Astrometric Redshifts of Supernovae

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Motivation

- A vast amount of SNe Ia will be detected by *Rubin*: accurate non-spectroscopic redshifts crucial
- Astrometric redshifts known to be useful for distinctive emission line sources
- Independent redshift estimation from conventional photo-z's
- No extra information (other than what's already being measured) required

Background

Differential Chromatic Refraction (DCR)

- Atmospheric refractive index: λ-dependent => shorter λ (blue) gets refracted more than longer λ (red)
- More DCR at higher air mass (AM), or the amount of air along the line of sight

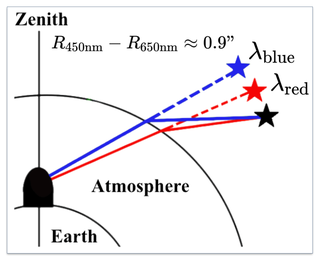
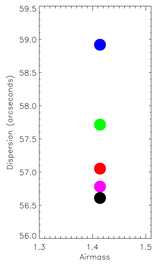


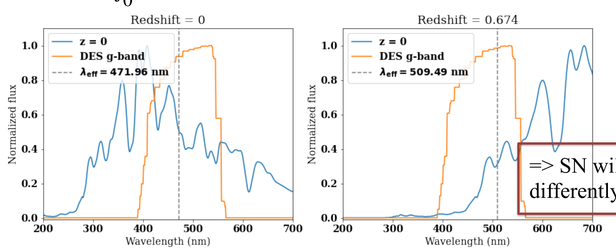
Diagram illustrating the effect of DCR



Refraction in the SDSS *ugriz* bands - Kaczmarczik et al. (2009)

Effective Wavelength (λ_{eff})

- DCR altitude shifts depend on λ_{eff} (to 1st order)
- $\lambda_{eff} = \dfrac{\int_0^\infty \lambda S(\lambda) F(\lambda)\, d\lambda}{\int_0^\infty S(\lambda) F(\lambda)\, d\lambda}$ $S(\lambda)$: Source Flux, $F(\lambda)$: Filter Function



=> SN will be shifted differently depending on z!

Methodology

- SIM: Simulate realistic coordinate shifts due to DCR using SNANA (SuperNova ANAlysis software) simulations
- MODEL: Calculate expected DCR shifts using the full SED depending on redshift, AM, epoch, x_1 (stretch), and c (color)
- With MODEL and SIM shifts and calculate χ^2 as a function of redshift:

$$\chi^2 = \sum \frac{(\text{SIM} - \text{MODEL})^2}{\sigma_{\text{total}}^2},\ \sigma_{\text{total}}^2 = \sigma_{\text{stat}}^2 + \sigma_{\text{syst}}^2,$$

$$\sigma_{\text{stat}} = f\left(\left[\frac{\text{PSF FWHM}}{\text{S/N}}\right]\right),\ \sigma_{\text{syst}} = \text{detection limit} = 5\ \text{mas}$$

- Calculate $P(z, x_1, c) = e^{\frac{-\chi^2}{2}}$, then marginalize over x_1 and c :

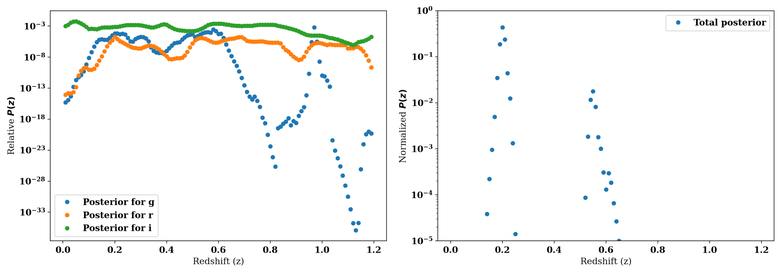
$$P(z) = \int_{c_{\min}}^{c_{\max}} \int_{x_{1,\min}}^{x_{1,\max}} P(z, x_1, c)\, dx_1\, dc$$

- Take the 50th percentile in the CDF (cumulative distribution function) as the predicted redshift, $\pm 1\sigma$ are the lower and upper limits

Posteriors

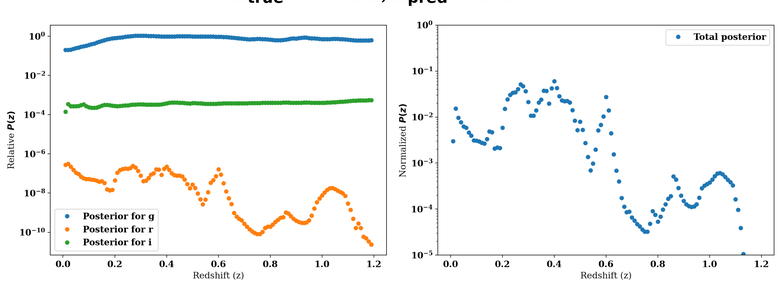
- Good example

$z_{true} = 0.199$, $z_{pred} = 0.196$



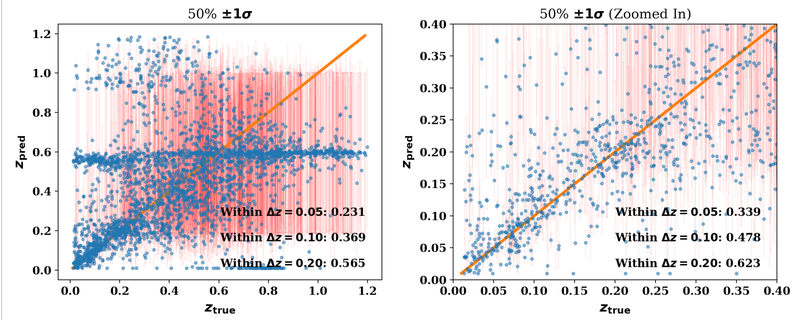
- Bad example

$z_{true} = 0.550$, $z_{pred} = 0.345$



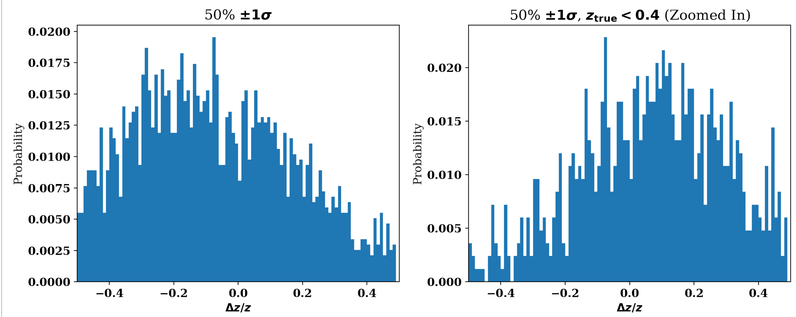
Preliminary Results

Predicted redshift vs. True redshift



- Parameter range: $-0.3 \le c \le 0.5, -3.0 \le x_1 \le 2.0$
- Gives reasonable estimates for $z < 0.4$
- Need to consider selection cuts, how to weight bands
- The horizontal streak at $z = 0.55$ is where the data is not constraining and error bars are large

Histograms



Goals

- Evaluate the accuracy of astro-z's and its dependency on observing strategies (filter choices, AM) & analysis methods
- Provide forecasts on DES data and *Rubin*-like simulations
- Combine with conventional photo-z's to see how much improvement there is
- Extend the analysis to SN II (also has distinct emission lines)