Einstein-de Sitter model re-examined for the newly discovered SNe Ia

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Abstract

Consistency of Einstein-de Sitter model with the recently observed SNe Ia by the Hubble Space Telescope is examined. The model shows a reasonable fit to the observation, if one takes into account the extinction of SNe light by the intergalactic metallic dust ejected from the SNe explosions. Though the fit to the new data is worsened considerably compared with the earlier data, it can still be regarded acceptable. We should wait for more accurate observations at higher redshifts (as expected from the coming space missions such as SNAP and JWST) in order to rule out a model, which seems to explain all the other existing observations well (some even better than the favoured ΛCDM model), is consistent with beautiful theoretical ideas like inflation and cold dark matter, and is not as speculative as the models of dark energy.

\textit{Subject heading:} cosmology: theory, whisker dust, SNe Ia.
\textbf{Key words:} cosmology: theory, whisker dust, SNe Ia observations.

1. INTRODUCTION

The high redshift supernovae (SNe) Ia explosions look fainter than they are expected in the Einstein-de Sitter (EdS) model (flat cold dark matter model with $\Omega_{\text{total}} = 1$), which used to be the favoured model before these observations were made a few years ago. The most popular explanation of this observed faintness is given by invoking ‘dark energy’, a homogeneously distributed energy component with negative pressure. This happens because the metric distance of an object, out to any redshift, can be increased by

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incorporating a ‘fluid’ with negative pressure in Einstein’s equations. The simplest and the most favoured candidate of dark energy is Einstein’s cosmological constant $\Lambda$.

Alternative mechanisms have also been suggested in order to explain the observed faintness of the distant SNe Ia, without invoking cosmic acceleration. One of such attempts considers photon-axion oscillations in the intergalactic magnetic field as a way of rendering supernovae dimmer without invoking dark energy (Csaki, et al 2002; 2004).

Another alternative way to explain the faintness of the high redshift SNe Ia is to consider the absorption of light by metallic dust ejected from the SNe explosions—an issue which is generally ignored while discussing $m$-$z$ relation for SNe Ia. It was shown earlier (Vishwakarma, 2003) that if this effect is taken into account, the EdS model explains the SNe Ia data from Perlmutter, et al (1999) (together with SN 1997ff at $z \approx 1.7$) successfully. Since then, many SNe Ia at higher redshifts have been discovered with the Hubble Space Telescope (HST) (Riess, et al 2004). Extending our earlier work further, we examine in this paper how well or badly the EdS model fits the new data which include 7 highest redshift SNe Ia known so far, all at $z > 1.25$.

2. EXTINCTION BY METALLIC DUST

Chitre and Narlikar (1976) were the first to discuss the role of intergalactic dust in the $m$-$z$ relation, which was however largely ignored that time. It is, however, generally accepted now that the metallic vapours are ejected from the SNe explosions which are subsequently pushed out of the galaxy through pressure of shock waves (Hoyle & Wickramasinghe, 1988; Narlikar et al, 1997). Experiments have shown that metallic vapours on cooling, condense into elongated whiskers of $\approx 0.5 - 1$ mm length and $\approx 10^{-6}$ cm cross-sectional radius (Donn & Sears, 1963; Nabarro & Jackson, 1958). It has been shown, by considering standard big bang and alternative cosmologies, that this kind of dust extinguishes radiation travelling over long distances (Aguire, 1999; Banerjee, et al 2000; Narlikar, et al 2002; Vishwakarma, 2002; 2003). The dust presumably re-radiates the absorbed radiation at another wavelength. For example, it degrades a radiation of high-frequency into the far infrared. The emergent radiation is then redshifted into the millimeter waveband due to the expansion of the universe. However, this is not the subject of the present paper. The density of the dust can be estimated along the lines of Hoyle et al (2000): If the metallic whisker production is taken as $0.1 M_\odot$
per SN and if the SN production rate is taken as 1 per 30 years per galaxy, the total production per galaxy (of spatial density ≈ 1 per \(10^{75}\) cm\(^3\)) in \(10^{10}\) years is \(\approx 2/3 \times 10^{41}\) g. The expected whisker density, hence, becomes \(2/3 \times 10^{41} \times 10^{-75} \approx 10^{-34}\) g cm\(^{-3}\). We shall see later that this value is in striking agreement with the best-fitting value coming from the SNe Ia data.

In the following we calculate the mean extinction of the SNe light from the whisker dust. Suppose that the light we observe today was emitted at the epoch of redshift \(z\) from a SN of luminosity \(L\). In traversing a distance \(d\ell\) through the intergalactic medium, the light loses its brightness by an amount \(dL\) due to the absorption by the whisker grains of mean density \(\rho_g\). This is given by

\[
dL = -\kappa \rho_g L \, d\ell,
\]

where \(\kappa\) is the mass absorption coefficient, which is effectively constant over a wide range of wavelengths and is of the order \(10^5\) cm\(^2\) g\(^{-1}\) (Wickramasinghe & Wallis, 1996). Hence the total loss in the luminosity \(\Delta L\) of SN light, in traversing a proper distance \(\ell(z)\), can be obtained by integrating equation (1):

\[
\Delta L(z) = \exp \left[ -\kappa \int_0^{\ell(z)} \rho_g \, d\ell \right].
\]

(2)

For the Robertson-Walker (RW) metric, this reduces to

\[
\Delta L(z) = \exp \left[ \kappa \rho_{g0} \int_z^0 (1 + z')^2 \frac{dz'}{H(z')} \right],
\]

(3)

where \(\rho_{g0}\) is the whisker grain density at the present epoch and \(\rho_g S^3 = \rho_{g0} S_0^3 = \text{constant}, \ S(t)\) being the scale factor of the RW metric. Here and henceforth we have considered the speed of light \(c = 1\). The corresponding increase in the magnitude \(\Delta m\) \((= -2.5 \log \Delta L)\) is thus given by

\[
\Delta m(z) = 1.0857 \times \kappa \rho_{g0} \int_z^0 (1 + z')^2 \frac{dz'}{H(z')}.
\]

(4)

The net magnitude is then given by

\[
m^{\text{net}}(z) = m(z) + \Delta m(z),
\]

(5)

where the first term on the right corresponds to the usual apparent magnitude of the object resulting from the cosmological evolution:

\[
m(z) = 5 \log[H_0 \, d_L(z)] + M,
\]

(6)
with the luminosity distance \(d_L\) given by

\[
d_L(z) = (1 + z) \int_0^z \frac{dz'}{H(z')},
\]

for the \(k = 0\) case of the RW metric. The constant \(\mathcal{M}\) appearing in equation (6) is given by \(\mathcal{M} \equiv M - 5 \log H_0 + \text{constant}\), where \(M\) is the absolute magnitude of the SNe. For the EdS model (\(\Omega_{m0} = 1, \Omega_{\Lambda0} = 0\)), equation (5) reduces to

\[
m_{\text{net}}(z) = 5 \log[2\{(1+z)-(1+z)^{1/2}\}] + 0.7238 \times \kappa \rho_{g0} H_0^{-1}[(1+z)^{3/2} - 1] + \mathcal{M}.
\]

**3. DATA FITTING**

We consider the data recently published by Riess et al (2004) which, in addition to having previously observed SNe, also include 16 newly discovered SNe Ia, 6 of them being among the 7 highest redshift SNe Ia known, all at redshift \(> 1.25\). We particularly focus on their ‘gold sample’ of 157 SNe Ia which is believed to have a ‘high confidence’ quality of the spectroscopic and photometric record for individual supernovae. We note that the data points of this sample are given in terms of distance modulus \(\mu_o = m_{\text{net}} - M = 5 \log d_L + \text{constant}\). However, the zero-point absolute magnitude were set arbitrarily for this sample. Therefore, while fitting the data, we can compare the observed \(\mu_o\) with our predicted \(m_{\text{net}}\) given by equation (8) and compute \(\chi^2\) from

\[
\chi^2 = \sum_{i=1}^{157} \left[ \frac{m_{\text{net}}(z_i; \kappa \rho_{g0} H_0^{-1}, \mathcal{M}) - \mu_{o,i}}{\sigma_{\mu_{o,i}}} \right]^2.
\]

The constant \(\mathcal{M}\) thus plays the role of the normalization constant. The quantity \(\sigma_{\mu_{o,i}}\) is the uncertainty in the distance modulus \(\mu_{o,i}\) of the \(i\)-th SN.

There are only two free parameters in this model which are to be estimated from the data: \(\kappa \rho_{g0} H_0^{-1}\) and \(\mathcal{M}\). The parameter \(\kappa \rho_{g0} H_0^{-1}\), which is dimensionless, is of the order of unity if one considers \(\kappa\) of the order \(10^5\) cm\(^2\) g\(^{-1}\), \(\rho_{g0}\) of the order \(10^{-34}\) g cm\(^{-3}\) and \(H_0 \sim 70\) km s\(^{-1}\) Mpc\(^{-1}\). However, we have kept it as a free parameter to be estimated from the data.

By varying the free parameters of the model, we find that the minimum \(\chi^2\) is obtained for \(\mathcal{M} = 43.41\) and \(\kappa \rho_{g0} H_0^{-1} = 4.77\) (where \(\kappa\), \(\rho_{g0}\) and \(H_0\) have been measured in units of \(10^5\) cm\(^2\) g\(^{-1}\), \(10^{-34}\) g cm\(^{-3}\) and \(100\) km s\(^{-1}\) Mpc\(^{-1}\).
respectively). These give a value $\chi^2 = 200.99$ at 155 degrees of freedom (dof), that is, $\chi^2$/dof = 1.29, which represents a reasonable fit. In the absence of the extinction from the whisker dust, i.e. for $\rho_{g0} = 0$, one obtains a too high $\chi^2$/dof = 324.70/156 = 2.08, with $\mathcal{M} = 43.58$.

Though there is not a clearly defined value of $\chi^2$/dof for an acceptable fit, a ‘rule of thumb’ for a moderately good fit is that $\chi^2$ should be roughly equal to the number of dof. A more quantitative measure for the goodness-of-fit is given by the $\chi^2$-probability which is very often met with in the literature and its compliment is usually known as the significance level (should not be confused with the confidence regions). If the fitted model provides a typical value of $\chi^2$ as $x$ at $n$ dof, this probability is given by

$$ Q(x, n) = \frac{1}{\Gamma(n/2)} \int_{x/2}^{\infty} e^{-u} u^{n/2-1} du. $$

(10)

Roughly speaking, it measures the probability that the model does describe the data and any discrepancies are mere fluctuations which could have arisen by chance. To be more precise, $Q(x, n)$ gives the probability that a model which does fit the data at $n$ dof, would give a value of $\chi^2$ as large or larger than $x$. If $Q$ is very small, the apparent discrepancies are unlikely to be chance fluctuations and the model is ruled out. It may however be noted that the $\chi^2$-probability strictly holds only when the models are linear in their parameters and the measurement errors are normally distributed. It is though common, and usually not too wrong, to assume that the $\chi^2$-distribution holds even for models which are not strictly linear in their parameters, and for this reason, the models with a probability as low as $Q > 0.001$ are usually deemed acceptable (Press et al, 1986). Models with vastly smaller values of $Q$, say, $10^{-18}$ are rejected.

The probability $Q$ for the best-fitting EdS model is obtained as 0.008, which is though very small, but acceptable. In the absence of the whisker dust, this probability reduces to $1.5 \times 10^{-12}$, which is too small to be accepted. In order to compare these results with those in the $\Lambda$CDM cosmology, we note that for a constant $\Lambda$, the best-fitting models are obtained as

Global best-fitting model: $\Omega_{m0} = 0.46$, $\Omega_{\Lambda0} = 0.98$, $\mathcal{M} = 43.32$, with $\chi^2$/dof = 175.04/154 = 1.14, $Q = 0.118$;

Best-fitting flat model: $\Omega_{m0} = 1 - \Omega_{\Lambda0} = 0.31$, $\mathcal{M} = 43.34$, with $\chi^2$/dof = 177.07/155 = 1.14, $Q = 0.109$. 

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Concordance model \((\Omega_m = 1 - \Omega_\Lambda = 0.27): \chi^2/dof = 178.17/155 = 1.15\) with \(Q = 0.098\).

We note that the fit to the EdS model, even with the whisker dust, is considerably worse than those in the \(\Lambda\)CDM models. However we also note that the new data has a general tendency to worsen the fit to any model. For example, the earlier data with 57 points (Vishwakarma, 2003) gave better fits to the models mentioned above:

\[
\begin{align*}
\text{EdS model (with whisker dust):} & \quad \chi^2/dof = 68.97/55 = 1.25, \quad Q = 0.098; \\
\text{Best-fitting } \Lambda\text{CDM: } & \quad \Omega_m = 0.64, \quad \Omega_\Lambda = 1.20 \quad \text{with } \chi^2/dof = 57.78/54 = 1.07, \\
& \quad Q = 0.337; \\
\text{Best-fitting flat } \Lambda\text{CDM: } & \quad \Omega_m = 1 - \Omega_\Lambda = 0.32 \quad \text{with } \chi^2/dof = 59.67/55 = 1.08, \quad Q = 0.31.
\end{align*}
\]

We note that the new data have worsened the fit to the EdS model to a greater extent compared to the \(\Lambda\)CDM model, however, considering the successes of the EdS model, we should be tolerant of the low probability associated with it, until it goes down to some value like the one obtained without the whisker dust. The reasons are many:

(i) The EdS model is fully consistent with the recent CMB observations made by the WMAP. In fact, there is a degeneracy in the \(\Omega_m - \Omega_\Lambda\) plane along a line \(\Omega_m + \Omega_\Lambda \approx 1\) and a wide range of \(\Omega_m\) is consistent with the observations (Vishwakarma, 2003). For example, with \(\Omega_b = 0.1\) and \(H_0 = 55\) km s\(^{-1}\) Mpc\(^{-1}\), this model yields the positions of the first three acoustic peaks at the multipole values \(\ell_{peak1} = 220.4, \ell_{peak2} = 521.4, \ell_{peak3} = 784.9\), which are in good agreement with WMAP. Additionally a lower value of \(H_0\) is favourable for this model to have sufficient age. For example, \(H_0\) should be \(\leq 54\) km s\(^{-1}\) Mpc\(^{-1}\) for EdS model to have an age of the universe \(\geq 12\) Gyr, so that the age of the oldest objects detected so far, e.g., the globular clusters of age \(t_{GC} = 12.5 \pm 1.2\) Gyr (Cayrel et al. 2001; Gnedin et al. 2001), can be accommodated. There are many observations, like the HST observation giving \(H_0 = 0.72 \pm 3\) (stat) \(\pm 7\) (systematic) km s\(^{-1}\) Mpc\(^{-1}\) (Freedman et al. 2001), which give a rather higher value of \(H_0\). However, there are several observations which also measure smaller values of \(H_0\). For example, there is another HST Key Project which gives \(H_0 = 64^{+8}_{-6}\) km s\(^{-1}\) Mpc\(^{-1}\) (Jha et al. 1999). Sandage and his collaborators find a value even as low as \(H_0 = 58 \pm 6\) km s\(^{-1}\) Mpc\(^{-1}\) from an analysis of SNe Ia distances (Parodi et al. 2000).
Additionally, unlike the Λ-dominated models, the EdS model has no strong integrated Sachs-Wolfe effect, so is in better agreement with the low quadrupole seen by WMAP (Blanchard, 2003).

(ii) The recent data on distant x-ray clusters obtained from XMM and Chandra projects indicate that the observed abundances of clusters at high redshift, taken at face value, give $0.9 < \Omega_{m0} < 1.07$ (at 1 σ) (Blanchard, 2005). This is in striking agreement with a matter-dominated EdS model and is hard to reconcile with the concordance ΛCDM model.

(iii) The estimated value of the parameter $\kappa \rho_{g0} H_0^{-1}$ from the SNe fit is indeed of order of unity, as expected from the theoretical reasoning described in section 2.

(iv) Unlike the models of dark energy, the EdS model is not very speculative.

In order to have a visual comparison of the fits of different models to the actual data points, we magnify their differences by plotting the relative magnitude with respect to a fiducial model ($\Omega_{m0} = 0$, $\Omega_{\Lambda0} = 0$, without whiskers), [which has a reasonably good fit ($\chi^2$/dof = 191.701/156 = 1.2) with $\mathcal{M} = 43.40$]. This has been shown in the ‘modified’ Hubble diagram in Figure 1. In Figure 2, we have shown the allowed regions in the parameter space $\kappa \rho_{g0} H_0^{-1} - \mathcal{M}$ at 95% and 99% confidence levels.

4. BAYESIAN APPROACH

The frequentist’s goodness-of-fit test of models, described in the previous section, uses the best-fitting parameter values to evaluate relative merits of the models under consideration. Thus it judges only the maximum likely performance of the models. The Bayesian theory, on the contrary, does not hinge upon the best-fitting parameter values and evaluates the overall performance of the models. It has thus appeared as a powerful tool of model comparison. The Bayes factor, which is a ratio of average likelihoods (rather than the maximum likelihoods used for model comparison in frequentist statistics) is given by

$$B_{ij} = \frac{\mathcal{L}(M_i)}{\mathcal{L}(M_j)} \equiv \frac{p(D|M_i)}{p(D|M_j)},$$

(11)

where the likelihood for the model $M_i$, $\mathcal{L}(M_i)$ is the probability $p(D|M_i)$ to obtain the data $D$ if the model $M_i$ is the true one (for more details on the Bayesian theory, see Drell et al, 2000; John and Narlikar, 2002). For a model
Figure 1: Hubble diagram of the ‘gold sample’ of SNe Ia minus a fiducial model ($\Omega_m0 = 0$, $\Omega_{\Lambda}0 = 0$): The relative magnitude ($\Delta m_{\text{net}} \equiv m_{\text{net}} - m_{\text{fiducial}}$) is plotted for some best-fitting models. The solid curve corresponds to the EdS model with the whisker dust, the dotted curve corresponds to the flat $\Lambda$CDM model, the dashed curve corresponds to the spherical $\Lambda$CDM model, and the dashed-dotted curve corresponds to the EdS model without any whisker dust. Some SNe with redshift between 0 and 1 (mostly with $z \sim 0.5$) are missed by all the models and seem to be outliers.

$M_i$ with free parameter, say, $\alpha$ and $\beta$ (generalization for the models with more parameters is straightforward), this probability is given by

$$\mathcal{L}(M_i) \equiv p(D|M_i) = \int d\alpha \int d\beta \ p(\alpha|M_i) \ p(\beta|M_i) \ \mathcal{L}_i(\alpha, \beta),$$

(12)

where $p(\alpha|M_i)$ and $p(\beta|M_i)$ are the prior probabilities for the parameters $\alpha$ and $\beta$ respectively, assuming that the model $M_i$ is true. $\mathcal{L}_i(\alpha, \beta)$ is the likelihood for $\alpha$ and $\beta$ in the model $M_i$ and is usually given by the $\chi^2$-statistic:

$$\mathcal{L}_i(\alpha, \beta) = \exp \left[ - \frac{\chi^2(\alpha, \beta)}{2} \right],$$

(13)
Figure 2: The allowed regions by the ‘gold sample’ of SNe Ia data (with 157 points) are shown in the parameter space $\kappa \rho_0 H_0^{-1} - M$ of the Einstein de Sitter model. The parameters $\kappa$, $\rho_0$ and $H_0$ are measured in units of $10^5 \text{ cm}^2 \text{ g}^{-1}$, $10^{-34} \text{ g cm}^{-3}$ and $100 \text{ km s}^{-1} \text{ Mpc}^{-1}$ respectively. The inner ellipse denotes the 95% confidence region and the outer one, the 99% confidence region.

where $\chi^2_i$ is the $\chi^2$-statistic for the model $M_i$, like the one for the EdS model given by equation (9). For flat prior probabilities for the parameters $\alpha$ and $\beta$, i.e., assuming that we have no prior information regarding $\alpha$ and $\beta$ except that they lie in some range $[\alpha, \alpha + \Delta \alpha]$ and $[\beta, \beta + \Delta \beta]$, we have $p(\alpha|M_i) = 1/\Delta \alpha$ and $p(\beta|M_i) = 1/\Delta \beta$. Hence the expression for the likelihood of the model $M_i$ reduces to

$$L(M_i) = \frac{1}{\Delta \alpha \Delta \beta} \int_\alpha^{\alpha + \Delta \alpha} \int_\beta^{\beta + \Delta \beta} \exp \left[ - \frac{\chi^2_i(\alpha, \beta)}{2} \right] \, d\beta \, d\alpha. \quad (14)$$

The Bayes factor $B_{ij}$, given by (11), which measures the relative merits of model $M_i$ over model $M_j$, is interpreted as follows. If $1 < B_{ij} < 3$, there is an evidence against $M_j$ when compared with $M_i$, but it is not worth more than a bare mention. If $3 < B_{ij} < 20$, the evidence against $M_j$ is definite but
not strong. For $20 < B_{ij} < 150$, this evidence is strong and for $B_{ij} > 150$, it is very strong.

In order to compare the $\Lambda \neq 0$ cosmology with EdS one, we presume that the universe is flat spatially. This gives a fair comparison as well, since both the models are similar and have the same number (two) of free parameters. As we do not have any prior information on the common parameter $\mathcal{M}$, we take help from its best-fitting values, which lie between 43 and 44. Hence we assign a flat prior on $\mathcal{M}$ that it lies in the range $[41, 45]$. (This probability does not have any consequences though, as it cancels out in the Bayes factor.) Similarly, for the other parameter $\kappa \rho_{g0} H_0^{-1}$ in the EdS model (the best-fitting value $\sim 4.8$), we assume that $\kappa \rho_{g0} H_0^{-1} \in [0, 10]$. For the parameter $\Omega_{m0}$ in the flat $\Lambda$CDM model (the best-fitting value $\sim 0.3$), we assume that $\Omega_{m0} \in [0, 1]$. When calculated for the ‘gold sample’, this gives a Bayes factor favouring a model with $\Lambda \neq 0$ over one with $\Lambda = 0$ (EdS) as $B = 1.98$, which though indicates an evidence against the EdS model, but not more than a bare mention.

However, if no prior assumptions are made about the spatial geometry of the universe, there is a strong evidence against the EdS model: In this case, we assign the prior probabilities $\Omega_{m0} \in [0, 3], \Omega_{\Lambda0} \in [-3, 3]$, as have also been considered by Drell et al (2000) and John & Narlikar (2002). This is because the best-fitting values are towards higher side. This gives a Bayes factor for $\Lambda$CDM model compared to EdS model as $B = 113.23$, for a conservative prior probability $\kappa \rho_{g0} H_0^{-1} \in [4, 5]$. This shows a strong evidence against the EdS model, though it is not very strong. For a more liberal prior, however, this evidence moves towards very strong side.

One should also note that a proper assessment of the probability for a model is given by $p = 1/(1 + B)$. Thus if the universe is presumed to be flat, the probability for the EdS model is 0.34, a reasonably good probability. In the absence of any prior assumption about the spatial geometry of the universe, this probability is only 0.009 (which is still larger than 0.008 obtained from the frequentist approach). These results, together with the results and discussion of the previous section, make a reasonable case for the EdS model.

5. EFFECTS OF WEAK LENSING

Weak gravitational lensing is an unavoidable systematic uncertainty in the use of SNe Ia as standard candles. As the universe is inhomogeneous in matter distribution, the SNe fluxes are magnified by foreground galaxy ex-
cess and demagnified by foreground galaxy deficit, compared to a smooth matter distribution. Recently Williams & Song (2004) have reported such a correlation between the magnitudes of 55 SNe from the sample of Tonry et al. (2003) and foreground galaxy overdensity. They have found the difference between the most magnified and the most demagnified SNe as about 0.3–0.4 mag. Wang (2004) has claimed further evidence of weak lensing in the high redshift sample of SNe Ia from the Riess et al. (2004) data. She has found a high magnification tail at the bright end of the distribution, and a demagnification shift of the peak of the distribution towards the faint end, which are signatures of weak lensing. She has estimated the possible magnification of the three intrinsically most luminous SNe (in the absence of lensing) in the bright end tail as:

SN1997as ($z = 0.508, \mu_o = 41.64$): magnified by $2.10 \pm 0.68$;
SN2000eg ($z = 0.540, \mu_o = 41.96$): magnified by $1.80 \pm 0.70$;
SN1998I ($z = 0.886, \mu_o = 42.91$): magnified by $2.42 \pm 1.98$.

These high magnification factors $\sim 2$ from weak lensing are though somewhat surprising, as also mentioned by Menard & Dalal (2004) who claim not to find any significant correlation between SN magnification and foreground galaxy overdensity. However, excluding these three lensed SNe from the sample indeed improves the fit: $\chi^2$/dof = 192.49/152 = 1.27, $Q = 0.015$ obtained for $M = 43.41$ and $\kappa \rho_0 H_0^{-1} = 4.82$. The fit to the $\Lambda$CDM models also improves considerably:

$\chi^2$/dof = 164.20/151 = 1.09, $Q = 0.219$ obtained for $\Omega_m = 0.47, \Omega_\Lambda = 1.02$, with $M = 43.32$;
$\chi^2$/dof = 166.86/152 = 1.10, $Q = 0.194$ obtained for $\Omega_m = 1 - \Omega_\Lambda = 0.30$, with $M = 43.34$.

Though the weak lensing effects are estimated to be small for SNe at $z < 1$, they are non-negligible for higher redshift SNe. As more SNe are discovered at higher redshifts, it becomes increasingly important to minimize the effect of weak lensing by, for example, using flux-averaging (Wang, 2000).

6. CONCLUSION REMARKS

Since the early 1980s, inflation and cold dark matter have been the dominant theoretical ideas in cosmology. However a key prediction of these ideas - the canonical Einstein-de Sitter model ($\Omega_m = 1, \Lambda = 0$) - seems to be in trouble in explaining the high redshift SNe observations, as is widely believed. How-
ever, it can still explain these observations successfully if one takes account of the extinction of light by intergalactic metallic dust ejected from the SNe explosions, as has been shown earlier (Vishwakarma, 2003) by considering Perlmutter et al’ data (Perlmutter et al., 1999). We have shown, in this paper, that the model also has an acceptable fit to the recently published ‘gold sample’ of 157 SNe Ia by Riess et al (2004) which, in addition to having previously observed SNe, also includes 16 newly discovered SNe Ia, 6 of them being among the 7 highest redshift SNe Ia known so far, all at redshift $> 1.25$. Though the fit to this new data is deteriorated considerably, we believe that one should wait for more accurate SNe Ia data with $z$ significantly $> 1$ (as expected from the coming space missions such as SNAP and JWST) in order to rule out a model which seems to explain all other existing observations well, some even better than the ΛCDM models. This point of view is also corroborated by the Bayesian analysis of the data, which indicate that there is no significant evidence against the EdS model if one assumes a spatially flat universe. Even in the absence of such an assumption, there is not a very strong evidence against this model, for suitable priors.

We should also examine more critically, than has been done hitherto, the assumption of a non-evolving standard candle for SNe Ia with high redshifts. Though most studies confirm that the luminosity properties of SNe at different redshift and environments are similar (Perlmutter et al., 1999; Sullivan et al, 2003), however, there are other theoretical studies which have found variations indicating evolutionary effects (Dominguez et al, 1998; Hoflich et al, 1998). Additionally, it has been shown by Drell et al (2000) that a comparison of the peak luminosities estimated for individual SNe Ia by two different methods are not entirely consistent with one another at high redshifts, $z \sim 0.5$. If evolution was entirely absent, the differences between them should not depend on redshift. Moreover the three luminosity estimators in practice (the multicolor light curve shape method, the template fitting method, and the stretch factor method) reduce the dispersion of distance moduli about best fit models at low redshift, but they do not at high redshift, indicating that the SNe may have evolved with redshift (Drell et al, 2000).

The possible role of gravitational lensing in amplifying the supernova luminosity at high redshifts has been discussed by several authors and we have applied those ideas here to illustrate the difference it can make to any conclusion drawn from the data. Additionally, the role of intergalactic whisker dust still remains to be appreciated fully and we have demonstrated here the
possible difference it can make to the viability of a model.

One may think that the whisker dust can create too much optical depth for the high redshift objects and they need to be excessively bright in order to be seen. However, from our calculations, we find that even the objects with redshift as high as 5 will be fainter by $\sim 4$ magnitudes only, with the kind of whisker dust (best-fitting value) we have been talking about. Thus the microwave emission from the high redshift quasars will also be visible without unrealistically high demands on their luminosities.

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