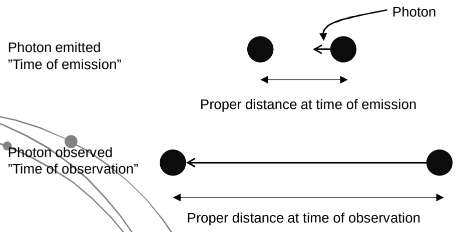
Cosmology AS7009, 2011
Proper distance

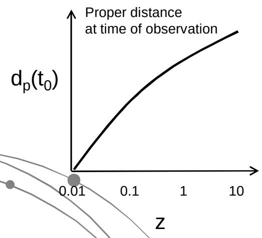
Consider two objects, not gravitationally bound to each other.

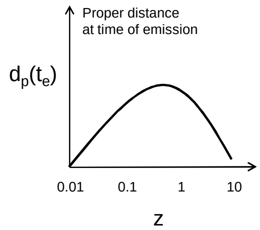


If the time of observation is now, the d_p at the time of emission is smaller by a factor of (1+z)

Proper distance II

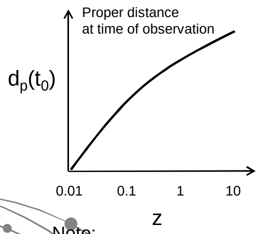
Typical behaviour (see Fig. 5.3, p. 72 in Ryden):

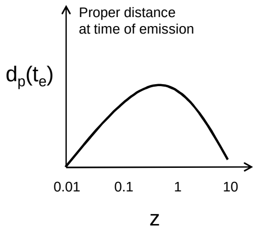




Consider a galaxy observed at redshift z:
How far away is it now? $d_p(t_0)$!
How far away was it when its light was emitted? $d_p(t_e)$!

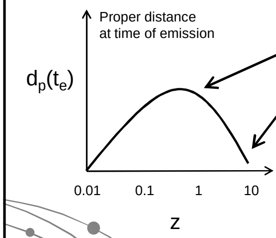
Proper distance III





Note:
1. $d_p(t_0) \approx d_p(t_e)$ if z is very small, because the Universe did note have time to expand much between the time of emission and expansion
2. $d_p(t_0) >> d_p(t_e)$ if z is big, because the Universe expanded substantially during the time it took the photon to get here

Proper distance IV



Weird! So if I detect light from one galaxy at z=1 and one at z=10, the latter was actually closer to me when its light was emitted?

Sure, but this was also earlier in the history of the Universe…

Extreme case:
Recall that prior to inflation, *everything* in our observable Universe was located within a subatomic distance from our present position…

Proper distance V

Proper distance at the time of observation (i.e. now):

$$d_{\mathrm{p}}(t_0) = c\int_{t_{\mathrm{e}}}^{t_0} \frac{\mathrm{d}t}{a(t)}$$

Depends on the cosmological model

Proper distance at the time of emission:

$$d_{\mathrm{p}}(t_e) = \frac{d_{\mathrm{p}}(t_0)}{(1+z)}$$

Redshift corresponding to t_e

Proper distance VI

Horizon distance: Proper distance to the most distant regions in space in casual contact with us

$$d_{\mathrm{hor}}(t_0) = c\int_{0}^{t_0} \frac{\mathrm{d}t}{a(t)}$$

t_e=0 (i.e. time of the Big Bang)