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Flux Calibration of the BATC Survey and Its Application for Checking the Consistency of the Oke-Gunn Standards

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Abstract Four Oke-Gunn (OG) standards, HD 19445, HD 84937, BD+26 2606 and BD+17 4708 are used as standard stars for flux calibration in the BATC project. They are also widely used in the visual wavelength region in many other photometric projects. Over the years we have observed on 58 good photometric nights, and the data obtained are used for flux calibration. Normally two or three OG standards are observed in every photometric night. The data are used for getting the atmospheric extinction coefficients and instrumental magnitude zero point. We also use these data to make inter-comparisons among the magnitudes of these standard stars. As a result, we found the magnitudes of HD 19445, HD 84937 and BD+17 4708 to agree well with those estimated in previous work to within 0.03 magnitude. However, BD+26 2606 shows a larger deviation especially at short wavebands. Possible reasons are analyzed and the revised magnitudes are obtained for these standards. It is shown that the quality of flux calibration of the BATC fields is significantly improved by applying the new magnitudes.

Key words: techniques: photometric: calibration

1 INTRODUCTION

The Beijing-Arizona-Taipei-Connecticut Color Survey of the Sky (Hereafter BATC) utilizes the 15 intermediate band filters to make CCD image photometric observation. The BATC photometric system ties its magnitude zero point to the spectro-photometric AB magnitude system. The AB system is a monochromatic $\widetilde{f_\nu}$ system first introduced by Oke in 1969 with a provisional calibration designated AB69.

The AB system selects F subdwarfs around visual magnitude 9 as standards, which are faint enough for use in large telescopes. The spectra of these cool, metal-deficient stars are much simpler than those of A dwarfs, with very strong, wide Balmer absorption lines and large Balmer discontinuities. Their moderately flat spectral energy distribution (SED) and weak lines

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also minimize the error of synthetic magnitudes that arise from uncertainties in the detailed shape of the system response function. AB69 included 3 F subdwarfs, HD 19445, HD 84937, and BD+17 4708, while BD+26 2606 was introduced later in 1978 as an additional standard. It was realized that small color and magnitude errors would be present near the Balmer lines and in the 3700–4100 Å region, because the stars are not calibrated in these regions. The AB79 system was introduced by Oke and Gunn (1983, hereafter OG) to refine the calibration of the older system which had already been ideally used for several years.

Since the work of OG, much effort has been made in improving the SED of α Lyr (Hayes 1985, hereafter H85, Casteli & Kurucz 1994). The SEDs of the four AB79 subdwarfs have also been revised by Oke (1990). The most recent compilation of the α Lyr SED is given by H85. The relative SED presented by H85 agrees very well with that of Castelli & Kurucz (1994) based on a detailed stellar atmosphere calculation, except for small discrepancies in the Balmer absorption lines and Paschen region. Fukugita et al. (1996) compared the observed V and B magnitudes with the synthetic magnitudes for the four subdwarfs using the data compiled by Mermilliod (1991). They found a deviation in the V and B bands with the brighter synthetic magnitudes. They made the subdwarfs fainter by 0.04 at all wavelengths. Similar offsets were already noted by Oke (1990). The latest updated magnitudes of the four AB standards by Fukugita et al. (1996) is accepted by the previous work of BATC (Yan et al. 2000).

The errors in the present AB magnitude system may arise from the errors in the measurement of the SED of α Lyr, (Azusienis & Straizys 1969; Buser 1978; Castelli & Kurucz 1994), the errors in the SED of the four standards relative to that of α Lyr (Oke 1990) and the errors in the shape of the response functions. The over-all error will be about 0.03 mag including the normalization error (Fukugita 1996).

During the programmed observations in years from 1994 to the end of 1999, 58 good photometric nights were used to observe the standard stars for making flux calibration of the BATC object fields. Normally, there are two or three standards which can be observed during each photometric night. After careful data processing, the observation of standards can be used to obtain the extinction coefficient and the instrumental magnitude zero point. By inter-comparison among the standards, the data can also be used for checking the consistency of the four OG standards. In this paper we will present our method of data reduction and the revised magnitudes of these standard stars.

In Section 2, we describe our new data process method for getting the extinction coefficients and the instrumental magnitude zero point. The standard star observations, the revised standard star magnitude revision and the flux calibration are given in Section 3. Tests and discussion are presented in Section 4. Finally in Section 5, we give the conclusion of our work on flux calibration.

2 STANDARD STAR OBSERVATIONS AND DATA REDUCTION

2.1 The Observations of Standard Stars

The large field multi-color observations are done with the BATC photometric system. The telescope used is the 60/90 cm f/3 Schmidt Telescope of Beijing Astronomical Observatory (BAO), located at the Xinglong station. A Ford Aerospace 2048×2048 CCD camera with 15μ pixel size is mounted at the main focus of the Schmidt telescope. The field of view of the CCD is 58×58 arcmin^2 with a pixel scale of 1.7 arc-second. BATC utilizes 15 intermediate-band filters, which cover the total optical wavelength range from 3000 to 10000 Å (cf. Fan et al. 1996, Yan et al. 2000). The filters are specifically designed to avoid contamination from the brightest and most variable night sky emission lines. The filter transmissions were shown in Yan et al. (2000).

BATC accepts the AB magnitude system. The great advantage of the AB magnitude system is that the magnitude is directly related to physical units. The BATC magnitude is defined by

$$m_{\rm batc} = -2.5 \cdot \log\widetilde{F_\nu} - 48.60,$$

where $\widetilde{F_\nu}$ is the flux per unit frequency in unit of erg s^{-1} cm^{-2} Hz^{-1}. In the BATC system (Yan et al. 2000), the $\widetilde{F_\nu}$ is defined as

$$\widetilde{F_\nu} = \frac{\int {\rm d}(\log\nu) f_\nu R_\nu}{\int {\rm d}(\log\nu) R_\nu},$$

which ties the magnitude to the number of photons detected by CCD rather than to the input flux (cf. Fukugita et al. 1996). The difference is trivial (at the 0.001 mag level), due to the relative narrowness of the BATC pass-bands. The system response $\widetilde{R_\lambda}$ is actually used to relate f_ν and $\widetilde{F_\nu}$, and includes only the filter transmissions. Other effects, such as the quantum efficiency of CCD, the response of the telescope optics, and the transmission of atmosphere, etc., are ignored. This makes the BATC system filter-defined, because the bandwidths are intermediate in size and all the other responses are essentially flat within a specified passband.

The calibration is performed in the following way (see also Yan et al. 2000): in a night considered to be photometric, two or more standard stars as well as the programmed fields were observed between one and two air masses using four to six selected filters. The standards are observed as frequently as possible using the central part of the CCD (size 300×300) for saving readout time and disk space. The extinction coefficient and magnitude zero obtained from the standard stars are used for making the flux calibration on the BATC field images.

Aperture photometry is done on images of standard stars. For getting the total flux of the standard stars, the radius of aperture is selected to be 15 pixels (about 25 arcsec). The zero point of instrumental magnitude is set to be 25.0.

2.2 The Method of Flux Calibration

The present flux calibration differs from our previous method in four ways:

2.2.1 Extinction curve

In the magnitude vs. airmass diagram showing the extinction curve, the magnitude is the difference between instrumental magnitude $m_{\rm inst}$ and BATC magnitude $m_{\rm batc}$ of the standard stars. By fitting a straight line we can get the extinction coefficient of the filter K and the instrumental zero point:

$$m_{\rm inst} - m_{\rm batc} = KX + C,$$

here X is the airmass of the image. K and C are derived by median fitting of the data points with a straight line. A subroutine named "*medfit*" from Numerical Recipe (Press et al. 1992) is used for the fitting.

2.2.2 Variation of the extinction

As expected, the change in the instrumental zero point is very small within a time scale of a few hours. The main variation in the calibration with time is from the weather. We need a time dependent term to trace the variation of the transparency of the Earth's atmosphere. In our previous work, a correction term on zero point C, named $f(ut)$, was used. It is independent of the airmass and the color of the filter bands. It can be regard as the mean variation of all possible factors as a function of the time. As shown in the previous paper (Yan et al. 2000), it can much reduce the fitting error and give values of K and C that are good enough for the propose of BATC. We consider the variation of Earth atmosphere extinction on wavelength and airmass, and introduce a variation term on the extinction coefficient K instead of on the zero point,

$$K = K_0 + \mathrm{d}K(UT)\,.$$

Two kinds of variation are presented in our programs. One is variation of the extinction coefficient of a single filter band $\mathrm{d}K_{\mathrm{band}}$, the other is mean variation of all filter bands, $\mathrm{d}K_{\mathrm{mean}}$. In most cases, $\mathrm{d}K_{\mathrm{band}}$ gives good results on tracing the sky variation. But if we do not have enough observing points for a single filter band, we have to use $\mathrm{d}K_{\mathrm{mean}}$ instead of $\mathrm{d}K_{\mathrm{band}}$. $\mathrm{d}K_{\mathrm{mean}}$ can be used under the assumption that the variations of extinction in all the filter bands are similar.

2.2.3 Fitting of variation of extinction

Different from what we have done before, we use a smooth, continuous curve to trace the variation instead of several jointed straight lines. Each fit point is the mean value of all observing points within two hours. We give a higher weight to nearby points in time,

$$1/(1.0 + (T_{\mathrm{fit}} - T_{\mathrm{obs}})^2)\,,$$

here T_{fit} is fitting time points and T_{obs} is times of each observation point in unit of hour.

2.2.4 Iteration

A good trace of extinction variation needs a set of good estimations of mean extinction coefficient K and instrumental zero point C, and a good estimation of K and C needs information of the variation. In practice, some iterations are needed in the determination of K, C and variation. Fortunately, for almost all the nights, the iteration converges in less than four times. For security, ten iterations were run before stop.

2.3 The Correction of the Standard Magnitude

By using the new calibration codes, we checked all the BATC data in the database and found that, from JD 09648 to JD 11525, the standard stars were observed on 77 nights. Among these, the individual observations of standards on 58 days were useful for the BATC calibration. Normally two or three standards were observed during each photometric night for getting the extinction coefficient and instrumental magnitude zero point. From the extinction curves of all the photometric nights, we can get residuals of the observing points from the fitting straight line. If the AB magnitude of one standard is not consistent with others, the observed points of this star will systematically fall above or below the fitting extinction versus airmass curve. In the same way as was done in Yan et al. (2000), we obtained the average residual of the observed points filter by filter and star by star. The average values were used for correcting the AB magnitude of the standards. Then, we found the new average residual again. The same procedure was repeated until the average residual of each standard reached minimum. At the end of the iterations, we obtained a corrected SEDs of the four standards.

The corrected SEDs are listed in Table 1. In the table columns 1 to 3 list the order number, BATC filter name, and the center wavelength, respectively. The revised magnitudes are listed in columns 4 to 7.

Table 1 The Revised BATC Standard AB Magnitude

No.	Filter	Wavelength (Å)	HD 19445	HD 84937	BD+26 2606	BD+17 4708
1	a	3371.5	9.238	9.477	10.813	10.703
2	b	3906.9	8.653	8.805	10.231	10.071
3	c	4193.5	8.448	8.629	10.061	9.829
4	d	4540.0	9.293	8.528	9.940	9.699
5	e	4925.0	8.189	8.430	9.855	9.595
6	f	5266.8	8.073	8.331	9.731	9.497
7	g	5789.9	7.969	8.258	9.630	9.390
8	h	6073.9	7.935	8.240	9.614	9.363
9	i	6655.9	7.885	8.212	9.577	9.330
10	j	7057.4	7.852	8.181	9.531	9.292
11	k	7546.3	7.826	8.169	9.518	9.256
12	m	8023.2	7.800	8.149	9.488	9.234
13	n	8484.3	7.790	8.153	9.479	9.236
14	o	9182.2	7.784	8.151	9.463	9.212
15	p	9738.5	7.801	8.172	9.486	9.229

Table 2 gives the differences. The first column shows the filter numbers. The other columns give the check result of each standard stars. Note that there are three column entries for each standard star. The first is the difference between the new and old magnitudes of the star, $\delta_{\rm mag} = m_{\rm new} - m_{\rm old}$. The second is the RMS error of $\delta_{\rm mag}$ at different filter bands between the observed point and the fitting extinction curve in the final iteration process. The third column gives the number of individual observations of the standards.

Table 2 The Comparison Between New and Old BATC Standard AB Magnitude

	HD 19445			HD 84937			BD+26 2606			BD+17 4708		
No.	Dev.	RMS	Num.	Dev.	RMS	Num.	Dev.	RMS	Num.	Dev.	RMS	Num.
1	0.004	0.026	18	–0.009	0.007	12	–0.120	0.007	2	–0.023	0.025	13
2	0.000	0.012	71	0.005	0.017	47	–0.068	0.010	23	0.014	0.014	65
3	0.001	0.020	52	0.003	0.014	67	–0.034	0.014	43	–0.012	0.018	37
4	–0.001	0.015	78	0.023	0.022	56	–0.022	0.027	28	0.006	0.012	68
5	0.002	0.021	113	0.001	0.020	151	0.007	0.020	53	0.003	0.015	46
6	0.001	0.011	125	–0.007	0.012	116	–0.012	0.012	47	0.009	0.009	73
7	0.000	0.010	131	–0.001	0.011	134	–0.022	0.008	58	–0.006	0.014	57
8	0.000	0.012	141	0.008	0.011	117	–0.003	0.015	50	–0.002	0.011	74
9	0.000	0.014	183	0.007	0.012	168	0.001	0.015	86	0.012	0.012	126
10	0.001	0.010	162	0.010	0.011	154	–0.010	0.017	54	0.019	0.012	81
11	0.000	0.011	140	0.004	0.012	150	–0.004	0.013	61	0.001	0.014	67
12	0.000	0.011	104	–0.001	0.009	85	–0.013	0.006	24	–0.004	0.008	75
13	0.000	0.007	69	0.009	0.006	73	–0.010	0.009	22	0.010	0.012	33
14	0.000	0.010	47	0.002	0.006	52	–0.026	0.010	17	–0.014	0.010	30
15	0.000	0.010	54	–0.001	0.006	40	–0.021	0.009	16	–0.015	0.014	51

Using the revised magnitude values of the four standards, and the magnitude zero point and extinction as functions of time obtained from the observations of the standards, we calibrate all the BATC fields observed during these 58 photometric nights. For each of the BATC images, we know the airmass, observing time and its exposure time. By these parameters, we can get a magnitude correction from the magnitude zero point and atmosphere extinction obtained. With these parameters, the instrumental magnitudes, $m_{\rm inst}$, can be transferred to the uniform BATC photometric system $m_{\rm batc}$ through the routine procedure of photometric calibration.

3 TEST AND DISCUSSION

3.1 Cross Observation of Standard Stars

As stated in the previous section, there are normally two or three standards observed in one photometric night. This provides us with an opportunity to make a cross check of the magnitude values of the standards. In Table 4, we list the statistics of the number of times that a given standard star was observed together with the others. The number indicates that how many data sets could be used for such a cross-check. The night number counts of one standard observed with other standards in the same photometric night for all the photometric nights and all the colors are listed in Table 3 and Table 4. These two tables show how many other standards observed together with a given standard star during the same photometric night and/or observed in the same filter band. The number means the count of the nights that one standard star is compared with other standards. In general, HD 19445 is the most often observed standard. Based on these observations, comparisons among the standards can be done.

3.2 The Magnitude Correction

By comparison between the new standards' magnitudes and the ones in AB96 (Table 2), we find that the standards HD 19445, HD 84937 and BD+17 4708 show good agreement. However, BD+26 2606 is obviously brighter than the previous determination. The results are plotted in Fig. 1. From the figure, we can see the deviation of each standard, especially BD+26 2606. The deviations in the short wavelength bands are even larger.

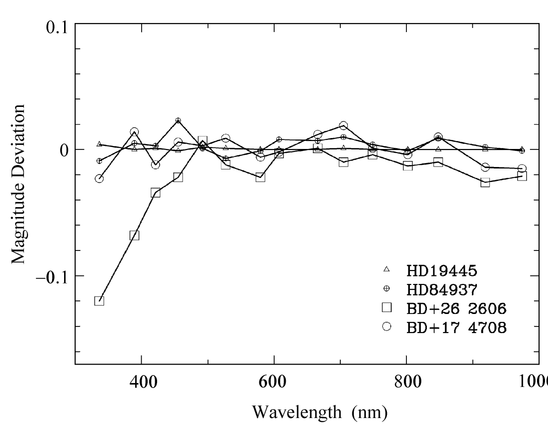

Fig. 1 The difference between old and new magnitude of standards

Table 3 Observing Times of Each Standard Star Together with Other Standards

	HD 19445	HD 84937	BD+26 2606	BD+17 4708
HD 19445	54	42	28	31
HD 84937	42	45	28	19
BD+26 2606	28	28	32	7
BD+17 4708	31	19	7	32

Table 4 Observing Times of Each Standard Star Together with Other Standards by Each Filters

		a					b					c		
Std	c001	c002	c003	c005	Std	c001	c002	c003	c005	Std	c001	c002	c003	c005
c001	4	3	1	3	c001	16	9	6	11	c001	12	8	7	8
c002	3	3	1	2	c002	9	10	6	5	c002	8	8	6	4
c003	1	1	1	0	c003	6	6	7	2	c003	7	6	7	3
c005	3	2	0	3	c005	11	5	2	11	c005	8	4	3	8
		d					e					f		
Std	c001	c002	c003	c005	Std	c001	c002	c003	c005	Std	c001	c002	c003	c005
c001	17	12	8	12	c001	24	20	13	10	c001	27	22	14	14
c002	12	13	8	7	c002	20	20	12	6	c002	22	23	14	9
c003	8	8	9	3	c003	13	12	13	2	c003	14	14	15	2
c005	12	7	3	12	c005	10	6	2	10	c005	14	9	2	14
		g					h					i		
Std	c001	c002	c003	c005	Std	c001	c002	c003	c005	Std	c001	c002	c003	c005
c001	24	20	14	11	c001	28	20	13	15	c001	37	27	20	22
c002	20	23	16	7	c002	20	22	14	9	c002	27	29	19	12
c003	14	16	18	3	c003	13	14	16	3	c003	20	19	23	6
c005	11	7	3	12	c005	15	9	3	16	c005	22	12	6	23
		j					k					m		
Std	c001	c002	c003	c005	Std	c001	c002	c003	c005	Std	c001	c002	c003	c005
c001	29	23	16	15	c001	24	20	14	12	c001	16	11	2	13
c002	23	24	15	9	c002	20	21	13	8	c002	11	13	4	8
c003	16	15	17	3	c003	14	13	15	3	c003	2	4	5	1
c005	15	9	3	15	c005	12	8	3	13	c005	13	8	1	14
		n					o					p		
Std	c001	c002	c003	c005	Std	c001	c002	c003	c005	Std	c001	c002	c003	c005
c001	12	10	3	8	c001	9	7	2	6	c001	12	8	5	7
c002	10	11	4	6	c002	7	8	3	4	c002	8	9	5	3
c003	3	4	4	0	c003	2	3	3	0	c003	5	5	6	1
c005	8	6	0	8	c005	6	4	0	6	c005	7	3	1	7

Note: c001=HD 19445, c002=HD 84937, c003=BD+26 2606, c005=BD+14 4708

From the deviations shown in Fig. 1, it seems that the deviation of each star is wavelength-dependent. It may come from the data reduction of previous spectral observations. In our CCD image observations, the observing points of each filter band are totally free from other filter bands. If there are observational errors or data reduction errors, they should not have any relation with wavelength. In the original spectral observations of these standards, only one star, Vega, was used for making the calibration. It needs a much higher sky quality than our observation. Two reasons may exist. One is that, a very small observing error on determining the Earth atmosphere extinction can lead to a difference in the flux calibration between the object star and comparison star, especially in the short wavelengths. This deviation is wavelength-dependent. Secondly, spectral observations need a good determination of the instrumental response of the spectrograph. It is usually obtained by fitting with a low order smooth curve. It can also lead to wavelength-dependent discrepancies. Only HD 19445, HD 84937, and BD+17 4708 were included in AB69, while BD+26 2606 was added later in 1978 as an additional standard. It may have got different treatment from the other stars. Furthermore, BD+26 2606 is the faintest of the four standard stars. The quality of its observation should be not so good as the others. We can also see BD+17 4708 has slightly higher errors than that of the other two brighter stars, HD 19445 and HD 84937.

3.3 The Quality of BATC Calibration with Updated Standard Magnitude

As an example, we use the data of February 16/17, 2000 (JD11591) of o (9182Å) band images to show the quality of flux calibration by our method. The weather on JD11591 was estimated as changing from "very good" to "good enough" by the observers. It was mostly moon-less with small wind. Figure 2 shows the results of the data reduction in o band (9190Å). The three left panels are for the old magnitudes and the right panels are for the revised magnitudes. The top panels show the extinction curves which were directly fitted by the original magnitude and airmass. The sky quality was bad, and the data set can hardly be used for flux calibration. The two plots in the middle panels show the variation of the atmospheric extinction with time. They are the results of final iteration. The curves show the variation of the transparency which was good and stable in the beginning of the night, and then changed to worse in the middle of the night and became stable again in the last part of the night. The curves trace the variation of the extinction very well with very small scatter. The bottom panels of Figure 2 show the fitting of extinction curve at the end of the final iteration after correction of sky variation. The points in the plots distribute well along a straight line that reflects the relation of magnitude vs. airmass, from which we get a reliable extinction curve by linear fitting.

From the figures, we can also tell the difference of using old and the revised magnitudes of standards in practical calibration. In the figures, different symbols represent three different standards. From the extinction and its variation, we see that the data points of BD+26 2606 (circles) are systematically lower than those of other standards relative to the fitting curve. After the magnitude correction of the standards, it can be seen that the results are better in the right plots than in the left in which the old standards magnitudes are used. The variation of the extinction is smoother and with less scatter. The following two tables list the results of the zero point of instrumental magnitude and the extinction coefficient using the old magnitudes and our new revised magnitudes. The errors of the fitting by the revised magnitudes in the four filter bands are all smaller than those by using the old magnitudes.

Table 5 Result of Fitting by old AB Standard System

Filter	Int. Zero Point	Extinction Coef.	RMS. of fitting
c	1.802	0.426	0.012
h	0.193	0.216	0.010
n	1.905	0.054	0.007
o	2.489	0.080	0.009

Table 6 Result of Fitting by Revised AB Standard System

Filter	Int. Zero Point	Extinction Coef.	RMS. of fitting
c	1.802	0.434	0.008
h	0.196	0.212	0.008
n	1.879	0.072	0.004
o	2.488	0.087	0.005

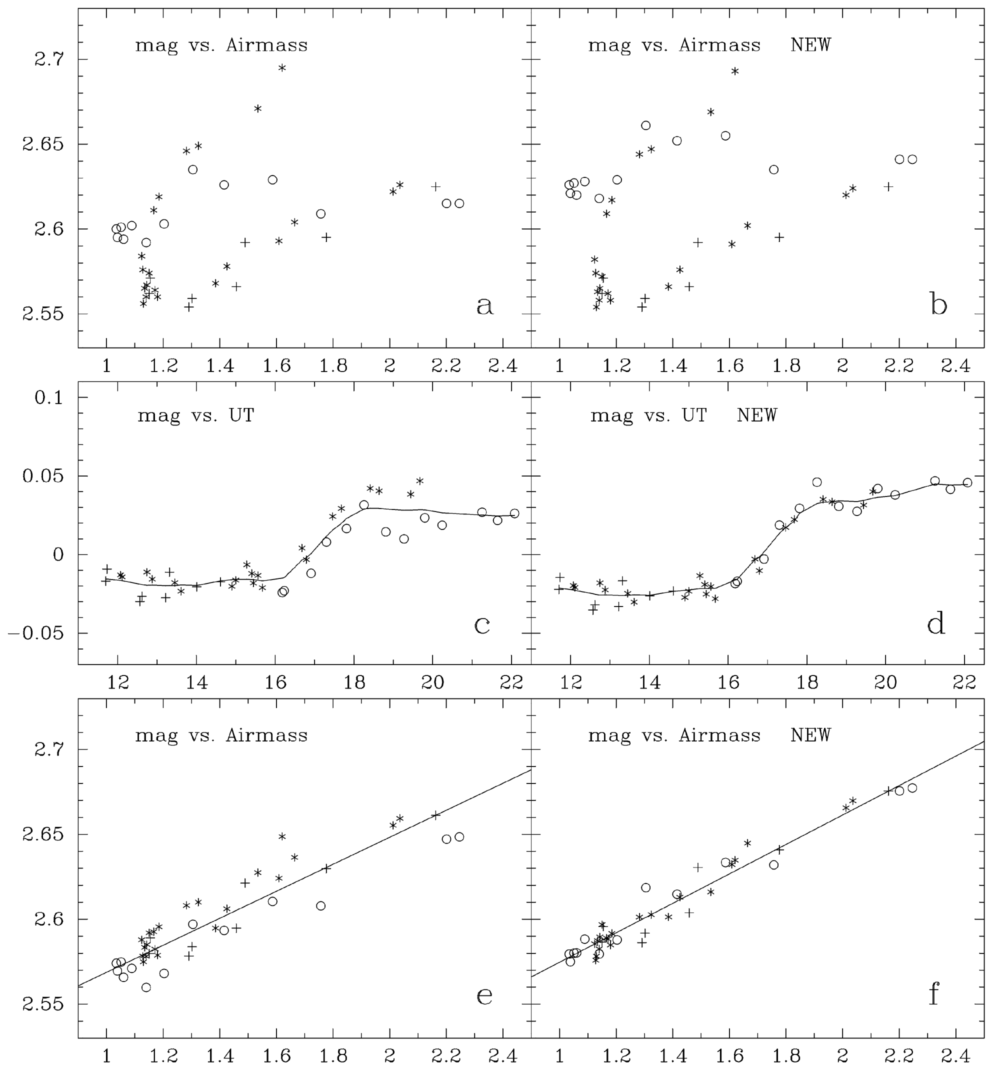

Fig. 2 Ex: Fitting result of JD11591 by old and new magnitudes of standard

3.4 Test by Bright Stars in Images of TA03 Field

Some of the BATC fields have been calibrated many times on each of the filter bands. The repeated flux calibrations can be used for checking the calibration method and the overall quality of the flux calibration.

TA03 field is one of the BATC field centered at the galaxy cluster Abell 566. There are 88 images in the 15 BATC bands taken on 21 nights. The stars of these images have their own calibrated magnitudes in the standards observations during each night. From the measurement of all stars brighter than 15 magnitude, we get the differences between the mean calibrated magnitude and each individual calibration. Only isolated stars are used and instrumental magnitudes are obtained using aperture photometry. Table 7 gives the results of the test.

Table 7 The Comparison among Calibrations of TA04 Field

No.	Filter	Wavelength (Å)	Calibration (times)	RMS difference (mag.)
2	b	3906.9	5	0.021
3	c	4193.5	3	0.011
4	d	4540.0	5	0.008
5	e	4925.0	4	0.006
6	f	5266.8	9	0.007
7	g	5789.9	8	0.008
8	h	6073.9	7	0.010
9	i	6655.9	11	0.015
10	j	7057.4	10	0.015
11	k	7546.3	4	0.015
12	m	8023.2	3	0.016

In the table, only those filter bands that are calibrated more than two times, are listed. The calibration times are included in the third column. A successful calibration needs a good photometric night. Based on hundreds brightest stars, the RMS differences between the mean calibrated magnitude and each calibration result are listed in the last column of the table. The difference in an image is the mean difference of all the bright stars. From the last column, we see that the calibration precision can be better than 0.02 magnitude. Because of the sensitivity of our thick CCD, the calibration precision of the shortest and longest wavelength filters is relatively lower.

4 CONCLUSIONS

Over a few years of BATC observations, there have been 58 photometric nights usable for flux calibration. Normally, two or three standard stars are observed during one photometric night. By using the data of the calibration observation, three tasks have been done and described in this paper: (1) We develop a new method for getting the atmosphere extinction coefficient and instrumental magnitude zero point. It can be used to trace the variation of extinction during the observing night, and it gives a very good flux calibration, in which the extinction has slow variations with time. (2) We make inter-comparison among the four standard stars: HD 19445, HD 84937, BD+26 2606 and BD+17 4708. By cross checking, we find HD 19445, HD 84937 and BD+17 4708 are well consistent within an error of 0.03 magnitude with previous estimates. BD+26 2606 shows a larger deviation relative to the other standards, especially in the short wavelengths. Mainly by comparing with HD 19445, which is the brightest standard star, we revise the magnitudes of all four standards. (3) Some tests on the method are made and the results are reported, which include a test based on a BATC field that has been calibrated many times by the data of many photometric nights.

References

Azusienis A., Straizys V., 1969, AZ, 13, 316 (AS69)

Buser R., 1978, A&A, 62, 411

Castelli F., Kurucz R. L., 1994, A&A, 281, 817

Fukugita M., Ichikawa T., Gunn J. E. et al., 1996, AJ, 111, 1748

Hayes D. S., Latham D. W., 1975, ApJ, 197, 593

Hayes D. S., 1985, Calibration of Fundamental Stellar Quantities, In: D. S. Hayes, et al., ed., IAU Symp. No.111, Stellar Quantities, Dordrecht: Reidel, p.225 (H85)

Mermilliod J.-C., 1991, Photoelectric Catalogue of Homogeneous Measurements in the UBV System (NASA Goddard Space Flight Center)

Oke J. B., 1990, AJ, 99, 1621

Oke J. B., Gunn, J. E., 1983, ApJ, 266, 713 (OG)

Oke J. B., Schild R. E., 1970, ApJ, 161, 1015

Press W. H., Teukolsky S. A., Vetterling W. T. et al., 1992, Numerical Recipes in Fortran, Second Edition, Cambridge University Press, p.699

Yan H. J., et al., 2000, PASP, 112, 691