**Key points from Lecture 5 of ASTR 350**

1. Another consequence of special relativity: lengths appear to change in differently-moving inertial frames. For example, if you move by me at high speed then your meter stick looks shorter than a meter, and to you my meter stick looks shorter than a meter.

2. Again, though, to each of us our own meter stick looks normal.

3. Doppler shift: the frequency of a source moving toward us appears higher than it would in the reference frame of the source; this is called blueshift. Similarly, the frequency of a source moving away from us appears lower than it would in the reference frame of the source; this is called redshift.

4. Yet another consequence: two events that are simultaneous in one reference frame need not be simultaneous in another reference frame.

5. To save causality (if A causes B in one frame, A causes B in all other frames), the speed of light in a vacuum must be an absolute upper bound to speed.

6. Our law of the addition of velocities must be modified to take all of this into account. For example, suppose that someone sees a particle at a speed $v_p$ and that from your perspective that someone is moving (in the same or the exact opposite direction as the particle) at speed $v_s$, then you see the particle's speed as

$$V = \frac{v_p + v_s}{1 + v_p v_s / c^2} \ . \tag{1}$$

   Among other things, if you put $v_p = c$ you find that $V = c$ regardless of the value of $v_s$. This corresponds to the postulate the the speed of light in a vacuum is the same to all observers.

7. Measured mass is also altered by speed. If we have a speed $v$ for a particle, we define the Lorentz factor to be $\gamma = 1/\sqrt{1 - v^2/c^2}$. Then if the particle's mass measured at rest is $m$, then the momentum of the particle is $p = \gamma m v$ and the total energy of the particle *including the energy associated with its rest mass* is $E = \gamma mc^2$.

8. Why do we believe all of this? It's not because it's pretty or aesthetic. It's because thousands of tremendously precise experiments have corroborated the predictions of special relativity.