Basic Stellar Properties

We’ve already discussed several, but have a few more to do, and a few loose ends.

Clusters M46 and M47 (from APOD).

We’ve already covered most of the important methods. However, now that we’ve covered thermal radiation we can add one more, the **Baade-Wesselink method** for pulsating or explosive stars.

To begin, note that measured and intrinsic flux are related as:

\[
\frac{f_\nu}{\pi B_\nu} = \frac{R^2}{d^2},
\]

Assuming that the intrinsic flux is that of a thermal radiator, \(\pi B_\nu\), \(R\) is the size of the radiator (stellar atmosphere) and \(d\) is its distance.

Suppose that the size of the atmosphere varies approximately as, \(R = vt + R_0\).

Measure: \(v_1 = v(t_1), v_2 = v(t_2)\) (from spectral blueshifts), \(f_\nu^1, f_\nu^2\), and \(T_{1,2}\) (from spectra).
Then solve the equations:

\[
R_1 = v_1 t_1 + R_o, \\
R_2 = v_2 t_2 + R_o, \\
\frac{R_2^2}{R_1^2} = \left( \frac{f^1}{f^2} \right),
\]

for \( R_o, R_1, \) and \( R_2. \)

Then,

\[
d^2 = R^2 \frac{\pi B_\nu (T)}{f_\nu},
\]

at \( t_1 \) or \( t_2. \)

The weakness of this method is the set of assumptions made along the way.
2. How big are stars? Stellar Radii.

There are few ways to measure sizes directly.

Occultations and Eclipses

In binary star systems, viewed nearly edge-on, the 2 stars eclipse each other. The duration of the eclipse is measure via the light curve. The orbital velocity is also measured, and then: size \( \approx v \Delta t \).

The Moon wanders over a 10° band around the ecliptic. It occasionally eclipses a bright, nearby star. If the angular size of the star is not too small, it will not disappear instantly in the eclipse. A characteristic, interference-type pattern is seen in the intensity vs. time plot. This pattern depends on the stellar angular size.
Zubenelgenubi and Friends (APOD) Occultation + Lunar eclipse
Radii from the Radiation Laws:

The Stefan-Boltzmann Law can be solved for the stellar radius:

\[
\left( \frac{L}{L_{\text{sun}}} \right) = \left( \frac{R}{R_{\text{sun}}} \right)^2 \left( \frac{T}{T_{\text{sun}}} \right)^4.
\]

However, the continuum must be reasonably well approximated by a Planck curve, and we must know the distance to determine L.

Thus, this method provides more of an estimate than an accurate determination.
The Colors of Stars

To get an idea of the range of stellar colors observe Sirius and Betelguese in winter, or Vega and Antares in summer.

To understand this range of variation, consider blackbodies of different T viewed through wide filters: especially a blue filter and a red-centered filter. (See pic. from text.)

Reversing the process, a comparison of the intensity in 2 broad bands, a so-called photometric color, can give the thermal T.

From B-V to $T_{\text{eff}}$ (or vice versa):

U, B, V are broad band photometric indices (equal to $m_U$, $m_B$, $m_V$), with the following sensitivities:

\[
\begin{array}{ccc}
\lambda_{\text{eff}} & \text{range} \\
U & 360\text{nm} & 300-400\text{nm} \\
B & 420 & 380-540 \\
V & 540 & 480-640
\end{array}
\]
A number of IR broad band indices are also common (Johnson system):

<table>
<thead>
<tr>
<th></th>
<th>$\lambda_{\text{eff}}$</th>
<th>range</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>0.70µm</td>
<td>±0.22µm</td>
</tr>
<tr>
<td>I</td>
<td>0.90</td>
<td>±0.24</td>
</tr>
<tr>
<td>K</td>
<td>2.2</td>
<td>±0.48</td>
</tr>
<tr>
<td>L</td>
<td>3.4</td>
<td>±0.70</td>
</tr>
<tr>
<td>N</td>
<td>10.2</td>
<td></td>
</tr>
</tbody>
</table>

Differences between bands, e.g., B-V, U-B, measure the relative fluxes in the two bands, and are generally called colors.

Colors are obviously very temperature sensitive, since $\lambda_{\text{max}} \sim 1/T$. 