Constraining the geometry of the Universe using Type Ia supernovae

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Type Ia supernovae have the unique trait of being standard candles, their light curves can be used in cosmology to calculate and constrain cosmological parameters. In observing Type Ia supernovae and fitting model light curves to such data one can attempt to derive such values. We have monitored, collected, and analysed data for supernova explosions over a period of 34 days. A $16''$ and a 0.5 m telescope situated in Durham and La Palma was used for this project. After calculating the magnitudes for a Type Ia (2017hhz) and Type Ia-91bg (2017hle) supernova object, we fitted template light curves with the Python program, *SNooPy*. The quality of fit for the program's `fit()` function was deemed to be acceptable in accordance to the average reduced χ^2 values calculated for the B and V photometric bands, $\chi^2_{\nu,B} \approx 1.38$ and $\chi^2_{V,\nu} \approx 2.95$ - a good fit requiring $\chi^2_\nu \approx 1$. The distance modulus to the supernova 2017hhz was calculated by SNooPy to be 36.121 ± 0.106 mag, using this value we were able to compute $H_0 = 70 \pm 20$ km s^{-1} Mpc^{-1}. However, the quoted error negates the meaning of H_0 as it is too large of an uncertainty. In improving the accuracy and uncertainties we suggest that more observations of the supernovae were required, and constraining values should be used for the parameters in SNooPy's templates.

I. INTRODUCTION

In cosmology, one can argue that one of the most important observable events are supernova explosions. As a massive main sequence star runs out of nuclear fuel to burn, the equilibrium configurations which initially provided structure will cease to exist. What follows is a cataclysmic supernova explosion [3].

We can generally class supernova explosions into two separate groups, Type I and Type II supernovae. The main distinction arises due to the fact that Type I's have an optical spectra which contains no Balmer hydrogen features, whilst Type II supernovae do contain this hydrogen feature [1].

Within these two subclasses there are further divisions which can be characterised through their spectra and through features as found in their light curves [2]. Light curves are a way to show the evolution of a supernova's magnitude as time passes. With two of the subclasses of Type II supernovae, Type II-L and Type II-P, they have been classed by features of their respective light curves: a rapid linear decrease in magnitude and constant magnitude [1].

For the application of supernovae in cosmology, we must turn to supernovae of the Type Ia variety and to the light curves that they produce.

a. Type Ia Supernovae

It is generally accepted that the light curves of Type Ia supernovae are homogeneous [4], this means that they can be utilised as standard candles, therefore allowing us another measure of cosmic distance.

Their homogeneity arises due to the mechanism behind their explosion. The progenitor system behind Type Ia's consist of a binary system with a white dwarf and another star which has a mass close towards the Chandrasekhar limit of $1.4 M_\odot$ [1, 4].

b. Cosmological Parameters

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c. Cosmological Parameters from Type Ia Supernovae

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d. Project Aims

Through computational analysis it is possible to employ data sets of Type Ia supernovae to constrain values for cosmological parameters. In Section **??** we discuss the results from our entire experimental period, from our early work with Least-Square statistics to later experimentation with the Markov-Chain-Monte-Carlo method.

II. RESULTS AND DISCUSSION

From our experimentation we have therefore found results which ??

a. χ^2 Statistics

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b. Bayesian Statistics

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c. Further Investigation

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III. CONCLUSIONS

In conclusion, we have found that it is possible to constrain cosmological parameters of the universe using Type Ia supernova data.

References

[1] B. W. Carroll and D. A. Ostlie. *An Introduction to Modern Astrophysics*. Pearson, 2nd edition, 2007.

[2] A. Gal-Yam. *Handbook of Supernovae: Observational and Physical Classification of Supernovae*. Springer International Publishing AG, 2017.

[3] M. Longair. *High Energy Astrophysics*. Cambridge University Press, 3rd edition, 2011.

[4] S. E. Woosley and T. A. Weaver. The Physics of Supernova Explosions. *Annual Review of Astronomy and Astrophysics*, 24:205–253, 1986.

Appendix A: ??