Theory Walk Through for Cross-Correlating Redshift-Free Standard Candles

Mukherjee and Wandelt (2018) Paper

Megan Tabbutt

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1 Abstract:

LSST will supply up to 10^6 supernovae (SNe) to constrain dark energy through the distance - redshift (D_L - z) test. Obtaining spectroscopic SN redshifts (spec-zs) is unfeasible; alternatives are suboptimal and may be biased. We propose a powerful multi-tracer generalization of the Alcock- Paczynski test that pairs redshift-free distance tracers and an overlapping galaxy redshift survey. Cross-correlating 5×10^4 redshift-free SNe with DESI or Euclid outperforms the classical D_LL - z test with spec-zs for all SN. Our method also applies to gravitational wave sirens or any redshift-free distance tracer.

2 Introduction:

- Accurate trace of the expansion history, e.g. through the D_L?z relation, is one of the foremost goals of current and next-generation surveys such as SDSS-IV, DES, DESI, EUCLID, LSST, and WFIRST
- LSST going to generate large type Ia SN sample at a rate of $\geq 10^4 yr^{-1}$. Already now, the $\geq 10^3 yr^{-1}$ SNe being observed over a wide redshift range make it impossible to obtain time-consuming spectroscopic follow-up for every SN, (the traditional approach underlying the success of cosmology with standard candles over the last two decades).
- Alternative approach combines photometric types with spectroscopic redshift measurements of the presumed SN host galaxy, Errors may lead to biases and loss of information in the inferred cosmological parameters.
- Future galaxy redshift surveys (DESI, EUCLID) going to measure tens of millions of galaxy redshifts over large fractions of sky. It is realistic to expect a galaxy catalog with 10^7 spectroscopic redshifts overlapping SN data

sets over a wide redshift range on the time scale of LSST.

3 Idea:

Propose a new method to infer cosmological parameters accurately from distance tracers (e.g. SNe) without redshifts:

- Exploit fact that both distance tracers and galaxies are tracers of the matter density, and therefore spatially correlated through the underlying matter field
- Can tightly constrain cosmology by maximizing the spatial cross-correlation of overlapping distance catalog and redshift catalogs
- Approach shows a classical cosmological test in a new light as a limit of a multi-tracer generalization of the Alcock-Paczynski (A-P) test
- Particular feature of this cross-correlation approach is its robustness to both data systematics and modeling assumptions

4 Set-Up:

4.1 Apparent Magnitude:

Constrain Luminosity Distance, D_L through relationship between apparent, m, and absolute, M, magnitudes calibrated from light curves:

$$m = 5log_{10}(\frac{D_L(z)}{pc}) + M - 5 \tag{1}$$

- Get light-curves from photometric observations, then calibrate the relationship and get D_L. For some data might already have this, like for DES-Sn.

- Equation is a definition of D_L, which is the thing you want to get and carry forward.

- m is the apparent magnitude, this comes from observations, at what point in the light curve do you pick for m ???

- M is the absolute magnitude, this is gotten from fitting the light curve

4.2 Luminosity Distance:

The luminosity distance is related to the cosmological model and redshift through this equation:

$$D_L(z) = \frac{c}{H}(1+z)\int_0^z \frac{dz'}{\sqrt{\mathcal{E}(z)}} \tag{2}$$

$$\mathcal{E}(z) \equiv \Omega_m(1+z')^3 + \Omega_{de}\exp(3\int_0^z d\, ln(1+z')(1+\omega(z'))) \tag{3}$$

- Assume a flat universe ($\Omega_K = 0$, or $\Omega_{de} = 1 - \Omega_m$) with dark energy equation of state: $\omega(z) = \omega_0 + \omega_a(z/(1+z))$