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Error Analysis of Ia Supernova and Query on Cosmic Dark Energy

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Abstract. Some serious faults in error analysis of observations for SNIa have been found. Redoing the same error analysis of SNIa, by our idea, it is found that the average total observational error of SNIa is obviously greater than 0.55^m, so we can not decide whether the Universe is an accelerating expansion or not.

Key words. Error analysis—Ia supernova—accelerating expansion of the Universe.

1. Origin of the question of cosmic dark energy

A direct evidence of accelerating expansion of the Universe is by observation of SNIa (Riess *et al.* 1998, 2004, 2007; Perlmutter *et al.* 1999; Guy *et al.* 2007); Amanullah *et al.* 2010), based on the advanced Philips' relations (Guy *et al.* 2007; Isern 2010), which are based on statistics of the absolute magnitudes at the maximum luminance of SNIa related with both the width of the light-curve (m_{15}, the decline in magnitudes 15 days after the peak luminosity) and variation of the color index (B-V) of SNIa. The distance modulus may be calculated from the absolute magnitude (M) and the apparent magnitude (m) of SNIa. Distance modulus is defined as $5\log D - 5 = \mu = m - M - A + K + \cdots$, where D is the distance (in a unit pc), A is the intergalactic extinction, K is the K-correction, and '$\cdots$' includes the error caused by gravitational lensing and peculiar motion of the host galaxy. The advanced Philips relation is the most accurate method till now. But we would like to point out that m_{15} is closely related to the quantity of the radioactive nuclide produced in the explosive nucleosynthesis processes, and the color index change responses to the expansion and the cooling down rate of outer aerosphere during explosion. Based on the advanced Philips' relations (Guy *et al.* 2007), Spectral Adaptive Light-curve Template (SALT2) is a software package for Type Ia Supernovae light curve fitting. Following SALT2, UNION2 (Amanullah *et al.* 2010) deals with the data of 685 SNIa. The system error of the absolute magnitude of SNIa is found by minimizing χ^2 which is the normalized quadratic sum of distance modulus residual (Guy *et al.* 2007, 2010). As a result, they came to a conclusion that universe is accelerating and expanding. Saul Perlmutter, Brian Schmidt and Adam Reiss who shared the 2011 Nobel Prize in Physics for their observations that type Ia supernovae indicated that the expansion of the universe is accelerating.

However, recent researches from 2008 to 2010 about Tycho SNR have shown the idea of single accreting white dwarf model (called the 'standard model') of SNIa explosion that has been negated due to recent researches (Phillips 1993; Wang *et al.* 2013) about the Tycho SNR from 2008 to 2010. The peak luminosity of SNIa is taken as standard candles, no longer due to different progenitors of SNIa. This suggests that the mechanism of the SNIa explosion, i.e. the explosive nuclear burning, the production of radioactive nuclides in the thermonuclear explosion, the expansion and cooling down of outer aerosphere during explosion is not certain. We analyse the data of UNION2 compilation (it is the latest and most complete SNIa compilation) in this paper and put forward our opinion.

2. Some serious faults in error analysis

2.1 *Error in absolute magnitude*

The absolute bolometric magnitude error at the maximum light of SNIa consists as follows:

- The intrinsic error ($M_{\rm int}$) of the absolute magnitude at the maximum luminance, in our idea, is just the Half-Width at Half-Maximum (HWHM) of the statistic distribution curve of the number of SNIa with the maximum luminance, rather than the systematic error found using the χ^2 (Riess *et al.* 1998; Perlmutter *et al.* 1999; Guy *et al.* 2007; Amanullah *et al.* 2010).
- An error of M originating from delivered errors caused by statistical errors of the parameters a and b in the original Phillips' relation (Isern 2010) or α_x, β in the advanced Philips' relations (Guy *et al.* 2007; Amanullah *et al.* 2010), we call it as the delivered error, $\triangle M_{(a,b)}$.
- An error of M, $M_{\rm Obs}$ is caused by the errors of some observational quantities of both light-curve and color index in advanced Phillips relation. The total error of absolute bolometric magnitudes at the maximum light ($\triangle M_{\rm total}$) is

$$(\triangle M_{\rm total})^2 = (\triangle M_{\rm int})^2 + (\triangle M_{\rm max}^{\rm (Phillips)})^2,$$

$$(\triangle M_{\rm max}^{\rm (Phillips)})^2 = (\triangle M_{(a,b)}^2)^2 + (\triangle M_{\rm Obs})^2.$$

SALT2 (Guy *et al.* 2007) and UNION2 (Amanullah *et al.* 2010) did not give the aforementioned errors separately. In fact, they broadly merged them into the system error caused by χ^2-minimization. The advanced Phillips relation is very complex, but it is sure that the minimum of $(\triangle M_{\rm max}^{\rm (Phillips)})^2$ is at least larger than observational apparent magnitude error, $|\triangle M_{\rm max}^{\rm (Phillips)}| > |\delta m|$ (the observational error of apparent magnitude). Furthermore, high z SNIa is faint when observed, so its $|\delta m|$ is much larger than nearby SNIa.

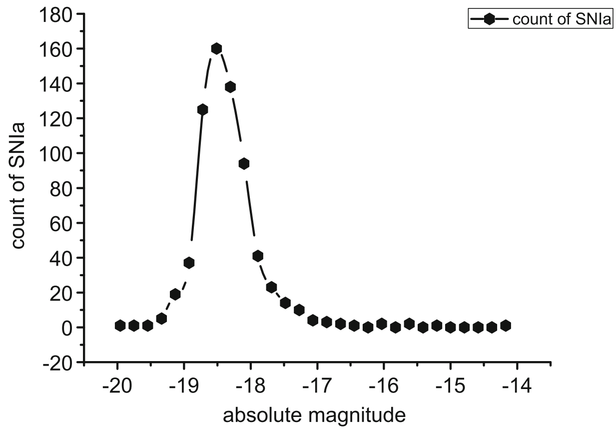

Figure 1. Distribution of the number of SNIa with their maximum luminance.

2.2 *The systematic error found using χ^2 check test is incorrect*

However, premise of χ^2 check test is the errors of distance modulus for the set of SNIa obeying a Gaussian distribution. But the set of modeling SNIa in UNION2 (Amanullah *et al.* 2010) including 685 SNIa is really not Gaussian distribution. Although the average error of UNION2 which contains 685 SNIa is 0.16^m , over 10% of the total SNIa is an outline of 10σ. If we take a subsample including 217 SNIa with relatively small observational average error to perform the same statistical analysis, it is found that over 10% of the total SNIa is an outline of 5σ. The critical permitted outside value for outline of 2.6σ in the standardized normal distribution is

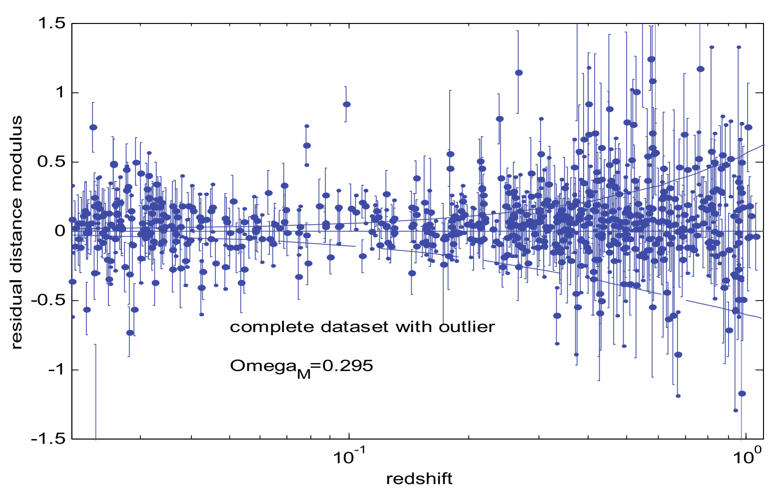

Figure 2. The relation between the residual distance modulus (with error bar) and redshift for SNIa. The three curves from top to bottom correspond to Universe expanding being accelerating, uniform or decelerating respectively. The calculation of the three curves is with reference to Guy *et al.* (2007) and Amanullah *et al.* (2010).

0.805%. Using the χ^2 check test following SALT2 (Guy *et al.* 2007), we find that 3.796% of the data is an outline of 2.6σ based on the average total observational error of the distance modulus of SNIa, 0.31^m. Obviously, the distance modulus error deviates Gaussian distribution seriously, and it is not suitable to calculate the systematic error σ_{sys} of SNIa by the χ^2 check test method. In our idea the real intrinsic error of a SNIa compilation should be based on the statistical distribution diagram of the number of SNIa for their absolute bolometric magnitudes (see Fig. 1). As we do not know the exact luminosity of high z SNIa, it is the only way to use SALT2 to get the absolute bolometric magnitude of 'modeling SNIa'. The intrinsic error (or proper error) of the absolute magnitude at the maximum luminosity is just the HMHW of a statistic distribution curve of the number of SNIa with the maximum luminosity. It is $\triangle M_{\text{int}} = 0.38^m$, and it is much larger than the systematic error given by the χ^2 check test.

3. Summary and conclusions

The average total observational errors of distance modulus is $(\triangle\mu)^2 = (\triangle M_{\text{total}})^2 + (\delta m)^2$. Using the data of SNIa and observational apparent magnitude error in UNION2, and dividing intervals per $\triangle z = 0.1$, we repeat the statistics (by the same χ^2 check test method) to calculate this modeling SNIa sample's average total observational errors of distance modulus. It is found that the average total observational error of SNIa is obviously greater than 0.55^m (this is much larger than 0.4^m. If we want to tell the state of the Universe, the total error should be under 0.4^m. So at the moment the total error is too big to decide whether the Universe is accelerating expansion or not (see Fig. 2) and the direct observational evidence of the idea of 'dark energy' is also lost by the observational error analyses of SNIa.

References

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