Wednesday, October 28, 2020

Example: Mass consumption of a massive blue star ($M = 40\ M_{sun}$)

Luminosity of Sun $= 3.9 \times 10^{26}\ W = L_{sun}$

$\Rightarrow$ Luminosity of massive blue star $= L_{mbs} = 40^{3.9}\ L_{sun}$

$= 1,770,247\ L_{sun}$

$\simeq 1.77 \times 10^{6}\ L_{sun}$

Table in lecture slides gives $L_{mbs} = 700,000 = 7 \times 10^{5}\ L_{sun}$

The relationship $\frac{L_{star}}{L_{sun}} = \left(\frac{M_{star}}{M_{sun}}\right)^{3.9}$ is only approximate.

$\Rightarrow L_{mbs} = 7 \times 10^{5}\ L_{sun} = 7 \times 10^{5} \times (3.9 \times 10^{26})$

$= 2.73 \times 10^{32}\ W$

$= 2.73 \times 10^{32}\ J/s$

Convert to mass: $E = mc^2 \Leftrightarrow m = E/c^2$

$\Rightarrow L_{mbs}\Big|_{kg/s} = \frac{2.73 \times 10^{32}\ J \text{ per second}}{(3 \times 10^{8})^2\ kg}$

$= 3.03 \times 10^{15}\ kg/s$

The star consumes (converts to starlight) $3.03 \times 10^{15}\ kg/s$

In one year, the consumption is

$$3.03 \times 10^{15}\ kg/s \times \underbrace{365 \times 24 \times 60 \times 60}_{\simeq 3.15 \times 10^{7}\ s}$$

$$= 9.566 \times 10^{22}\ kg/year$$

The star consumes $9.57 \times 10^{22}\ kg/year$

The star has a lifetime on the main sequence of 1 million years

$$\text{Lifetime consumption} = 9.57 \times 10^{22}\ kg/year \times 10^{6}\ years$$

$$= 9.57 \times 10^{28}\ kg$$

$$\simeq 10^{29}\ kg$$

$$\simeq \frac{10^{29}}{\underbrace{1.99 \times 10^{30}\ kg}_{M_{sun}}} = 0.048\ M_{sun}$$

$$\simeq 5\%\ \text{of}\ M_{sun}$$

Over it's lifetime, the massive blue star consumes 5% of the Mass of the Sun