The Sun Compared to Other Stars

- **Hertzsprung-Russell (HR) Diagram**: A graph plot indicating individual stars as points, with stellar luminosity on the vertical axis & surface temperature (spectral type) on the horizontal axis.

- We can use spectroscopy to determine the spectral type & luminosity of a star.

- **Main Sequence (MS)**: Prominent line of points running from the upper left to lower right on an HR Diagram; these stars shine by fusing hydrogen in their core.

- For the Main Sequence
  - Mass increases from right to left along the MS
  - Most stars have low mass
  - High-mass stars have short MS lives; low mass stars have long MS lives
Basic HR Diagram
MS masses & lifetimes
Stellar radii on HR Diagram
## Spectral Sequence

<table>
<thead>
<tr>
<th>Spectral Type</th>
<th>Example(s)</th>
<th>Temperature Range</th>
<th>Key Absorption Line Features</th>
<th>Brightest Wavelength (color)</th>
<th>Typical Spectrum</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>Stars of Orion's belt</td>
<td>&gt;30,000 K</td>
<td>Lines of ionized helium, weak hydrogen lines</td>
<td>&lt;97 nm (ultraviolet)*</td>
<td></td>
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<tr>
<td>B</td>
<td>Rigel</td>
<td>30,000 K-10,000 K</td>
<td>Lines of neutral helium, moderate hydrogen lines</td>
<td>97–290 nm (ultraviolet)*</td>
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<tr>
<td>A</td>
<td>Sirius</td>
<td>10,000 K-7,500 K</td>
<td>Very strong hydrogen lines</td>
<td>290–390 nm (violet)*</td>
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<tr>
<td>F</td>
<td>Polaris</td>
<td>7,500 K-6,000 K</td>
<td>Moderate hydrogen lines, moderate lines of ionized calcium</td>
<td>390–480 nm (blue)*</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>Sun, Alpha Centauri A</td>
<td>6,000 K-5,000 K</td>
<td>Weak hydrogen lines, strong lines of ionized calcium</td>
<td>480–580 nm (yellow)</td>
<td></td>
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<tr>
<td>K</td>
<td>Arcturus</td>
<td>5,000 K-3,500 K</td>
<td>Lines of neutral and singly ionized metals, some molecules</td>
<td>580–830 nm (red)</td>
<td></td>
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<tr>
<td>M</td>
<td>Betelgeuse, Proxima Centauri</td>
<td>&lt;3,500 K</td>
<td>Molecular lines strong</td>
<td>&gt;830 nm (infrared)</td>
<td></td>
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</tbody>
</table>

*All stars above 6,000 look more less white to the human eye because they emit plenty of radiation at all visible wavelengths.*
Life of a Low-Mass Star

1) Fusion of hydrogen into helium
2) Core hydrogen ends, star collapses, hydrogen fusion begins in outer shell
3) Core continues to collapse, outer shell expands because of hydrogen fusion, star becomes luminous
4) Core becomes degenerate (sustained by electron pressure), outer shell dumps helium ash onto core
5) Helium flash! Helium fusion (into carbon) begins in core
6) Core helium fusion ends, eventually leading to both hydrogen & helium fusion shells & a degenerate carbon core
7) End results → outer layers drift away (planetary nebula), leaving a naked core (white dwarf)
Life Track of 1 Solar Mass Star
Example of a Planetary Nebula
Planetary Nebula Formation – A Simulation
Life Cycle of a Massive Star

1) Successive episodes of shell fusion occur, leading up to a degenerate iron core
2) Iron is unlike other elements in that no energy is released through fusion or fission
3) Thus, core continues to accrete iron ash until degeneracy is finally broken
4) Supernova results from:
   → core bounce associated with collapse into a neutron star
   → release of neutrinos which blow off the outer envelope of the star
     (i.e, proton + electron $\rightarrow$ neutron + neutrino)
Massive star core near end of life
The importance of Iron (Fe)
Supernova Remnant
Supernova Explosion – A simulation