

# Cosmology problems

1/ One physics hour (Ph) =  $35 \times 60$  s

$1.5 = \frac{1 \text{ Ph}}{35 \times 60}$

Age of universe (T) =  $13.8 \times 10^9$  yr

1 yr =  $365 \times 24 \times 3600 \times (\pi \times 10^7)$  s

$\therefore T = 13.8 \times 10^9 \times 365 \times 24 \times 3600 \times \frac{1}{35 \times 60}$  Ph

$T = 2.07 \times 10^{14}$  Ph

2/	<u>Real time</u>	<u>Cosmic calendar</u>
	Big Bang	Midnight on January 1 <sup>st</sup>
	Now	Midnight on January 1 <sup>st</sup> } + 1 year

(i) Earth birth

$$\frac{4.5 \times 10^9}{13.8 \times 10^9} \times 365 = 119 \text{ days}$$

So April 29<sup>th</sup>

(ii) Homo Sapiens emerge from Africa

$$\frac{60,000}{13.8 \times 10^9} \times 365 = 1.59 \times 10^{-3} \text{ days}$$

$$= 137 \text{ seconds before end of year}$$

$= 2 \text{ mins } 17 \text{ seconds " " " "}$

		Cumulative
Sa	31	31
Feb	28	59
Mar	31	90
Apr	30	120
May	31	151
Jun	30	181
Jul	31	212
Aug	31	243
Sept	30	273
Oct	31	304
Nov	30	334
Dec	31	365
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	365	

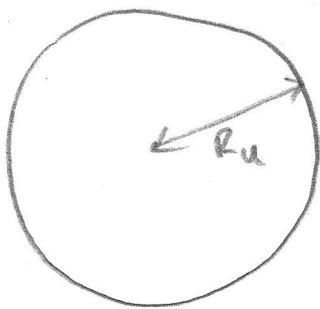
(iii)  $2015 - 1384 = 631$  years  
(Age of Winchester Gilegal)

$$\frac{631}{13.8 \times 10^9} \times 365 = 1.67 \times 10^{-5} \text{ days}$$

$= 1.44 \text{ seconds}$

before the end of the year.

3/



" Universe "

$$2R_u = 93 \times 10^9 \text{ light years}$$

$$1 \text{ light year} = 2.998 \times 10^8 \times 365 \times 24 \times 3600 \\ = \boxed{9.45 \times 10^{15} \text{ m}}$$

$$\therefore \text{(i)} \quad R_u = \frac{93 \times 10^9}{2} \times 9.45 \times 10^{15} \\ = \boxed{4.40 \times 10^{26} \text{ m}}$$

$$\text{(ii)} \quad V_u = \frac{4}{3} \pi R_u^3 \\ = \frac{4}{3} \pi (4.40 \times 10^{26})^3 = \boxed{3.56 \times 10^{80} \text{ m}^3}$$

$$\text{(iii)} \quad \text{Total mass of universe} \approx 10^{53} \text{ kg} \\ \therefore \text{if proton mass is } m_p = 1.673 \times 10^{-27} \text{ kg}$$

$$\# \text{ protons in universe} \approx \frac{10^{53}}{1.673 \times 10^{-27}}$$

$$\therefore \# \text{ protons / cubic metre} \approx \frac{10^{53}}{1.673 \times 10^{-27} \times 3.56 \times 10^{80}} \\ \approx \boxed{0.17} \text{ protons per cubic metre}$$

[ According to WMAP\*, actual density is  $\approx \boxed{0.25 \text{ protons per cubic metre}}$ . BUT mean 'energy density'  $\Rightarrow$  mass density of  $\approx \boxed{6 \text{ protons / m}^3}$ .  $\uparrow E=mc^2$   $\therefore$  95% of mass/energy in the universe is 'dark matter' or 'dark energy' ... or our models of gravity on this scale are wrong! ]

\* Accurate measurements of the Cosmic Microwave Background Radiation

(2)

$$4/ \quad M_{\text{ordinary}} \approx 10^{53} \text{ kg}$$

$$a) \quad M_{\text{Tot}} \times 0.049 = M_{\text{ordinary}}$$

$$M_{\text{Tot}} \approx \frac{10^{53}}{0.049} = \boxed{2.04 \times 10^{54}} \text{ kg}$$

$$\therefore E_{\text{Tot}} = M_{\text{Tot}} c^2 = 2.04 \times 10^{54} \times (2.998 \times 10^8)^2$$

$$\boxed{E_{\text{Tot}} = 1.83 \times 10^{71} \text{ J}}$$

b) If Big Bang 'released'  $1.83 \times 10^{71} \text{ J}$

$$\text{Tsar Bomba energy } E_{\text{TB}} = 210,000 \times 10^{12} \text{ J}$$

$$\therefore \text{Big Bang is equivalent to } \frac{1.83 \times 10^{71}}{210,000 \times 10^{12}}$$

$$= \boxed{8.73 \times 10^{53}} \text{ Tsar Bombas!}$$

$$\text{Note } 1 \text{ kg of matter has energy} = 1 \text{ kg} \times (2.998 \times 10^8)^2 \\ = 8.99 \times 10^{16} \text{ J}$$

$$\text{This is } \frac{8.99 \times 10^{16}}{210,000 \times 10^{12}} = \boxed{0.43} \text{ Tsar Bombas}$$

So in  $\boxed{\text{every } 2\frac{1}{3} \text{ kg}}$  of matter, we have sufficient energy to equal the most powerful explosion detonated by humans. If only this energy could be easily released!