A star’s lifetime on the main sequence is proportional to its mass divided by its luminosity

<table>
<thead>
<tr>
<th>Mass (M☉)</th>
<th>Radius (R☉)</th>
<th>Spectral class</th>
<th>Luminosity (L☉)</th>
<th>Main-sequence lifetime (Gyr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>30,000</td>
<td>O</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>1</td>
<td>30,000</td>
<td>B</td>
<td>5</td>
<td>0.5</td>
</tr>
<tr>
<td>1.5</td>
<td>30,000</td>
<td>A</td>
<td>0.9</td>
<td>0.1</td>
</tr>
<tr>
<td>1.5</td>
<td>70,000</td>
<td>F</td>
<td>5</td>
<td>400,000</td>
</tr>
<tr>
<td>1.5</td>
<td>40,000</td>
<td>G</td>
<td>1</td>
<td>12,000</td>
</tr>
<tr>
<td>1.5</td>
<td>30,000</td>
<td>K</td>
<td>0.5</td>
<td>25,000</td>
</tr>
<tr>
<td>6.5</td>
<td>40,000</td>
<td>N</td>
<td>0.1</td>
<td>75,000,000</td>
</tr>
</tbody>
</table>

- The duration of a star’s main sequence lifetime depends on the amount of hydrogen in the star’s core and the rate at which the hydrogen is consumed
- N.B. - The more massive a star, the shorter is its main-sequence lifetime

The Sun has been a main-sequence star for about 4.56 billion years and should remain one for about another 7 billion years.

When core hydrogen fusion ceases, a main-sequence star becomes a red giant.

During a star’s main-sequence lifetime, the star expands somewhat and undergoes a modest increase in luminosity.
Red Giants

- Core hydrogen fusion ceases when the hydrogen has been exhausted in the core of a main-sequence star.
- This leaves a core of nearly pure helium surrounded by a shell through which hydrogen fusion works its way outward in the star.
- The core shrinks and becomes hotter, while the star’s outer layers expand and cool.
- The result is a red giant star.

As stars age and become giant stars, they expand tremendously and shed matter into space.

- When the central temperature of a red giant reaches about 100 million K, helium fusion begins in the core.
- A process called the triple alpha process, converts helium to carbon and oxygen.

H-R diagrams and observations of star clusters reveal how red giants evolve.
- The age of a star cluster can be estimated by plotting its stars on an H-R diagram.
The cluster’s age can be estimated by the age of the main-sequence stars at the turnoff point (the upper end of the remaining main sequence).

As a cluster ages, the main sequence is “eaten away” from the upper left as stars of progressively smaller mass evolve into red giants.
Populations (generations) of stars

- Relatively young Population I stars are metal rich; ancient Population II stars are metal poor.
- The metals (heavy elements) in Population I stars were manufactured by thermonuclear reactions in an earlier generation of Population II stars, then ejected into space and incorporated into a later stellar generation.

Variable Stars

When a star’s evolutionary track carries it through a region in the H-R diagram called the instability strip, the star becomes unstable and begins to pulsate.

Variable Stars

Cepheid variables are high-mass variable stars.
- RR Lyrae variables are lower-mass, metal-poor variable stars with short periods.
- Long-period variable stars also pulsate but in a fashion that is less well understood.

There is a direct relationship between Cepheid periods of pulsation and their luminosities.

The light curve of δ Cephei (a graph of brightness versus time).

Radial velocity versus time for δ Cephei (positive: star is contracting; negative: star is expanding).
Mass transfer can affect the evolution of close binary star systems. Gas flowing from one star to the other passes across the inner Lagrangian point. Semi-detached binary: One star fills its Roche lobe.
This mass transfer can affect the evolutionary history of the stars that make up the binary system.

Key Words

- alpha particle
- Cepheid variable
- close binary
- color-magnitude diagram
- contact binary
- core helium fusion
- core hydrogen fusion
- degeneracy
- degenerate-electron pressure
- detached binary
- globular cluster
- helium flash
- helium fusion
- horizontal-branch star
- ideal gas
- inner Lagrangian point
- instability strip
- long-period variable
- main-sequence lifetime
- mass loss
- mass transfer
- metal-poor star
- metal-rich star
- overcontact binary
- Pauli exclusion principle
- period-luminosity relation
- Population I and Population II stars
- pulsating variable star
- red giant
- Roche lobe
- RR Lyrae variable
- semidetached binary
- shell hydrogen fusion
- triple alpha process
- turnoff point
- Type I and Type II Cepheids
- zero-age main sequence (ZAMS)
- zero-age main-sequence star