

Review

temperature : T

flux at star surface: $B(T) = \mathbf{s} T^4$

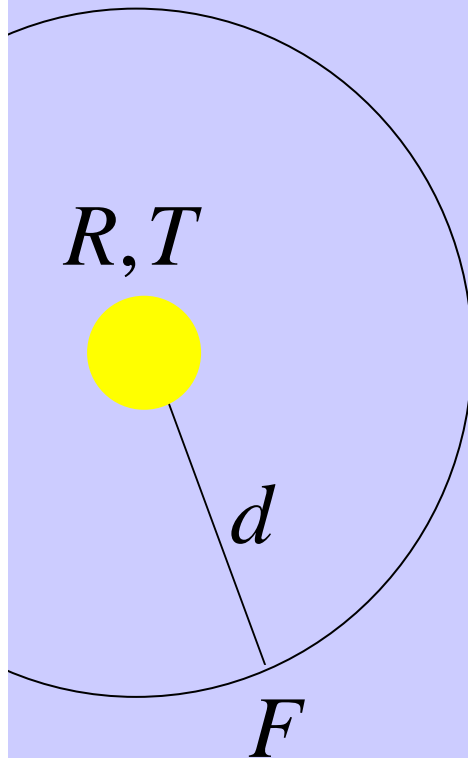
radius : R area : $4\mathbf{p} R^2$

luminosity : $L = 4\mathbf{p} R^2 \mathbf{s} T^4$

distance : d area : $4\mathbf{p} d^2$

luminosity : $L = 4\mathbf{p} d^2 F$

flux : $F = \frac{L}{4\mathbf{p} d^2} = \mathbf{s} T^4 \left(\frac{R}{d} \right)^2$



White Dwarf vs Red Giant

(Earth-sized star)

$$R_1 = 0.01 R_{\text{sun}} \quad \circ$$

$$T_1 = 30,000 \text{ K}$$

$$R_2 = 100 R_{\text{sun}}$$

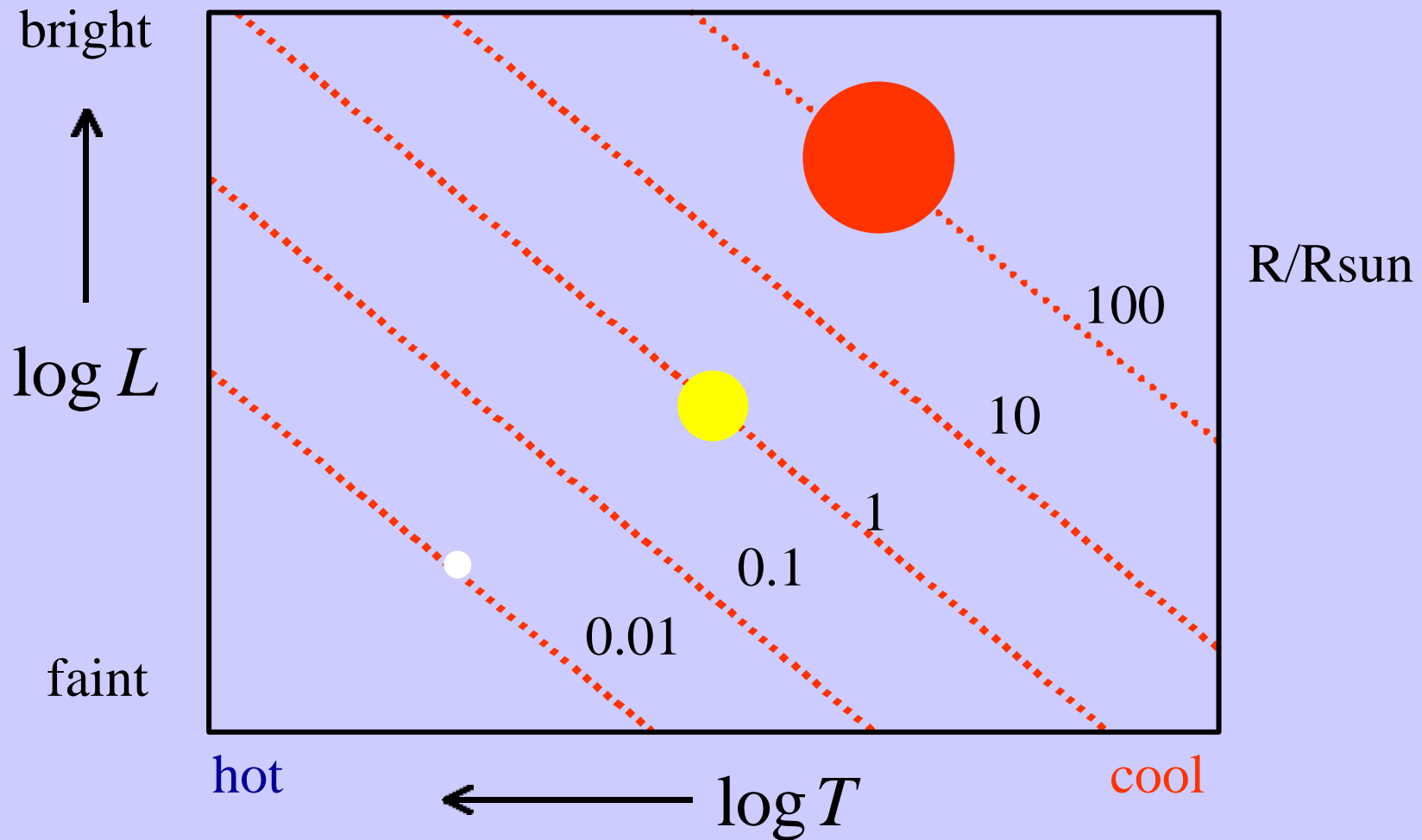
$$T_2 = 3,000 \text{ K}$$

$$\left(\frac{L_1}{L_2} \right) = \left(\frac{R_1}{R_2} \right)^2 \left(\frac{T_1}{T_2} \right)^4$$
$$= 10^{-8} \times 10^4 = 10^{-4}$$

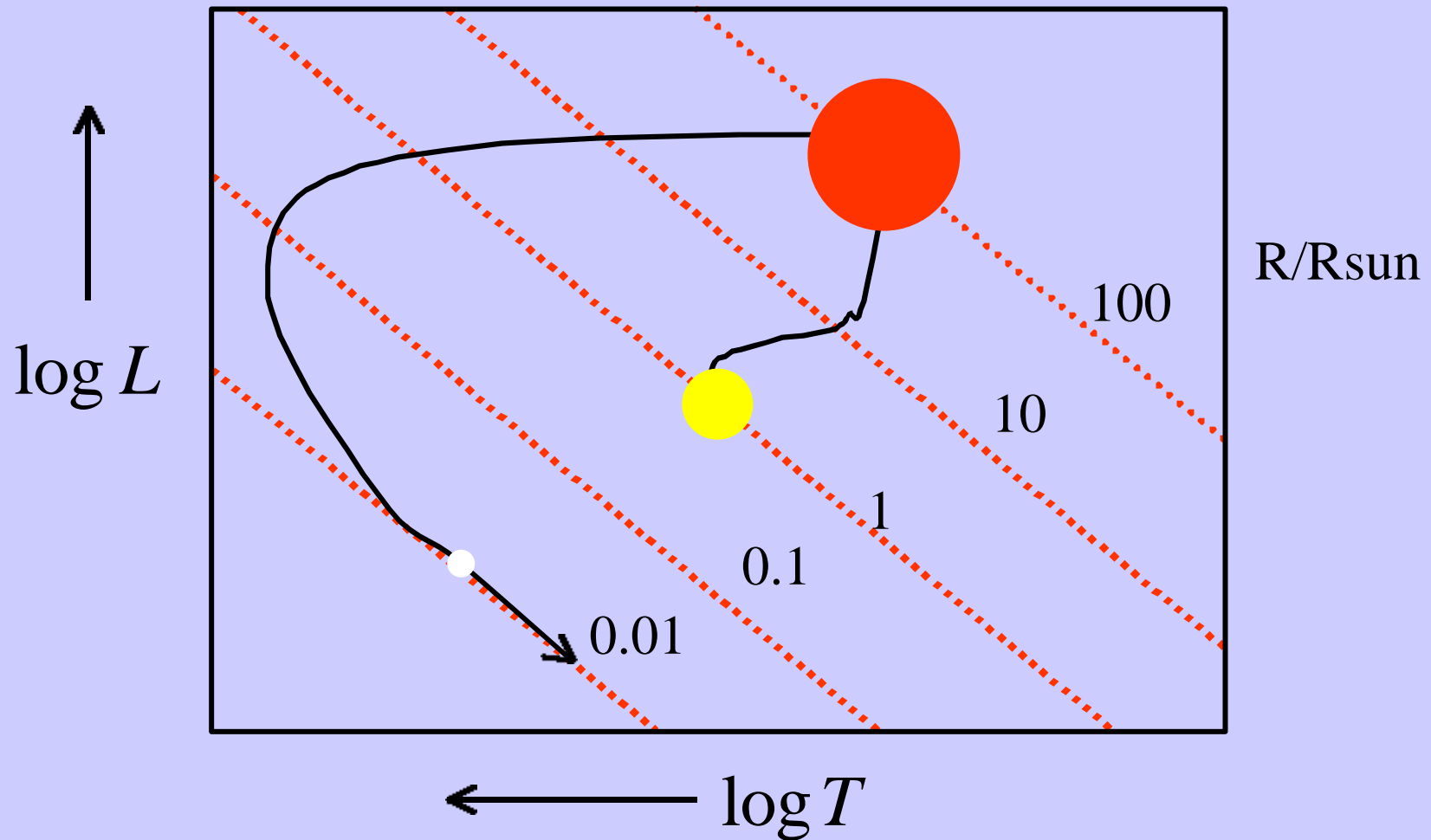
$$L = 4\pi R^2 \sigma T^4$$

$$\log L = \log(4\pi\sigma) + 2 \log R + 4 \log T$$

$$\log L = 2 \log R + 4 \log T + \text{const}$$



Our Sun's Future



How a Star works

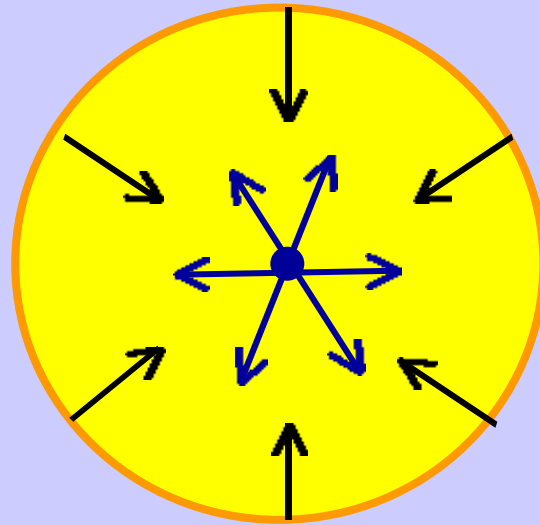
Nuclear furnace

H --> He --> C, N, O, ... Fe

Hot gas pushes out.

Force:

$$F_{\text{out}} \sim \frac{k T M}{m R}$$



Gravity pulls in.

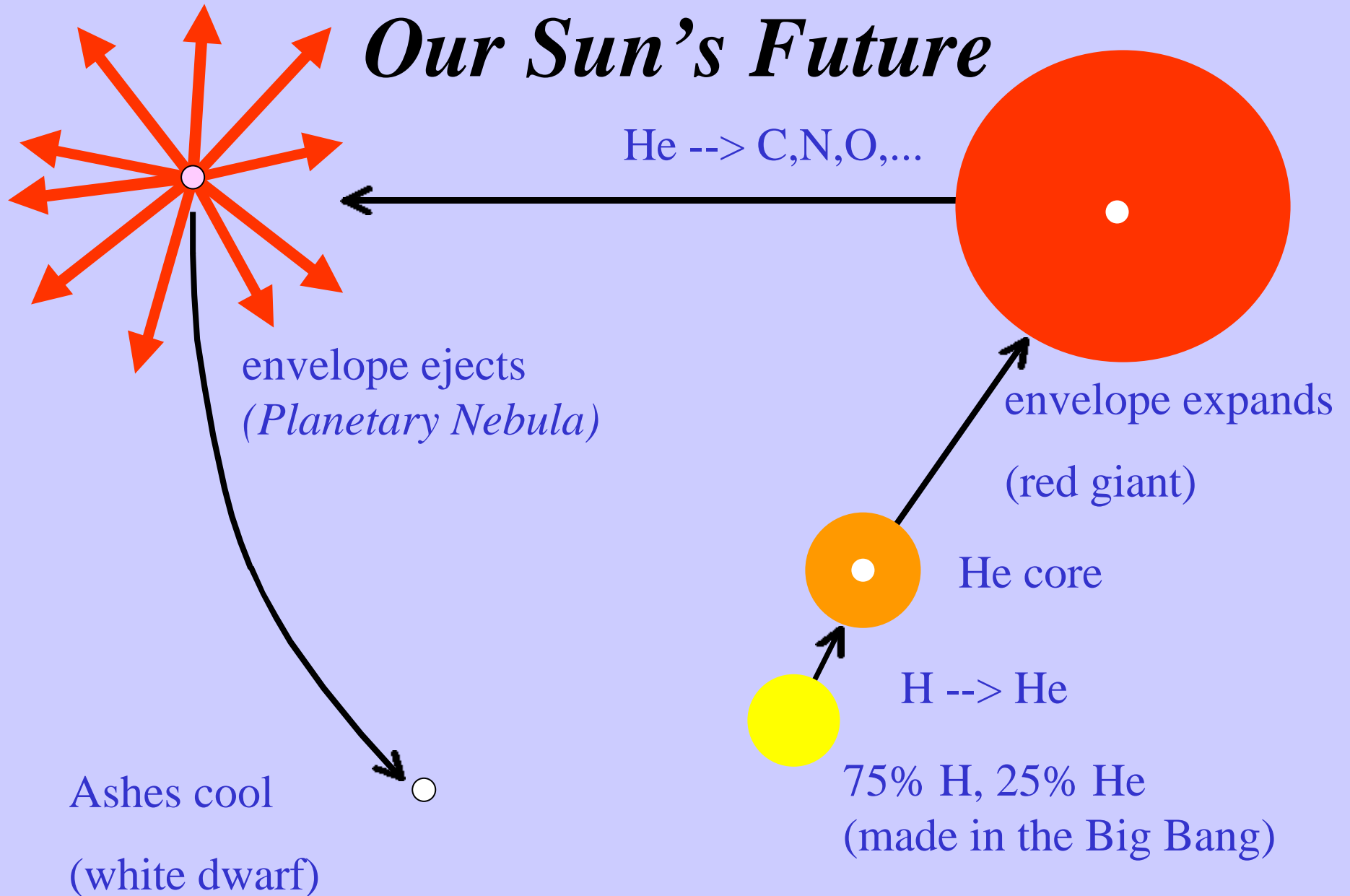
Force:

$$F_{\text{in}} \sim \frac{G M^2}{R^2}$$

Sun's Core Temperature:

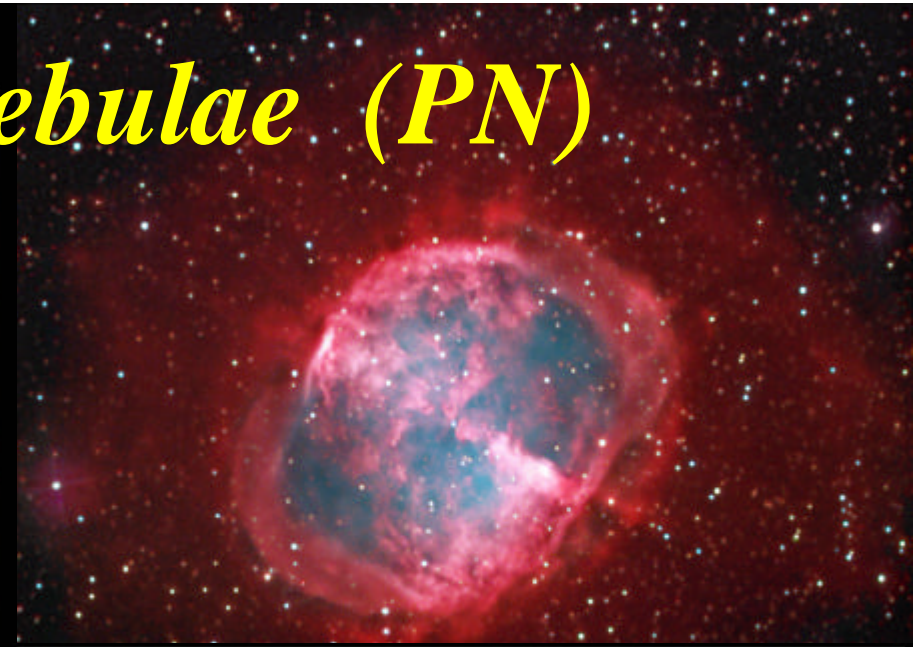
$$T \sim \frac{G M m}{k R} \approx 2 \times 10^7 \text{ K}$$

Our Sun's Future



The Egg Nebula

Planetary Nebulae (PN)



Planetary Nebula NGC 3132



Hubble

Dumbbell Nebula (M27)



The Egg Nebula

Egg Nebula (polarised)



Planetary Nebula NGC 3132

NGC 3132



Hubble
Heritage

Hourglass



The Egg Nebula



Hubble
Heritage

Planetary Nebula NGC 3132

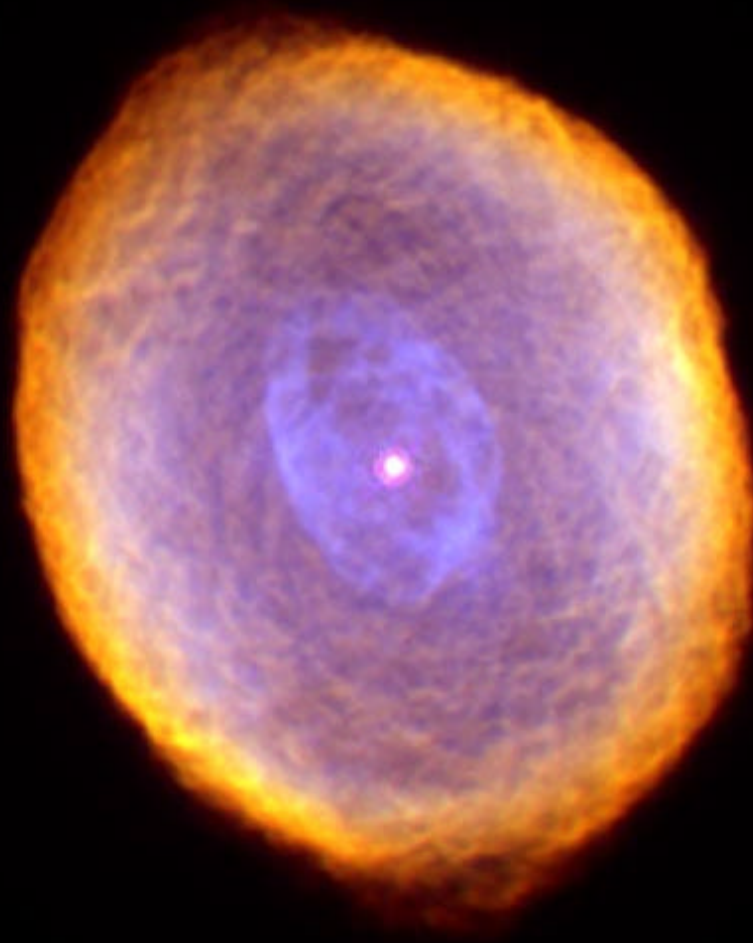


Hubble
Heritage



Planetary Nebula IC 418

Spirograph



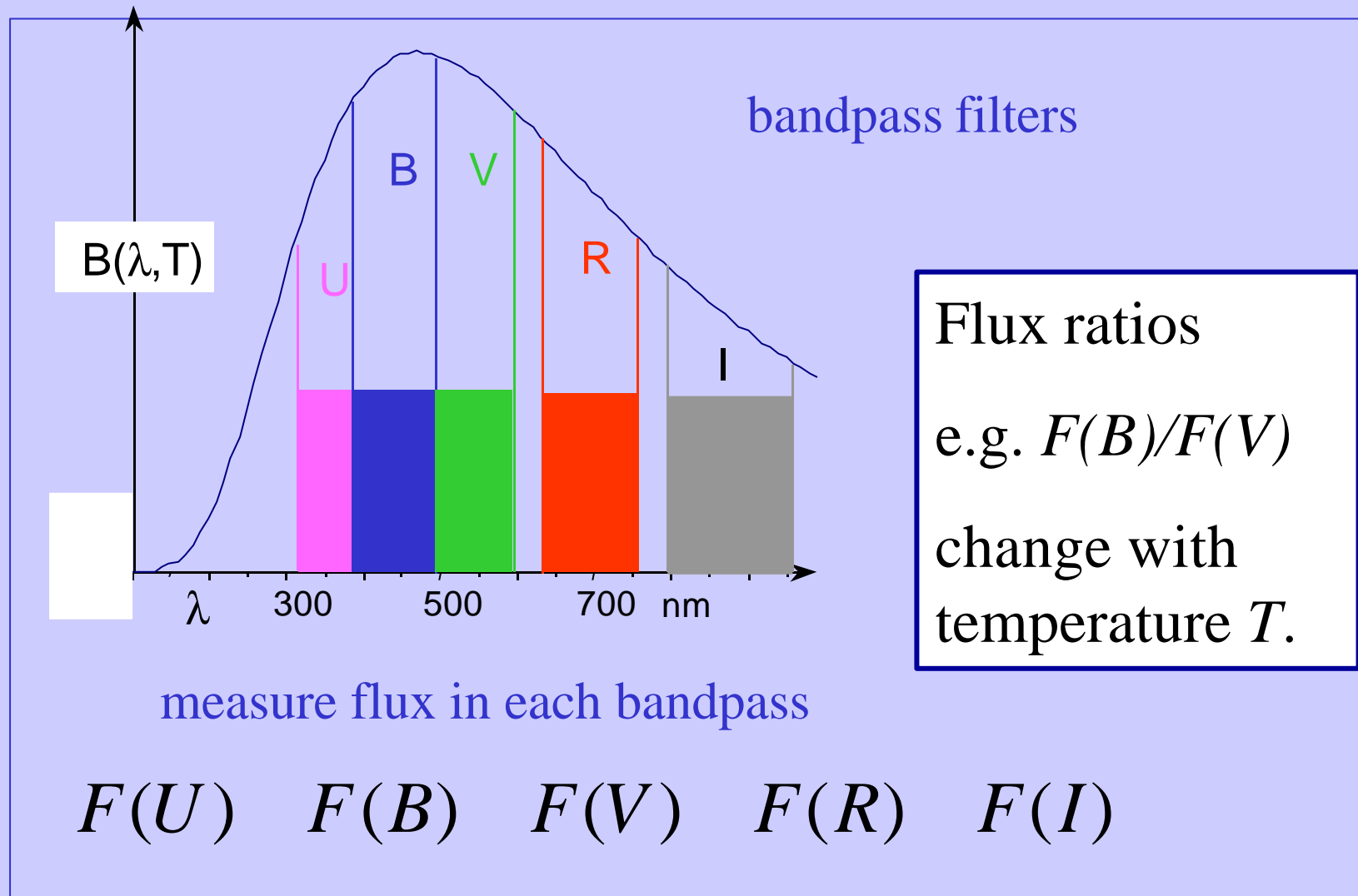
Hubble
Heritage

Ring (M57)



*Death of a Star,
Birth of a White Dwarf*

Broadband Photometry



refspec=\$XCVEGA/vega.dat
obsmode=@UBVRI

Vega Spectrum

f_{λ} (ergs cm⁻² s⁻¹ Å⁻¹)

4000 6000 8000 10⁴

wavelength (Å)

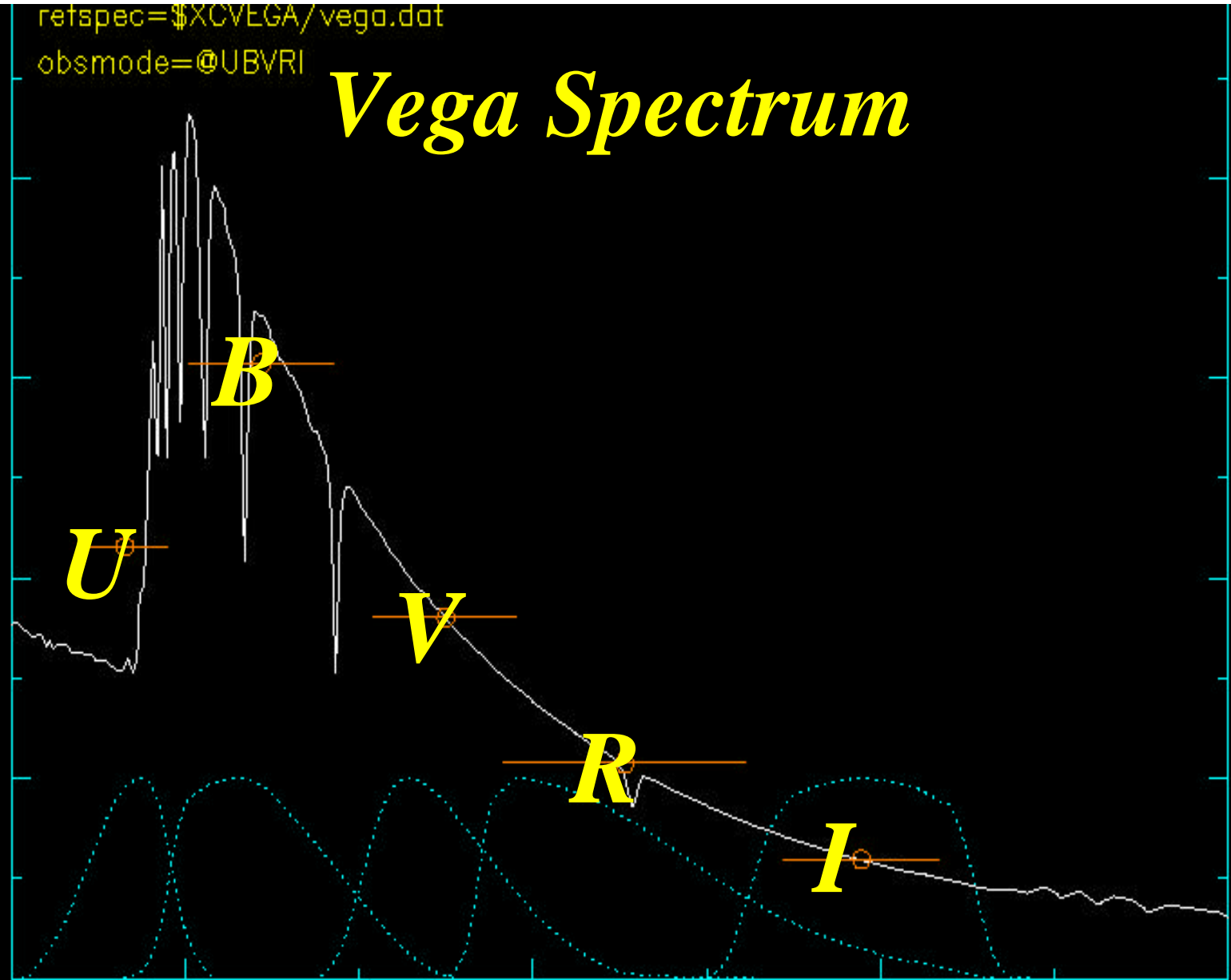
U

B

V

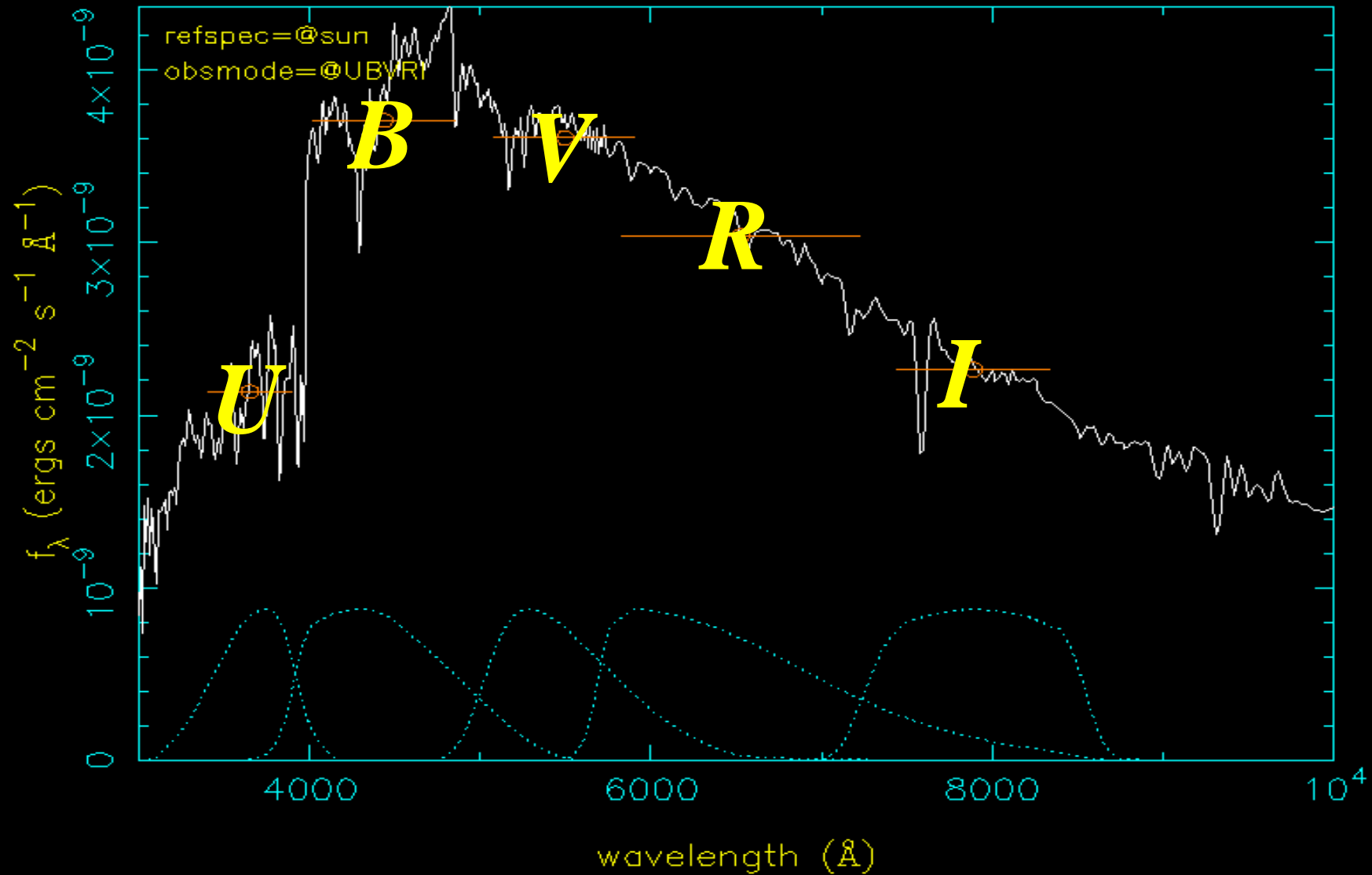
R

I



Sun-like Spectrum

Sun



Colour Indices

apparent mag : $V = m_V = -2.5 \log \left(\frac{F(V)}{F_0(V)} \right)$

absolute mag : $M_V = m_V - 5 \log(d / 10 \text{ pc})$

(and similarly for U, B, R, I , etc.)

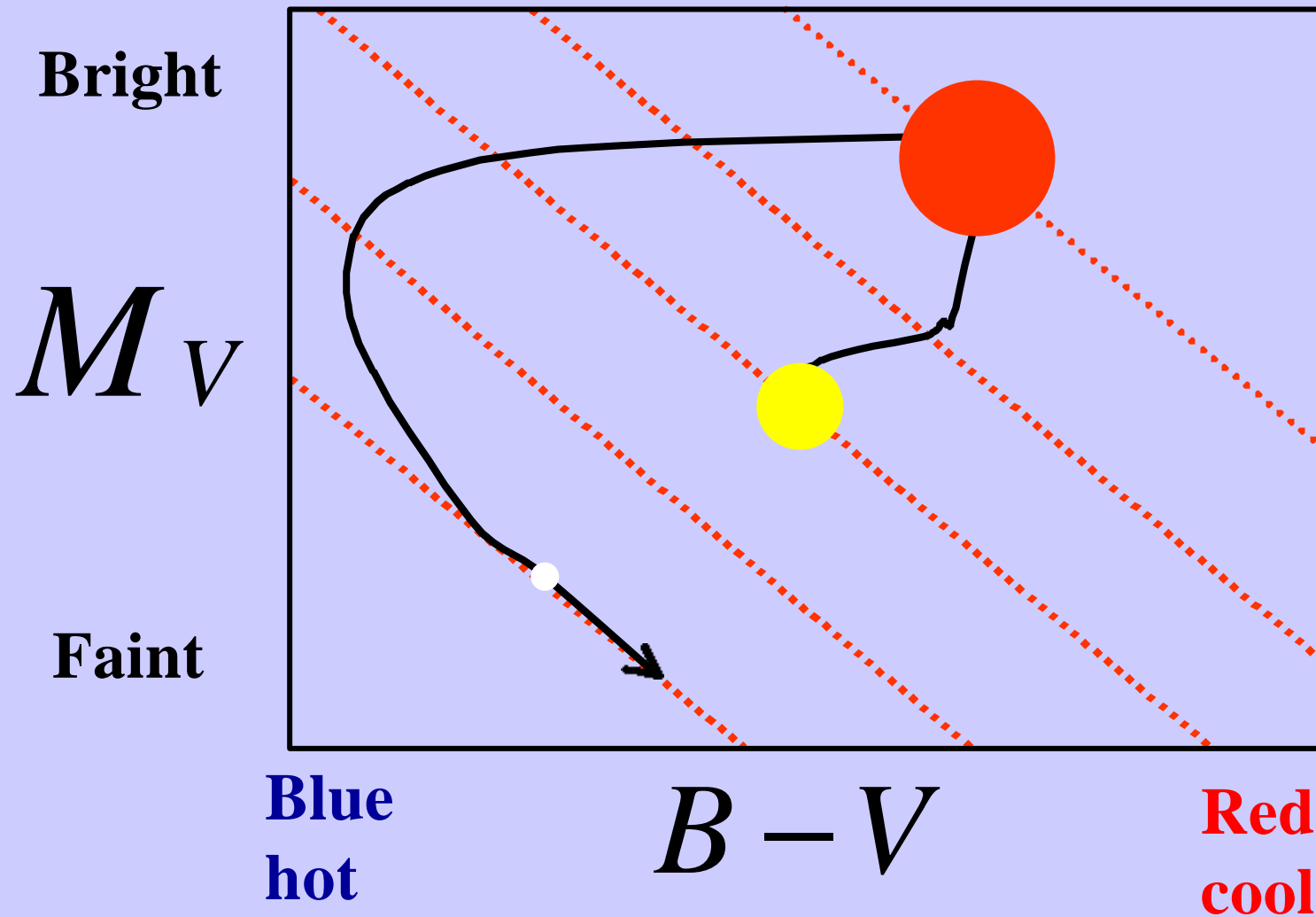
colour index :

$$B - V = -2.5 \log \left(\frac{F(B)/F_0(B)}{F(V)/F_0(V)} \right)$$

(and similarly for $U-B, V-R, R-I$, etc.)

<i>Theory</i>	<i>Observation</i>
flux F	apparent mag U, B, V, \dots
luminosity L	absolute mag $M_V = V - 5 \log(d / 10\text{pc})$
temperature T	colour index $B - V$

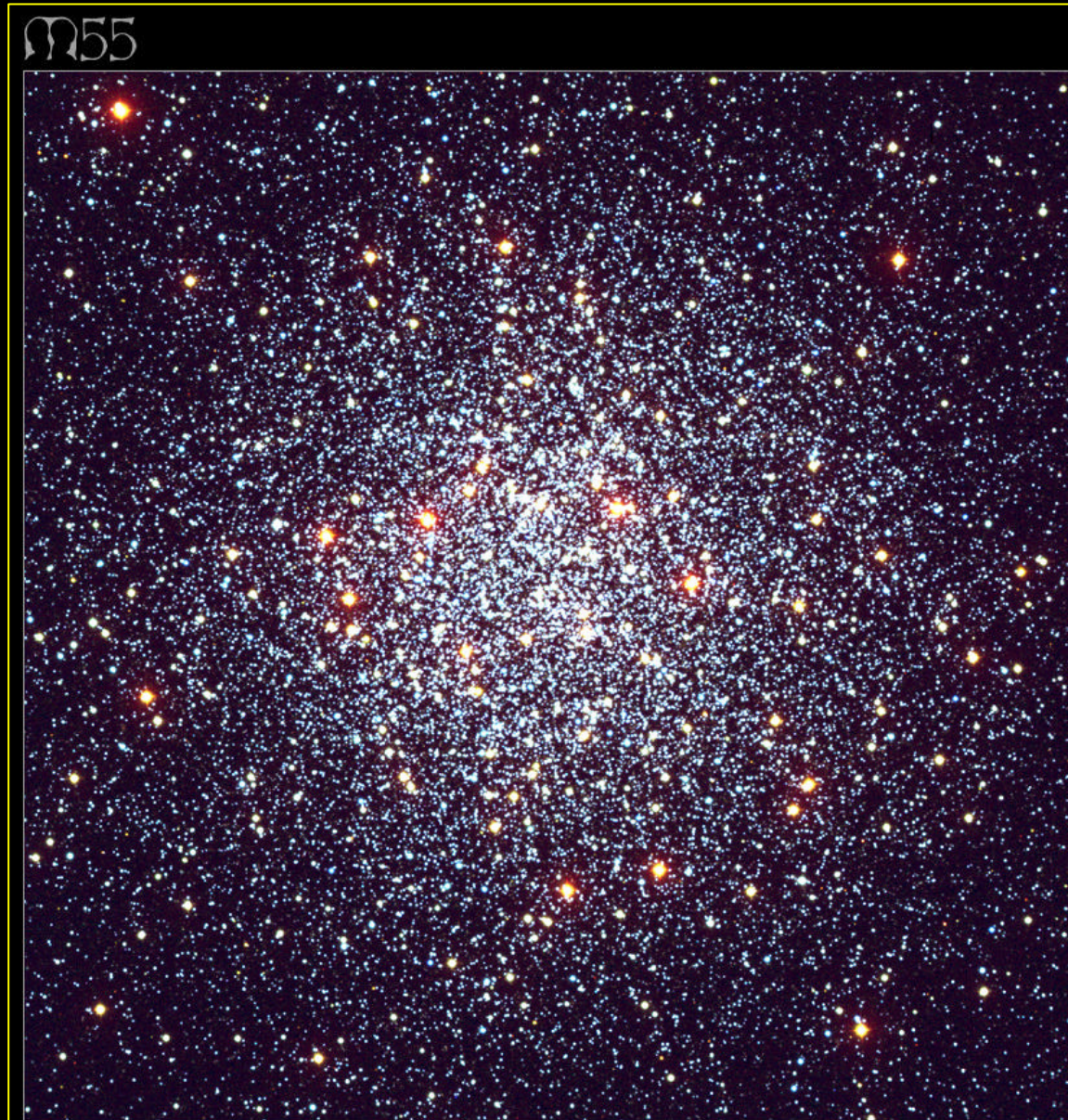
Hertzsprung-Russell (or H-R) Diagram



Globular Cluster (M55)

Most stars
are born in
Star
Clusters.

Same
distance,
age



H-R Diagram

M55

