Low Redshift Type 1a Supernovae Calibration

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Abstract

The calibration of 20 supernovae discovered and observed by the Supernova Cosmology Project and EROS collaboration in 1999 is described. Using novel calibration techniques, we calibrate the supernova images in the Johnson-Cousins U, B, V, R and I bands at the 1% level.

Key words: supernovae, photometric calibration, cosmology

Recent results by Riess et al (1998) and Perlmutter et al (1999) have shown that type 1a supernovae (SNe1a) can, to some extent, be used as standardizable candles to make cosmological measurements of the acceleration of the universe. While high-redshift SNe1a ($z > 0.4$) are used to determine the cosmological parameters, Ω_M and Ω_Λ, SNe1a at low redshifts are important in evaluating the systematic uncertainties in the cosmological measurements, determining the homogeneity of SNe1a and testing the linearity of the Hubble Law.

The Supernova Cosmology Project and EROS collaboration discovered and observed 20 supernovae at redshifts below 0.24 in 1999 and followed up these observations with reference images of the host galaxies in 2000. The 20 supernovae were initially classified as SNe1a, although SN1999as has now been re-classified as a Hypernova 1c (Hatano et al , 2001). The supernovae were observed in the U, B, V, R and I bands using 17 different instruments with about 25 images per supernova per band, totalling ∼2600 images. However, unlike most other photometric measurements, calibration images were not taken on all instruments and on all nights on which supernovae were observed. As a result, an unconventional photometric calibration strategy is employed to determine the supernovae lightcurves. The rest of this paper summarizes the calibration strategy used.

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1 Calibration Procedure

1.1 Identification of Objects and Flux Determination

Before calibrating each image, we identify the objects (stars and galaxies) in each image and determine their fluxes. Objects are identified using a neural network-based algorithm and the flux of each object is determined by fitting the point-spread function (PSF) to a Moffat distribution with image coordinates, x and y, and fit parameters, σ_x, σ_y, ρ and β:

$$PSF(x,y) \sim (1 + \frac{1}{2}(\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2} - 2\frac{\rho xy}{\sigma_x \sigma_y}))^{-\beta}. \quad (1)$$

1.2 Determination of Tertiary Standard Catalog

Since calibration images were not taken on every night, it is necessary to create a tertiary standard catalog of the absolute magnitudes of the objects in each supernova field. We convert the measured object fluxes to absolute magnitudes using the relation:

$$m_x = \tilde{m}_x + zp + \alpha_x \chi + \beta_x (m_x - m_y) \quad (2)$$

where $\tilde{m}_x$ is the flux measured in band x, m_x and m_y are the absolute magnitudes in bands x and y, χ is the airmass, zp is the zero point term for the night and α_x and β_x are the extinction and filter correction terms for band x. Using only supernova and calibration images from photometric nights on which calibration images were taken, we perform a simultaneous fit in 2 bands to determine the absolute magnitude of the objects in the supernova field, zp, α and β. The absolute magnitudes for objects in calibration fields are obtained from Landolt (1992). The fit requires β to be the same for all images on the same instrument and band, and α and zp to be the same for all images in the same instrument, band and night.

As shown in Figure 1, we reduce the statistical uncertainties in the tertiary standard catalog and improve the inter-telescope calibration by performing a simultaneous fit to a large number of images on several telescopes.

1.3 Calibration of All Images

Based on the absolute magnitudes in the tertiary standard catalog and the measured fluxes, we determine the zero point, zp_I, for each image and filter

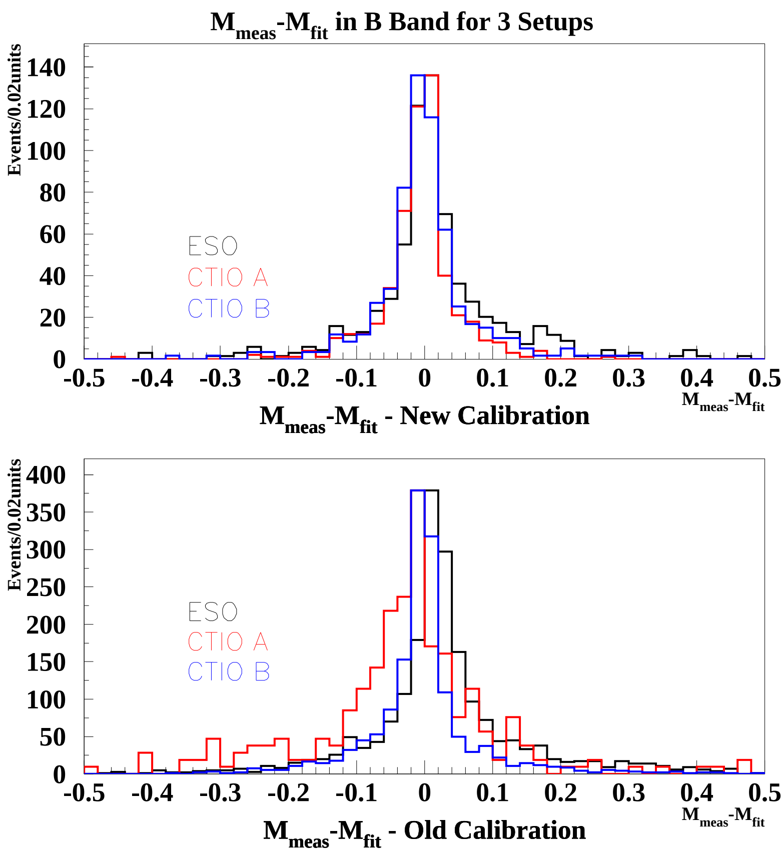

Fig. 1. Distribution of B Band Magnitude Residuals, $M_{meas} - M_{fit}$, for supernova field stars using the current calibration scheme (top) and for a calibration scheme where the tertiary standard catalog was determined using the ESO telescope alone. Only nights on which calibration data was taken are considered.

corrections, $\beta_{1,tel}$ and $\beta_{2,tel}$, for each instrument using the relation:

$$\tilde{m_x} = m_x - zp_I - \beta_{1,tel,x}(m_x - m_y) - \beta_{2,tel,x}(m_x - m_y)^2 \quad (3)$$

Each instrument and band is calibrated separately. To avoid the effect of outliers, a data robustification scheme is used. As shown in Figure 2, the uncertainties in zp_I and $\beta_{1,tel}$ are ∼0.007 and ∼0.004, respectively.

1.4 Determination of Supernova Lightcurves

By applying the zero points and filter correction terms for each image to the measured supernova fluxes and performing a simultaneous fit in 2 bands, we determine the supernova absolute magnitudes as a function of time. The fit is iterated till the supernova lightcurve converges.

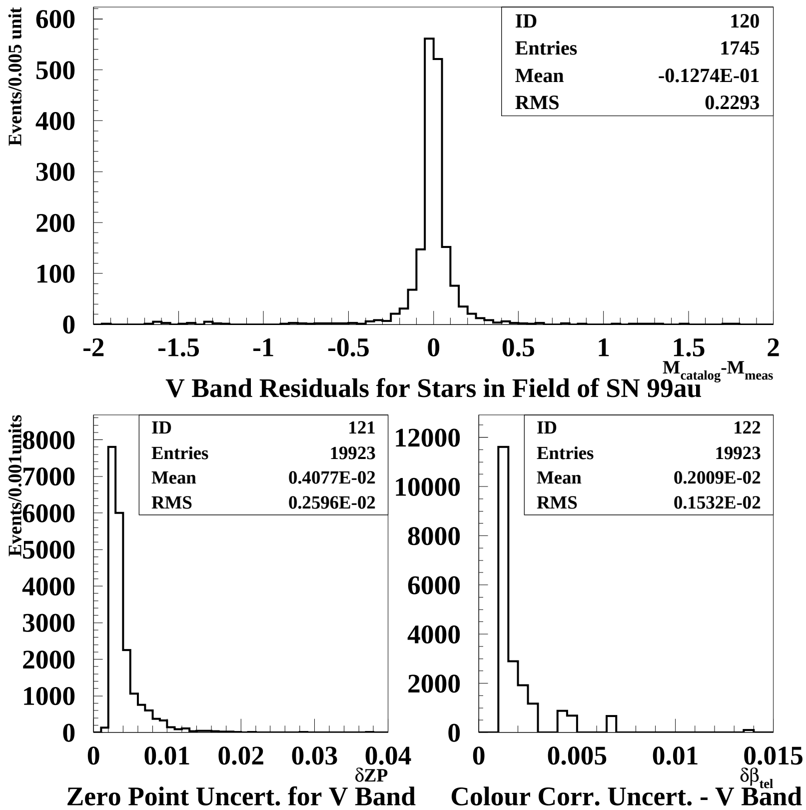

Fig. 2. Top: V Band Magnitude Residuals for stars in the field of SN 1999au. Bottom Left: Uncertainty in the zero points for all supernova images. Bottom Right: Uncertainty in the linear V-filter (B-V) correction terms for all supernova images. Quadratic filter corrections terms are negligible except for the YALO and CFHT R bands. Both nights with and without calibration data are considered.

2 Conclusions

We have been able to calibrate the images of 20 nearby supernovae discovered in 1999 at the 1% level in the U, B, V, R and I bands. We look forward to lightcurves and results from this sample of low-redshift SNe1a.

References

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