The accelerating universe

- Type Ia supernovae are best standard candles.
- Least scatter in luminosity
- 2 independent groups get same answer

- Supernova Cosmology Project
  - High-z Supernova Search
    - Found acceleration
      - Not deceleration as expected.

[CO fig. 29.27]

Supernova results

Brightest cluster galaxies

[CO fig. 29.29]

Angular Diameters

- RW metric:
  \[ (d\xi)^2 = (dx)^2 + R(t)^2 \left[ \left( \frac{d\phi}{1-\omega t} \right)^2 + (\dot{\omega}\sin\phi d\phi)^2 \right] \]

- What is angular size of galaxy at distance \( \omega t \)?
  \[ d\theta = d\omega = d\phi = 0 \]

Galaxy’s diameter is proper distance linear diameter:

\[ D = \int (d\xi)^2 = R(t) \omega \]

\[ \theta = \frac{D}{R(t) \omega} \]

Using \( \psi \) coordinate

Looks like Euclidean result, regardless of curvature of space.

but must use \( R(t) \omega \)
More angular diameter

\[ \theta = \frac{D (1+z)^2}{d_L} \]

\[ \theta = \frac{H_0 D}{c} \frac{\vartheta z^2 (1+z)^2}{\vartheta z^2 - \left( \frac{c}{H_0} \right)^2 \left( 1 + z \vartheta z^2 - 1 \right)} \]

- **Surprise!**
  - Even for flat universe, \( \theta \) first decreases but then increases with increasing \( z \).
  - Two competing effects:
    - \( \theta \propto 1/distance \)
    - Universe expands under photons while they are in transit.

**VLBI measurements of compact radio sources:**

Authors say "consistent with" \( \theta_0 = 0.5 \), no evolution.

In practice (because of that @#$% cosmological constant)

\[ \frac{c \theta}{H_0 D} = \frac{(1 + z)}{S(z)} \]

[CO Fig. 29.30]