Friday, October 30, 2020

Example: Luminosity of a white Dwarf (just born)

[in the Butterfly Nebula NGC 6302]

$T = 200,000 K = 2 \times 10^5 K$

$M = 0.64 M_{sun}$

→ According to white dwarf radius vs. mass plot

$M = 0.64 M_{sun}$ corresponds to $R = 0.012 R_{sun}$

i.e. $R(0.64) = 0.012$

(Wien's law) peak wavelength emission: $\lambda_{max\,nm} = \frac{2.9 \times 10^6}{200,000} = 14.5$ nm

$\Rightarrow$ $\boxed{\lambda_{max\,nm} = 14.5 \text{ nm}}$

This wavelength is in the extreme ultraviolet. (EUV) ← this light will ionize any atom/molecule

Stefan–Boltzmann law:

surface intensity $= \sigma T^4$

$= \left(5.67 \times 10^{-8} \frac{W}{m^2 \cdot K^4}\right)\left(2 \times 10^5 K\right)^4$

$= 9.07 \times 10^{13} \simeq 9 \times 10^{13} W/m^2$

$\Rightarrow$ $\boxed{\text{surface intensity} = 9 \times 10^{13} W/m^2}$

↑ ~million times more intense than Sun's surface!

note: for our Sun surface intensity $= 6.4 \times 10^7 W/m^2$

Surface area of white dwarf:

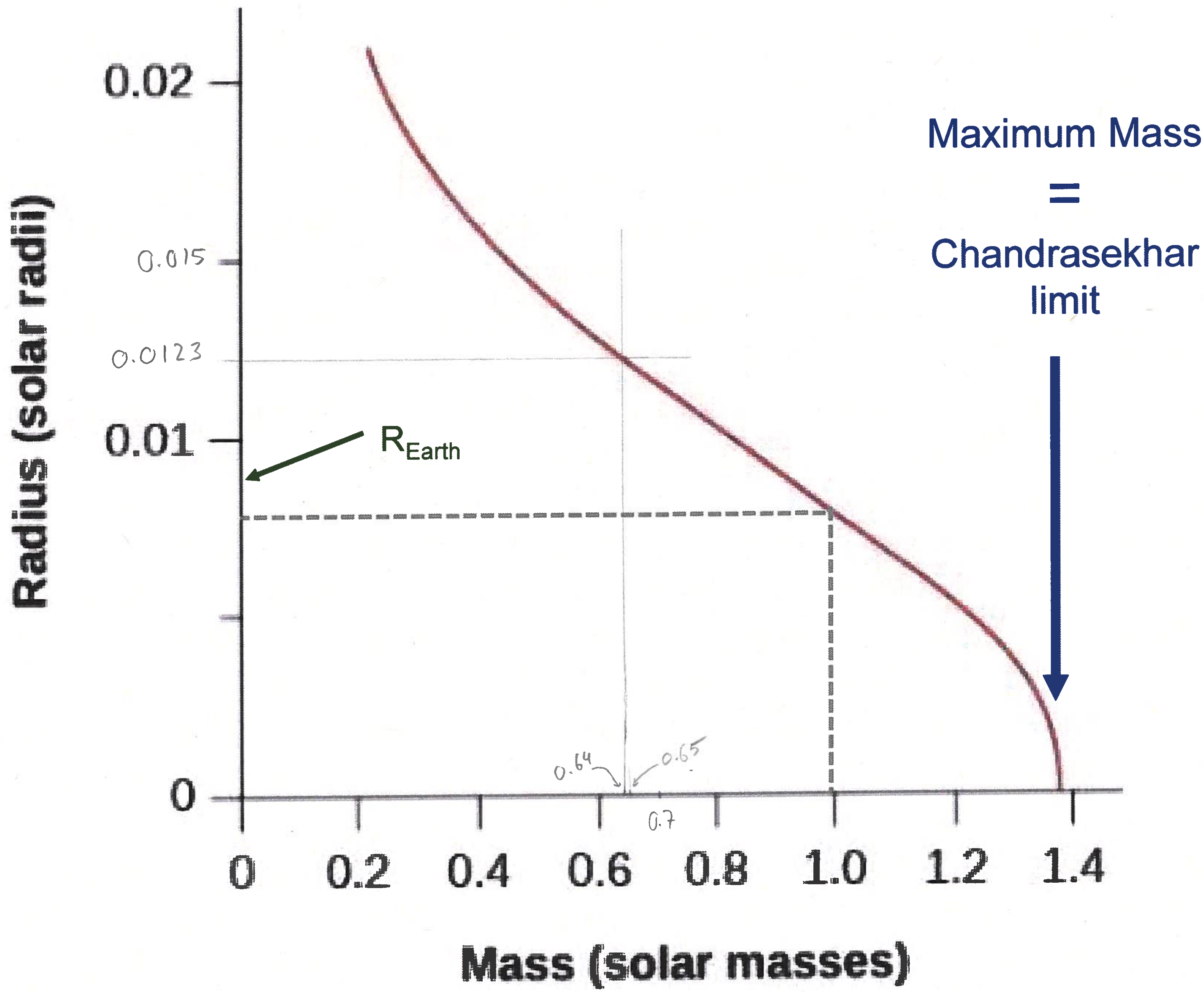
$$\text{Surface Area} = 4\pi R^2 = 4(3.1415926)(8.35\times10^7)^2$$
$$= 8.77\times10^{14}\ m^2$$

$$R = 0.12\ R_{sun} = (0.012)(\underbrace{6.96\times10^5\ km}_{6.96\times10^8\ m})$$
$$= 8.35\times10^6\ m$$

$$\text{Luminosity} = \text{total output power} = \underbrace{\text{surface intensity}}_{W/m^2} \times \underbrace{\text{Surface area}}_{m^2}$$
$$= (9\cdot10^{13}\ W/m^2)(8.77\times10^{14}\ m^2)$$
$$= 7.75\times10^{28}\ W$$
$$\simeq 8\times10^{28}\ W$$

Luminosity of white dwarf (just born) $= 8\times10^{28}\ W$ $\simeq 200\ L_{sun}$

note: luminosity of Sun $\approx 4\times10^{26}\ W = L_{sun}$
(200 times less luminous)



Maximum Mass
=
Chandrasekhar
limit
R Earth
Radius (solar radii)
0.02
0.015
0.0123
0.01
0
0.64
0.65
0.7
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
Mass (solar masses)