Classical Tests of Cosmology

Toni Sagristà Sellés

Universitat de Barcelona
Departament d'Astronomia i Meteorologia

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Outline

1 Introduction

2 Classical Tests
- Luminosity Distance
- Angular Diameter distance
- Number Counts

3 Conclusions

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Introduction

What are classical tests of cosmology?

- Techniques to determine values of cosmological parameters
- Discover global geometry and dynamics of Universe
- Only cosmology before *precision cosmology*
- Most tests require some *standard* object
- Basically, seek value of H_0, Ω_0 and q_0

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Classical cosmology

- **Identify** Standard candles, Standard rods and Standard populations at different z
- **Use their properties** to gauge geometry and dynamics

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Luminosity Distance I

Inverse-square law to determine distance through flux

$$M - m = -5(log_{10} D_L - 1)$$

$$D_L = 10^{\frac{m-M}{5}+1} [pc]$$

But usually

$$D_L = \left(\frac{L}{4\pi l}\right)^{1/2}$$

- Luminoisty distance $\neq$ real distance
- Inverse-square law does not hold due to expansion, geometry

Luminosity Distance II

Expansion and redshift effect

$$D_L = a_0 r_0 (1 + z)$$
$$D_{phy} = a_0 r_0$$

For small distances, $D_L = D_{phy}$

Luminosity Distance III

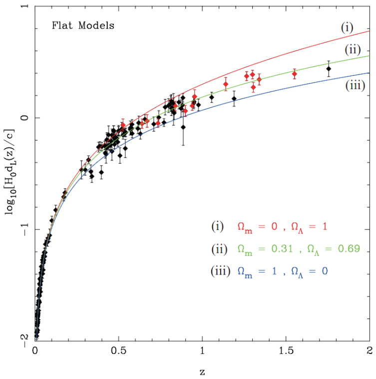

Figure: Luminosity distance versus redshift for various flat models. Red dots are recent HST observations

Luminosity Distance IV

Standard candles

Pulsar stars Cepheids and RR Lyrae, period-luminosity relation known

Red clump stars Absolute magnitude depends on age and metallicity

SNIa Δm_{15} index, luminosity decrease 15 days after maximum

PNLF Old stars evolved into red giant phase, use OIII (doubly ionized oxygen) line to find them. They seem to all have the same luminosity

X-ray bursts Mass related to burst luminosity

Luminosity Distance V

Tully-Fisher Relation Relates rotational velocity of spiral galaxies with their luminosity

Faber-Jakcson Relation Relates velocity dispersion of spiral galaxies with their luminosity

Angular Diameter Distance I

Measures how large objects appear to be

$$D_A = \frac{d}{sin\theta} \simeq \frac{d}{\theta}$$

$$D_A = \frac{a_0 r_0}{1+z} \left(= \frac{D_L}{(1+z)^2} \right)$$

$z \to \infty$, $D_A \to 0$ - Distant objects seem larger!

Angular Diameter Distance II

- The further objects are from us, the older they are, so their comoving size is larger
- Inflection point position depends on q_0 and Ω

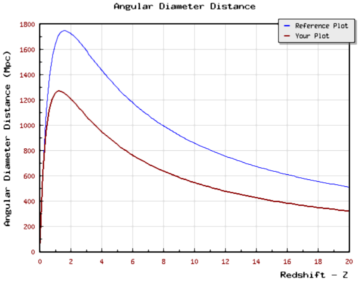

Figure: Angular diameter distance vs redshift. The blue line corresponds to $\Omega_m = 0.3, \Omega_\Lambda = 0.7$, and the red line corresponds to $\Omega_m = 1, \Omega_\Lambda = 0$

Angular Diameter Distance III

Standard rods

Cluster elliptical galaxies: The fundamental plane relation combined with a correction for luminosity evolution can be used

Spiral galaxies: Their angular diameter can be determined through observation

BAO: Baryonic acoustic oscillations, based on size of acoustic waves produced in baryonic matter clustering zones in the primitive universe

Number Counts I

- Focus on cumulative count of objects instead of their physical properties
- We know cumulative number, we may know integration distance
- Number of objects per sterad up to a distance r_0

$$N(r_0) = n(t_0)a_0^3 \int_0^{r_0} \frac{r^2 dr}{\sqrt{1 - kr^2}}$$

Number Counts II

Problems

- Statistical method, uses great number of objects, more prone to errors
- Limiting observable magnitudes may bias sample
- We lack info on actual redshift distribution of observed galaxies

Number Counts III

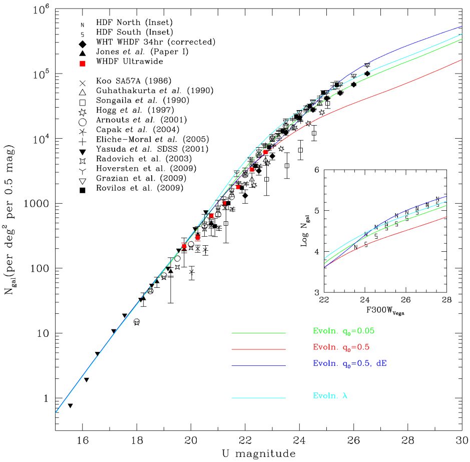

Figure: Number counts in models and observations by HST and others

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Conclusions

- **Evolution problem**: Standard callibrators work at short distances
- Standard callibrators affected by the evolution of the Universe
- **Bias problem**: All observations affected by biases (due to sensitivity, angular resolution, faint luminosity. . .)
- Classical tests key to development of cosmology
- From 2000 on, precision cosmology
- Gravitational lensing can be used to accurately describe geometry of space

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