Brightness of stars – measurement

Flux of energy ~~from~~ received from star f :

energy per unit area per unit time

units ergs/cm^2/sec

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)

$$f_1/f_2 = 100^{(m_2-m_1)/5}$$

Kirchoff's Laws

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

Examples??

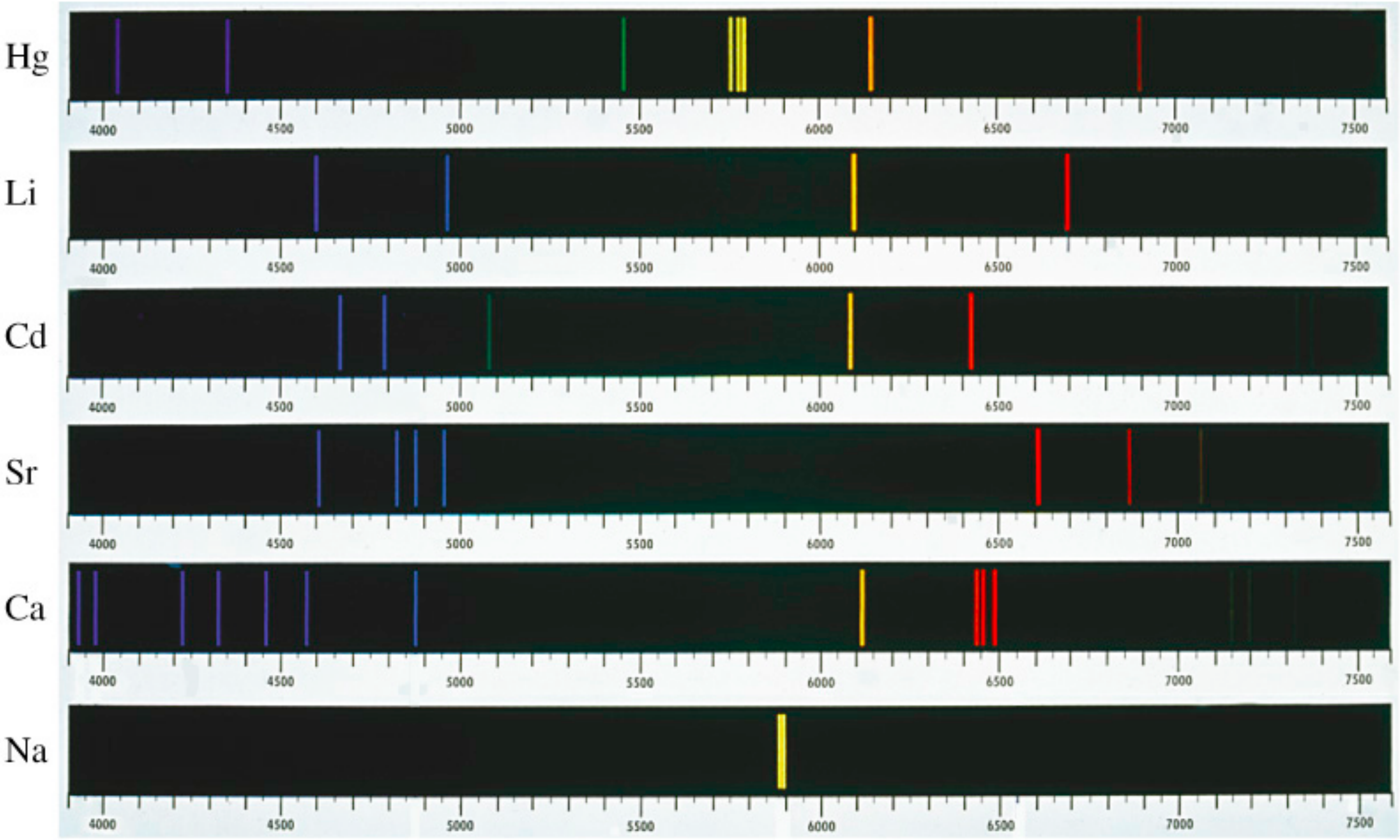
(ii) A hot diffuse gas produces bright emission lines (electron moves to orbital of lower energy)

Examples??

(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)

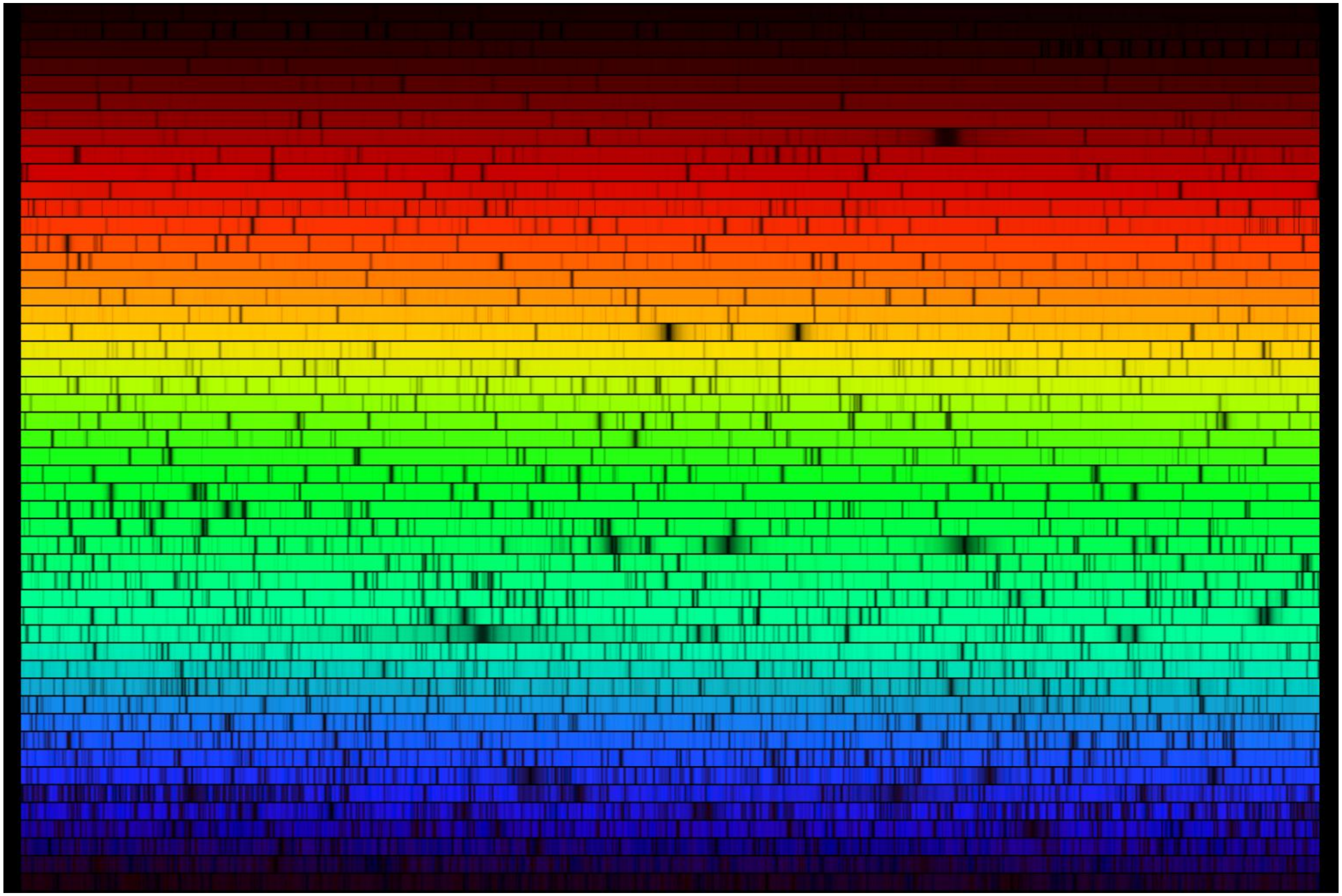
Example?

Emission line spectra: eg neon tube, Na or Hg street lights



Wavelength (Angstroms)

Absorption spectra: solar spectrum



NOAO

Wavelength axis horizontal; divided into strips and stacked vertically

Blackbody radiation

Continuous radiation from body in thermal equilibrium

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

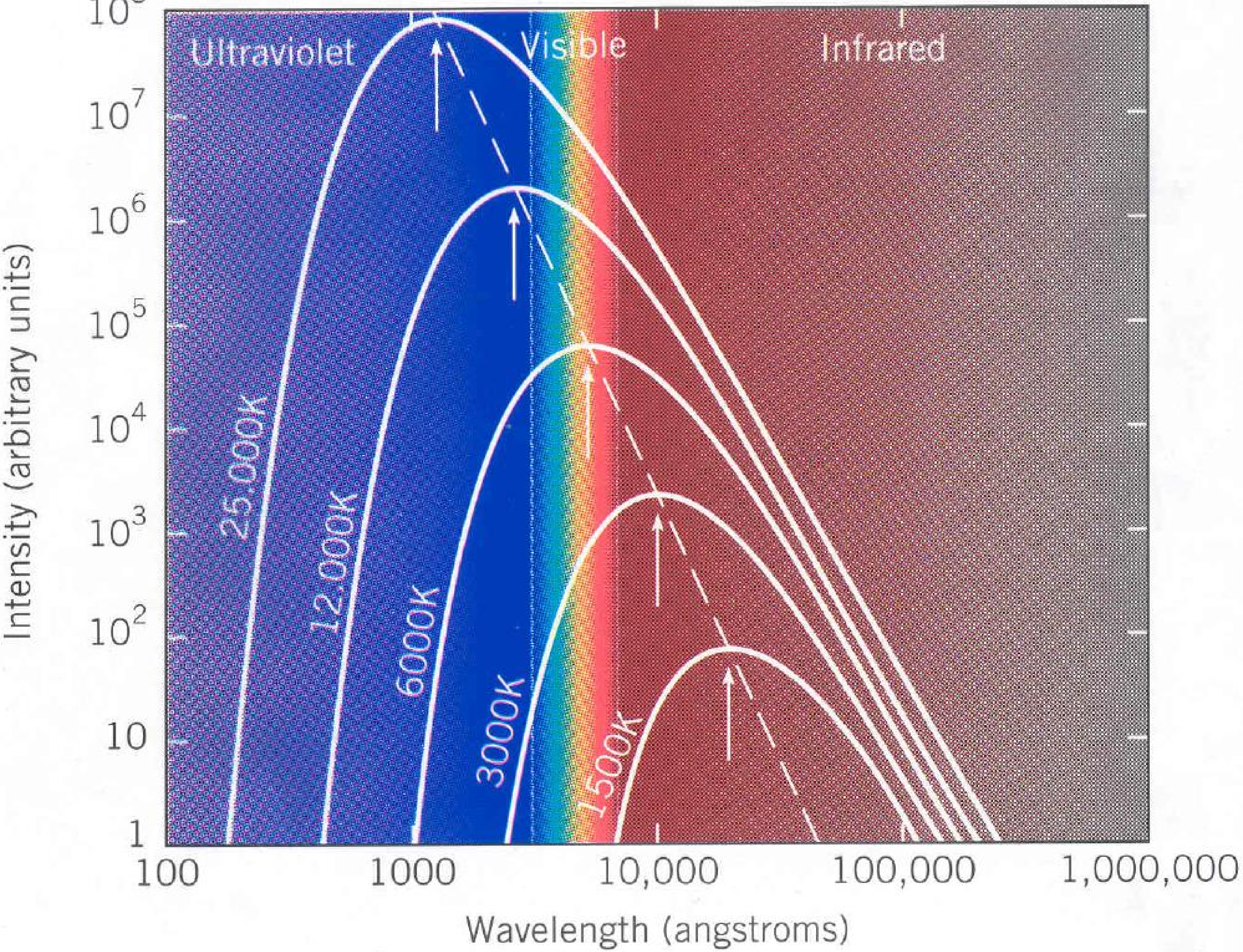
$$I(\nu, T) = \frac{2h\nu^3/c^2}{e^{h\nu/kT} - 1}$$

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

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

$$= \frac{2hc^2/\lambda^5}{e^{hc/\lambda kT} - 1}$$

(stars are reasonable approximations to blackbodies)



Ultraviolet
Visible
Infrared
25,000K
12,000K
6000K
3000K
1500K
Intensity (arbitrary units)
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10
1
100
1000
10,000
100,000
1,000,000
Wavelength (angstroms)

Wein's law

For a blackbody,

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

$(1 \text{ Å} = 10^{-10} m = 0.1 nm)$

Stefan - Boltzmann law

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

Energy / unit time / unit surface area (flux)

$$E = \sigma T^4$$

σ 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

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

> Note the difference between <u>luminosity</u>, an intrinsic property of a star, and <u>brightness</u>, how it appears on Earth, depends on both L and distance.

Q The temperature of a star tells us a lot (although not everything) about its physical & evolutionary state.

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

A

- Color
- 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)

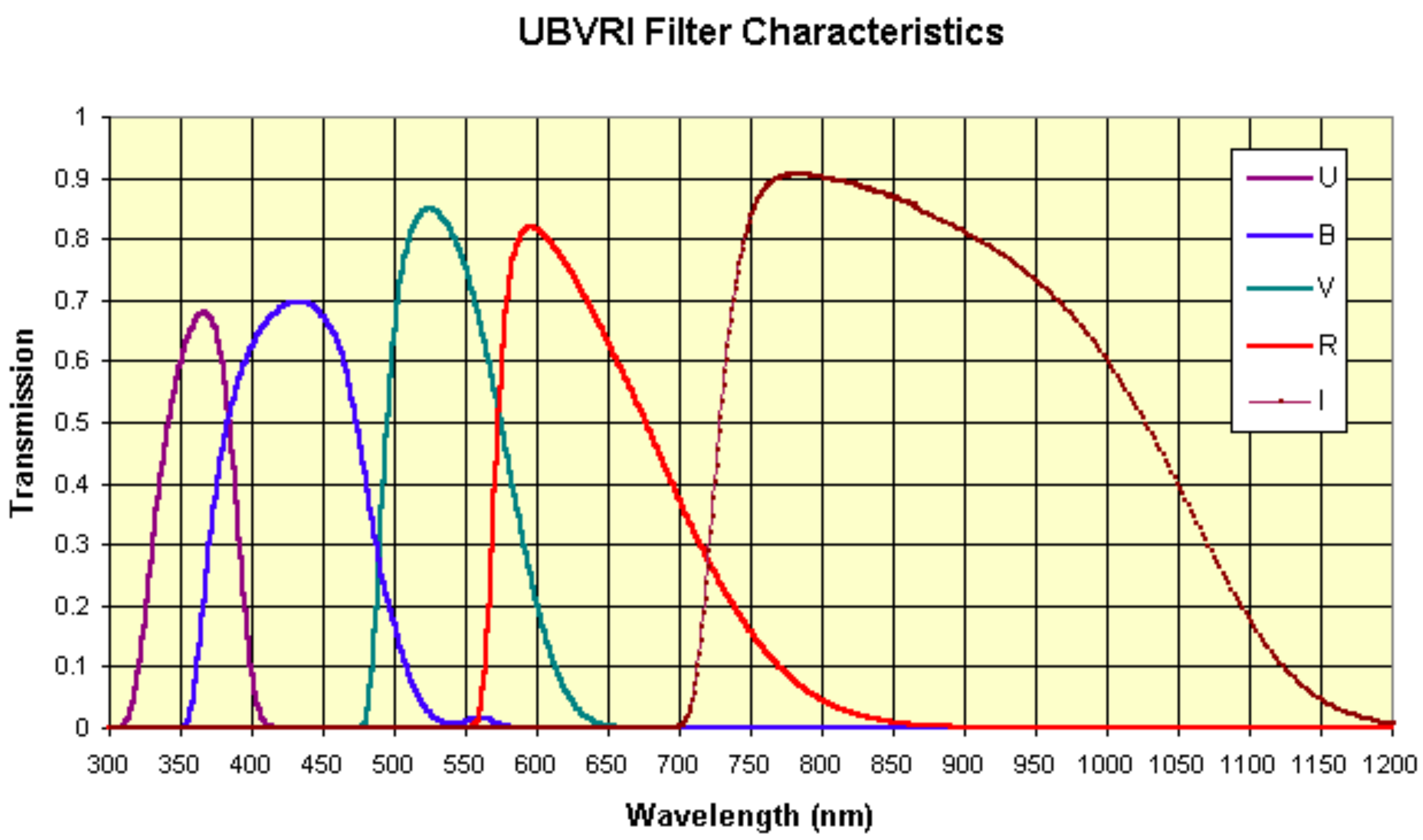
Colors are brightness ratios, so calculated by subtracting magnitudes

eg B−V color $= 2.5 \log_{10}\left(\frac{I_V}{I_B}\right)$

$= m_B - m_V$

(written for convenience B−V)

Common filter systems: UBVRI



ugriz : Sloan digital sky survey filters

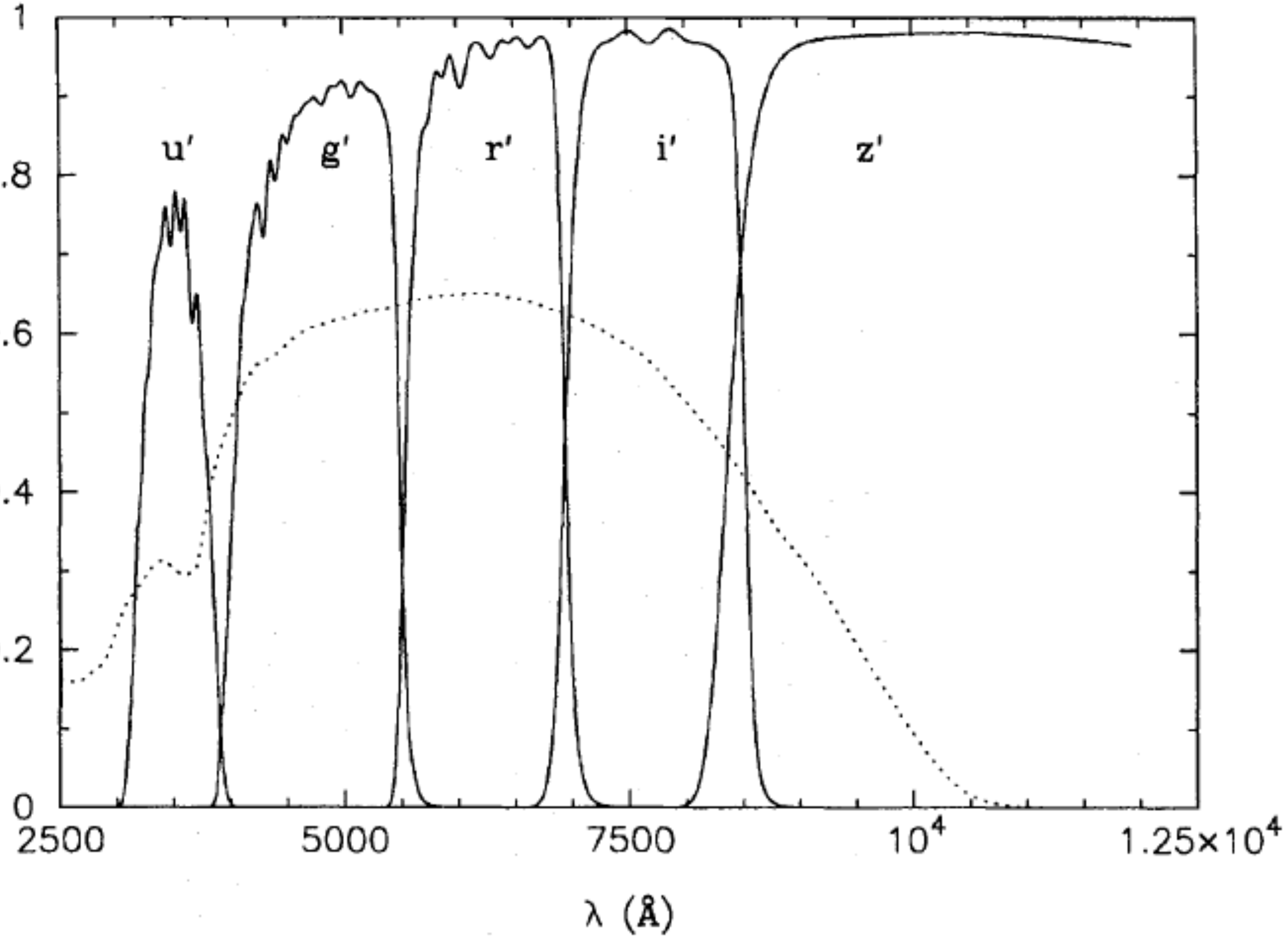


FIG. 1. Transmission of the $u'g'r'i'z'$ filters. Redleaks shortward of 11,000

Magnitudes

- We measure stellar brightness through a filter: the magnitude measured through the V filter is known as the V magnitude, etc
- Colors are ratios of brightness through different filters, and since magnitudes are logs, we talk about, say, the B-V color

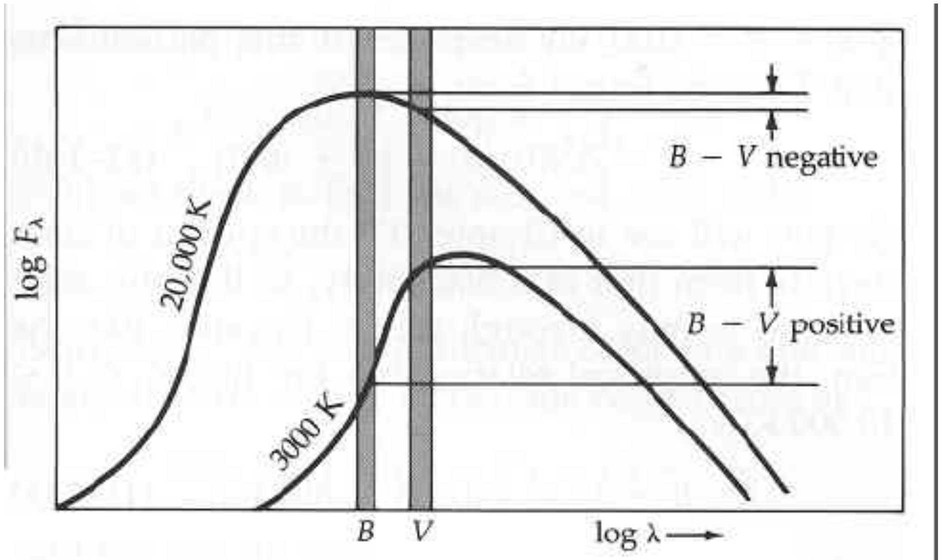


Figure 11–4 Color index in the *BV* system. Blackbody curves for 20,000 and 3000 K, along with their intensities at *B* and *V* wavelengths. Note that $B - V$ is negative for the hotter star and positive for the cooler one.

Q Stellar temperatures range from > 20,000 K to ~ 3000 K.

~~Why~~ 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