Class Exercise

Flux is related to the luminosity by

$$f = \frac{L}{4\pi d^2}$$

The luminosity of the Sun is 4×10^{26} W and the Earth-Sun distance is 1 AU $= 1.5 \times 10^{11}$ m. So

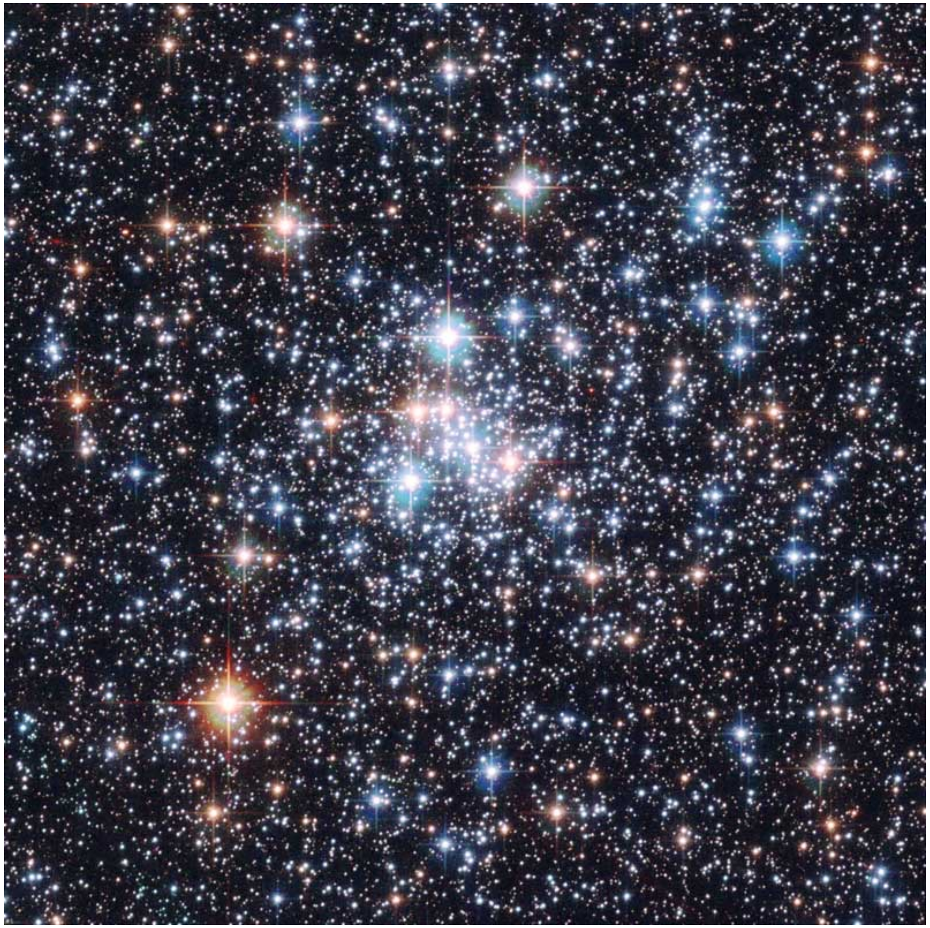
$$f = \frac{4 \times 10^{26}}{4\pi \left(1.5 \times 10^{11}\right)^2}$$

$= 1400$ Wm^{-2}

A typical solar panel produces ~500 Wm^{-2}

Magnitudes and Colours

- Brightness
- Apparent magnitude
- Absolute magnitude
- Colour



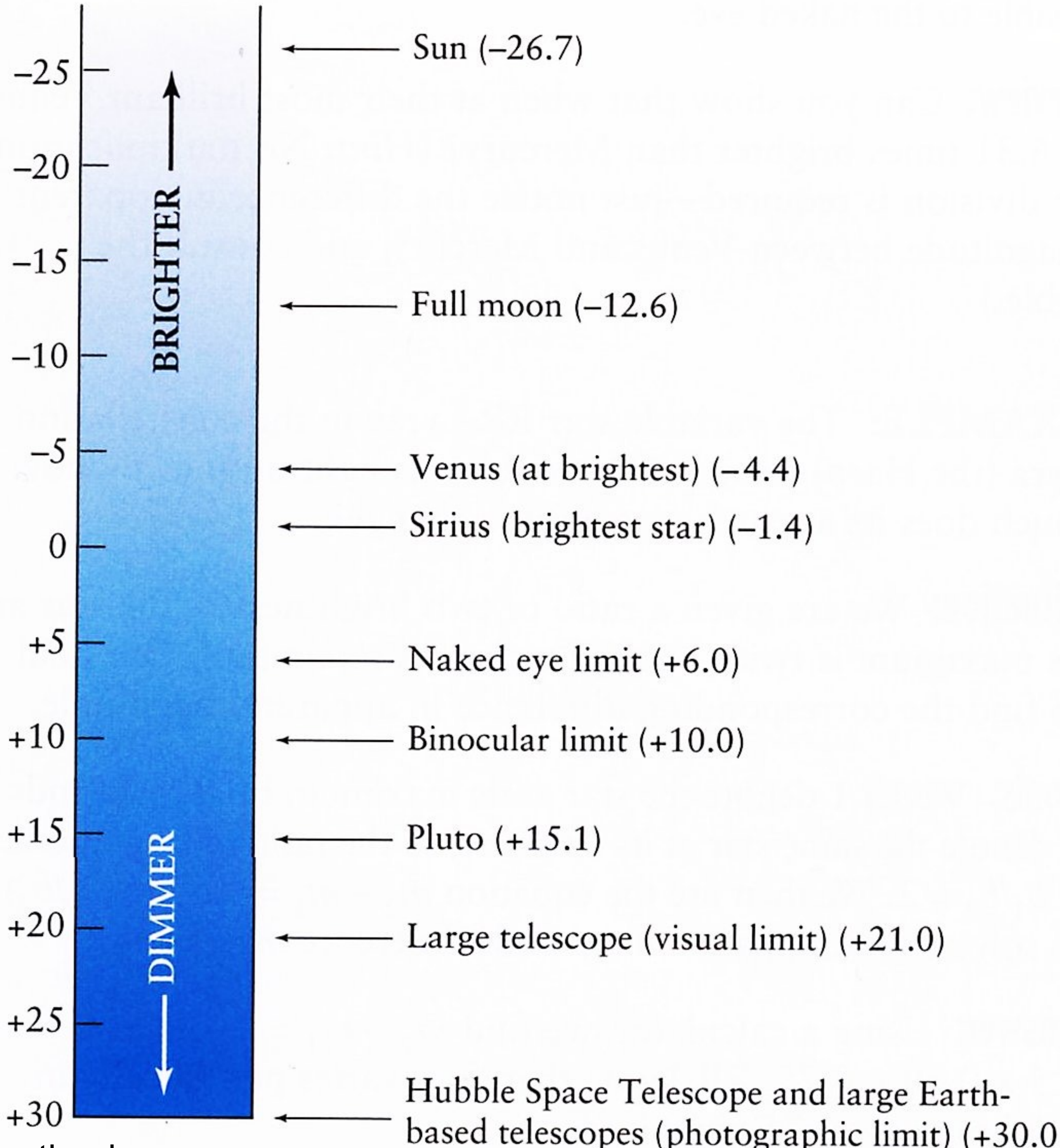
Brightness

- apparent brightness of stars is measured in magnitudes.
- historically this was a 1 to 6 scale for stars visible to the naked eye.

  magnitude 1 = brightest

  magnitude 6 = faintest

- now magnitude is quantified as a logarithmic scale, such that a difference of 5 magnitudes corresponds to a factor of 100 in monochromatic flux, f_λ



From Universe textbook

Pogson's Relation

- the apparent magnitudes of two stars m_1 and m_2 are related to their fluxes f_1 and f_2 by

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

$$= 10^{2(m_2 - m_1)/5} = 10^{0.4(m_2 - m_1)}$$

$$\therefore \log\frac{f_1}{f_2} = \frac{2}{5}(m_2 - m_1)$$

$$m_2 - m_1 = 2.5\log\frac{f_1}{f_2}$$

known as Pogson's Relation

Class Example

- How many times fainter can the Hubble Space Telescope see (limiting magnitude +30.0) compared to a large ground-based telescope with limiting magnitude +21.0?

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$$m_2 - m_1 = 2.5\log\frac{f_1}{f_2}$$

$$30 - 21 = 2.5\log\frac{f_1}{f_2}$$

$$\log\frac{f_1}{f_2} = \frac{9}{2.5} = 3.6$$

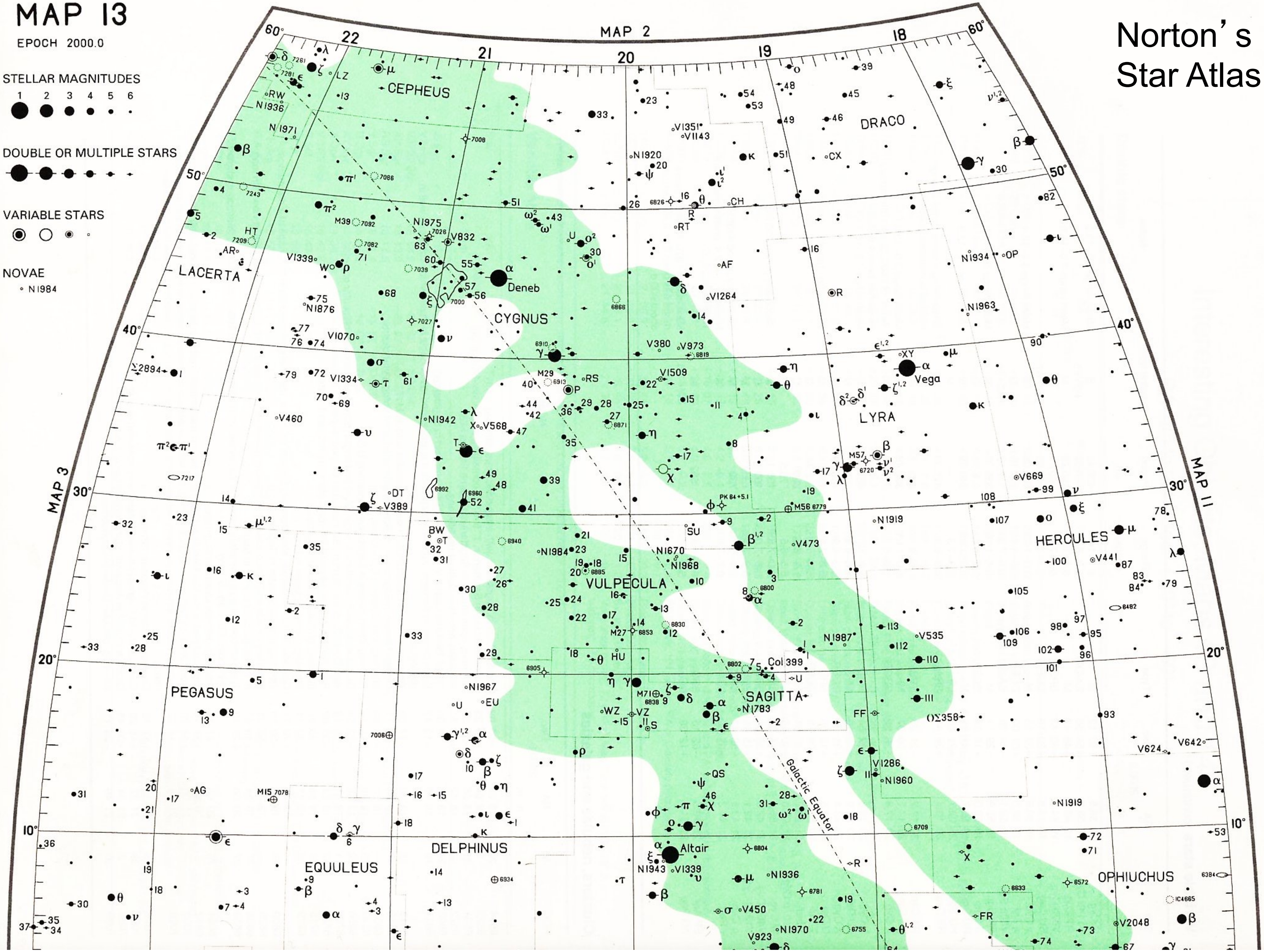
$$\frac{f_1}{f_2} = 10^{3.6} = 4000$$

Apparent Magnitude

- The apparent magnitude, m, of a star is defined relative to the star Vega, which is defined to have a magnitude of zero.
- The flux of Vega is referred to as the 'zero magnitude flux' and is the zero point for the magnitude scale.

MAP 13
EPOCH 2000.0

Norton's Star Atlas



Absolute brightness

- Apparent brightness depends on both the luminosity or power *L* (W) of the star and its distance *d* (m or pc)
- (the parsec (pc) will in Workshop 2)
- An intrinsically luminous star which is far away can have a similar apparent brightness to an intrinsically faint one nearby.

Absolute Magnitude

- To compare absolute brightness need to define a reference distance D.
- Absolute magnitude M is the apparent magnitude a star would have if it was at a distance D=10 parsecs.

Since $\dfrac{f(D)}{f(d)} = \left(\dfrac{d}{D}\right)^2$

$$m - M = 2.5\log\frac{f(D)}{f(d)} = 2.5\log\left(\frac{d}{D}\right)^2$$

Taking $D = 10$ pc and if d is in pc

$$m - M = 5\log\frac{d}{10}$$

$$m - M = 5\log d - 5$$

Class Example

- What is the absolute magnitude of the star Betelgeuse that has apparent magnitude m=+0.5 and distance of 220 pc?

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$$m - M = 5\log d - 5$$

$$M = m - 5\log d + 5$$

$$= 0.5 - 5\log 220 + 5$$

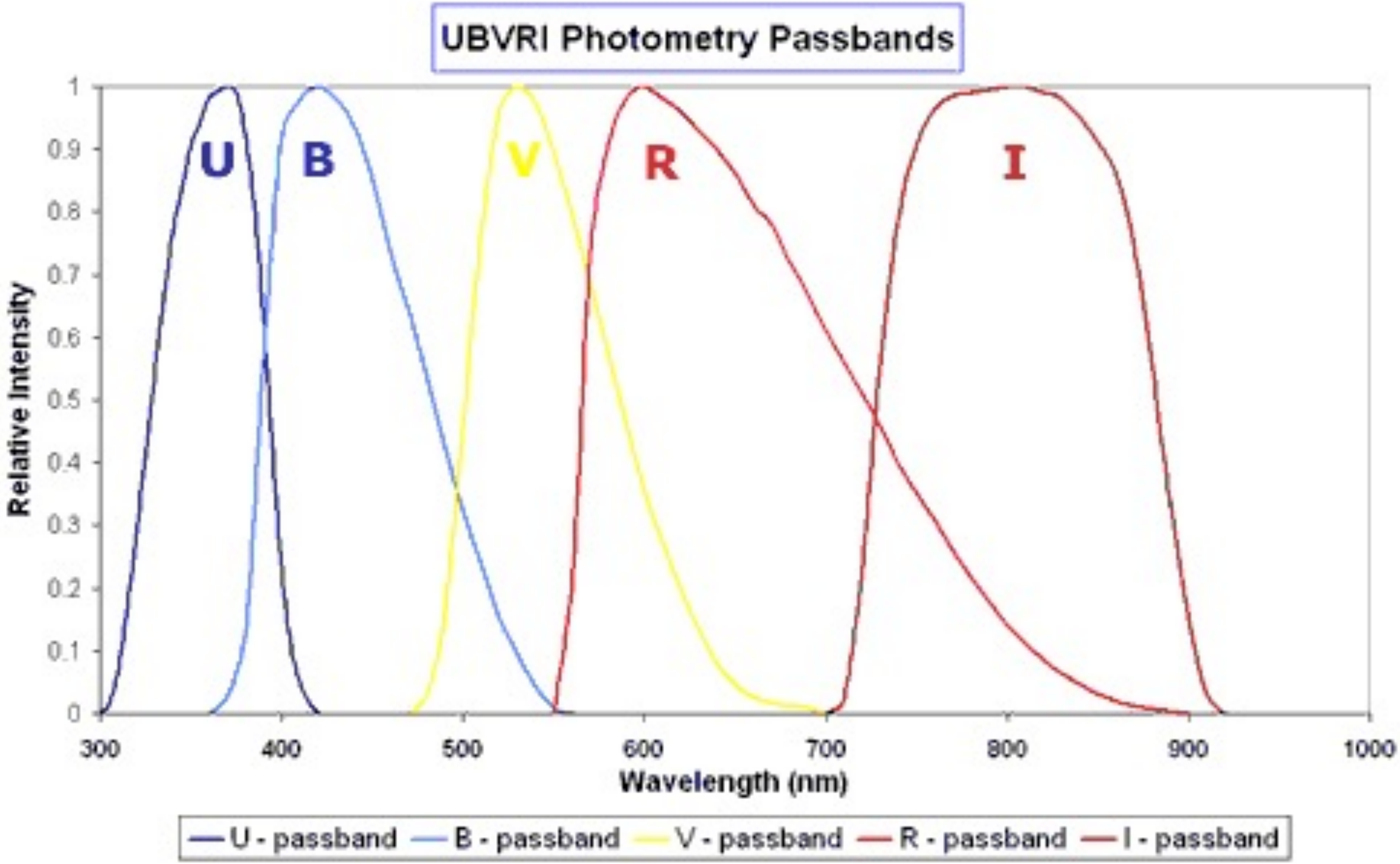
$$= -6.2$$

- Compare to the Sun that has *M*=+4.8

Stellar Colours

- Stars will have different brightnesses in different wavelength regions.
- Hot stars are relatively blue
- Cool stars are relatively red.
- Measure this by obtaining brightness through different filters such as the Blue (B band) at 430 nm and Visible (V band) at 550 nm

Credit: ESA & NASA; Acknowledgement: E. Olszewski (U. Arizona) HST



Credit: Data from M. Bessell

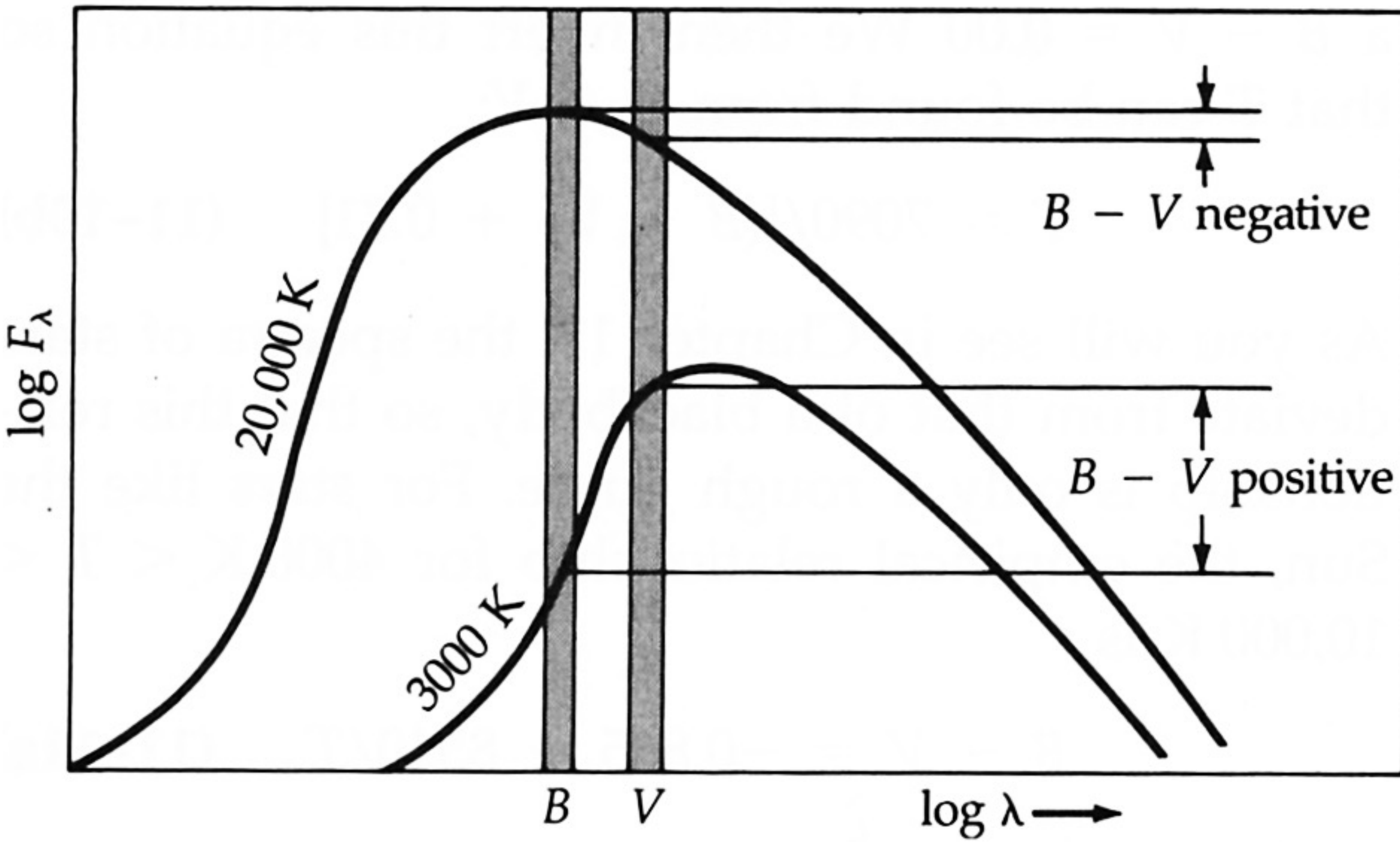
B-V Colour

- can measure apparent magnitude through these filters to give:

  m_B and m_V also written as B and V
- if $m_B < m_V$ or B-V is negative then the star is blue
- if $m_B > m_V$ or B-V is positive then the star is red

Zero Point

- Magnitudes are calibrated relative to the star Vega which is defined to be zero magnitude in all wavebands
- Vega (T_{eff}=10 000 K) $m_B = m_V = 0.0$ and B-V=0.0
- Other examples:
  - Sun (T_{eff}= 5 800 K) has B-V=+0.6
  - ε Ori (T_{eff}=25 000 K) has B-V=-0.2



From Zeilik Fig 11-4

Summary

- the logarithmic magnitude scale is used to measure the brightness of star, both apparent and absolute
- the brightness of stars in different colour filters is used to quantify the colour of stars
- the colour of a star is related primarily to its surface temperature

Class Example

- The star Vega is used as the standard star for the magnitude system and has its magnitude at all wavebands defined as 0. The flux measured in the V-band for Vega is $f_{m=0}$=3.8x10^{-11} Wm^{-2}nm^{-1}. What is the V-band flux for a star with an apparent magnitude m_V =26.0?