Preface

The work presented in my thesis develops advanced Bayesian statistical methods for using astrophysical data to probe our understanding of the universe, I cover three main areas:

Should We Doubt the Cosmological Constant?

While Bayesian model selection is a useful tool to discriminate between competing cosmological models, it only gives a relative rather than an absolute measure of how good a model is. Bayesian doubt introduces an unknown benchmark model against which the known models are compared, thereby obtaining an absolute measure of model performance in a Bayesian framework. I apply this new methodology to the problem of the dark energy equation of state, comparing an absolute upper bound on the Bayesian evidence for a presently unknown dark energy model against a collection of known models including a flat Lambda cold dark matter (ΛCDM) scenario. I find a strong absolute upper bound to the Bayes factor between the unknown model and ΛCDM. The posterior probability for doubt is found to be less than 13 % (with a 1 % prior doubt) while the probability for ΛCDM rises from an initial 25 % to almost 70 % in light of the data. I conclude that ΛCDM remains a sufficient phenomenological description of currently available observations and that there is little statistical room for model improvement

Improved Constraints on Cosmological Parameters from Supernovae Type Ia Data

I present a new method based on a Bayesian hierarchical model to extract constraints on cosmological parameters from SNIa data obtained with the SALT-II lightcurve fitter. I demonstrate with simulated data sets that our method delivers considerably tighter statistical constraints on the cosmological parameters and that it outperforms the usual chi-square approach 2/3 of the times. As a further benefit, a full posterior probability distribution for the dispersion of the intrinsic magnitude of SNe is obtained. I apply this method to recent SNIa data and find that it improves statistical constraints on cosmological parameters from SNIa data. From the combination of SNIa, CMB and BAO data I obtain $\Omega_m = 0.28 \pm 0.02$, $\Omega_\Lambda = 0.73 \pm 0.01$ (assuming $w = -1$) and $\Omega_m = 0.28 \pm 0.01$, $w = -0.90 \pm 0.05$ (assuming flatness; statistical uncertainties only). I constrain the intrinsic dispersion of the B-band magnitude of the SNIa population, obtaining $\sigma_\mu^{\mathrm{int}} = 0.13 \pm 0.01$[mag].

Robustness to Systematics for Future Dark Energy Probes

I extend the figure of Merit formalism usually adopted to quantify the statistical performance of future dark energy probes to assess the robustness of a future mission to plausible systematic bias. I introduce a new robustness figure of Merit which can be computed in the Fisher Matrix formalism given arbitrary systematic biases in the observable quantities. I argue that robustness to systematics is an important new quantity that should be taken into account when optimizing future surveys. I illustrate our formalism with toy examples, and apply it to future type Ia supernova (SNIa) and baryonic acoustic oscillation (BAO) surveys. For the simplified systematic biases that I consider, I find that SNIa are a somewhat more robust probe of dark energy parameters than the BAO. I trace this back to a geometrical alignment of systematic bias direction with statistical degeneracy directions in the dark energy parameter space.

This thesis is structured as follows: After the Introduction there are three chapters describing the background pertaining to the subsequent work chapters. Chapter 2 briefly describes the cosmological background to this work, outlining the Friedman Robertson Walker and ΛCDM model of the universe. Chapter 4 describes in some detail the supernovae type Ia which are the major astrophysical probe treated in this work, in particular in Chap. 7, whilst Chap. 5 describes the statistical methods (primarily Bayesian) utilised. These background chapters are not intended to give an exhaustive description of current cosmology and statistics, but serve to place in context and give sufficient technical background for the understanding of the work chapters.

Following the work chapters, Chap. 9 summarises the main conclusions of the work presented in this thesis and gives an overview of the future directions of this work.

Springer

http://www.springer.com/978-3-642-35059-7

Advanced Statistical Methods for Astrophysical Probes
of Cosmology
March, M.C.
2013, XX, 180 p., Hardcover
ISBN: 978-3-642-35059-7