Pls had in PS #7
(PS #8 posted tomorrow)
Names & staples greatly appreciated!

Past & Future of Universe

\[ \Rightarrow \text{scale factor } \Omega = 0 \]

\[ \Omega < 1 \]

\[ 2 \times 10^{-18} \]

\[ 2 \times 10^{-18} \]

\[ \Omega > 1 \]

\[ \text{define current scale factor to be unity} \]

\[ \Omega_{\text{current}} = \frac{1}{9.8 \times 10^{-17}} \]

In 10^6 years there are

\[ 3 \times 10^7 \times 10^6 = 3 \times 10^{13} \]

Scale factor increases by

\[ 3 \times 10^{13} \times 2 \times 10^{-18} = 6 \times 10^{-5} \]
Direct measurement of $\Omega$

$\rightarrow$ Dark Matter

Mass in galaxies $\rightarrow \Omega \sim \frac{1}{3}$

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

As one view, redshift $\rightarrow$ velocity

Cosmological redshift is not same as velocity
An error view: wavelengths of light expand along with the universe.

So when we observe distant objects, they appear farther away when the light was emitted.

\[ \text{distance} = m - M = 5 \log \left( \frac{P_{\text{obs}}}{P_{\text{em}}} \right) \]

\[ \text{time} = \text{distance} / c \]

\[ \frac{a_{\text{now}}}{a_{\text{then}}} = \frac{\lambda_{\text{obs}}}{\lambda_{\text{em,t}}} = \frac{\lambda_{\text{em,t}} + \Delta \lambda}{\lambda_{\text{em,t}}} = 1 + \frac{\Delta \lambda}{\lambda_{\text{em,t}}} \]

\[ a_{\text{now}} = 1 \]

\[ \frac{1}{a} = 1 + \varepsilon \quad \text{or} \quad a = \frac{1}{1 + \varepsilon} \]

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$m - M = 5 \log \left( \frac{D}{10 \text{pc}} \right)$

$S = \begin{cases} 0 & \eta \leq 1 \\ > 1 & \eta > 1 \end{cases}$

$\eta = \frac{1}{a} = 1 + \frac{2}{3} \log \frac{1 - a}{a}$

$\text{REALLY BRIGHT STANDARD CANDLE}$

$\Rightarrow \text{see it at large distances}$
The diagram illustrates the relationship between distance and magnitude in astronomy. The text below the diagram explains:

- Distance moduli
- \( \Delta (m-M) \)
- Difference between measured \( m-M \) and \( m-M \) without given 3 in empty cases.

The annotations suggest comparing measured magnitudes with a theoretical or standard value, indicating deviations or corrections needed.
$\Delta(m-M)$ from empty universe

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"

What is the composition of Dark Energy compared to matter?
energy/1 m³ \rightarrow \frac{E/c^2}{m^3}

- \Omega_m = 1/4
- \Omega_{DE} = 3 \times \Omega_m

**Pie Chart of Universe**

- Ordinary Matter
- Ordinary Energy
- Dark Matter
- Dark Energy

Einstein wanted a static Universe invented an additional term

A "Cosmological constant"

\rightarrow \text{static universe}
Hubble's expansion.

E: "And was my biggest mistake.”

FABLE: Einstein's biggest "mistake”

MORAL: "Heady ideas can turn up in other contexts.

\[ \Omega^\gamma \approx 10^{-120} \] (particle physics)

\[ \Omega^\gamma \approx 3/4 \]