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Dipole test on SCP supernovae: ⋆

confirming the expansion center model

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Abstract. A dipole test of the expansion center model (ECM) is here carried out on high-redshift Type Ia supernovae from the Supernova Cosmology Project. After a brief review of the main ECM equations, two samples of high-z SNe Ia (Perlmutter et al. 1999; Knop et al. 2003) plus two other combined samples are tested through the ECM dipole equation (Lorenzi 2003b) with luminous distances based on peak magnitudes corrected for Galactic extinction and for the cross-filter K-correction. The successful check of the mere cosine dipole equation confirms the model for remote high-redshift supernovae.

Key words. cosmology – supernovae – cosmic dipole

1. Introduction

Following the on line paper (Lorenzi 2003b: hereafter paper V) "The expansion center model as a challenge to cosmology, based on data, results and 3 historical models", which is the "attached paper" to that entitled "An expected revolution of the Galaxy around the expansion center" (Lorenzi 2003a: paper IV), here we deal with SNe Ia tests, specifically addressed to check the ECM dipole equation on the remote Universe, by high-z supernovae (Perlmutter et al. 1999; Knop et al. 2003) of the Supernova Cosmology Project (SCP).

2. Main ECM equations

The best values for H_0 and R_0 have been obtained from the solution of the ECM equation,

$$\frac{\dot{r}}{r} = H_0 \cdot \left(\frac{1+x}{1-x}\right) - a_0(1-x)^{-\frac{2}{3}} \cos\gamma \qquad (1)$$

applied to the sample of 83 individual nearby galaxies, listed by Sandage & Tammann (1975) in their tables 2,3 and 4, with $x = 3H_0 r/c$ and distances r obtained by calibration of galaxy luminosity classes from known H II region sizes, being $\gamma = 0$ for the expansion center direction ($\alpha_{VC} \approx 9^h; \delta_{VC} \approx +30^0$: Bahcall & Soneira 1982). The final solution in Hubble units, after

⋆ Integral version at http://sait.oat.ts.astro.it/MSAIS/5/POSTER/LLORENZI.pdf

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Table 1. ECM solution in H.u. based on data by Sandage & Tamman (1975)

$H_0 = 70 \pm 3$	$q_0 \cong -0.0605$	$R_0 \simeq 260$	$a_0 \simeq 12.66$

introducing $\dot{r} = cz$ (see paper V) with light-distances r referring to the epoch of the light emission, is that of paper II (Lorenzi 1999b), and here summarized in Table 1.

Note that recently the WMAP mission has furnished $H_0 = 71 \pm 4$ H.u.(Bennett et al., 2003). More concisely eq. (1) can be written, according to the new general Hubble law (see eqs. (59)(53)(39)(37)(36)(35) of paper I: Lorenzi 1999a), as follows

$$\frac{cz}{r} = H_* - a \cdot \cos\gamma \tag{2}$$

being

$$H_* = H_0 + 2\Delta H \qquad a = KR \tag{3}$$

with

$$\Delta H = H - H_0 = Kr \qquad H = H_0/(1-x) \qquad x = 3H_0 r/c \tag{4}$$
$$K = K_0/(1-x) \qquad K_0 = 3H_0^2/c \qquad R = R_0(1-x)^{1/3}$$

3. ECM dipole formula

As eq. (1) and (2) are equivalent, it results

$$\frac{1+x}{1-x} = \frac{H_*}{H_0} \qquad \textit{and} \qquad a = a_0(1-x)^{-\frac{2}{3}} \tag{5}$$

Consequently the cosmological luminous distance $D_C \equiv D_L$ of paper V (Lorenzi 2003b), also recalling the density law (15) and eq. (9) of paper III (Lorenzi 2002-partial version), takes the following multiple formulation

$$D_C = r \cdot (1+z)\left(\frac{1+x}{1-x}\right) = r \cdot (1+z) \cdot \frac{H_*}{H_0} = r \cdot (1+z)\left(1 + 2\frac{\Delta\rho}{\rho_0}\right) \tag{6}$$

where it is $\Delta\rho = \rho(t) - \rho_0$. After transferring the second formulation of D_C from eq. (6) into eq. (2), one obtains

$$\frac{cz(1+z)}{D_L} = H_0 - a\frac{H_0}{H_*} \cdot \cos\gamma \tag{7}$$

or, from (5), the mere cosine dipole equation of paper V

$$\frac{cz \cdot (1+z)}{D_L} = H_0 - a^*(x) \cdot \cos\gamma \qquad \textit{with} \qquad a^*(x) = a_0 \cdot \frac{(1-x)^{1/3}}{1+x} \tag{8}$$

or the final **ECM dipole formula** with both the constant H_0 and a_0, that is

$$\frac{cz \cdot (1+z)}{D_L} = H_0 - a_0 \cdot X \qquad \textit{with} \qquad X = \frac{(1-x)^{1/3}}{1+x}\cos\gamma \tag{9}$$

together with

$$M = m - 5\log D_L - 25 \Rightarrow D_L = 10^{0.2(m-M)-5} \tag{10}$$

Table 2. Main features of 4 tested SNe Ia samples

Sample	*source*	N	$\langle\cos\gamma\rangle$	$\langle m_B\rangle$	$\langle z\rangle$	$\langle r_z\rangle$	$\langle D_C\rangle$
XI	42SNe/P99	42	+0.40	23.00	0.495	710	3388
XII	38SNe/K03	38	+0.48	23.15	0.515	723	3606
XIII	42SNe/P99 + 11HSTSNe/K03	42 + 11	+0.43	23.11	0.514	722	3576
XIV	38SNe/K03 + 15SNe/P99	38 + 15	+0.43	23.14	0.514	722	3576

Table 3. Solution of two dipole tests applied to 4 SNe Ia samples

Sample	a^*_{ECM}	s_{Min}	$M_B(s_{Min})$	$a^*(x)$	s_{Min}	$M_B(s_{Min})$	a_0
XI	+6.7	10.8974	−19.55	+4.9 ± 2.8	10.8951	−19.54	+8.7 ± 5.2
XII	+6.6	9.83348	−19.51	+5.8 ± 2.7	9.74438	−19.52	+12.4 ± 5.0
XIII	+6.6	10.4225	−19.56	+6.2 ± 2.4	10.3956	−19.56	+12.0 ± 4.5
XIV	+6.6	10.3622	−19.53	+6.0 ± 2.4	10.3314	−19.53	+11.6 ± 4.5

4. Dipole test on SCP supernovae

Assuming directly $H_0 \equiv 70$ H.u. means limiting the fitting of the dipole formula to one unknown, through the eqs. (8)(9) rewritten in the form

$$Y = -a^* \cdot \cos\gamma \qquad Y = -a_0 \cdot X \qquad \textit{with} \quad Y = \frac{cz(1+z)}{D_L} - H_0 \tag{11}$$

where the adopted absolute magnitude M according to (10) minimizes the standard deviation of the fitting. Two dipole tests, using both the first and second eq. (11), have been carried out on two SCP high-redshift Type Ia supernovae samples, the former of 42 SNe Ia (by Perlmutter et al. 1999, hereafter P99), and the latter of 38 SNe Ia (by Knop et al. 2003, hereafter K03), and on two other combined samples of 53 SNe Ia, given by 42SNe/P99 plus 11 HST SNe of K03, and by 38SNe/K03 plus 15 SNe of P99. Such a check has been made possible thanks to the supernovae right ascensions and declinations listed on the Web (Harvard-IAU 2003). Recalling

$$\cos\gamma = \sin\delta_{VC}\sin\delta + \cos\delta_{VC}\cos\delta\cos(\alpha - \alpha_{VC}) \tag{12}$$

the model eq.(1), where $\dot{r} = cz$ and $r = cx/3H_0$, can be now rewritten as

$$z = \frac{x}{3}\left(\frac{1+x}{1-x}\right)\left[1 + 3q_0\frac{(1-x)^{1/3}}{1+x}\cos\gamma\right] \tag{13}$$

The main data for the present analysis is listed in tables A and B of the attached integral paper (Lorenzi 2004), where 4 columns report in order: supernova IAU name by P99 and K03; $-\cos\gamma$ value of the supernova according to eq. (12); redshift z of supernova or host galaxy in Local Group restframe, after correction of the geogentric redshift listed in column (2) of table 1 in P99, and of tables 3 and 4 in K03; inferred r_z distance of the supernova, as resulting from the numerical solution $x = 3H_0r_z/c$ of eq. (13) with listed z, and H_0 and q_0 from Table 1. The dipole test was carried out by calculating the luminous distances D_L of eq. (10) with SNe Ia peak magnitudes corrected only for galactic extinction and for the cross-filter K correction, that is with $m_B = m_X - K_{BX} - A_X$ as listed in the 8^{th} column of table 1 of P99 and in the 4^{th} column of tables 3 and 4 of K03. Hence a single value of absolute magnitude M_B has been choosen that minimizes the standard deviation s of the dipole fitting. The main features of the SNe Ia samples by P99 and K03, numbered XI-XII-XIII-XIV respectively, are compared in Table 2, where the following data is listed in order: sample ordinal number; sample range of m_B; number N of supernovae of the sample; mean $\langle\cos\gamma\rangle$ of the corresponding sample $\cos\gamma$, from 2^{nd}column in tables A and B of the attached paper (Lorenzi 2004); unweighed mathematical mean $\langle m_B\rangle$ of the magnitudes m_B listed in the 8^{th} column of table 1 in P99 and in the 4^{th} column of tables 3 and 4 in K03; unweighed mathematical mean $\langle z\rangle$ of the corresponding redshifts in Local Group restframe; inferred value of the average distance of the sample, as $\langle r_z\rangle$ in Mpc; average cosmological luminous distance of the sample, as $\langle D_C\rangle$ in Mpc from the mean of eq. (6). The obtained results of the unweighed fitting of the first eq. (11), through the least squares method applied to each sample, are listed in Table 3. Here, 4 columns report in order the following data and results: expected value a^*_{ECM} of the angular coefficient $a^*(x)$ of eq. (8), where $x = 3H_0\langle r_z\rangle/c$ with $H_0 \equiv 70$ and $a_0 = 12.66$ in H.u. from Table 1; minimum value of the fitting standard deviation, s_{Min}, in H.u., corresponding to the listed M_B; absolute magnitude M_B which minimizes the standard deviation s in the dipole fitting; resulting angular coefficient $a^*(x)$ in H.u. from the fitting. The last three columns of Table 3 list the results of the unweighed fitting of the second eq. (11), that holding the function $-X$. In this case the X computation (see eq. (9)) requires the introduction of the distance r_z, which can be obtained (by trial and error) from the z eq. (13) for each SNe Ia according to the nearby solution of Table 1. Such r_z values have been listed in the 4^{th}column of the tables A and B of the attached paper (Lorenzi 2004). All the previous dipole tests of Table 3, within the limits of the computed deviations of a^* and a_0, clearly confirm the ECM and its eqs. (11). Indeed, the results of the first four columns of Table 3 are very important as, in practice, the dipole anisotropy is model independent, having used only the H_0 value from Table 1.

5. Conclusion

The rendez-vous with high-redshift SNa Ie tests has permitted the successful confirmation of the ECM dipole equation, taking the check to the r_z distance-range from ~ 10 to ~ 1000 Mpc. However the presented test has limitations essentially due to the small size of the available high-z SNe Ia samples. Hence more precise and extensive tests are required.

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