Probing dark energy inhomogeneities with supernovae

Blomqvist et al. (2008) – submitted to JCAP

Introduction

The search for spatial variations in dark energy (DE) properties is an important complement to studies aiming at constraining the time evolution of DE. One way to probe models with inhomogeneous DE is to look for anisotropies in the observed peak magnitudes of type Ia supernovae (SNe Ia). In general, we expect the magnitudes to be correlated on scales similar to the clustering scale of the DE. In this work we devise a general methodology of detecting angular correlations in SN Ia magnitude residuals and apply this method to current SN Ia data. We also investigate how future data can put limits on possible correlations.

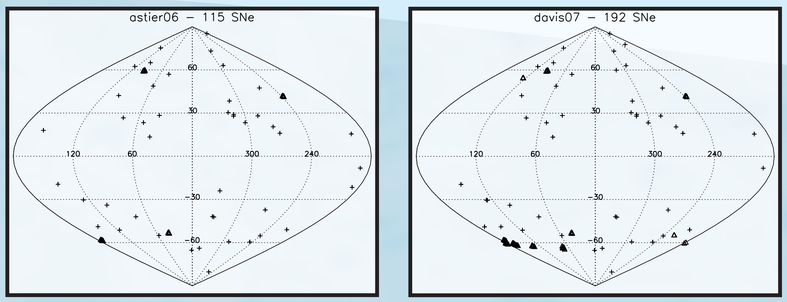
Method

The data sets we investigate contain both nearby and distant SNe Ia, for which we have redshifts and observed peak magnitudes with uncertainties, as well as positions on the sky. The angular correlation function as a function of the angular separation on the sky is defined as the correlation coefficient for the Hubble diagram magnitude residuals.

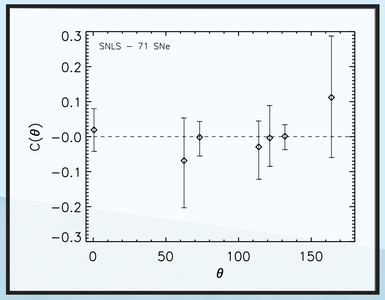
Current data

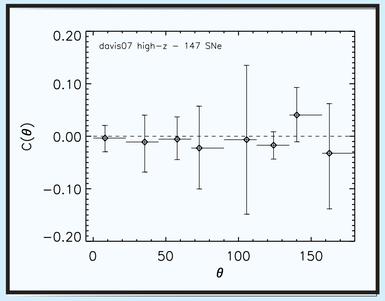
We apply the methodology on two current data sets from the literature. The first one is from Astier et al. (2006) and is the first year Supernova Legacy Survey (SNLS) data release (denoted astier 06) consisting of 115 SNe Ia. The SALT light-curve model was used to fit all SN Ia light-curves. The second data set is from Davis et al. (2007) and is a compilation of 192 SNe Ia (denoted davis07). The peak magnitudes and uncertainties were obtained with the MCLS2k2 light-curve model. The data sets are not independent, because they overlap partially for the high redshift sample, and include almost the same set of nearby SNe.

The high-z samples in both data sets are consistent with the magnitude residuals being uncorrelated. For the low-z samples we detect a feeble anticorrelation around 40°. Due to the weak statistical significance of this detection and the systematic errors involved, we cannot draw any conclusions about the possible implications for DE inhomogeneity.



Distribution of SNe Ia on the sky in galactic coordinates. Left panel: 115 SNe Ia in astier06, consisting of 71 SNLS SNe (triangles) and 44 low-z SNe (pluses). Right panel: 192 SNe Ia in davis07, with 147 high-z SNe (triangles) and 45 low-z SNe (pluses).

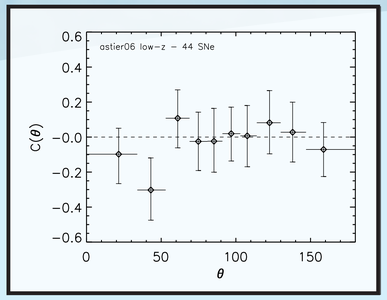


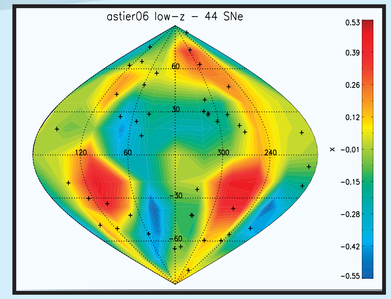


Correlation functions for the high-z SNe Ia in astier06 and davis07. The error bars represent the 68% confidence limit. Left panel: Correlation function for the 71 SNLS SNe in astier06. The bins are at the certain angular separations defined by the survey geometry. Right panel: Correlation function for the 147 high-z SNe in davis07, adopting a resolution of 22.5°. Note that the data points are not independent, since each SN contributes to several bins.

Future data

More SN data is needed if we are to detect presumably weak correlations and better constrain inhomogeneous/anisotropic models. The survey geometries govern on what scales, and to what precision, we will be able to detect possible angular correlations. Using data from the soon to be completed SDSS-II and SNLS surveys, we will typically be able to detect correlations in the magnitude residuals at the percent level. The same is true for the proposed SNAP satellite, which should also be able to detect the correlations induced by gravitational lensing on sub-degree scales.

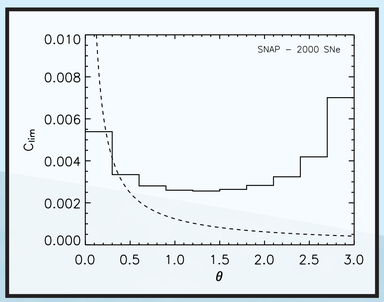




Left panel: Correlation function for the 44 low-z SNe in astier06. The error bars represent the 68% confidence limit. Each bin contains approximately the same number of SN pairs. The horizontal bars indicate the range of each bin. Right panel: Colour map of the scaled and normalized magnitude residuals for the 44 low-z SNe in astier06 smoothed over an angular scale of 15°.

Summary

- We investigate the possibility to identify anisotropic and/or inhomogeneous cosmological models using SN Ia data.
- A search for angular correlations in current SN Ia peak magnitudes yields a null result for the high-z SNe, but shows a feeble anticorrelation at 40° for the low-z samples.
- Upcoming SN data will improve our limits on the size of – or possibly detect – possible correlations at the percent level in the near future.



Detection limit for correlations in the magnitude residuals for the SNAP survey with 2000 SNe. The overplotted dashed line is the correlation induced by gravitational lensing for a source redshift of z = 1.

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