OUTLINE ANSWERS

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Module Code stating section (i.e. *PHY250 (a)*): Answers by:
Period of Examination: Autumn/Spring/Resit *(delete as appropriate)* Year:
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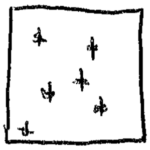
* CHANGE PROBLEM 1 *

Part		Mark	B/U/S

1



per unit physical area.
Total L ~~in sq kpc~~ $= L$

Measured total flux of all stars in ~~the~~ a ~~sq kpc~~: a unit physical area:

$$F = \frac{L}{4\pi d_p^2} \cdot \frac{1}{(1+z)^2}$$

For solid angle:

~~at~~ Say, at redshift z, 1 kpc corresponds to θ degrees:

$$\theta = \frac{l}{d_A} \qquad d_A = \frac{d_p}{(1+z)}$$

$$\theta = \frac{l\,(1+z)}{d_p}$$

So, at z, the stars in 1 sq. kpc are ~~spread~~ over ~~θ^2~~ a solid angle of:

$$\theta^2 = \frac{l^2\,(1+z)^2}{d_p^2}$$

$$\frac{F}{\theta^2} = \frac{L}{4\pi \cancel{d_p^2}} \cdot \frac{1}{(1+z)^2} \cdot \frac{\cancel{d_p^2}}{l^2\,(1+z)^2}$$

$$= \frac{L}{4\pi\,(1+z)^2}$$

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2	I only have to worry when the difference between d_p & d_L is greater than about 10%: ~~0.1~~ ~~d_p~~ $d_L^2 = d_p^2(1+z)^2$ $\frac{d_L^2}{d_p^2} = (1+z)^2$ For $\frac{d_L^2}{d_p^2} < 1.1$ $(1+z)^2 < 1.1$ $1+z < 1.049$ $z < 0.049$ $V = 14642$ Km/s 216 Mpc ~~Virgo~~? The Coma Supercluster of galaxies is 99 Mpc away. Do ~~we~~ I need to worry about which distance I need to use when calculating the luminosity of galaxies in the Coma cluster?		

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$$\left(\frac{\dot a}{a}\right)^2 = \frac{8\pi G}{3c^2}\sum \mathcal{E}_i - \frac{Kc^2}{R_0^2}\cdot\frac{1}{a^2}$$

$$\mathcal{E}_i = \mathcal{E}_{i,0}\, a^{-x} \qquad \mathcal{E}_{i,0} = \Omega_{i,0}\,\mathcal{E}_{c,0}$$

$$= \Omega_{i,0}\,\mathcal{E}_{c,0}\, a^{-x_i}$$

$$\left(\frac{\dot a}{a}\right)^2 = \frac{8\pi G}{3c^2}\mathcal{E}_{c,0}\sum \Omega_{i,0}\, a^{-x_i} - \frac{Kc^2}{R_0^2}\cdot\frac{1}{a^2}$$

$$H_0^2 = \frac{8\pi G\,\mathcal{E}_{c,0}}{3c^2} \Rightarrow \mathcal{E}_{c,0} = \frac{3H_0^2c^2}{8\pi G}$$

$$\frac{\dot a^2}{a^2} = \frac{\cancel{8\pi G}}{\cancel{3c^2}}\cdot\frac{\cancel{3}H_0^2\cancel{c^2}}{\cancel{8\pi G}}\sum \Omega_{i,0}\, a^{-x_i} - \frac{Kc^2}{R_0^2}\cdot\frac{1}{a^2}$$

$$= H_0^2\sum \Omega_{i,0}\, a^{-x_i} - \frac{Kc^2}{R_0^2}\cdot\frac{1}{a^2}$$

$$\dot a^2 = H_0^2\sum \Omega_{i,0}\, a^{-x_i+2} - \frac{Kc^2}{R_0^2}a^0$$

$$\text{SET} \quad \Omega_{K,0} = \frac{-Kc^2}{H_0^2R_0^2}$$

$$\dot a^2 = H_0^2\Big[\Omega_{m,0}\, a^{-3+2} + \Omega_{p,0}\, a^{-4+2} + \Omega_{d,0}\, a^2 + \Omega_{K,0}\Big]$$

$$\dot a^2 = H_0^2\left[\Omega_{m,0}\, a^{-1} + \Omega_{p,0}\, a^{-2} + \Omega_{K,0} + \Omega_{d,0}\, a^2\right]$$

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3 a)	$\dot{a}^2 = H_0^2 \left[\frac{\Omega_{r,0}}{a^2} + \frac{\Omega_{m,0}}{a} + \Omega_{K,0} \right]$		
	If $K = +1$, $\Omega_{K,0} < 1$		
b)	At small a, the +ve matter and radiation components dominate, but as a increases the term in brackets approaches ϕ which corresponds to $\frac{da}{dt} = \phi$, meaning a reaches a maximum. Because we can't have an imaginary $\frac{da}{dt}$, the only way to continue is for a to decrease again, ~~wh~~ with the decrease a mirror-image of the increase.		
~~3~~ 3			

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3	c)		

$$\frac{d\dot{a}^2}{dt} = \frac{d\dot{a}^2}{d\dot{a}} \cdot \frac{d\dot{a}}{dt}$$

$$= 2\dot{a} \cdot \ddot{a}$$

$$\frac{d\,(\mathrm{RHS})}{dt} = H_0^2\left[-\Omega_{m,0}\frac{da^{-1}}{dt} + \Omega_{\Lambda,0}\frac{da^{2}}{dt}\right]$$

$$\frac{da^{-1}}{dt} = \frac{da^{-1}}{da} \cdot \frac{da}{dt} = -a^{-2}\dot{a}$$

$$\frac{da^{2}}{dt} = \frac{da^{2}}{da} \cdot \frac{da}{dt} = 2a\dot{a}$$

$$2\dot{a}\ddot{a} = H_0^2\left[-\Omega_{m,0}a^{-2}\dot{a} + 2a\dot{a}\Omega_{\Lambda,0}\right]$$

$$2\ddot{a} = H_0^2\left[2a\Omega_{\Lambda,0} - \Omega_{m,0}a^{-2}\right]$$

FOR +ve ACCELERATION

$$2a\Omega_{\Lambda,0} - \Omega_{m,0}a^{-2} > 0$$

$$2a\Omega_{\Lambda,0} > \Omega_{m,0}a^{-2}$$

$a = 1$

$$2\Omega_{\Lambda,0} > \Omega_{m,0}$$

$$\Omega_{\Lambda,0} > \frac{\Omega_{m,0}}{2}$$

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4	$\left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3c^2}\varepsilon_0 a^{-3}$ $\dot{a} = \sqrt{\frac{8\pi G}{3c^2}\varepsilon_0}\, a^{-1/2}$ $a^{1/2}\, da = \sqrt{\frac{8\pi G\varepsilon_0}{3c^2}}\, dt$ $\int_0^1 a^{1/2}\, da = \sqrt{\frac{8\pi G\varepsilon_0}{3c^2}}\, t_0$ $\frac{2}{3}\left[a^{3/2}\right]_0^1 = \sqrt{\frac{8\pi G\varepsilon_0}{3c^2}}\, t_0$ $\frac{2}{3} = \sqrt{\frac{8\pi G\varepsilon_0}{3c^2}}\, t_0$ $H_0^2 = \frac{8\pi G\varepsilon_0}{3c^2}$ $\frac{2}{3} = H_0 t_0$ $H_0 = \frac{2}{3} t_0^{-1}$ $t_0 = 13.4 \times 10^9 \times 365.25 \times 24 \times 3600\,\mathrm{s}$ $= 4.26 \times 10^{17}\,\mathrm{s}$ $\therefore\ H_0 = 48.35\ \mathrm{Km/s/Mpc}$		

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5 a)	Redshifts are ~~as~~ easy to measure, and c is well known, so there isn't any problems calculating the velocities of high redshift objects. As such, there must have been unknown systematic errors ~~of~~ on the distance estimates. This would have arisen due to assumptions in the intrinsic luminosities of standard candles or sizes of standard rulers.		
b)	Since $t_0 \sim \frac{1}{H_0}$, a higher H_0 implies a smaller t_0. If H_0 is a factor of ~~~ 10~~ ~ 7 ~~times~~ times larger, this implies a t_0 of ~ 2 Gyr. ~~A~~ As such, ~~an H_0 of~~ a Benchmark model with $H_0 \sim 500$ km/s/Mpc implies a Universe that is 2 Gyr old. There are rocks in your garden older than that!		

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