Extragalactic Astronomy and Cosmology
Stellar Stages

Stars lighter than about 8 solar masses

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Core</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular Cloud</td>
<td>Huge*</td>
<td>(none)*</td>
<td>arbitrary</td>
</tr>
<tr>
<td>Protostar</td>
<td>Large</td>
<td>Hydrogen</td>
<td>0.1 Gyr</td>
</tr>
<tr>
<td>Main Sequence</td>
<td>Small</td>
<td>Burning Hydrogen</td>
<td>10 Gyr</td>
</tr>
<tr>
<td>First Giant Branch</td>
<td>Large</td>
<td>Helium</td>
<td>0.5 Gyr</td>
</tr>
<tr>
<td>Horizontal Branch</td>
<td>Medium</td>
<td>Burning Helium</td>
<td>0.4 Gyr</td>
</tr>
<tr>
<td>Asymptotic Giant Branch</td>
<td>Large</td>
<td>Carbon/Oxygen</td>
<td>0.1 Gyr</td>
</tr>
<tr>
<td>Planetary Nebula</td>
<td>Shrinking</td>
<td>Carbon/Oxygen</td>
<td>10,000 yr</td>
</tr>
<tr>
<td>White Dwarf</td>
<td>Tiny</td>
<td>Carbon/Oxygen**</td>
<td>forever</td>
</tr>
</tbody>
</table>

* - a molecular cloud typically becomes many stars. It is not really a stage.
** - only the core remains

All times are for a one solar mass star. Bigger stars go faster; smaller stars go slower.

Heavier stars become Type II supernovas, and then become neutron stars
Very heavy stars become black holes

Spectral Classes vs. Temperature

<table>
<thead>
<tr>
<th></th>
<th>O5</th>
<th>B0</th>
<th>B5</th>
<th>A0</th>
<th>A5</th>
<th>F0</th>
<th>F5</th>
<th>G0</th>
<th>G5</th>
<th>K0</th>
<th>K5</th>
<th>M0</th>
<th>M5</th>
<th>M8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>40,000</td>
<td>28,000</td>
<td>15,500</td>
<td>9900</td>
<td>8550</td>
<td>7400</td>
<td>6600</td>
<td>6050</td>
<td>5550</td>
<td>4900</td>
<td>4150</td>
<td>3500</td>
<td>2800</td>
<td>2400</td>
</tr>
</tbody>
</table>

The History of the Universe

<table>
<thead>
<tr>
<th>Time</th>
<th>$kT$ or $T$</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{-43}$ s</td>
<td>$10^{21}$ MeV</td>
<td>Planck Era; time becomes meaningless?</td>
</tr>
<tr>
<td>$10^{-39}$ s</td>
<td>$10^{19}$ MeV</td>
<td>Inflation begins; forces unified</td>
</tr>
<tr>
<td>$10^{-37}$ s</td>
<td>$10^{19}$ MeV</td>
<td>Inflation ends; reheating; forces separate; baryosynthesis (?)</td>
</tr>
<tr>
<td>$10^{-13}$ s</td>
<td>$10^5$ MeV</td>
<td>Supersymmetry breaking, LSP (dark matter)</td>
</tr>
<tr>
<td>$2 \times 10^{-11}$ s</td>
<td>$10^5$ MeV</td>
<td>Electroweak symmetry breaking</td>
</tr>
<tr>
<td>$5 \times 10^{-5}$ s</td>
<td>100 MeV</td>
<td>Quark Confinement</td>
</tr>
<tr>
<td>0.4 s</td>
<td>1.5 MeV</td>
<td>Neutrino Decoupling</td>
</tr>
<tr>
<td>1.5 s</td>
<td>0.7 MeV</td>
<td>Neutron/Proton freezeout</td>
</tr>
<tr>
<td>20 s</td>
<td>0.2 MeV</td>
<td>Electron/Positron annihilation</td>
</tr>
<tr>
<td>200 s</td>
<td>80 keV</td>
<td>Nucleosynthesis</td>
</tr>
<tr>
<td>39 ky</td>
<td>0.87 eV</td>
<td>Matter-Radiation equality</td>
</tr>
<tr>
<td>350 ky</td>
<td>0.32 eV</td>
<td>Recombination</td>
</tr>
<tr>
<td>0.5 Gy</td>
<td>30 K</td>
<td>First Globular Clusters Form/First Stars</td>
</tr>
<tr>
<td>13 Gy</td>
<td>2.726 K</td>
<td>Today</td>
</tr>
</tbody>
</table>