

Arvind Borde
AST10: Week 10b HW

Solutions

1) If $H_0 = 500$, $1/H_0 = 1/500 = 0.002$.

That's 1,000 times too small.

So, if we divide H_0 by 1,000, we get 0.5 and $1/0.5 = 2$.

1

The units for H_0 in the table shown in class are astronomers units: $\frac{km/sec}{Mpc}$ where a Mpc is a “mega parsec,” about 3.26 million light years.

2

If, say, $H_0 = 70$ in these units it means that the recession velocity of a galaxy increases by 70 km/sec for every mega parsec that you go further away.

Dividing by 1,000 effectively changes the units of H_0 to “per billion years.”

That’s why when you now calculate $1/H_0$ you get the age of the Universe in billions of light years.

3

2) Ages of the Universe

H_0 and T (billions of years)

Year	Mission/Instrument	H_0	T
2013	ESA Planck satellite	0.0678	14.75
2012	NASA Explorer 80	0.0693	14.43
2008	Chandra	0.0776	12.89
2005	Hubble	0.0720	13.89

4

3a) We get

$$\begin{aligned}\Delta\lambda &= 4.923 \times 10^{-7} - 4.861 \times 10^{-7} \\ &= 0.062 \times 10^{-7}.\end{aligned}$$

3b) So

$$\frac{\Delta\lambda}{\lambda} = \frac{0.062 \times 10^{-7}}{4.861 \times 10^{-7}} = 0.01275.$$

3c) $v/c = 0.01275$.

So $v = 0.01275 \cdot 3 \cdot 10^5 \approx 3,826$ km/sec.

3d) Moving away.

4a) $R = v/H_0 = 3826/0.075 = 51,018$ kpc.

4b) Distance in ly is $51018 \times 3.26 \times 10^3 \approx 166 \times 10^6$ ly

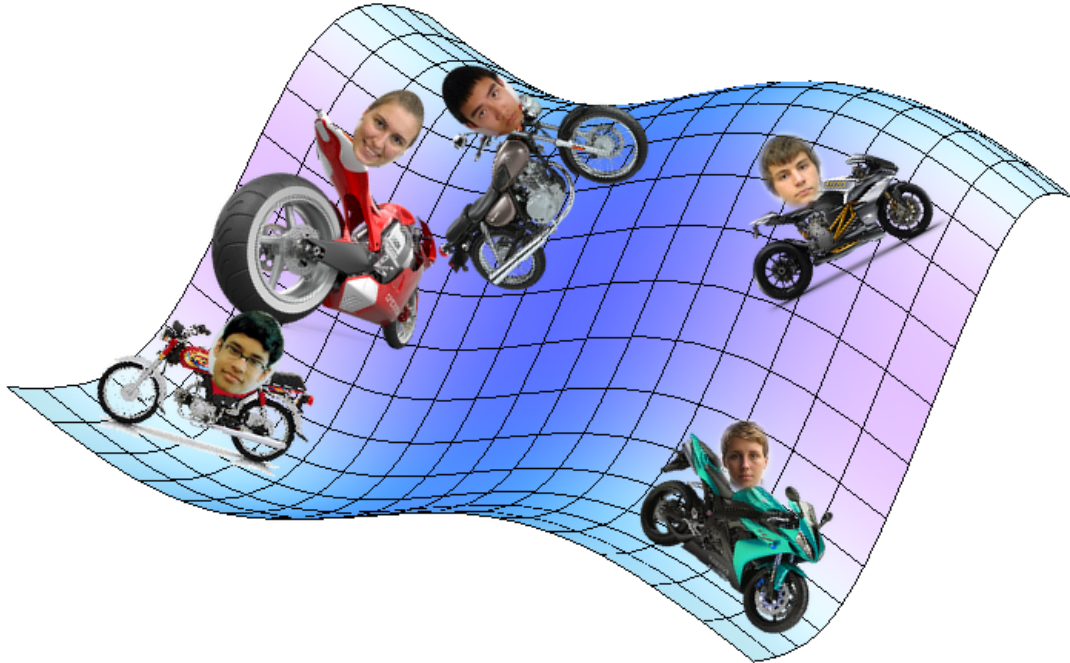
6

5a) $z > 1 \Rightarrow v/c > 1 \Rightarrow v > c.$

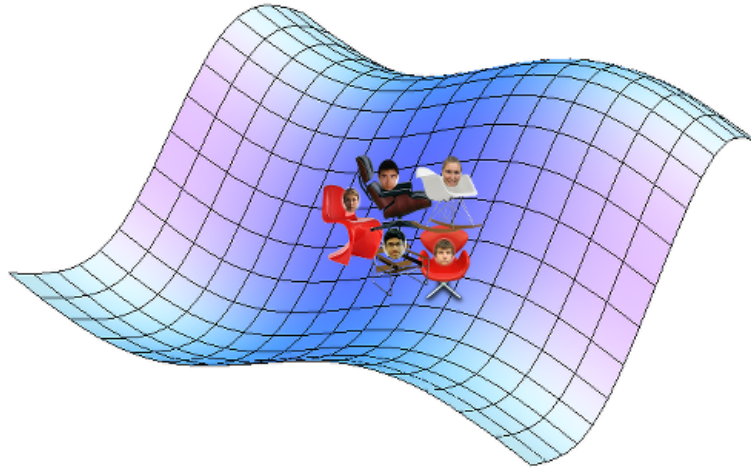
5b) Objects cannot move faster than light, but space can expand at any speed. These redshifts arise from the expansion of space, not the motion of objects in space.

7

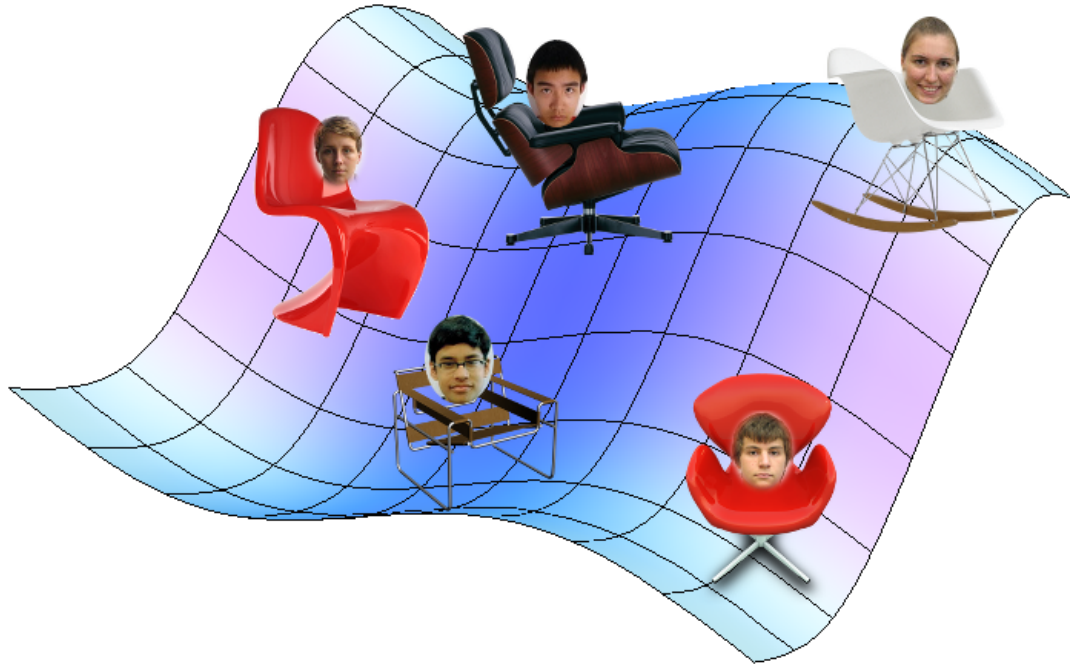
Galaxies not moving away from everything else
by actively running away:



Instead, they're sitting in place



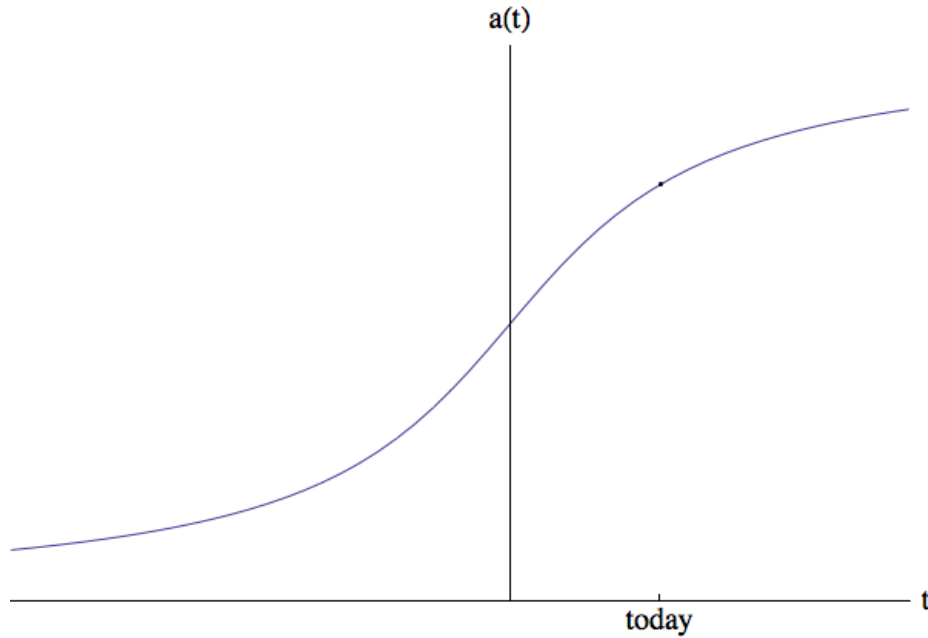
and enjoying the benefits of the expansion of the Universe:



Also $z = v/c$ is an approximate formula. For speeds close to that of light, a better one is used that adjusts the speeds to always be below c .

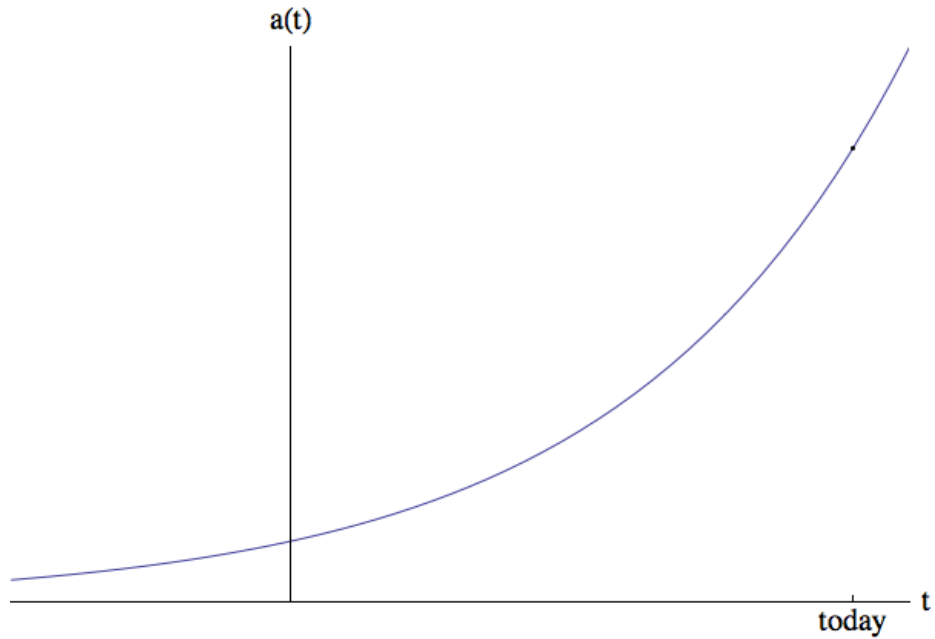
8 Quasars have known redshifts of up to $z = 7$. Their spectral lines were initially not understood.

6) One example



9

6) Another example



10