Brightness of stars - measurement

Flux of energy from star \( f \):
energy per unit area per unit time

Greeks invented magnitude scale
- logarithmic
- first magnitude stars brightest
- 6th mag. faintest visible with naked eye

A difference of 5 magnitudes is a difference of 100 in brightness (energy flux)

\[
\frac{f_1}{f_2} = \frac{(m_2 - m_1)}{5}
\]
Kirchhoff's Laws

(i) A hot dense gas (optically thick) or hot solid object produces a continuous spectrum (blackbody radiation)

(ii) A hot diffuse gas produces bright emission lines (electron moves to orbital of lower energy)

(iii) A cool diffuse gas in front of a continuum source produces absorption lines in the continuous spectrum (electrons absorb photons & move to higher energy level)
Blackbody radiation

Continuous radiation from body in thermal equilibrium

Intensity of blackbody radiation between $\nu$ and $\nu + d\nu$, temperature $T$,

\[ I(\nu, T) = \frac{2\hbar \nu^3/c^2}{e^{\hbar \nu / kT} - 1} \]

Can convert to $I(\lambda, T)$ via

\[ I(\lambda, T) = I(\nu, T) \frac{d\nu}{d\lambda} \]

\[ = \frac{2\hbar c^2 / \lambda^5}{e^{hc/\lambda kT} - 1} \]

(Stars are reasonable approximations to blackbodies)
Wein’s law

For a blackbody,

\[ \lambda_{\text{max}} \ T = 3 \times 10^7 \ \text{Å} \ \text{K} \]

\( (1 \text{Å} = 10^{-10} \text{m} = 0.1 \text{nm}) \)

Stefan-Boltzmann law

Relates temperature & radius of a star to its total energy output

Energy/unit time/unit surface area (flux)

\[ E = \sigma T^4 \]

\( \sigma \) is Stefan-Boltzmann constant

Surface area of star of radius \( R \) is \( 4\pi R^2 \)
Total energy per unit time produced by star $\equiv$ luminosity $L$

$L = 4\pi R^2 \beta^2 T^4$

Note the difference between luminosity, an intrinsic property of a star, and brightness, how it appears on Earth, depends on both $L$ and distance.
The temperature of a star tells us a lot (although not everything) about its physical and evolutionary state.

What are 2 ways that astronomers might measure the star's temperature?

A. Color
B. Shape of spectrum
Measuring colors of stars

Simplest observational route to stellar temperature:

→ image star through different color filters & take ratio of brightnesses.

(Simple because all you need is a CCD & some filters)

Colors are brightness ratios, so calculated by subtracting magnitudes

\[ \text{eg } B - V \text{ color} = 2.5 \log_{10} \left( \frac{I_B}{I_V} \right) \]

\[ = m_B - m_V \]

(written for convenience B - V)
FIG. 1—Transmission curves are shown for the $U$, $B$, $V$, $R$, $I$ filter combinations used in this program. They were measured with the Oriel spectrometer at CTIO. The long wavelength cutoff of a typical RCA 31034 photomultiplier is shown as a dashed curve.
Figure 11-4  Color index in the $BV$ system. Blackbody curves for 20,000 and 3000 K, along with their intensities at $B$ and $V$ wavelengths. Note that $B - V$ is negative for the hotter star and positive for the cooler one.
Stellar temperatures range from >20,000 K to ~3000 K.

Which filters would be the best choice for measuring the color of:

- a very hot, faint star
- a cool, faint star?

Why?

→ study a faint star where most of its light comes out

U-B for hot star
R-I for cool star
The parallax star is LHS 2924.
It has apparent magnitude $m_v = 19.5$
and color $V-I = 4.4$.

Is the star bluer or redder than the 'average' star with $V-I = 0.5$?