Summary of Lecture 18

Key points include:

1. As a reminder from last time: mass is the primary determinant of a star's lifetime and eventual fate. At birth, stellar masses range from 0.08 $M_\odot$ (below which ordinary hydrogen can't fuse into helium) to $\geq 100\ M_\odot$ (without a clear reason for the limit, but these are very rare). The *main sequence* is the phase of a star's life during which it shines because of the fusion of ordinary hydrogen into helium. On the main sequence, the lowest-mass stars have photospheric temperatures of around 3,000 K and luminosities of about $10^{-4}\ L_\odot$, and the highest-mass stars have temperatures of around 50,000 K and luminosities of about $10^6\ L_\odot$.

2. We measure stellar masses most easily when the stars are in binaries, because then we can use Kepler's laws (as generalized by Newton). This requires two out of the following three quantities: orbital period, binary separation, and orbital velocity.

3. Binaries come in different categories (which can overlap): *visual binaries* can be seen as two separate stars; *eclipsing binaries* are oriented so that we can see one go in front of the other (which therefore decreases the total amount of light that we see); *spectroscopic binaries* move rapidly enough in their orbit that we can see periodically changing Doppler shifts in the spectral lines from the stars, as the stars move toward us and away from us.

4. By mass, stars are roughly 3/4 hydrogen, 1/4 helium, and 2% everything else. The amount of "everything else" varies somewhat depending on when and where the star was formed.

5. Nuclear fusion occurs when small nuclei stick together to make larger nuclei. For example, hydrogen nuclei can come together to make helium nuclei, and helium nuclei can come together to make carbon nuclei. Because nuclei are positively electrically charged (protons have positive charge, neutrons have zero charge) they repel each other electrically. Thus fusion requires fast motion (and thus high temperatures) and/or high densities to occur.

6. On the main sequence, more massive stars are bigger and brighter than less massive stars. By brighter, we mean brighter by a *lot*. Near the Sun's mass, the luminosity scales like $L \propto M^{3.5}$ or $L \propto M^4$, This means that more massive stars run out of fuel much more rapidly than do less massive stars. The Sun will last about 10 billion years total, but a 10 solar mass star might live only 30 million years, and a 0.1 solar mass star will last for trillions of years.

7. When a star runs out of hydrogen in its core, it moves off of the main sequence. It then becomes much larger and redder, and thus becomes a *red giant* or *supergiant*. Once all fusion has ceased, stars that begin their lives with masses less than about 8 $M_\odot$ (which is the overwhelming majority of stars) contract to become *white dwarfs*. White dwarfs are about the size of the Earth while being $\sim 0.2 - 1$ times the mass of the Sun.

8. Stars aren't distributed uniformly. When they are born, most stars are in *open clusters*, which are a few thousand loosely packed stars. Some conglomerations are larger: *globular clusters* have hundreds of thousands to (in rare cases) millions of stars. When we look at the Hertzsprung-Russell (HR) diagram of a cluster, we can tell its age. We do this by assuming that all the stars in the cluster formed at about the same time, and then seeing which are the highest-mass stars that are still on the main sequence as opposed to being red giants or white dwarfs. The higher the mass, the younger the cluster. Some globular clusters approach 13 billion years in age.