The local to global $H_0$ ratio and the SNe Ia results

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ABSTRACT

The effects of differences between the local and global values of the Hubble parameter on the cosmologies consistent with studies of high-redshift Type Ia supernovæ are discussed. It is found that with a local Hubble parameter around 10 per cent higher than the global value then open cosmological models (such as $\Omega_M = 0.3, \Omega_\Lambda = 0$) are preferred and if the local value is around 20 per cent higher then standard cosmological models ($\Omega_M = 1, \Omega_\Lambda = 0$) can be recovered. Even in the case where the Hubble parameter ratio is 1, low $\Omega_M$ open cosmologies with $\Omega_\Lambda = 0$ are not rejected at the 95 per cent confidence level.

Subject headings: Cosmology — supernovae: general
1. Introduction

Recent exciting results from the searches for high-redshift type Ia supernovae (SNe Ia) have been interpreted as suggesting that there is indeed a cosmological constant and that the expansion of the Universe is accelerating (Perlmutter et al. 1999 and Riess et al. 1998).

The results on the cosmology are robust in that they are independent of the value of the Hubble parameter, $H_0$, (as they use redshift, $z$) and also of the local calibration of the SNe Ia luminosities (as the distance modulus is used). They do rest upon an underlying assumption that the local and global values of $H_0$ are the same (so that the distance-redshift relationship does not change).

Here we examine how different the local value of $H_0$ must be from the global value in order to significantly change the cosmology derived from the fitting of high-redshift SNe Ia data to the Hubble diagram. A similar approach was taken by Kim et al. (1997) to fit data from the first 7 high-redshift SNe Ia between $0.35 < z < 0.65$; in this paper we extend that work with a much larger number of supernovae in the range $0.3 < z < 0.85$. (It should also be noted that the data used by Kim et al. favoured an $\Omega_M = 1$ cosmology at the time.)

2. Local and global differences in $H_0$

The idea that the local Universe is atypical has been suggested by numerous authors (see Dekel 1994 for a review).

Hudson et al. (1999) report evidence for a large scale bulk flow on scales possibly greater than 14000 km s$^{-1}$. Plionis & Kolokotronis (1998) show that there may be contributions to the X-ray cluster dipole from beyond 16000 km s$^{-1}$. Lauer & Postman (1994) and Scaramella (1992) suggest the possibility of even larger density inhomogeneities out to a distance of 15000 - 30000 km s$^{-1}$. 
Phillips & Turner (1998) see that near-IR galaxy counts out to $z = 0.10 - 0.23$ are deficient which may be due to a local underdensity on such scales, implying that the local value of the Hubble parameter $H_0$ is up to 30 per cent higher than the global value. Tammann (1998) also sees a decrease in the value of $H_0$ out to 18000 km s$^{-1}$ of 7 per cent.

Whilst these claims are not without their detractors it is clear that a body of work exists to suggest that the local value of $H_0$ may not be the same as the global value and could be higher. See Turner, Cen & Ostriker (1992) for a detailed discussion of this topic.

3. Method and results

We assume that the value of $H_0$ on scales greater than $z = 0.1$ is equal to the global value, and then fit open and flat cosmologies to the high-redshift SNe Ia data, shifting the zero-point of the data to find the best fit to the various cosmologies. The difference in zero-points between the local and high-redshift supernovae is then used to calculate the difference between the local and global values of the Hubble parameter.

Using the corrected data for 10 high-redshift SNe Ia presented in tables 5 and 6 of Riess et al. (1998) and for 40 Supernova Cosmology Project (SCP) high-redshift SNe Ia from table 1 of Perlmutter et al. (1999) we reconstruct the Hubble diagrams. The shift in the local-to-global Hubble parameter required to fit various flat and open cosmologies are then calculated using a $\chi^2$ fit, also finding the 95 per cent confidence limits.
SCP SNe Ia data. The best fit when \( H_{0(L)}/H_{0(G)} = 1 \) in fig. 1(a) is the well-known \( \Omega_M = 0.28, \Omega_\Lambda = 0.72 \) cosmology found by Perlmutter et al. (1999).

More interestingly a variety of low \( \Omega_M \) open cosmologies are not rejected at the 95 per cent level even if \( H_{0(L)}/H_{0(G)} = 1 \). In order for an \( \Omega_M = 0.3 \) open cosmology to be the best fit to the data then \( H_{0(L)}/H_{0(G)} = 1.07 \) is required.

The recovery of critical mass density cosmologies is more difficult. They are rejected at greater than the 99 per cent level if \( H_{0(L)}/H_{0(G)} = 1 \) and need a large ratio \( H_{0(L)}/H_{0(G)} = 1.21 \).

The data of Riess et al. (1998) was also examined and the fits are very similar to those presented in fig. 1 although they are less significant due to the much lower number of data points. Generally the Riess et al. data are slightly less consistent with a low \( \Omega_M \) open cosmology and \( \Omega_M = 1 \) critical cosmologies are ruled out at a higher confidence level, requiring a 1.2 to 1.3 \( H_{0(L)}/H_{0(G)} \) ratio. To fit best a low \( \Omega_M \) open cosmology then the \( H_{0(L)}/H_{0(G)} \) ratio must be 1.1 - 1.2.

4. Conclusions

If the local value of the Hubble parameter is higher than the global value on scales of a few 100 \( h^{-1} \) Mpc then the fitting of cosmological parameters to the high-redshift SNe Ia data of Perlmutter et al. (1999) and Riess et al. (1998) may be inappropriate. Previously popular cosmologies such as open or critical matter density Universes with no cosmological constant may be acceptable if we live in a local underdensity. Whilst large underdensities of scales up to 300-600 \( h^{-1} \) Mpc are not expected from standard power spectra, there is some observational evidence that we may live in such an underdensity (see section 2), a possibility which is not ruled out by these results. It seems that is too early yet to abandon
the traditional models.

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Fig. 1.— The required ratio of local-to-global Hubble parameter to fit cosmologies of various $\Omega_M$ for SCP data in (a) a flat cosmology ($\Omega_M + \Omega_\Lambda = 1$) and (b) an open cosmology ($\Omega_\Lambda = 0$). The 95 per cent confidence limits are marked in both cases by dashed lines.
