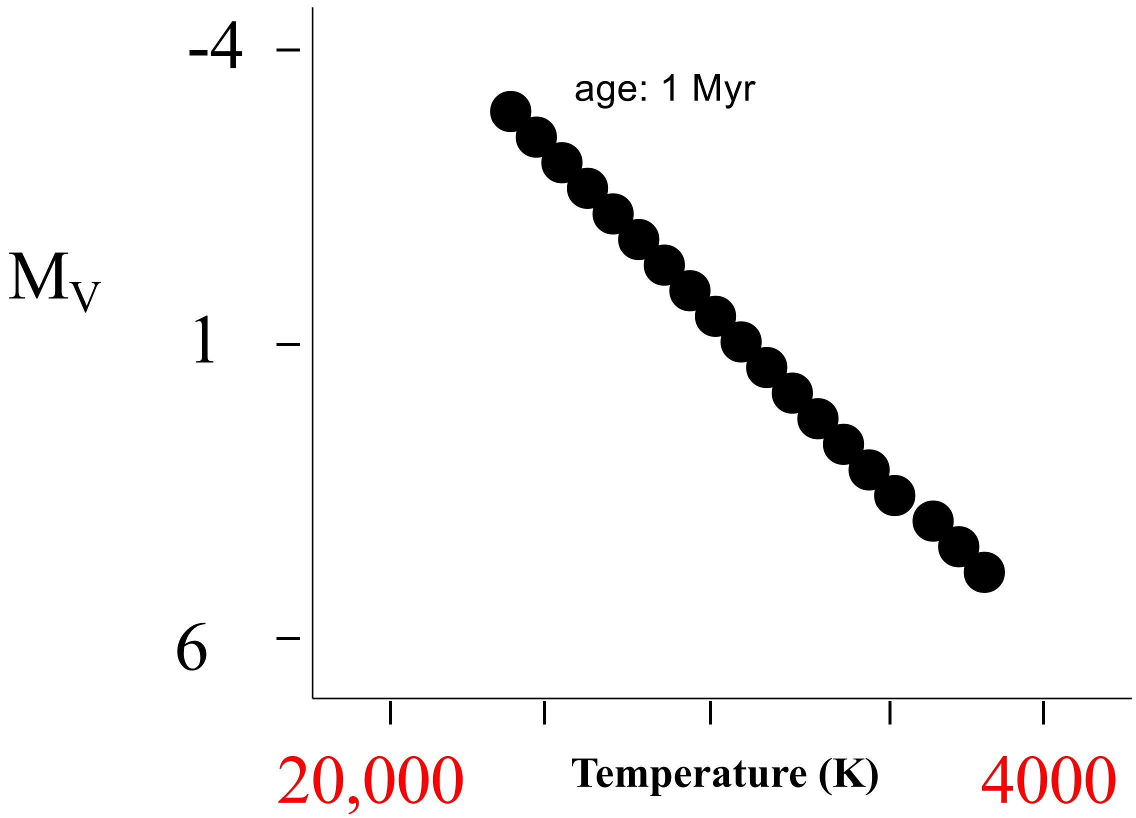
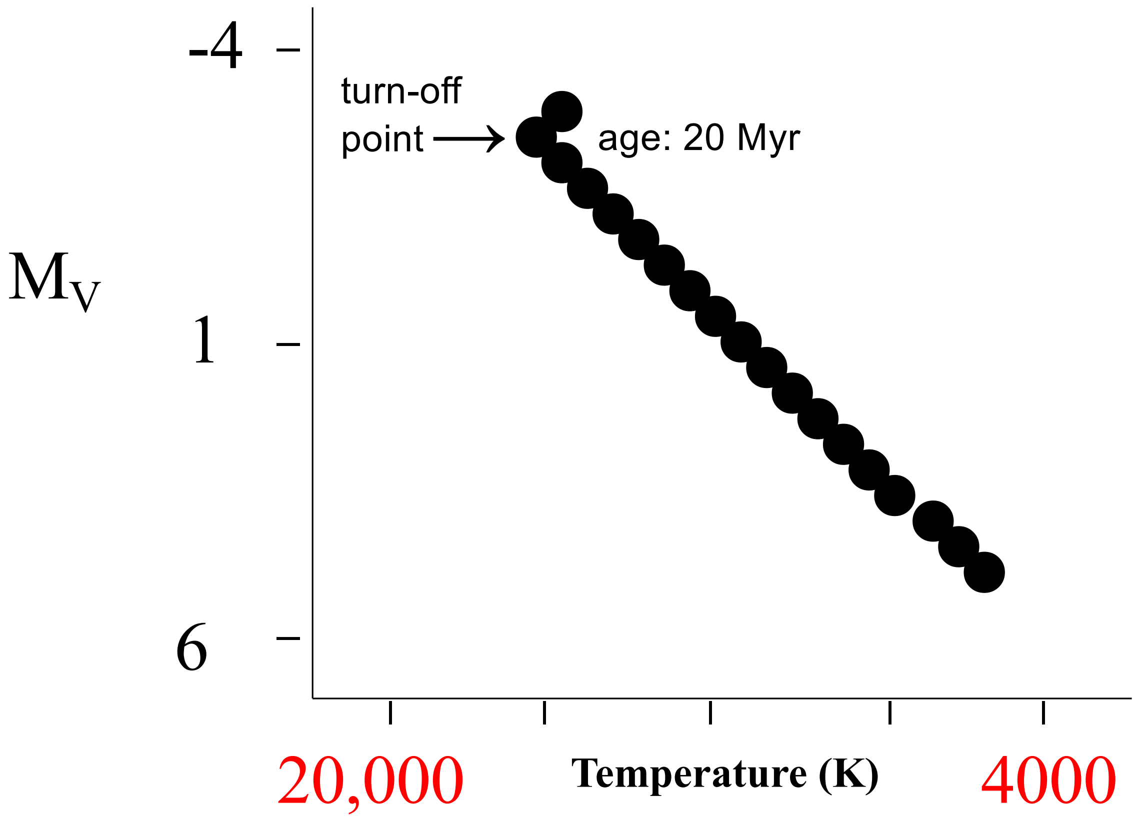
The HOT Blue Stars

Cluster Evolution



Cluster Evolution



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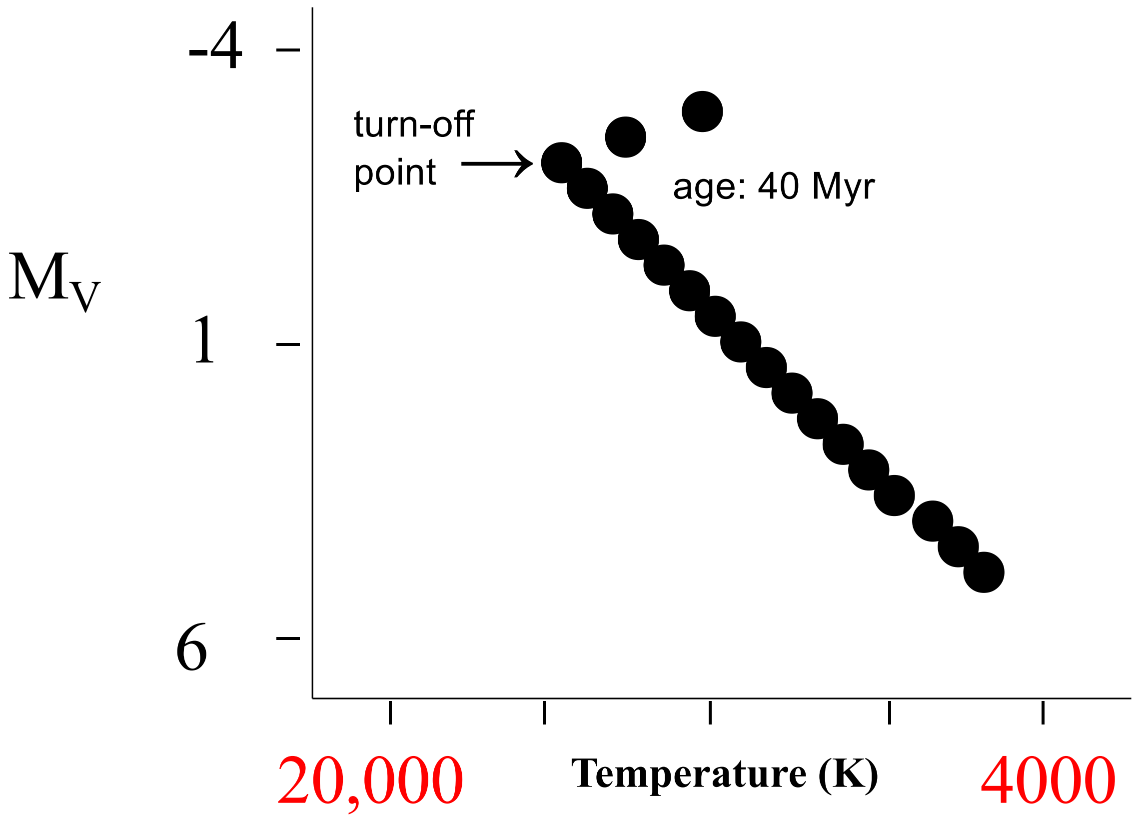

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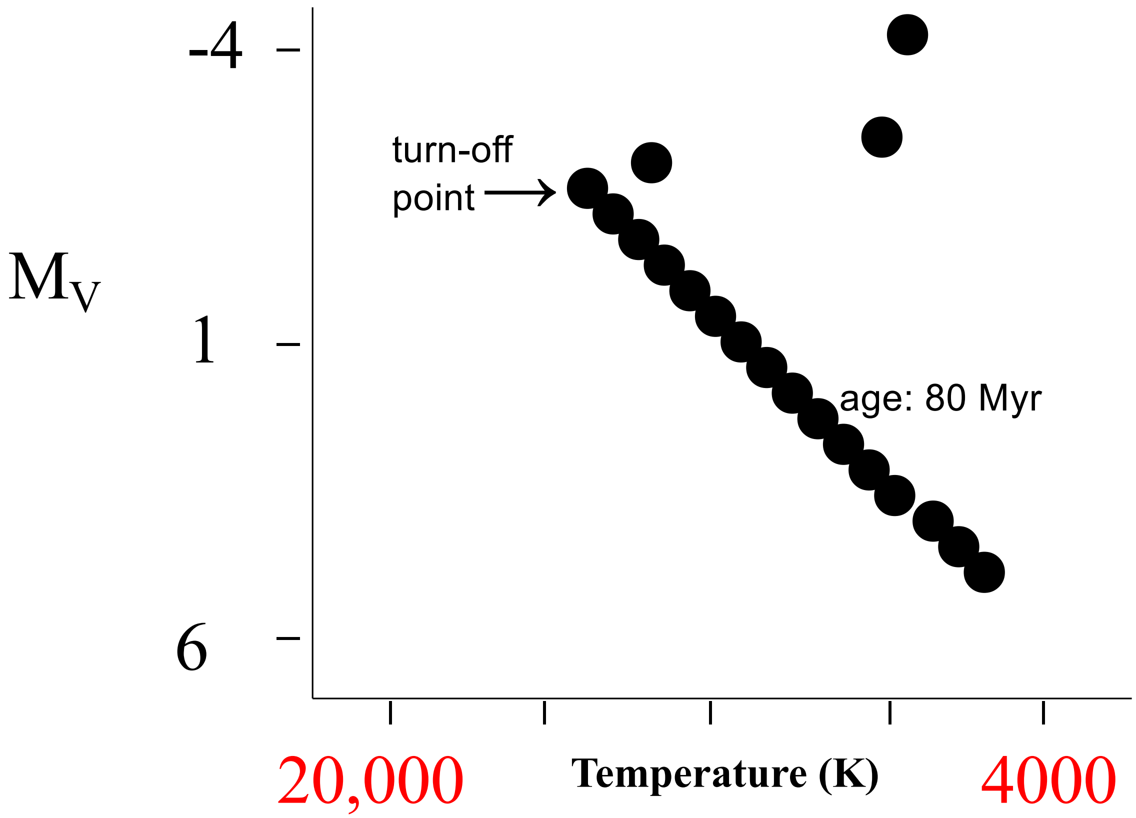

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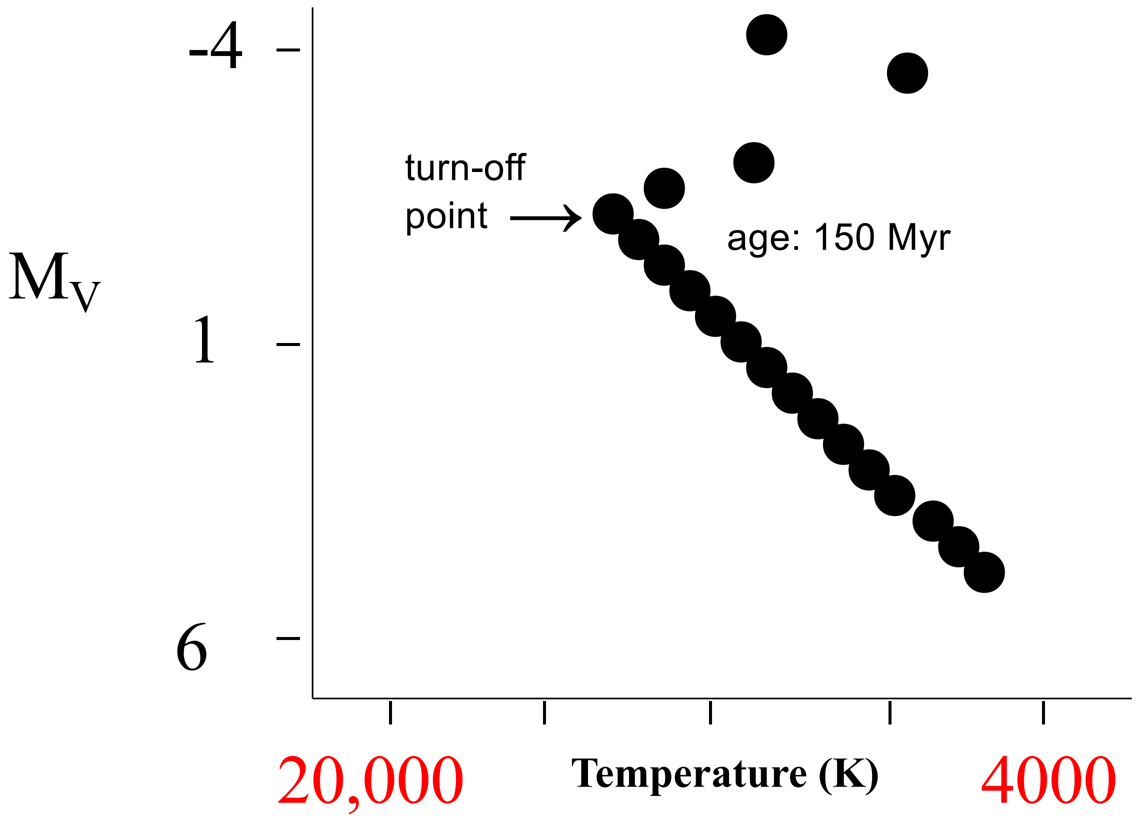

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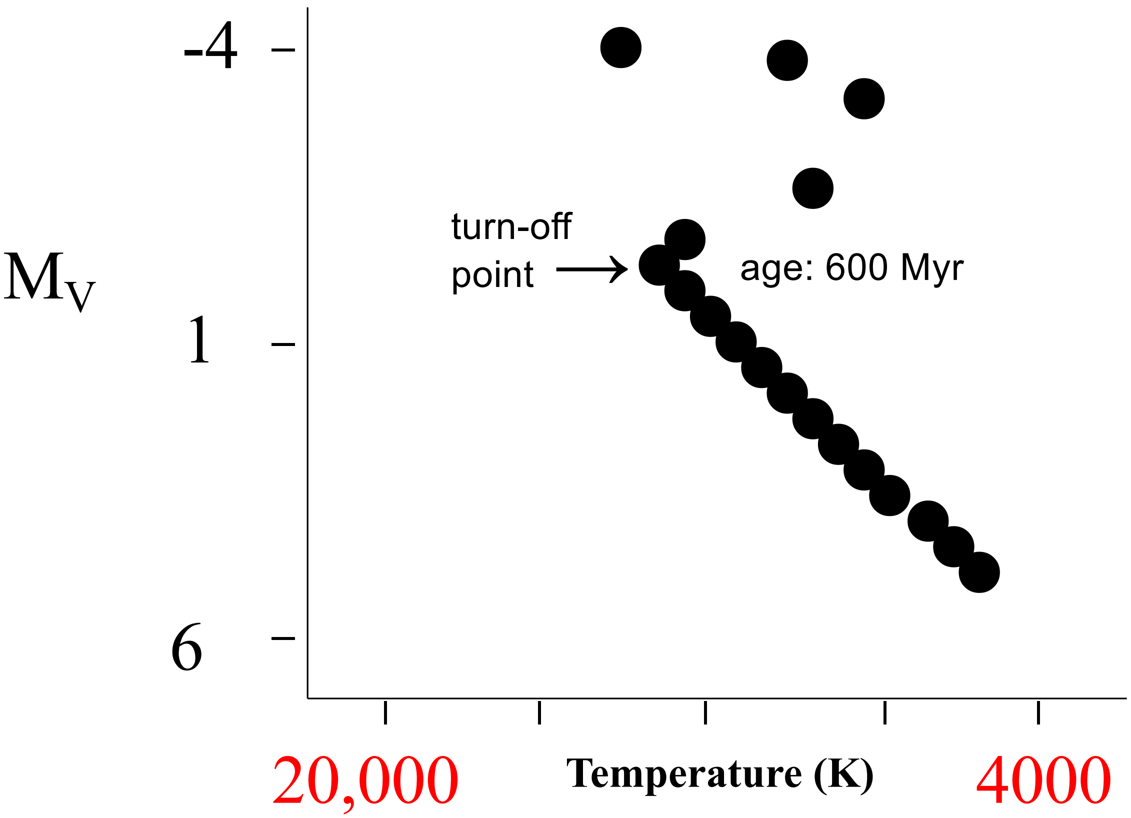

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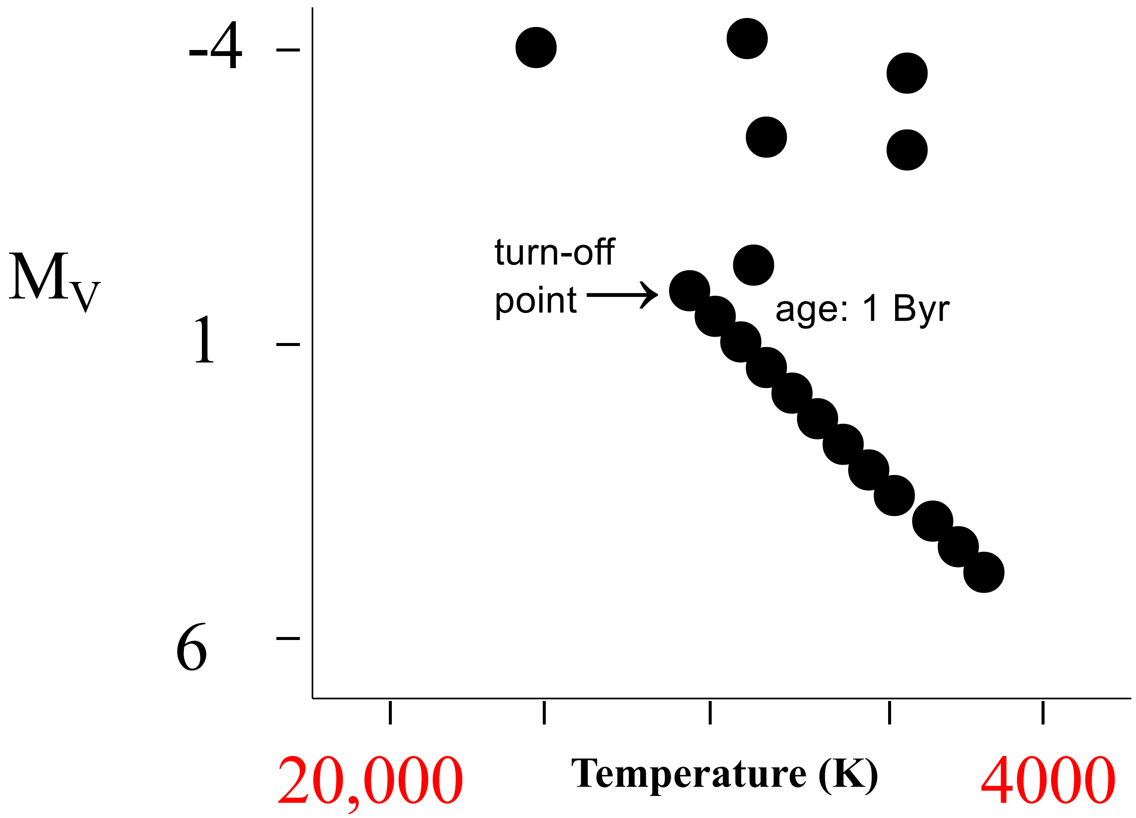
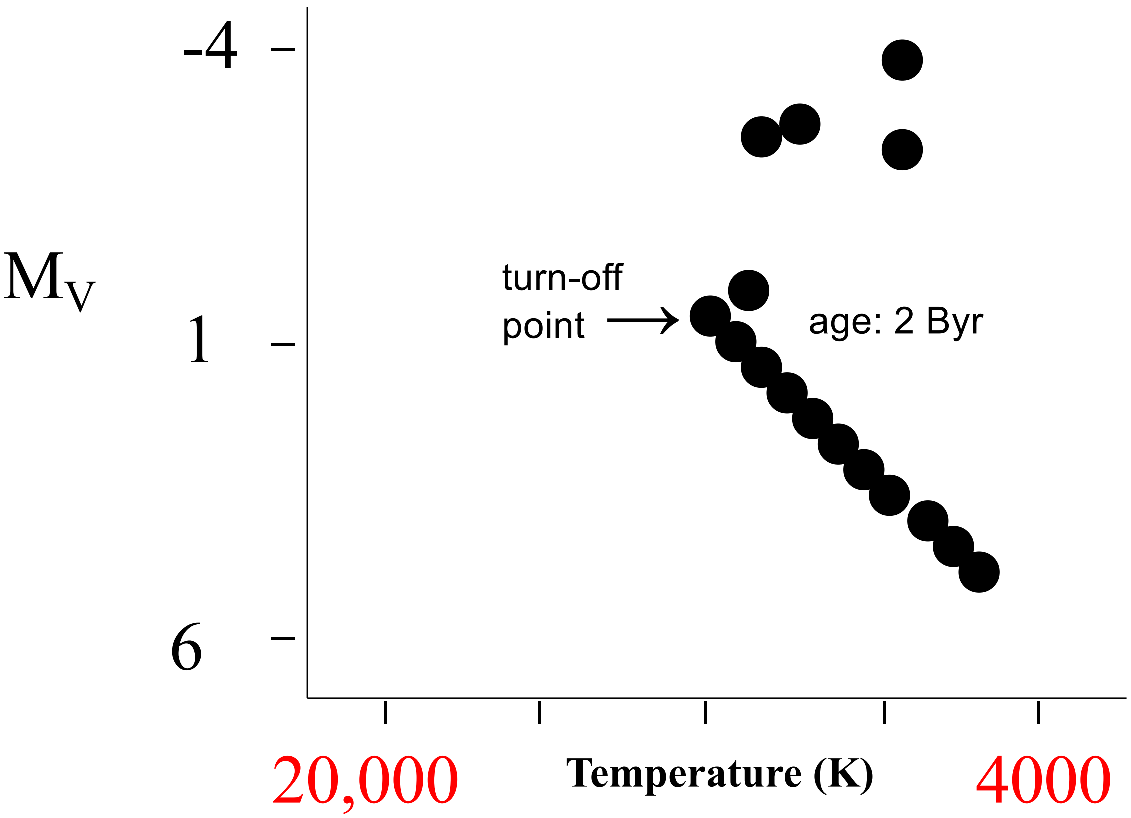
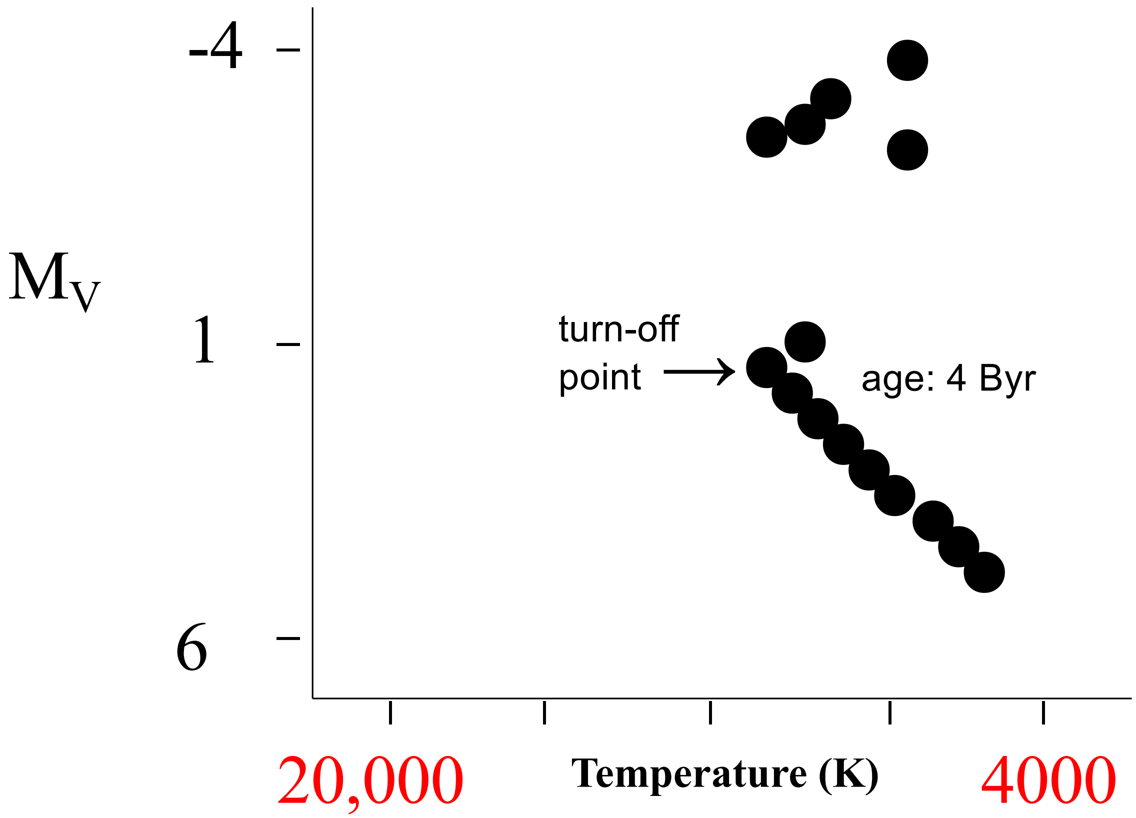


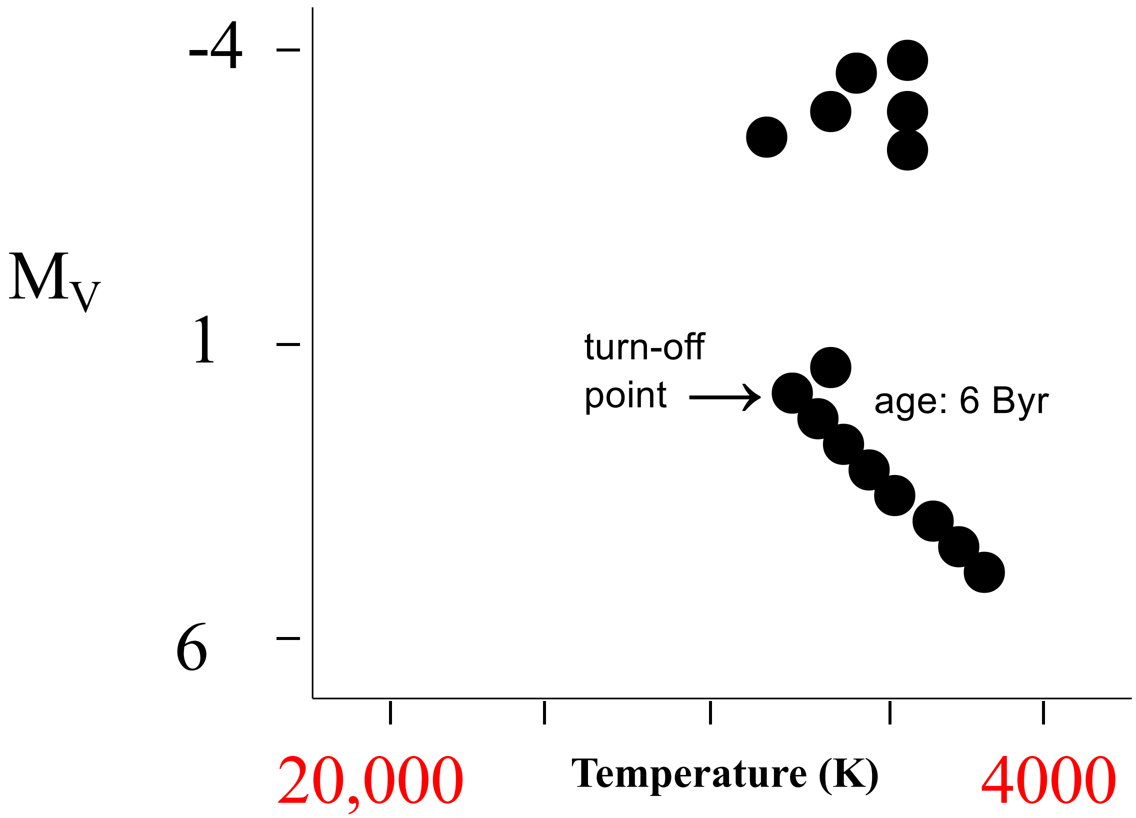
Cluster Evolution



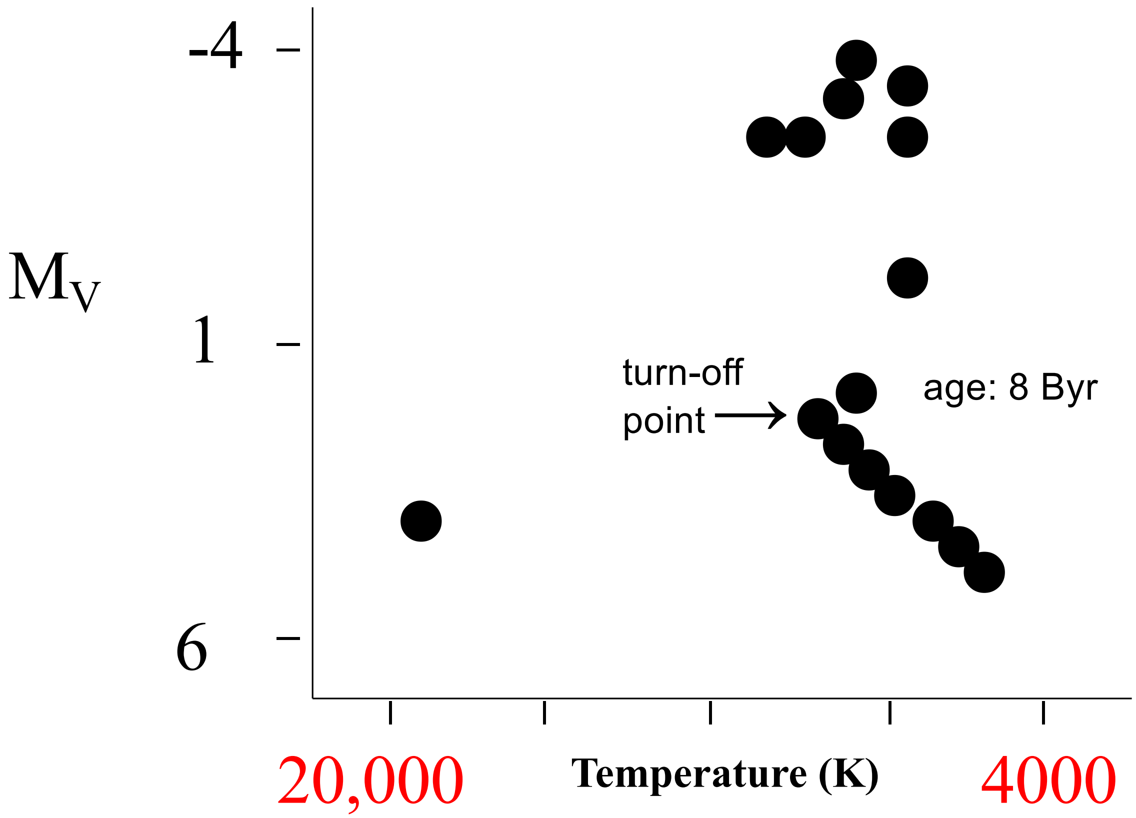
Cluster Evolution



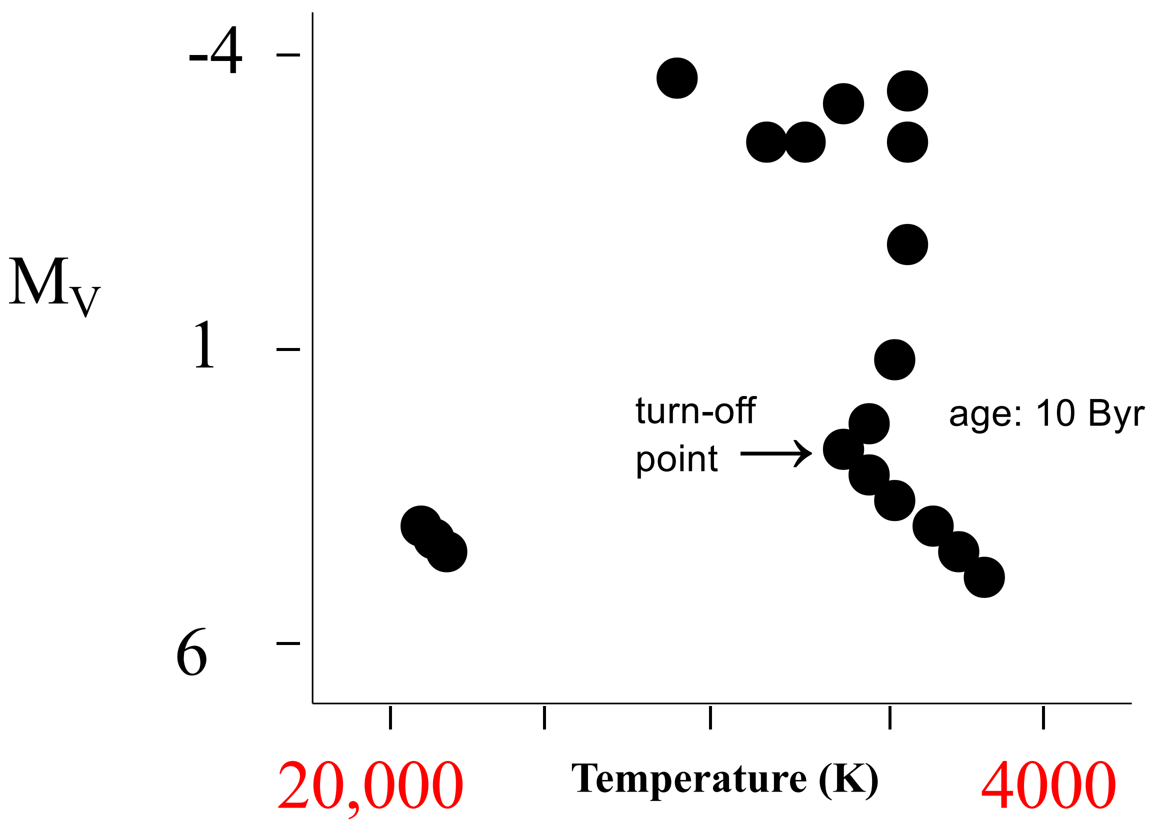
Cluster Evolution



Cluster Evolution

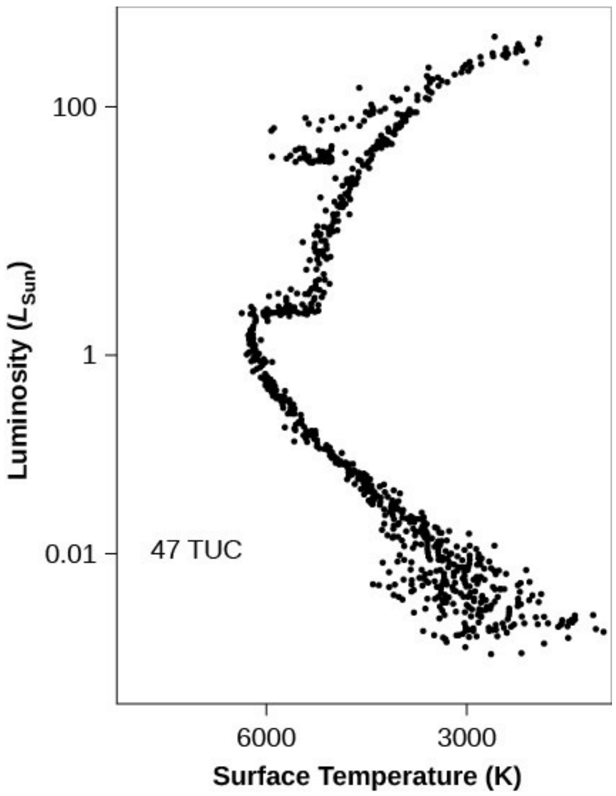


Cluster Evolution



Cluster Ages

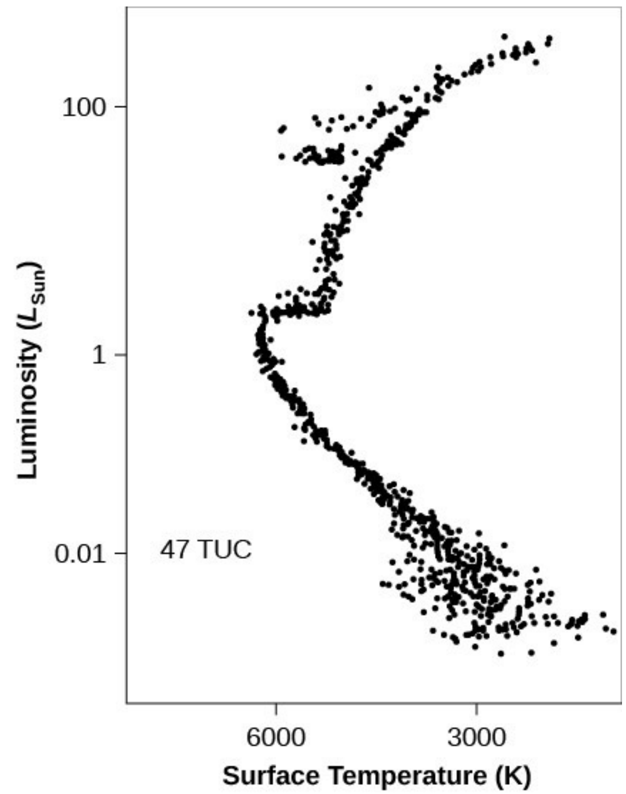
The cluster is as old as the main sequence lifetime of the hottest star on the main sequence! Why???



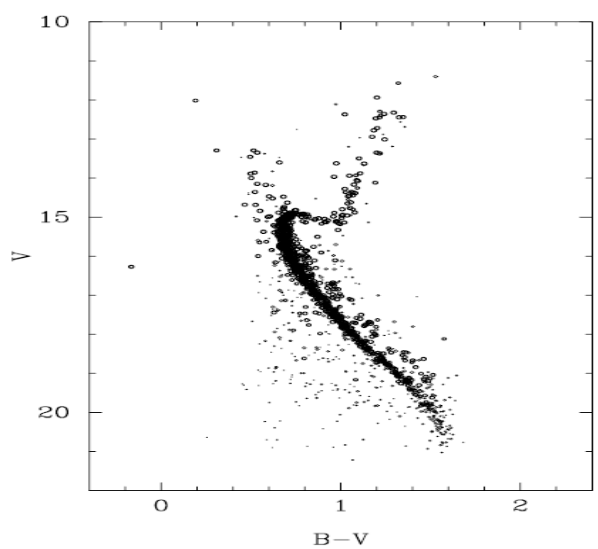
Cluster Ages

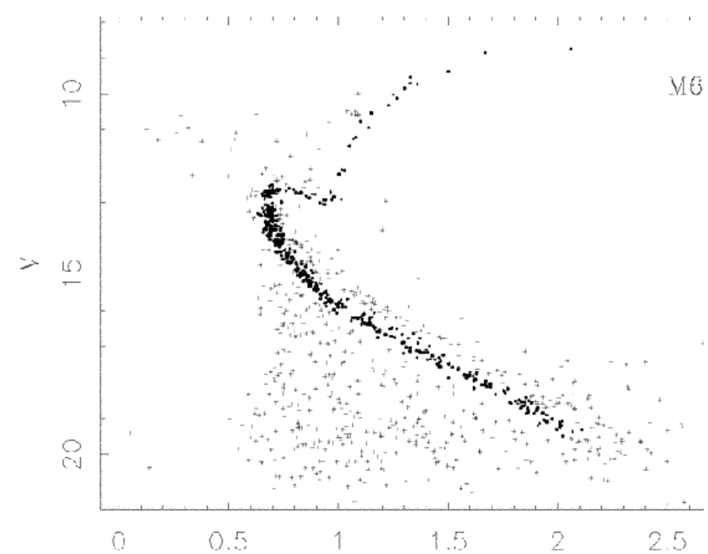
- All stars arrived on the main-sequence at about the same time.
- Any ‘missing’ stars at the top left of the MS have already used up their H fuel and are gone.
- The position of the hottest, brightest star on a cluster’s main-sequence is called the:

Main-Sequence Turnoff Point.



Turn Off Age!





How to Determine Lifetime on the Main Sequence?

- Through complicated astronomical models

OR

- Through the Mass-Lifetime equation:

$$\frac{t_{MS}}{t_{sun}} \approx \left(\frac{M}{M_{sun}}\right)^{-2.5}$$

How to Determine Lifetime on the Main Sequence?

$$\frac{t_{MS}}{t_{sun}} \approx \left(\frac{M}{M_{sun}}\right)^{-2.5}$$

Mass of star = 3 M_{sun}

Lifetime on main sequence:

$t_{MS} = M^{-2.5}$

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t_{sun} = 10 billion years or 10^{10} years

$t_{MS} = 0.06\ t_{sun}$ = 0.06 x 10^{10} years = 6 x 10^{8} years

Calculations:

Find the main sequence lifetime in years if the mass is:

0.1 M_{sun}

1 M_{sun}

20 M_{sun}

100 M_{sun}

Calculations:

Find the main sequence lifetime if the mass is:

$0.1\ M_{sun} = 316\ t_{sun} = 3 \times 10^{12}$ years

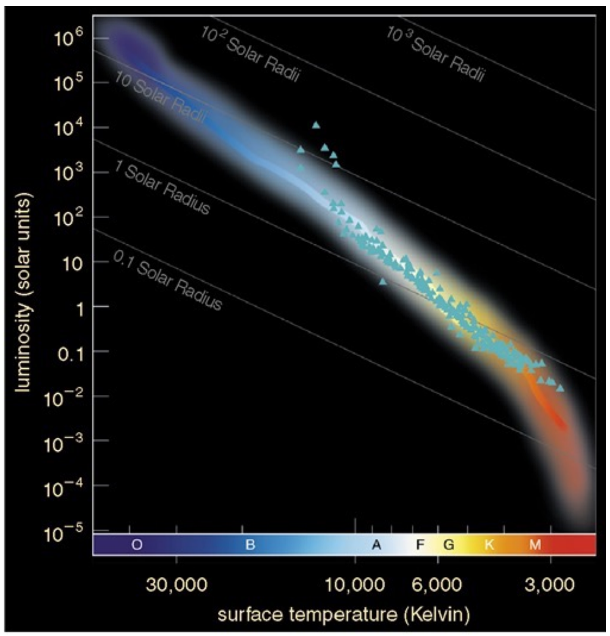
$1\ M_{sun} = 1\ t_{sun} = 1 \times 10^{10}$ years

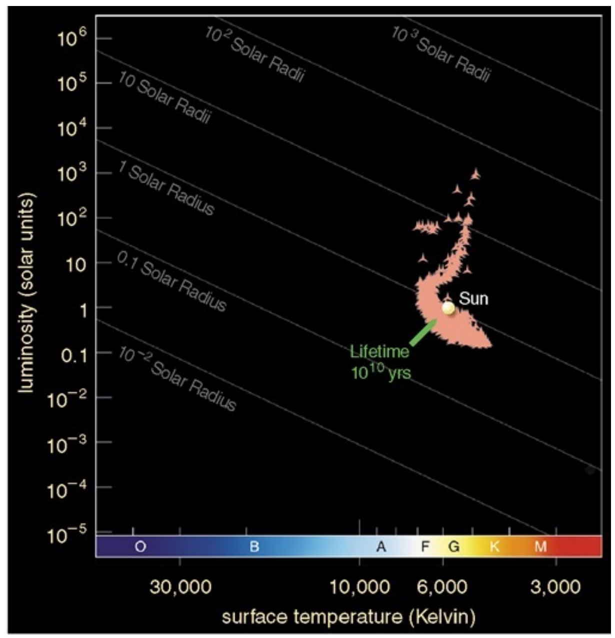
$20\ M_{sun} = 0.00056\ t_{sun} = 6 \times 10^{6}$ years

$100\ M_{sun} = 0.00001\ t_{sun} = 1 \times 10^{5}$ years

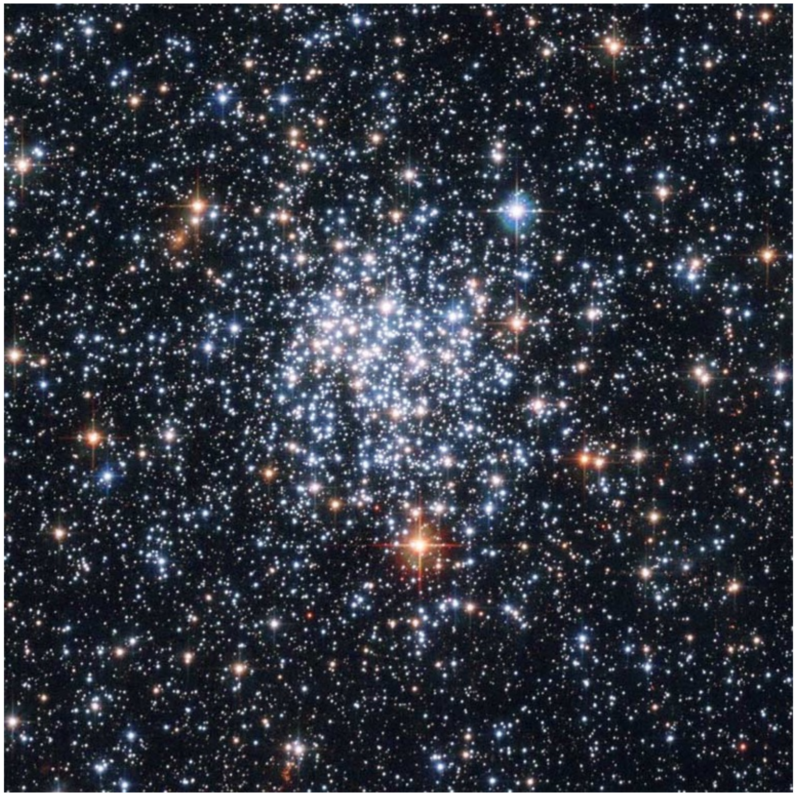
100,000 years!!!

Real Clusters





- Open Cluster (Pleiades - left)
- Globular Cluster (Palomar 3 - right)



A&A 408, 529–543 (2003)
DOI: 10.1051/0004-6361:20031003

Astronomy & Astrophysics

Distances and ages of NGC 6397, NGC 6752 and 47 Tuc★

R. G. Gratton[1], A. Bragaglia[2], E. Carretta[1], G. Clementini[2], S. Desidera[1], F. Grundahl[3], and S. Lucatello[1,4]

Abstract. New improved distances and absolute ages for the Galactic globular clusters NGC 6397, NGC 6752, and 47 Tuc are obtained using the Main Sequence Fitting Method.

We find that NGC 6397 and NGC 6752 have ages of 13.9 ± 1.1 and 13.8 ± 1.1 Gyr

47 Tuc is probably about 2.6 Gyr younger,