Dark Energy

David Spergel

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1 Astronomical Methods:Distance

1.1 Supernova

- explosive burning of type Ia SN
- calibrating by light curve width, color

$$d_L = (1+z)\frac{c}{H_0}\int \frac{dz}{h(z)} \tag{1}$$

Open Issues

- what are the progenitors of type Ia SN?
- dust (measure color effects, infer extinction)
- evolution (are there more then one path to SN Ia; relationship between SN rate and color)

1.2 Baryon Oscillations

$$d_A = d_L/(1+z)^2 \tag{2}$$

$$r_s = \int_0^{\eta_{LS}} c_s^2 d\eta \tag{3}$$

- CMB has a standard ruler
- Galaxy clustering as a standard candle

2 Astronomical Methods: Growth of Structure

Why is growth interesting?

What do we expected?

Growth as a consistency check

2.1 Cluster Counts

$$N(M > M_0) = \int_{\delta_{min}} \exp\left(-\frac{\delta^2}{2\sigma_0(M)^2 D(M,a)^2}\right) d\delta \tag{4}$$

- optical counts/velocity dispersion
- X-ray luminosity, size
- SZ luminosity

Mass-Observable relation and its redshift dependance— impact on measurements

2.2 Lensing

$$\begin{aligned} \kappa(\hat{n}) &= \frac{1}{2}\nabla^2_{hatn}\phi^{eff}(\hat{n}) \\ &= \int d\eta \frac{D_a(\eta_s - \eta) d_a(\eta)}{d_A(\eta_S)} \nabla^2_{perp}\Psi(\eta\hat{n};\eta) \end{aligned} \tag{5}$$

Systematics:

- seeing
- shear alignments and photometric redshifts

2.3 ISW Effect

2.4 Redshift Distortions

3 Dark Energy Candidates

3.1 Cosmological Constant

3.2 Quintessence and Its Friends

- scaling models and early dark energy
- $w < -1$ models

3.3 Modifications to Gravity