SOLUTION SET 8
Physics 2022

1. **Convert parsecs to light years**

$d = 2000 \text{ pc} \times 3.26 \text{ ly/pc} = 6520 \text{ ly}$

The supernova was observed in AD 1054. The light began its journey 6520 years before, so the explosion happened in

AD 1054 – 6520 = 5466 BC

2. **time = 2012 – 1054 = 958 years (x 60 x 60 x 24 x 365.25) =** 3.0×10^{10} **s**

radius = velocity x time = 1450 km/s x (3.0×10^{10} **s)**

$= 4.35 \times 10^{13}$ **km**

$= 2.90 \times 10^{5}$ **AU = 1.4 pc = 4.6 ly**

diameter = 9.2 ly

3. **For a neutron**

$\rho = \mathcal{M} / (4/3\ \pi R^3) = 1.7 \times 10^{-27} \text{ kg} / (4/3\ \pi (10^{-15} \text{ m})^3) = 4.1 \times 10^{17} \text{ kg/m}^3$

For a neutron star ($\mathcal{M}$ **= 1.4 solar masses; R = 9.7 km)**

$\rho = \mathcal{M} / (4/3\ \pi R^3) = 1.4 \times 2.0 \times 10^{30} \text{ kg} / (4/3\ \pi (9{,}700 \text{ m})^3) = 7.3 \times 10^{17} \text{ kg/m}^3$

4a. $\lambda_{max} = 0.0029 / T = 0.0029 / (3 \times 10^7) = 9.7 \times 10^{-11} \text{ m} = 9.7 \times 10^{-2} \text{ nm}$ **(X ray)**

4b. $L_* = 4\pi R_*^2 \sigma T_*^4 = 4\pi (10^4 \text{ m})^2 (5.669 \times 10^{-8}) (3 \times 10^7)^4$

$= 5.8 \times 10^{31}$ **W**

$= 5.8 \times 10^{31} (/ 3.9 \times 10^{26} \text{ W}) = 1.5 \times 10^5 L_{sun}$

5. $P = 7.75\ hr = 8.84 \times 10^{-4}\ yr$

$a = 2.8\ solar\ radii \times (6.96 \times 10^5\ km) / (1.5 \times 10^8\ km/AU) = 1.30 \times 10^{-2}\ AU$

$(\mathcal{M}_1 + \mathcal{M}_2) = a^3 / P^2 = (1.30 \times 10^{-2})^3 / (8.84 \times 10^{-4}\ yr)^2 = 2.8\ solar\ masses$

6. $R_{sch} = 2\,G\,\mathcal{M} / c^2 = [\,2\,(6.67 \times 10^{-11}) / (3 \times 10^8\ m/s)^2\,]\,\mathcal{M} = (1.48 \times 10^{-27}\ m/kg)\,\mathcal{M}$

a. $R_{sch} = (1.48 \times 10^{-27}\ m/kg)\,\mathcal{M}_{earth} = (1.48 \times 10^{-27}\ m/kg)\,(5.976 \times 10^{24}\ kg)$

$R_{sch} = 8.8 \times 10^{-3}\ m = 0.9\ cm$

b. $R_{sch} = (1.48 \times 10^{-27}\ m/kg)\,\mathcal{M}_{saturn} = (1.48 \times 10^{-27}\ m/kg)\,(5.685 \times 10^{26}\ kg)$

$R_{sch} = 8.4 \times 10^{-1}\ m = 84\ cm$

c. $R_{sch} = (1.48 \times 10^{-27}\ m/kg)\,\mathcal{M}_{sun} = (1.48 \times 10^{-27}\ m/kg)\,(1.99 \times 10^{30}\ kg)$

$R_{sch} = 2.95 \times 10^3\ m = 3\ km$

7. $R_{sch} = 2\,G\,\mathcal{M} / c^2 = [\,2\,(6.67 \times 10^{-11}) / (3 \times 10^8\ m/s)^2\,]\,\mathcal{M} = (1.48 \times 10^{-27}\ m/kg)\,\mathcal{M}$

$11 \times 10^3\ m = (1.48 \times 10^{-27}\ m/kg)\,\mathcal{M}_{sch}$

$\mathcal{M}_{sch} = (11 \times 10^3\ m) / (1.48 \times 10^{-27}\ m/kg)$

$\mathcal{M}_{sch} = 7.4 \times 10^{30}\ kg = 3.7\ solar\ masses$

8. $R_{sch} = 2\,G\,\mathcal{M} / c^2 = [\,2\,(6.67 \times 10^{-11}) / (3 \times 10^8\ m/s)^2\,]\,\mathcal{M} = (1.48 \times 10^{-27}\ m/kg)\,\mathcal{M}$

$R_{sch} = (1.48 \times 10^{-27}\ m/kg)\,(\,8\,\mathcal{M}_{sun}\,) = (1.48 \times 10^{-27}\ m/kg)\,(8 \times 1.99 \times 10^{30}\ kg)$

$R_{sch} = 8 \times 2.95 \times 10^3\ m = 23.6 \times 10^3\ m = 23.6\ km$

$\rho = \mathcal{M} / (4/3\,\pi\,R^3) = 8 \times 1.99 \times 10^{30}\ kg / (4/3\,\pi\,(23.6 \times 10^3\ m)^3)$

$= 2.89 \times 10^{17}\ kg/m^3$

Some possibly useful constants

$$1 \text{ pc} = 206{,}265 \text{ AU} = 3.26 \text{ ly}$$

$$1 \text{ AU} = 1.5 \times 10^{8} \text{ km}$$

$$1 \text{ yr} = 3 \times 10^{7} \text{ s}$$

$$c = 3 \times 10^{8} \text{ m/s}$$

$$\sigma = 5.669 \times 10^{-8} \text{ Wm}^{-2}\text{K}^{-4}$$

$$G = 6.7 \times 10^{-11} \text{ N m}^2 / \text{kg}^2$$

$$\mathcal{M}_{\text{sun}} = 2.0 \times 10^{30} \text{ kg}$$

$$R_{\text{sun}} = 6.96 \times 10^{5} \text{ km}$$