Lec 5: 09/07/2010

Stellar Magnitudes and Colors (Cont'd):

There are some practical issues related to measuring the luminosity of stars. An apparatus does not measure f_ν directly. Instead, the observed intensity can be expressed as:

$$f \equiv \int_0^\infty f_\nu \, T_\nu F_\nu \, R_\nu \, d\nu$$

where:

- T_ν: measures fractional transmission due to Earth's atmosphere. This is relevant for ground-based observations, but not space-based observations.

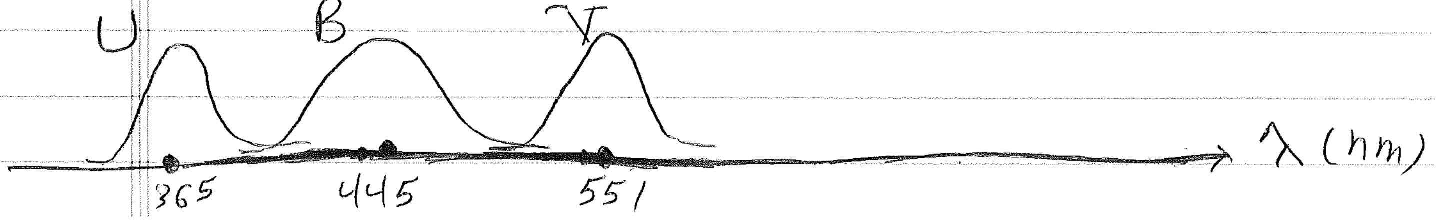
- F_ν: fractional sensitivity of the measuring apparatus. It is characterized by a mean frequency ν_0 (at which the apparatus is most sensitive) and a full width half maximum (FWHM) that specifies the band of frequencies over which significant sensitivity exists.

- $\mathcal{R}_N$: efficiency of the detector (ratio between energy detected and incident energy upon the detector). No apparatus has 100% efficiency.

Lets consider some commonly used frequency bands, their mean frequencies and FWHM's:

Band	λ_{eff} (nm)	W_λ (nm)
U (Ultraviolet)	365	66
B (Blue)	445	94
V (Visible)	551	88
R (Red)	658	138
I (Infrared)	806	149
⋮	⋮	⋮

Pictorially, we have:



For historical reasons, astronomical measurements (specially those in the optical band) are quoted in terms of magnitude, which is related to "f" in a logarithmic fashion:

$$\boxed{m = -2.5 \log\left(\int_0^\infty \underset{\overset{\shortparallel}{F}}{f_\nu \, d_\nu}\right) + C_{bol}} \quad *$$

"m" is the apparent bolometric magnitude, and C_{bol} is a constant decided by convention. It is chosen such that:

$$F = (2.75 \times 10^{-5})\, 10^{-0.4m} \ \text{erg cm}^{-2}\,\text{s}^{-1}$$

For a Sun-like star located at a distance of 10 pc we have $m \sim 4.8$.

The absolute bolometric magnitude is related to "m" as follows;

$$\boxed{m - M = 5 \log r - 5} \quad **$$

Here "r" is the distance in parsecs,

In reality, one need to take some corrections into account. Equation .. then becomes:

$m - M = 5\log r - 5 + A + K$

Here A takes photon absorption or scattering by the interstellar medium into account. K accounts for the redshift of photons (e.g., due to cosmological expansion, gravitational redshift, ...).

For different bands we can define corresponding magnitudes;

$U \equiv m_U$, $B \equiv m_B$, $V \equiv m_V$, . . .

Similarly M_U, M_B, M_V, ... The difference between these magnitudes is called color index: $U - B$, $B - V$, ...

These differences represent ratio of fluxes, and hence are an intrinsic property of the spectrum, which is independent of the distance.

Lets consider Sun. For Sun we have:

$m_U = -26.06$ $m_B = -26.16$ $m_V = -26.78$

$M_U = +5.51$ $M_B = +5.41$ $M_V = +4.79$

This results in:

$U - B = +0.10$, $B - V = +0.62$

Implying that Sun is deficient in the ultraviolet (hence not very hot). For a hot star we have $U-B, B-V < 0$.

Next, we consider the 60 nearest stars (within 5.2 pc) we know, of these:

- 32 (including Sun) are single, but 6 appear to have unseen Companions.
- 22 are in binary systems, but 2 of these pairs appear to have a third Companion (unseen).
- 6 are in two triple systems, which are in a close binary plus one outer star.

The range of luminosity and magnitude for these 60 stars is as follows:

Number	$L/L_\odot$	M_V
2	7.6 – 23	+1.3 → 2.4
3 (including Sun)	0.7 – 7	+2.5 → 4.9
6	0.07 – 0.7	+5.0 → 7.4
6	0.007 – 0.07	+7.5 → 9.9
19	7×10^{-4} – 7×10^{-3}	+10.0 → 12.4
18	7×10^{-5} – 7×10^{-4}	+12.5 → 14.9
6	2×10^{-5} – 7×10^{-5}	+15.0 → 16.7

This implies that:

- Most of the nearby stars are very dim.
- Only 4 are brighter than Sun.
- One (Sirius A) is 23 times brighter than Sun. It puts

out more light than the other 59 combined.

- Most light comes from few, very bright stars (also very massive).
- Most of the mass is in lots of dim little stars.

These are typical for our galaxy ($\sim 10^{11}$ stars).