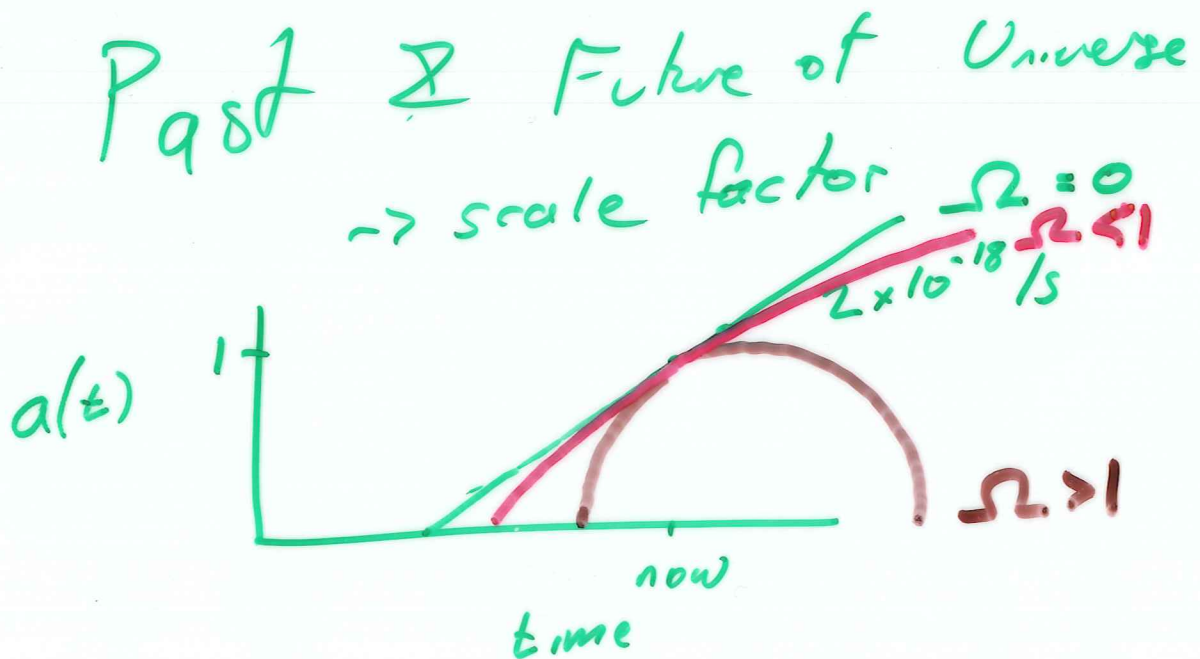


Pls had in PS #7

(PS #8 posted tomorrow)
names & staples greatly
appreciated!



define current scale factor to be unity

$\Omega = \frac{H^2}{8\pi G \rho}$

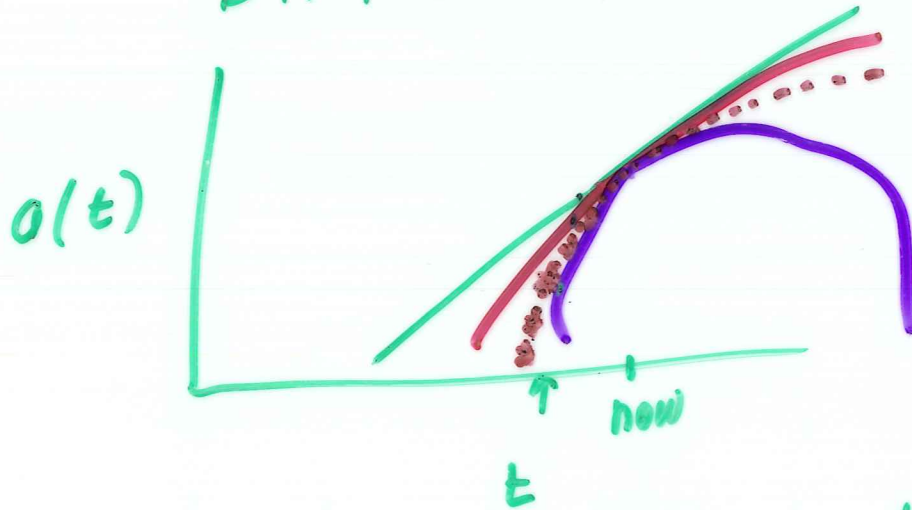
in 10^6 years there are
 $3 \times 10^7 \times 10^6 s = 3 \times 10^{13} s$

Scale factor increases
by $3 \times 10^{13} \times 2 \times 10^{-18}$
 $= 6 \times 10^{-5}$

Direct measurement of Ω
→ Dark Matter

Mass in galaxies → $\Omega \sim 1/3$

DIFFERENT APPROACH



look into past (light travel time)

measure distance
time in past: $\frac{D}{c}$

determine scale factor at that time

a different view of redshift

or one view: redshift → velocity

cosmological redshift is not same as
velocity

another view: wavelengths of light expand along with Universe

So when we observe distant object λ is longer than when it was emitted

$$\text{distance} = m - M = 5 \log(P/10pc)$$

$$\text{time} = \text{distance} / c$$

$$\frac{a_{\text{now}}}{a_{\text{then}}} = \frac{\lambda_{\text{obs}}}{\lambda_{\text{emit}}} = \frac{\lambda_{\text{emit}} + \Delta\lambda}{\lambda_{\text{emit}}} = 1 + z$$

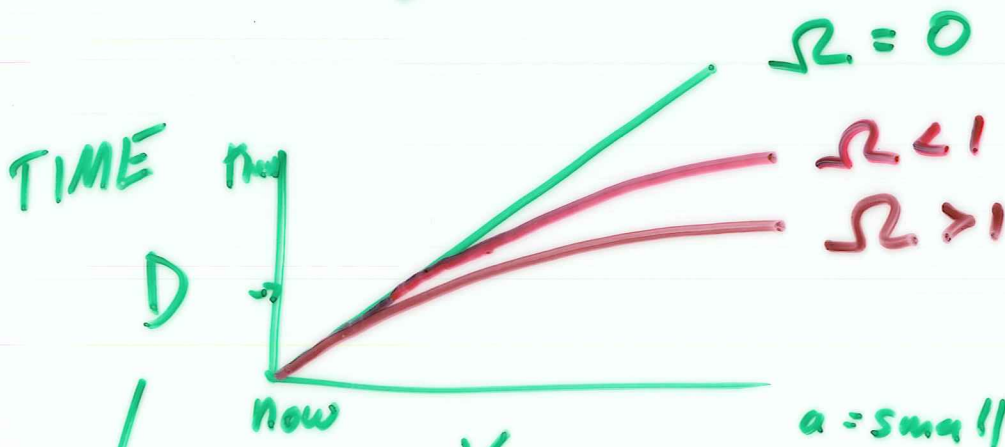
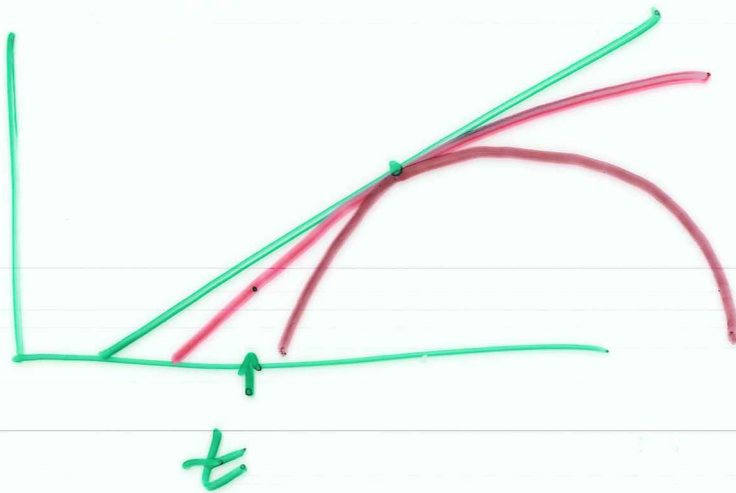
$\downarrow \frac{\Delta\lambda}{\lambda_{\text{emit}}}$

$$a_{\text{now}} \equiv 1$$

$$\frac{1}{a} = 1 + z \quad \text{or} \quad a = \frac{1}{1+z}$$

κ measure

a

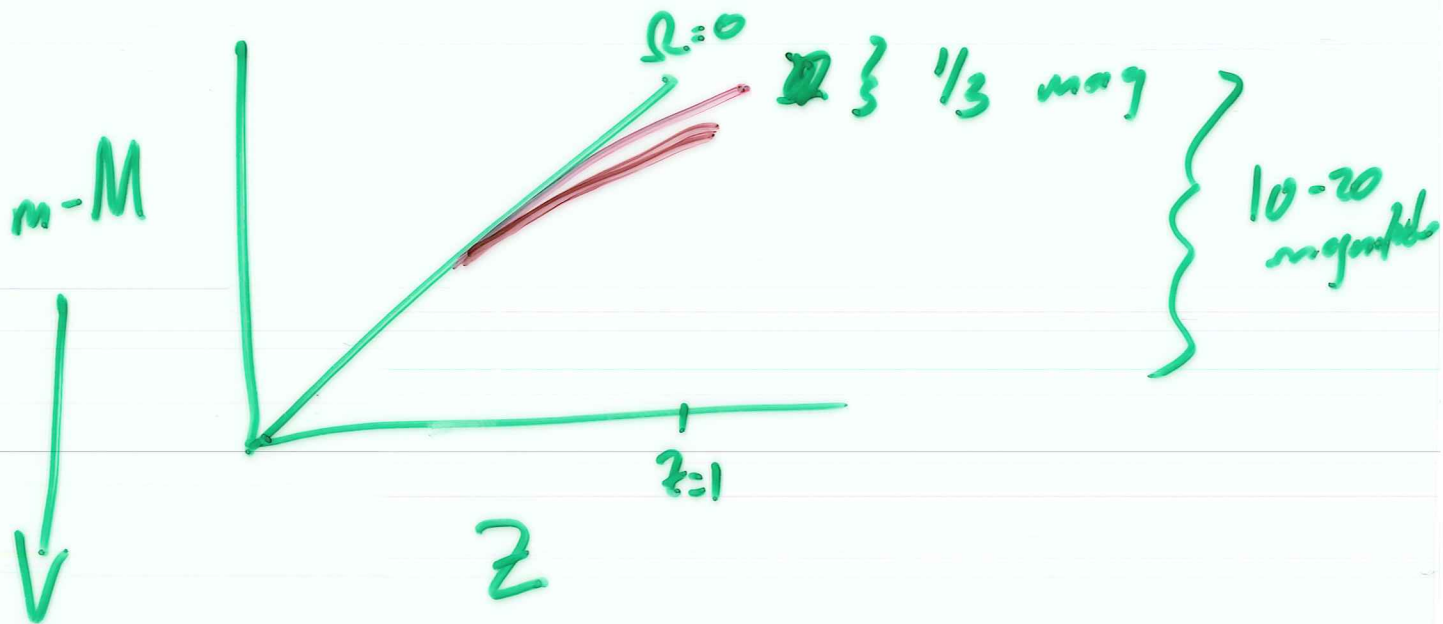


$\frac{1}{1+z} = a$ $\frac{1}{a} = 1+z$
 $\frac{1-a}{a} = z$

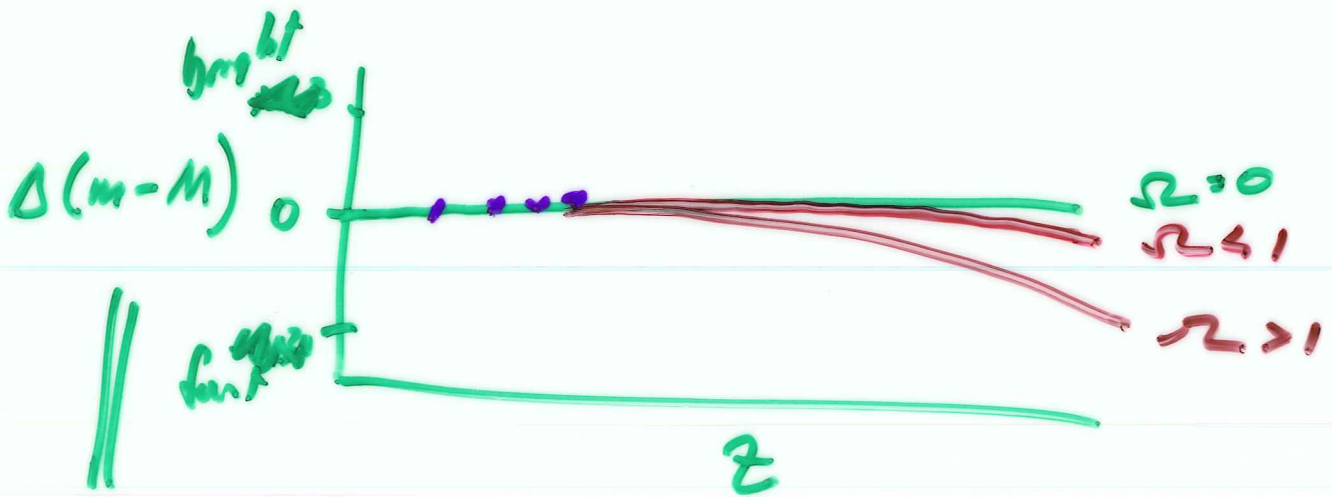
$m-M = 5 \log(P/10pc)$ SCALE FACTOR

REALLY BRIGHT STANDARD
 CANDLE
 => see it at large
 distances

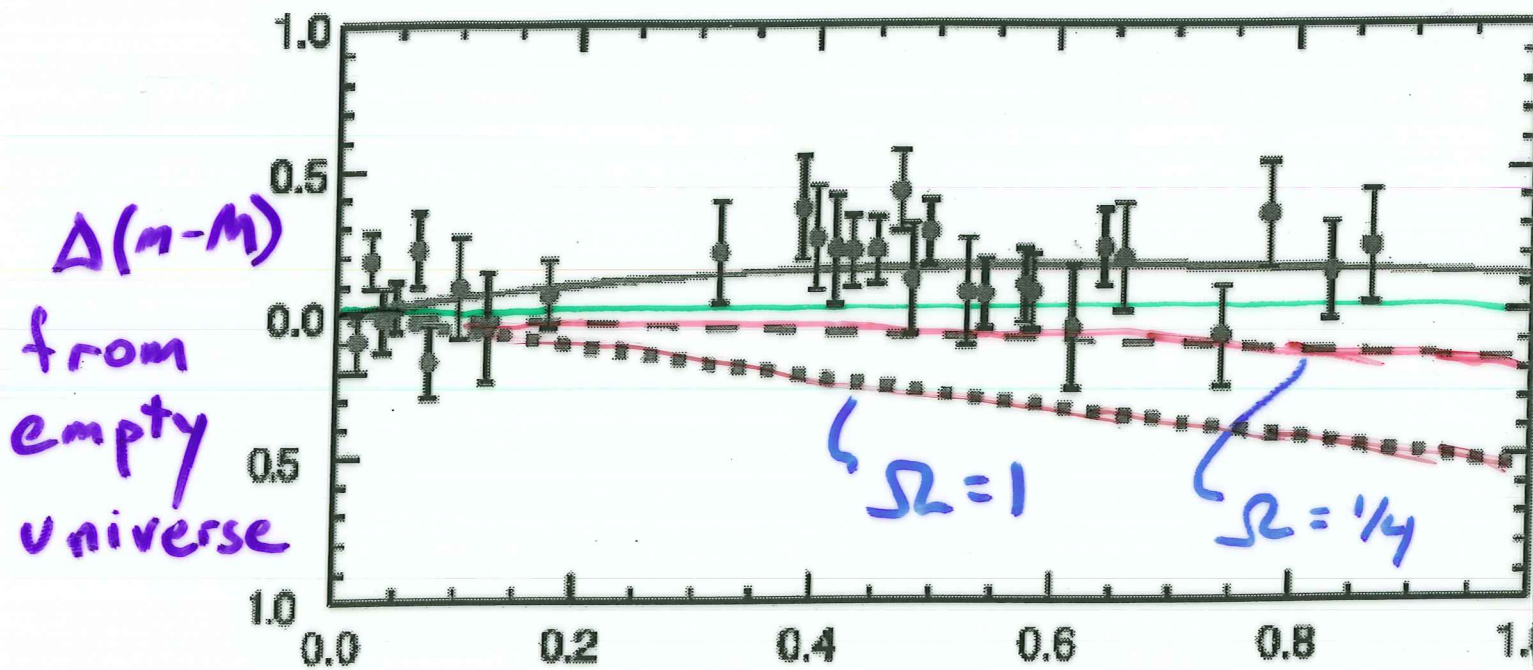
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"distance modulus"



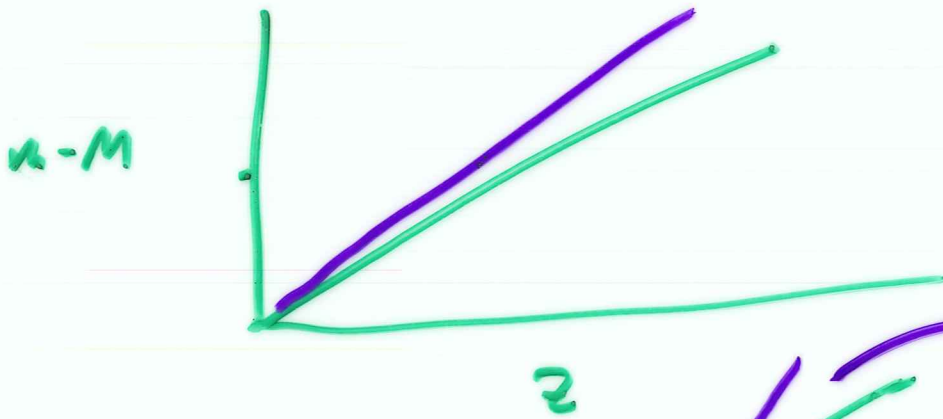
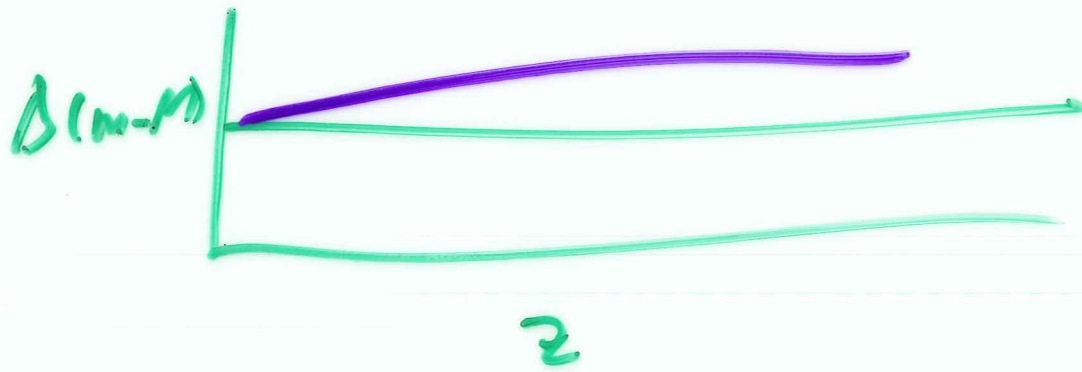
difference between measured $m-M$ and $m-M$ at given z in empty universes



z

from Supernova Cosmology
Project, Knop et al. 2003
Astrophysical Journal

two errors: measurement error (m)
accuracy of standard
candle (M)



Universe expanding
Expansion is
ACCELERATING

Universe is being pushed ahead
by repulsive gravity

"Dark Energy"

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What is the density of Dark Energy compared to matter?

$$\text{energy} / \text{m}^3 \Rightarrow \frac{E/c^2}{\text{m}^3}$$

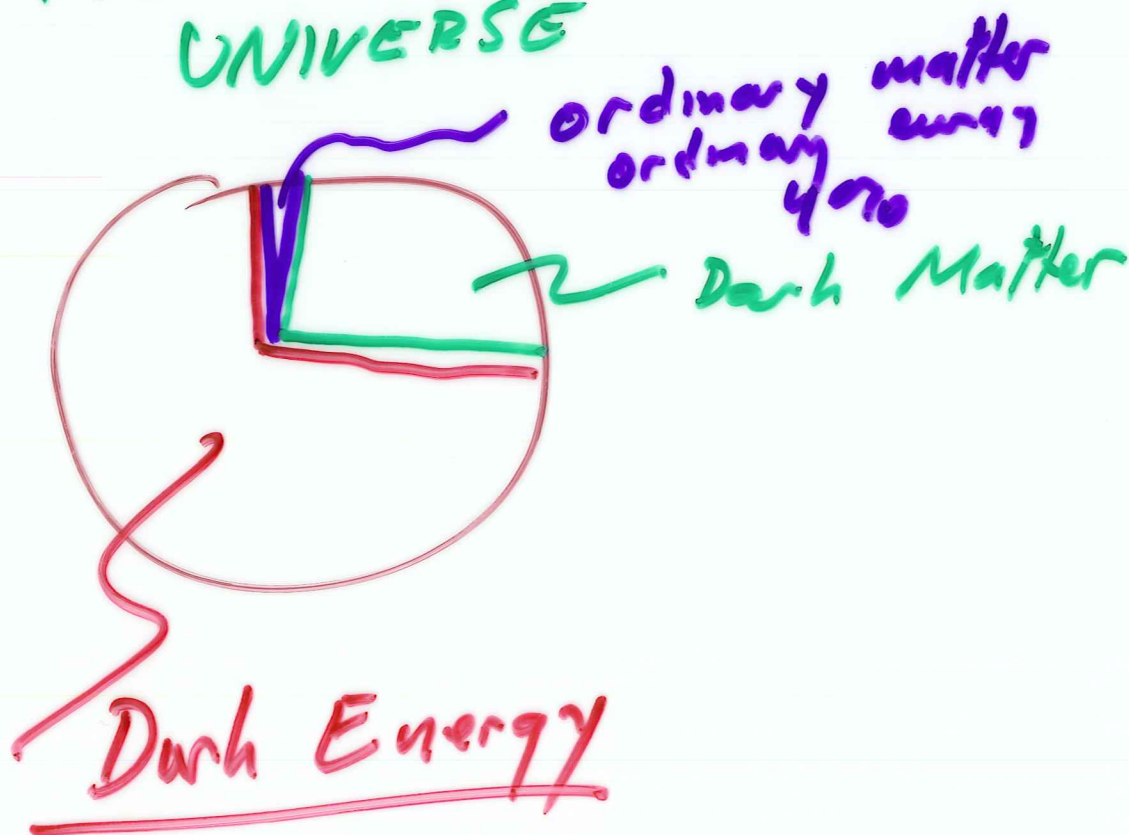
$$\Omega_m = 1/4$$

$$\Omega = \rho / \rho_{crit}$$

$$\Omega_{DE} = 3 \times \Omega_m$$

PIE CHART OF UNIVERSE

FRC
2007



Einstein wanted a static universe
invented an additional term
 Λ "Cosmological constant"

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force balance gravity
→ Static universe

Then Hubble discovers expansion

E: " Λ was my biggest mistake "

FABLE: Einstein's biggest "mistake"

MORAL: "interesting ideas can turn up in other contexts"

|| $\Omega_\Lambda \sim 10^{120}$ (particle physics)
|| $\Omega_\Lambda = 3/4$