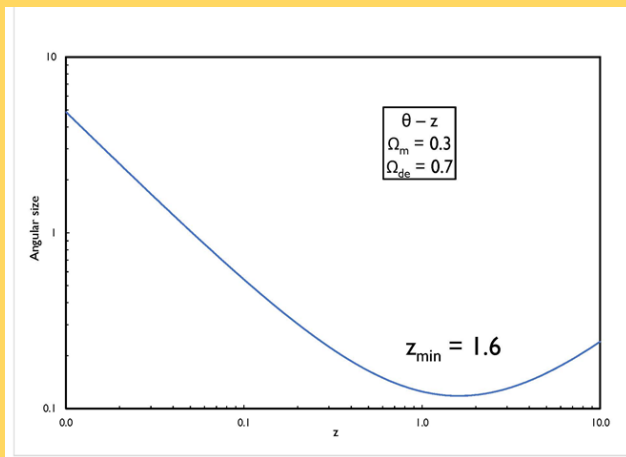
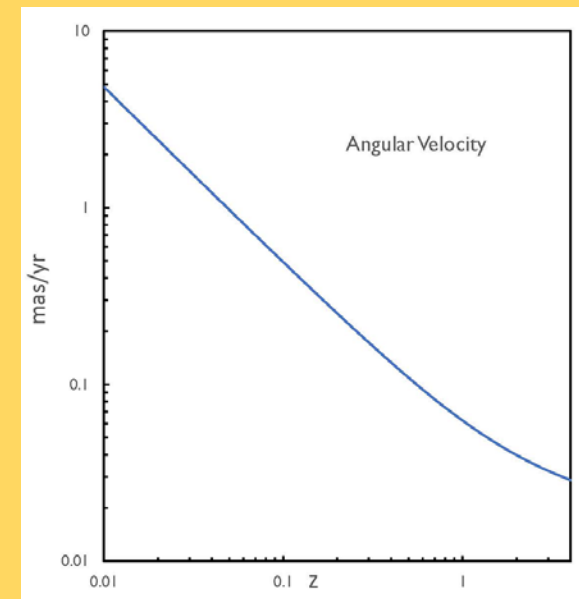


The Angular Size and Angular Velocity Relations for Quasars and AGN

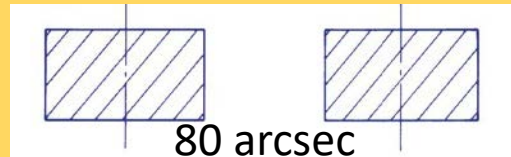


Ken Kellermann
NRAO

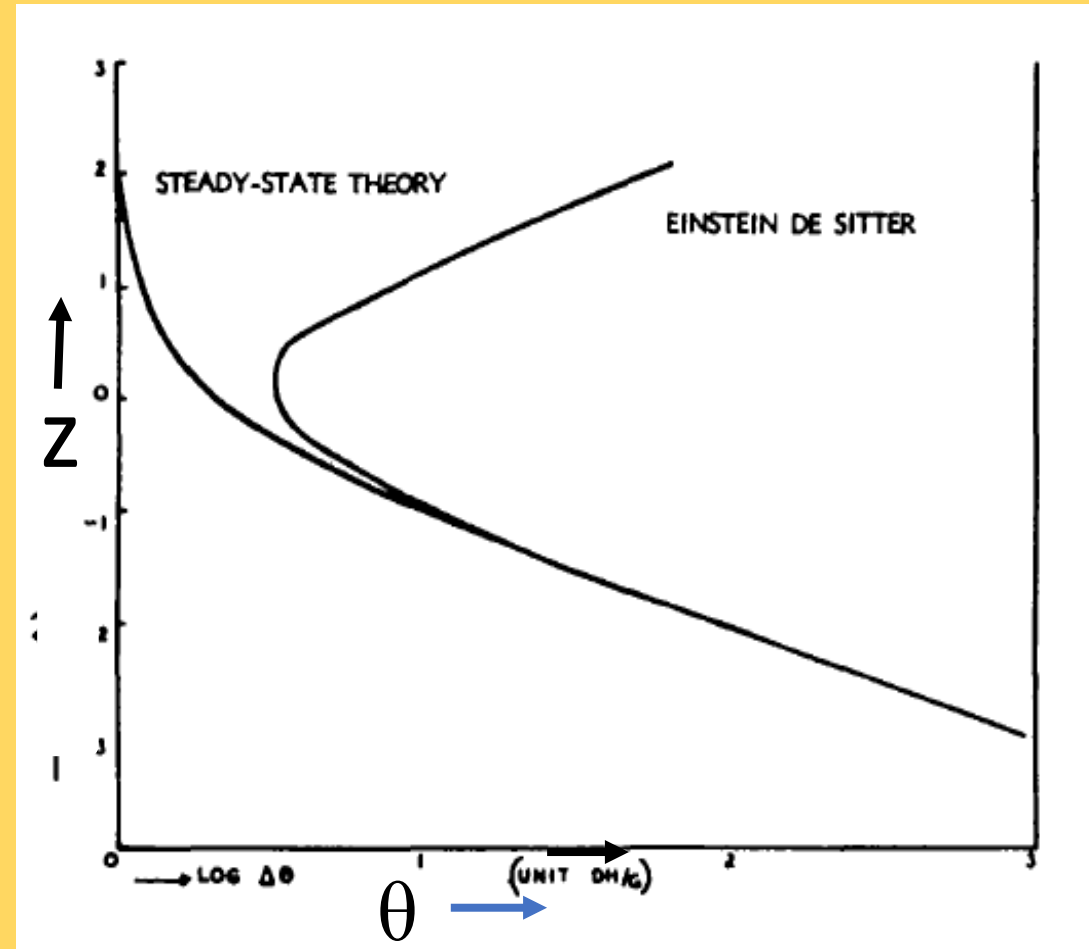


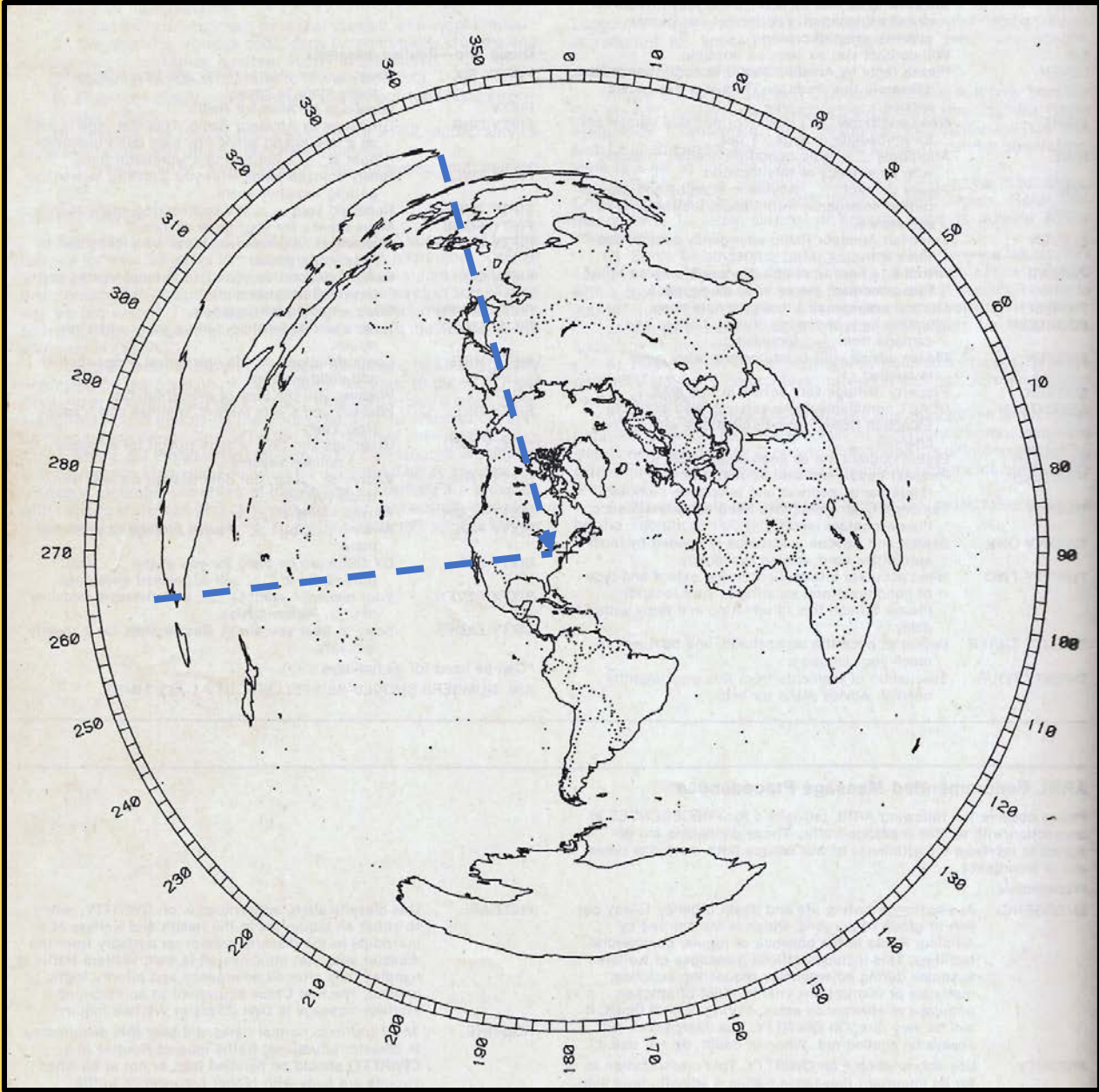
$\theta - z$ relation (Hoyle 1959)

Cygnus A

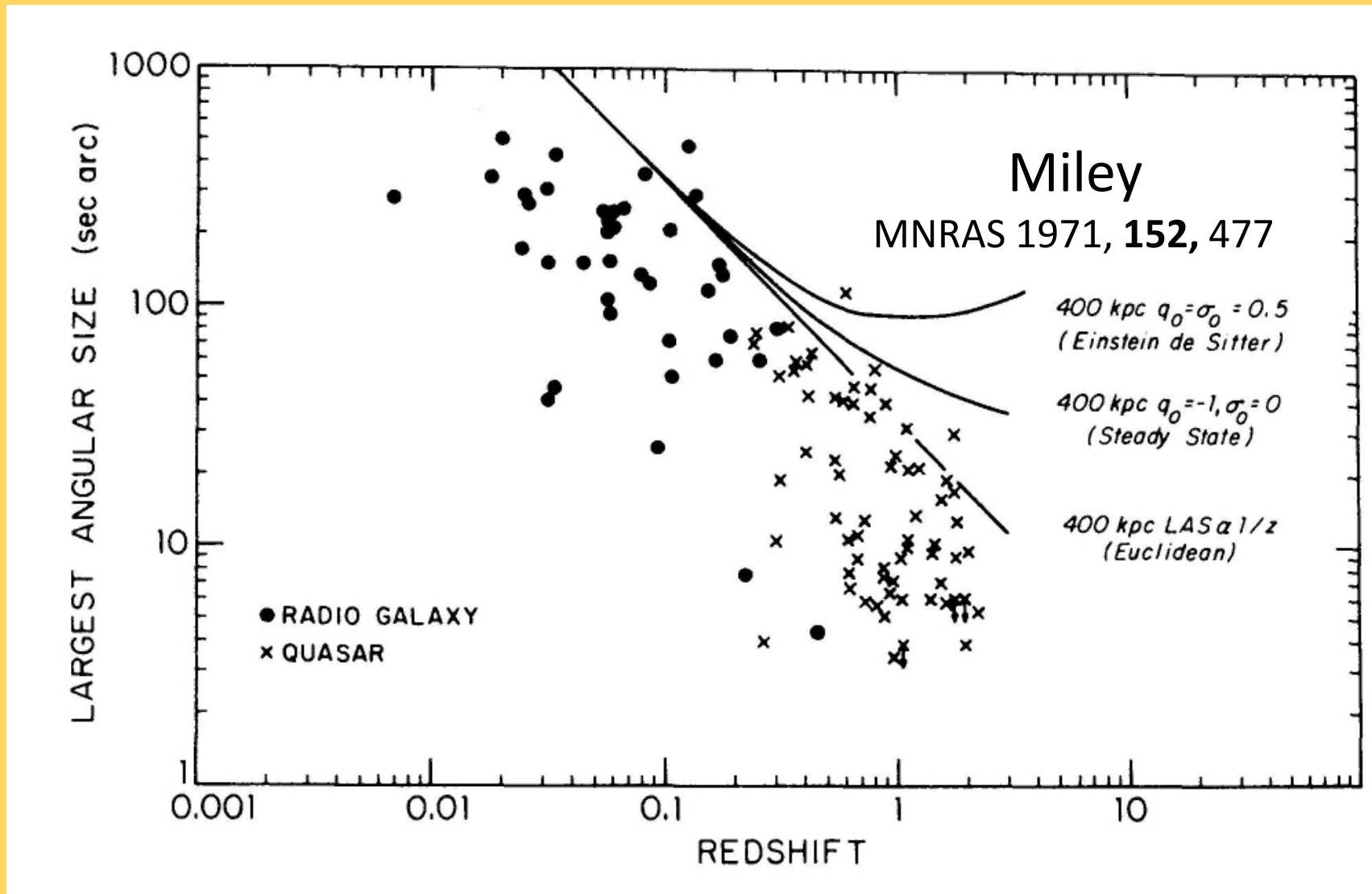


- E-dS Universe ($q_0 = 1/2, \Omega = 1$)
 - $\theta_{\min} (z = 5/4) = 15 \text{ arcsec}$
- S-S Universe
 - $\theta_{\min} (\text{asymptotic}) = 4 \text{ arcsec}$





$\theta - z$ for extended radio sources



Angular Size – Redshift Relation for Radio Galaxies

- Tom Legg, 1970 *Nature*, 226, 64
- Vijay Kapahi, 1987, IAU Symposium 124
- Ashok Singal, 1988, *MNRAS*, **233**, 87

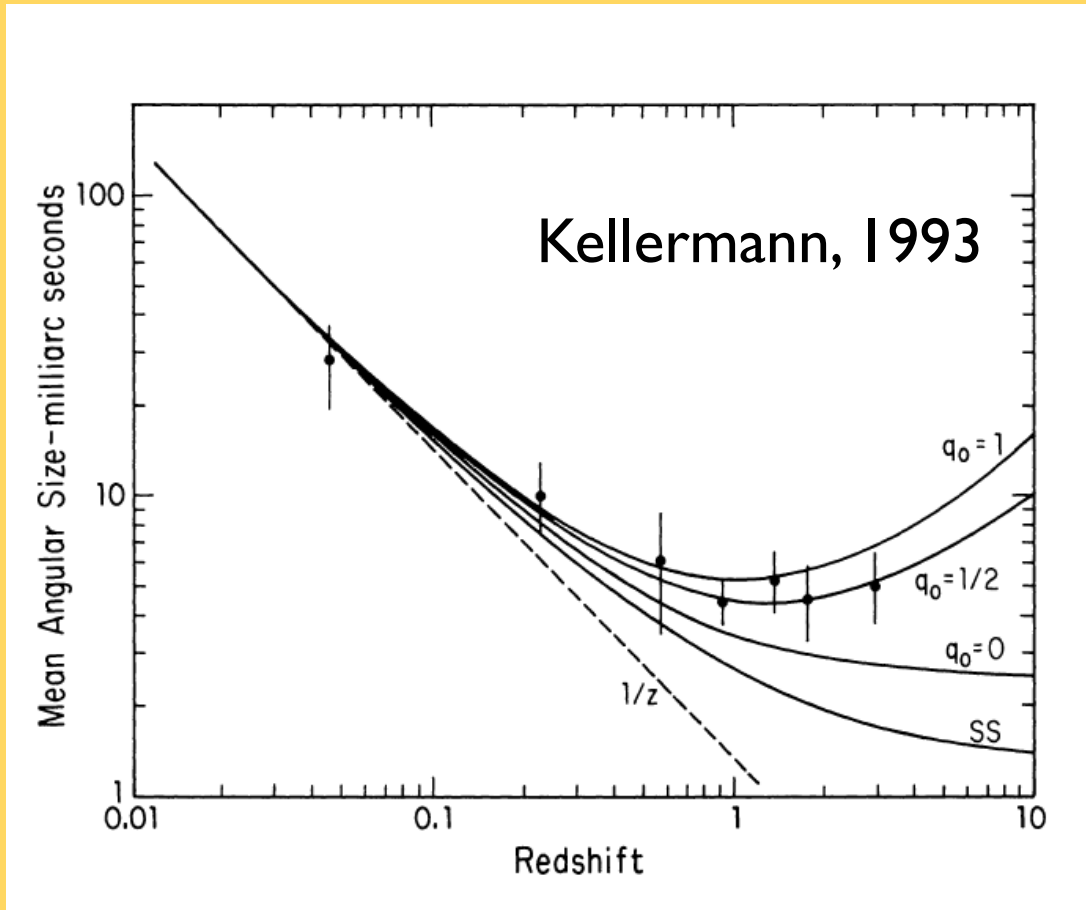
Cosmology with compact radio sources

- They are young – few hundreds years old
- Smaller than host galaxy - unaffected by the IGM, or CMB
- Compact sources are mostly quasars; high z

But!

- No powerful low z quasars
- Large spectral gradient: core-jet
- Apparent size is frequency dependent
- Rest frequency depends on z

Theta-z



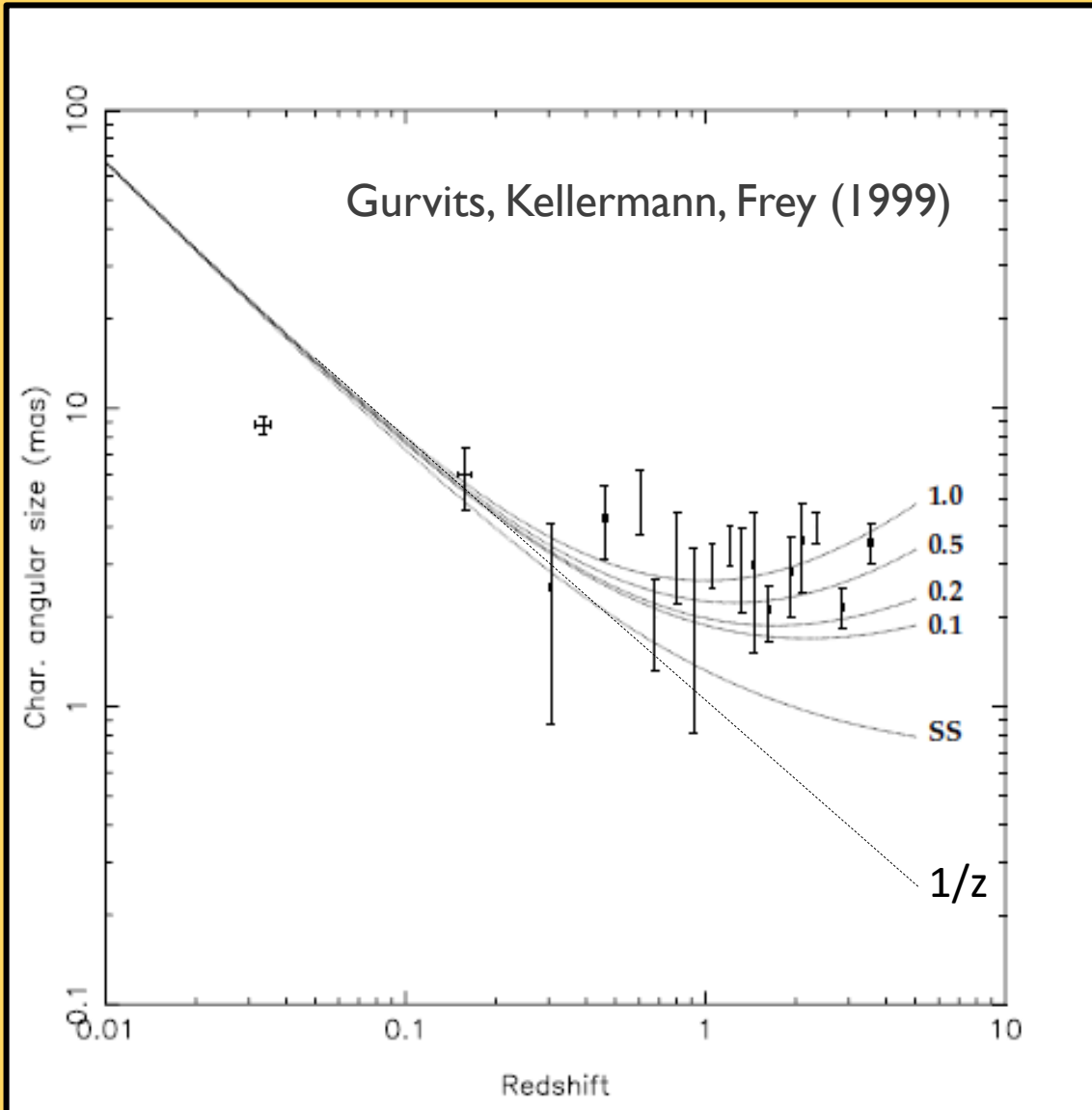
- $N = 82$ mostly core-jet sources
- $\lambda = 2, 3.8, 6$ cm
- $P > 10^{24}$ W/Hz (radio loud)
- DR > 100:1
- Distance to most distant jet > 2%

$$q_0 = 1/2, \Omega = 1$$

or

$$q_0 = 0.1, \Omega = 0.2, \Lambda \neq 0$$

Jackson & Dodgson, MNRAS, 378, 603



- $N = 350$ sources
- 5 GHz (6 cm)
- $L > 2 \times 10^{26} \text{ W/Hz}$
- $-0.38 < \alpha < 0.18$

$$q_0 = 0.21 \pm 0.30$$

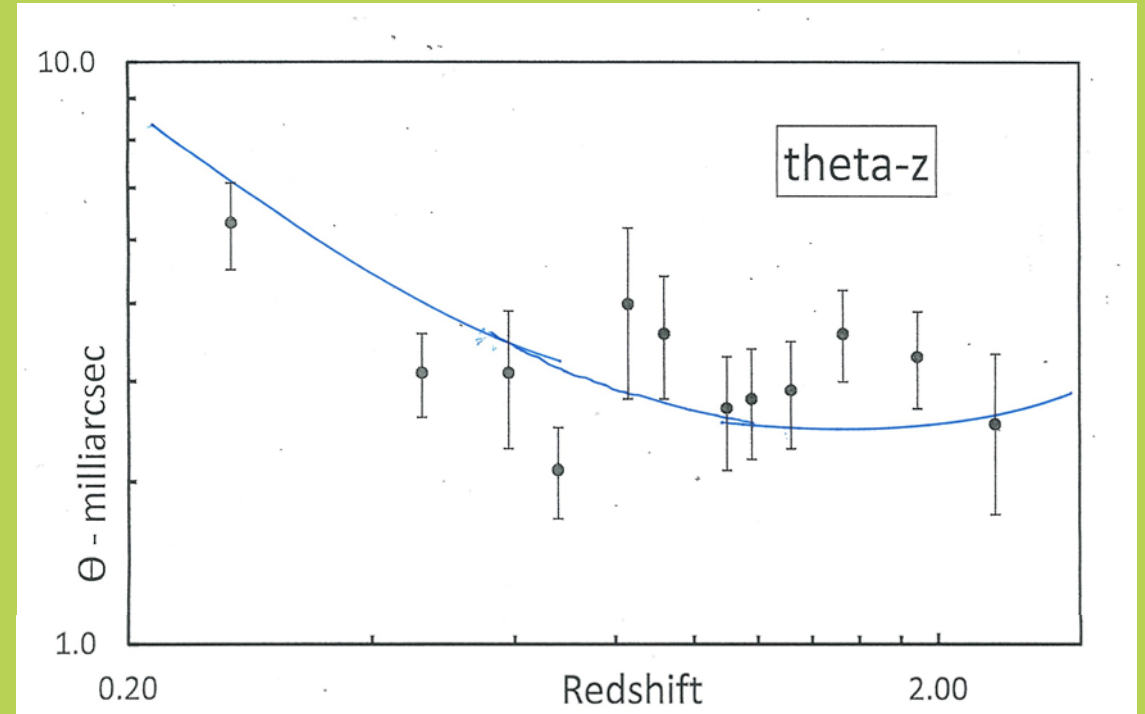
$$\Omega = 0.42 \pm 0.60$$

$\Omega < 1$, and $\Lambda \neq 1$.

Modern VLBI and Cosmology

- VLBA data is much better
- Cosmology more complex
 - Baryonic Matter: $\Omega_b = 0.05$
 - Dark Matter: $\Omega_b = 0.25$
 - Dark Energy $\Omega_{de} = 0.7$

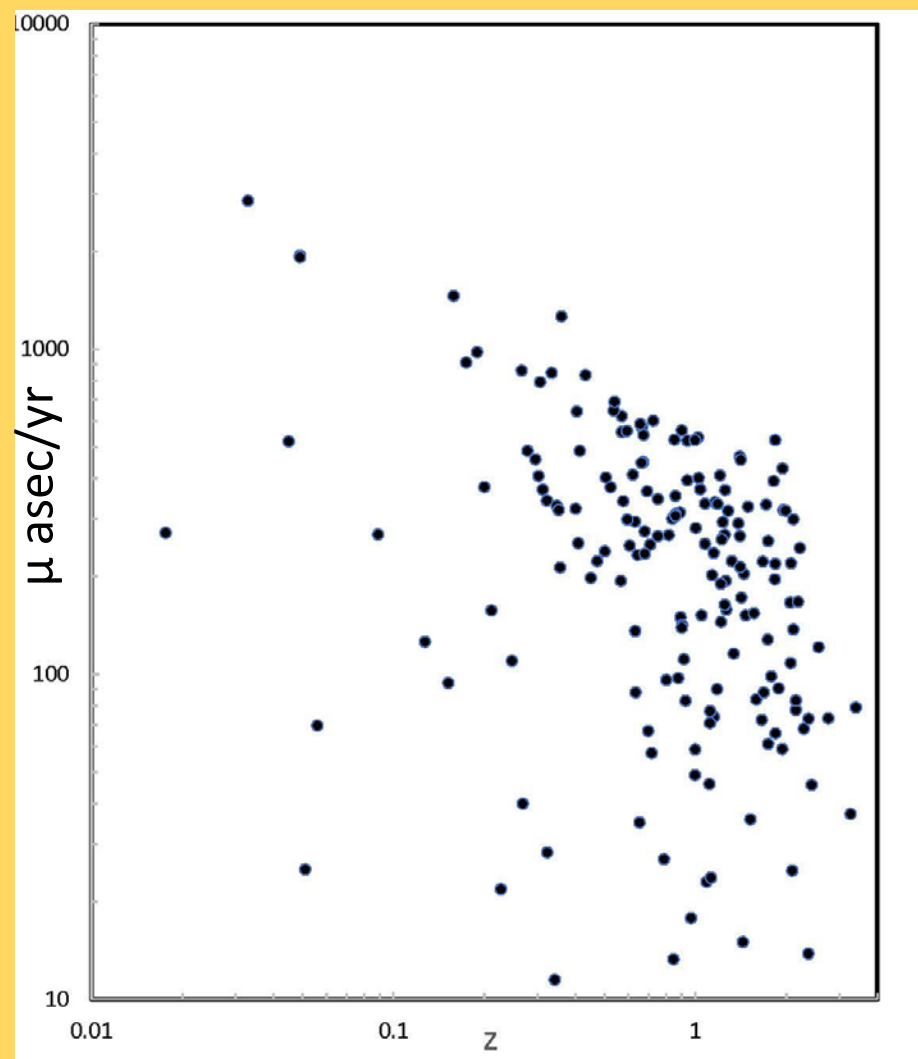
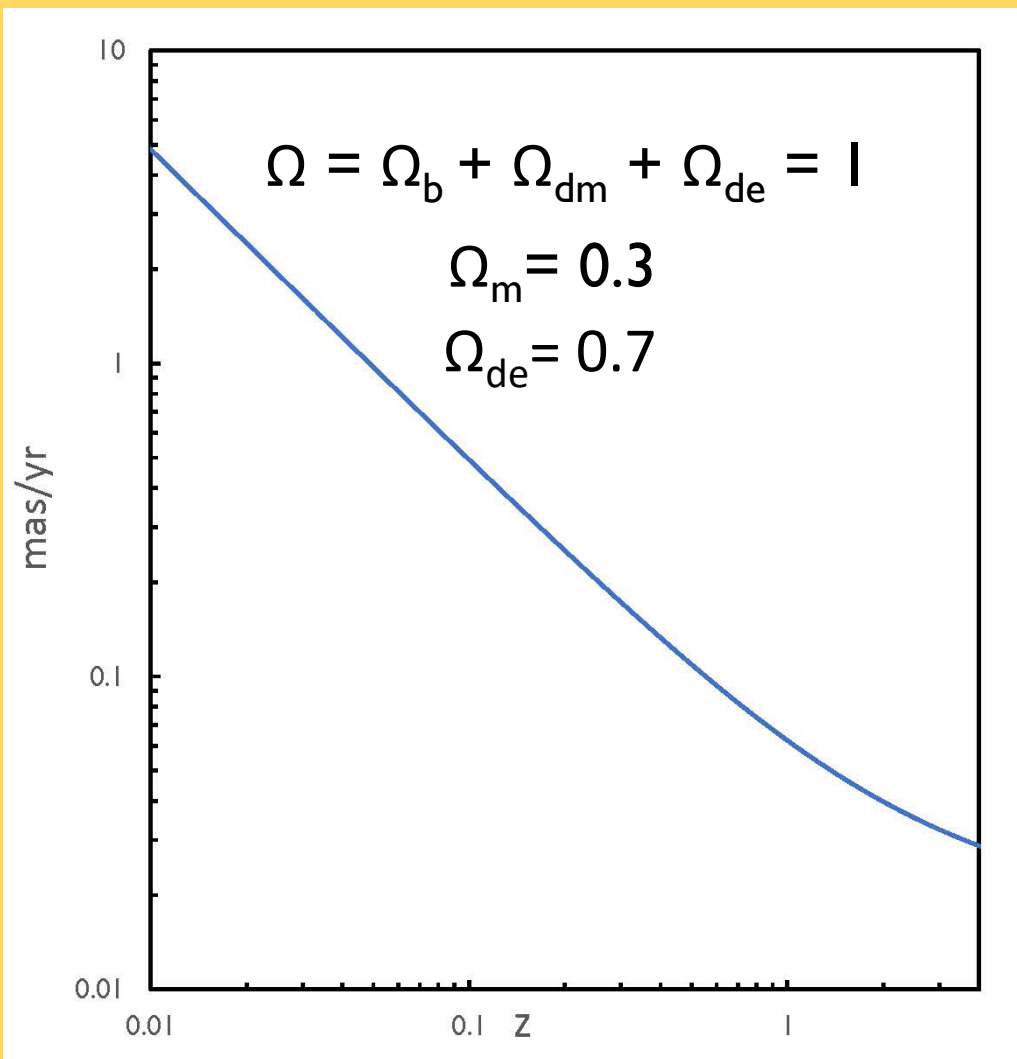
$$\Omega = \Omega_b + \Omega_{dm} + \Omega_{de} = 1$$



MOJAVE 1.5 Jy - ¼ Century Sample

- $P > 10^{25}$ W/Hz
- 136 Sources

Angular Velocity – Redshift Relation



Work in progress

- How to define size?
- How to define velocity (fastest, mean?)
- How to correct for orientation?
- Unresolved sources?
- How to define sample?
 - Luminosity Limits
 - Fixed rest frequency