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SN-BHM: A hierarchical Bayesian model for Supernova Cosmology

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ABSTRACT
Abstract Abstract

Key words: keyword1 – keyword2 – keyword3

1 INTRODUCTION

Almost two decades have passed since the discovery of the accelerating universe (Riess et al. 1998; Perlmutter et al. 1999). Since that time, of the number of observed Type Ia supernovae (SN Ia) have increased by more than an order of magnitude thanks to modern surveys at both low redshift (Bailey et al. 2008; Freedman et al. 2009; Hicken et al. 2009; Contreras et al. 2010; Conley et al. 2011), and higher redshift (Astier et al. 2006; Wood-Vasey et al. 2007; Balland et al. 2009; Amanullah et al. 2010). Cosmological analysis of these supernovae samples (Kowalski et al. 2008; Conley et al. 2011; Suzuki et al. 2012; Betoule et al. 2014; Rest et al. 2014) have been combined with complimentary probes of large scale structure (Alam et al. 2017) and the CMB (Hinshaw et al. 2013; Planck Collaboration et al. 2013), and yet, despite these prodigious efforts, the nature of dark energy remains an unsolved mystery.

In attempts to tease out the nature of dark energy, currently running and planned surveys are once again ramping up their statistical power. The Dark Energy Survey (DES, Bernstein et al. 2012; Abbott et al. 2016) will be observing thousands of Type Ia supernova, attaining both spectroscopic and photometric confirmation. The Large Synoptic Survey Telescope (LSST, Ivezic et al. 2008; LSST Science Collaboration et al. 2009) will produce scores of thousands of photometrically classified supernovae. Such increased statistical power demands a similarly increased fidelity and flexibility in modelling the supernovae for cosmological purposes, as systematic uncertainty will prove to be the limiting factor in our analyses.

As such, staggering effort is being put into developing more sophisticated supernovae analyses. Scolnic & Kessler (2016) and Kessler & Scolnic (2017) explore sophisticated simulation corrections to traditional analyses. Approximate Bayesian computation methods also make use of simulations, trading traditional likelihoods and analytic approximations for more robust models with only the cost of increased computational time (Weyant et al. 2013; Jennings et al. 2016). Hierarchical Bayesian Models abound (Mandel et al. 2009; March et al. 2011, 2014; Rubin et al. 2015; Shariff et al. 2016; Roberts et al. 2017), however often face difficulties finding sufficient analytic approximations for complicated effects such as Malmquist bias.

In this paper, we lay out a new hierarchical model that extends on past work. In Section 2 we outline our methodology and apply it to simulated datasets. Forecasts for the impending DES three year spectroscopic supernova survey are contain in Section 3. Section 4 investigates the effect of various systematics on our model, and Section 5 provides details on potential areas of improvement and unsuccessful methodologies.

Introduce significance of SN historically, and the quest to remain competitive with BAO and other probes, we have to reduce systematic uncert whilst larger surveys reduce stat.

Review old methods

Review current methods

Potential places for improvement

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2 OUR METHOD

General comments about the method (BHM), Stan

2.1 General Description

Mapping population of observables on a population of underlying SN, where the map function encodes cosmology. Difficulty is creating an underlying SN population that is flexible enough to not introduce bias whilst still being physically motivated.

Observables -> Transformation function (latent, mass, cosmology, systematics) -> Underlying pop (and outlier)

2.2 Applied to Spectroscopic Sample

Minimal outliers

3 APPLICATION TO DES

3.1 Simulating DES SN data

3.2 Model validation

appoximate_simple_test.py

multisim

bulk

3.3 Results on simulated data (ie projections)

3.3.1 Spectroscopic Sample

3.3.2 Photometric sample

3.4 Comparison with bells and whistles fixed

4 SYSTEMATICS STRENGTH TEST

systematics test

5 INTERESTING IMPLEMENTATION DETAILS

Anything interesting.

Also talk about non-analytic correction factors (and their failure - mc integration, GP, NNGP)

6 CONCLUSIONS

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APPENDIX A: PAPERS

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