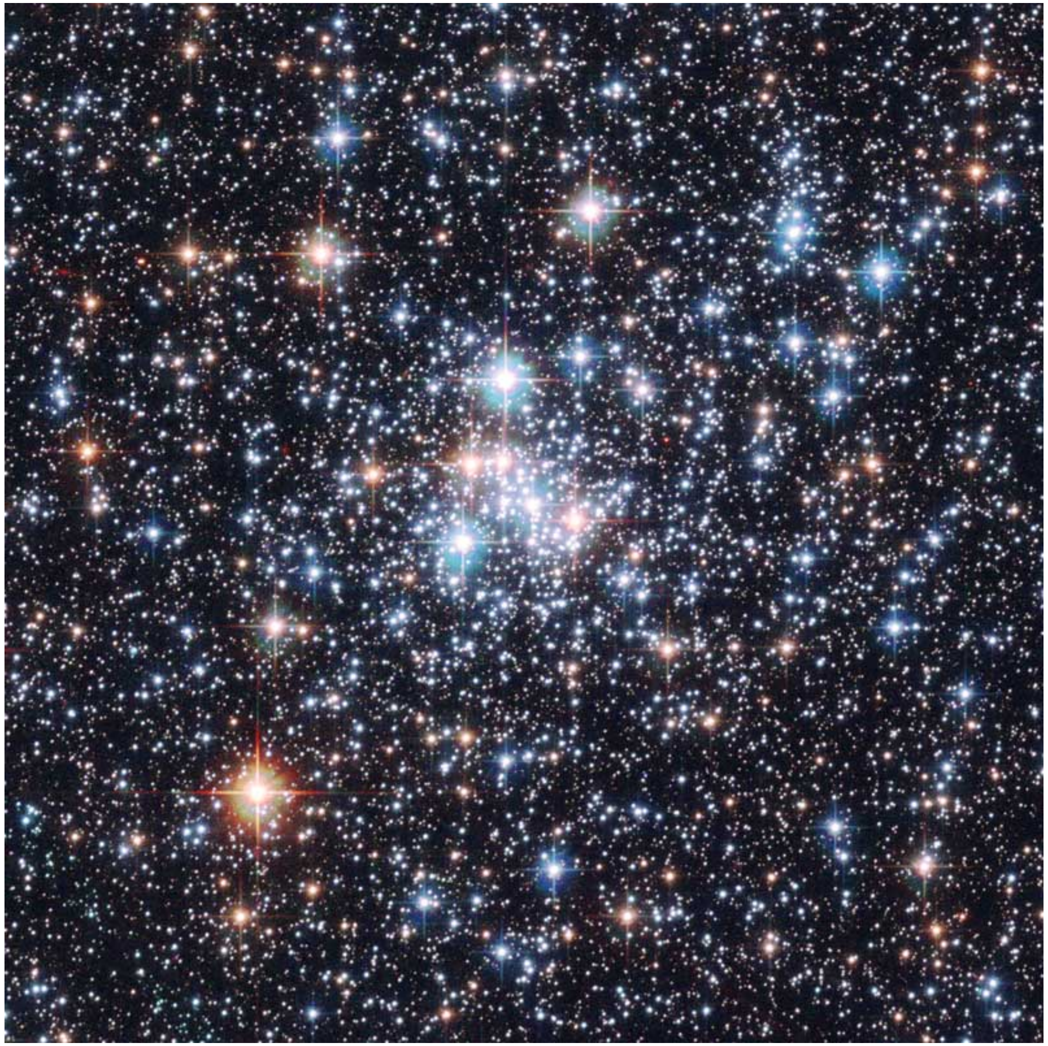
Magnitudes and Colours

- Brightness
- Apparent magnitude
- Absolute magnitude
- Colour



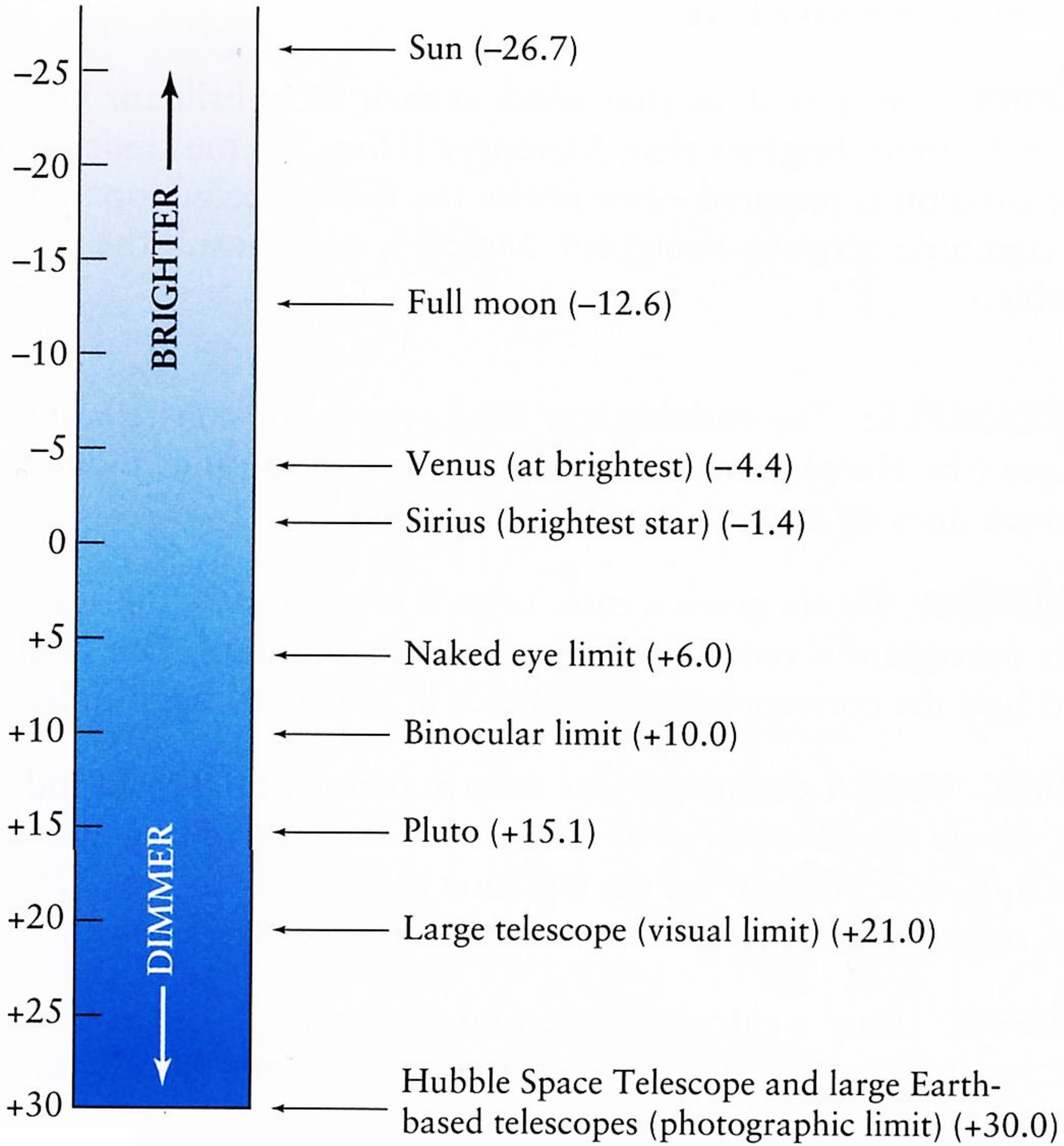
Brightness

- 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 brightness or monochromatic flux, f_λ in $Wm^{-2}\ \mu m^{-1}$



−25
−20
−15
−10
−5
0
+5
+10
+15
+20
+25
+30
BRIGHTER
DIMMER
Sun (−26.7)
Full moon (−12.6)
Venus (at brightest) (−4.4)
Sirius (brightest star) (−1.4)
Naked eye limit (+6.0)
Binocular limit (+10.0)
Pluto (+15.1)
Large telescope (visual limit) (+21.0)
Hubble Space Telescope and large Earth-based telescopes (photographic limit) (+30.0)

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

How bright is a star with a magnitude of +4.0 compared to a star with magnitude +5.0?

A. $1/2.5 = 0.4$ times as bright
B. equally bright
C. 1.25 times brighter
D. 2.5 times brighter
E. 10 times brighter

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

$$5 - 4 = 2.5 \log \frac{f_1}{f_2}$$

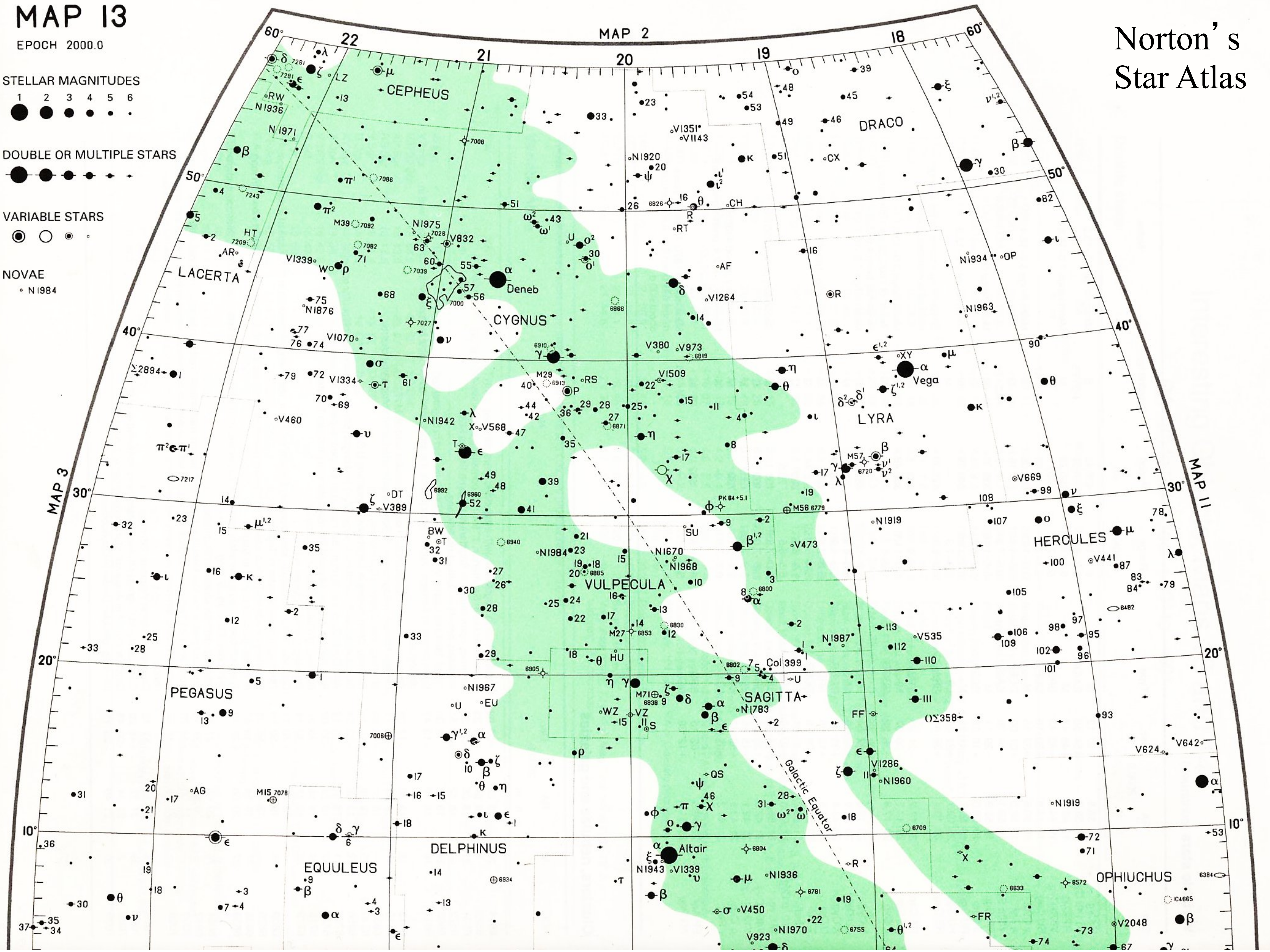
$$\log \frac{f_1}{f_2} = \frac{1}{2.5} = 0.4$$

$$\frac{f_1}{f_2} = 10^{0.4} = 2.51$$

Apparent Magnitude

- The apparent magnitude, *m*, of a star was defined relative to the star Vega.
- The flux of Vega is referred to as the 'zero magnitude flux' for Vega magnitudes.
- Modern magnitude scales are based on SI units rather than Vega ($m_{AB} = 0$ is a defined flux density, about 3631 Jy)
- m_{AB}-m_{Vega} around 0.1 mag in B, V, R

Norton's Star Atlas



Absolute brightness

- Apparent brightness depends on both the luminosity or power L (W or Js^{-1}) of the star and its distance d (m or pc)
- An intrinsically luminous star which is far away can have a similar apparent brightness to an intrinsically faint one nearby.
- To compare absolute brightness need to define a reference distance D.

Absolute Magnitude

- Absolute magnitude, *M,* is the apparent magnitude a star would have if it was at a distance D=10 parsecs.

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

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

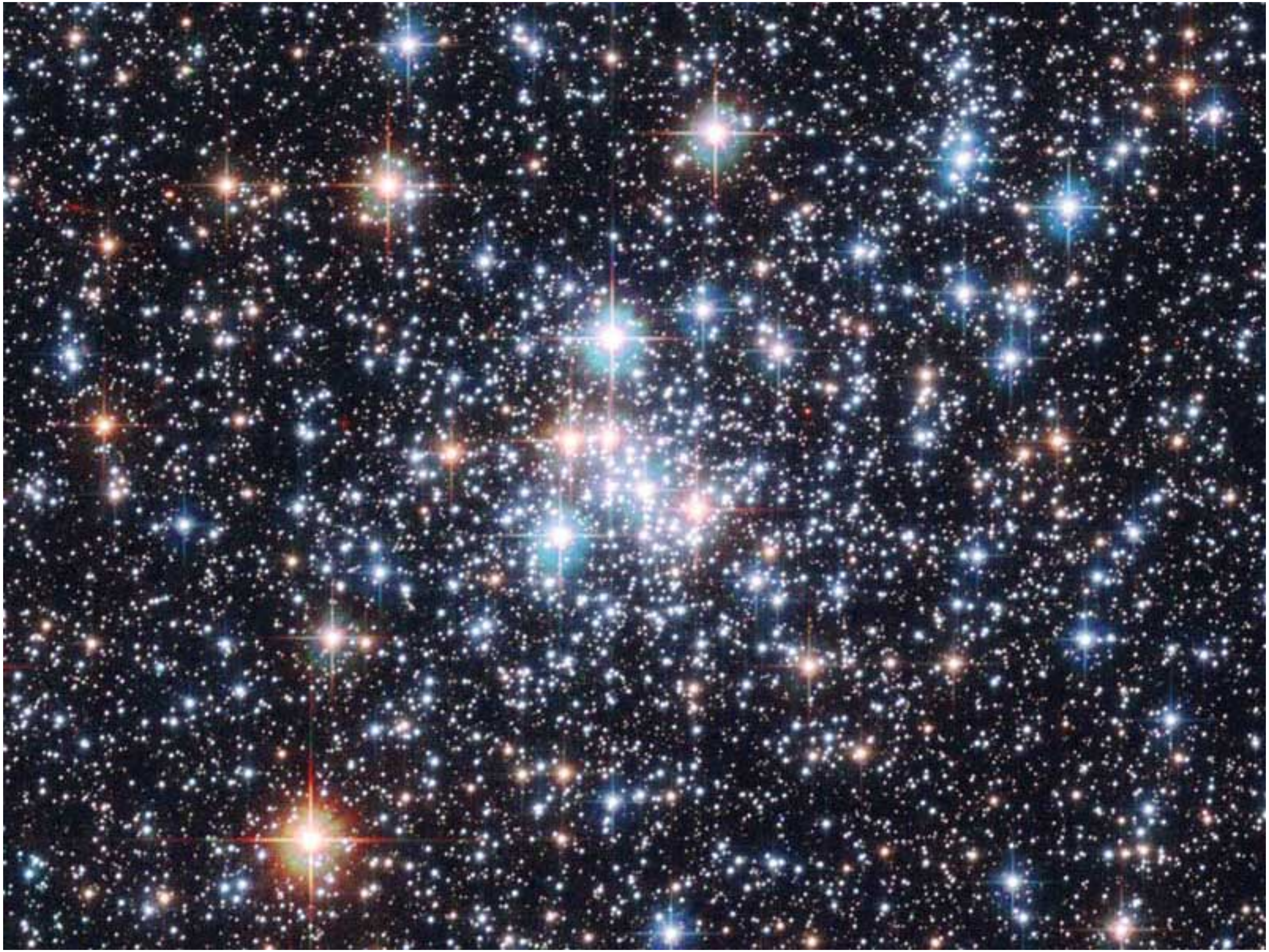
Taking $D = 10$ pc and if d is in pc

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

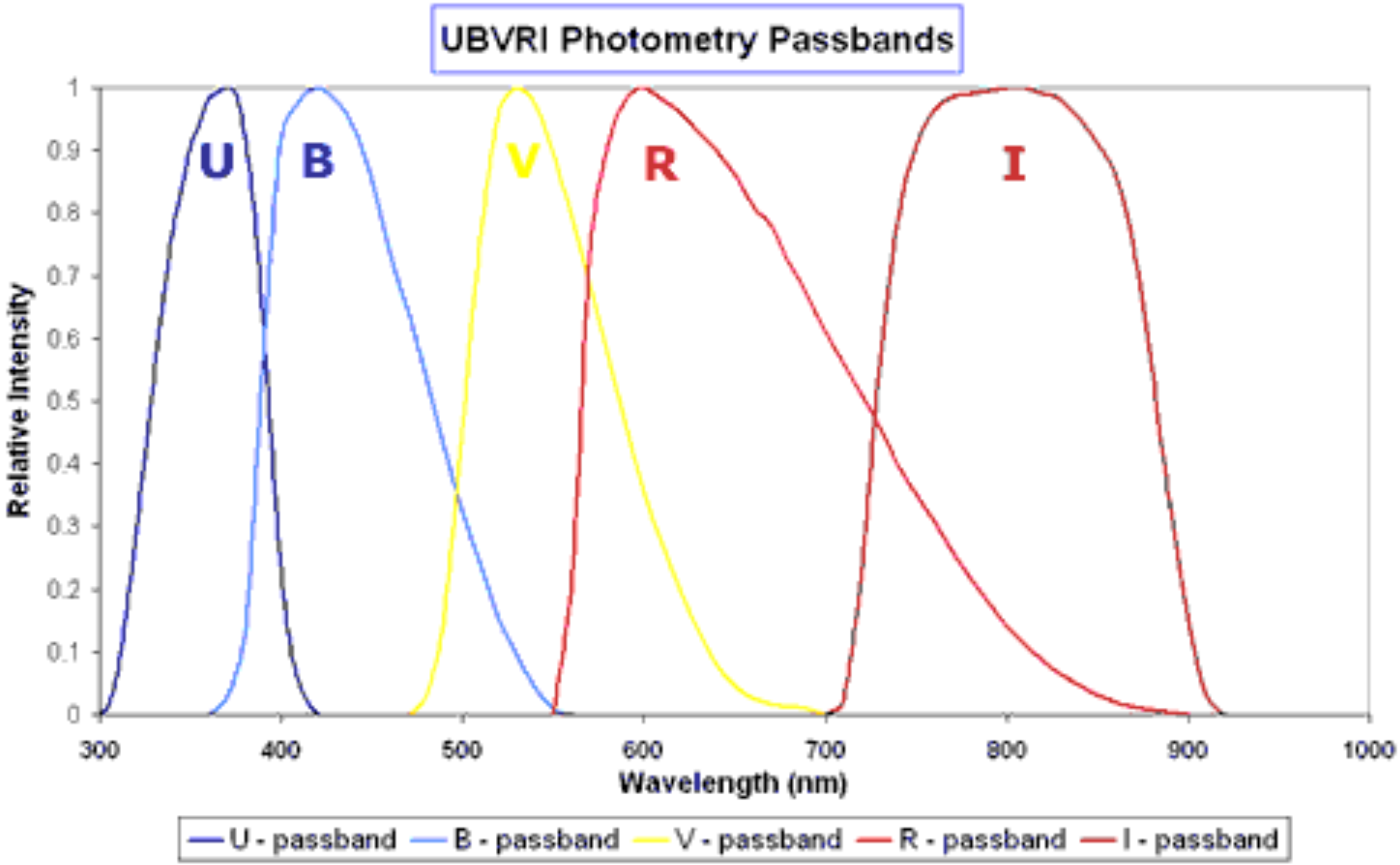
$$m - M = 5\log d - 5$$

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

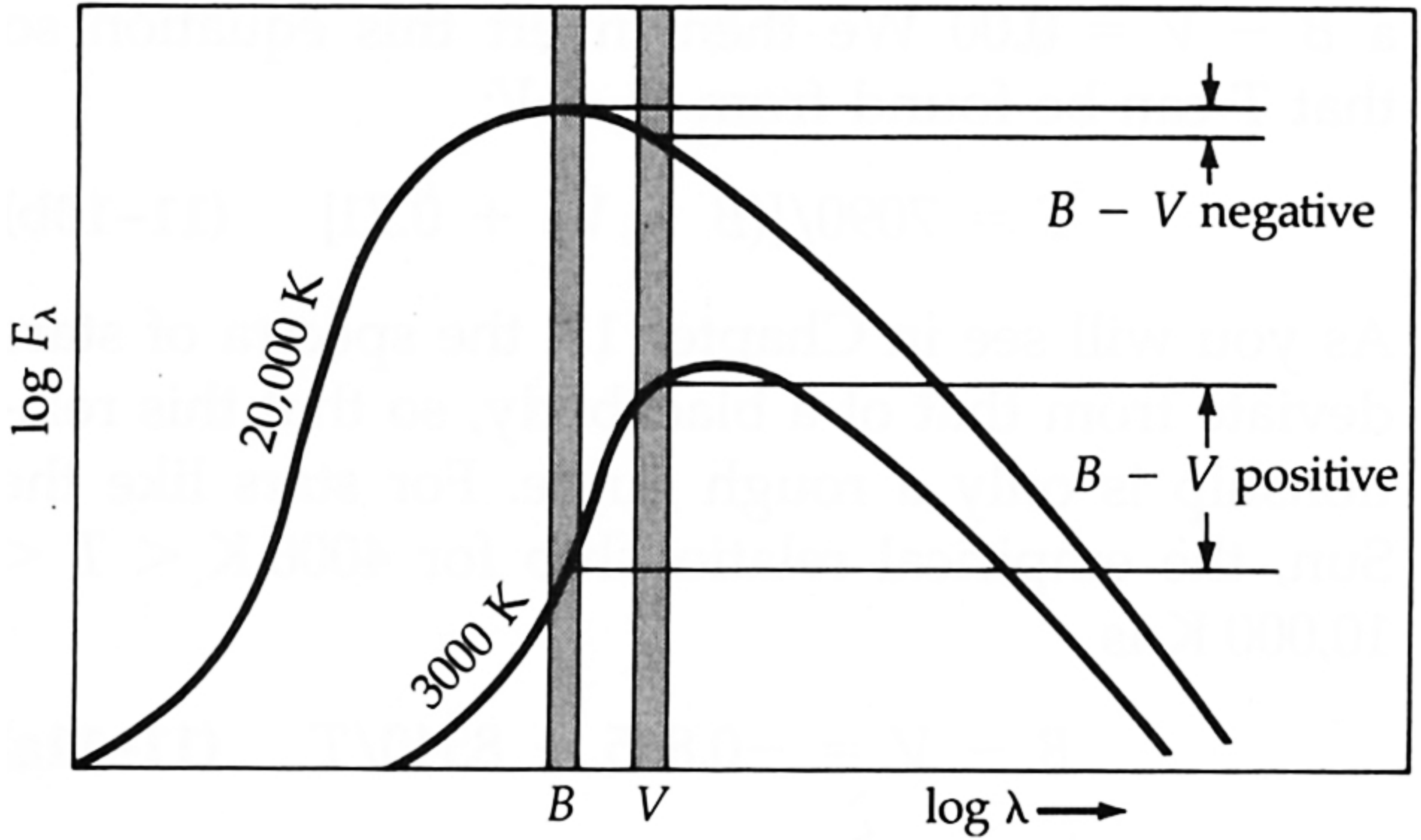
- can measure apparent magnitude through these filters to give:

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
- magnitude 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

  whilst the Sun (T_{eff}=5 800 K) has B-V=+0.6

  and e.g. ε Ori (T_{eff}=25 000 K) has B-V=-0.2



Zeilik Fig 11-4

Summary

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