Newsletter

Quarterly Newsletter of the Indian Institute of Astrophysics

Volume 6 Number 3 July 1991

Calibration of the Photometrics CCD System at the 1-m Reflector

T. P. Prabhu, Y. D. Mayya & G. C. Anupama have calibrated the system gain of the Photometrics CCD system at the 1-m Zeiss reflector at VBO at three different gain settings. The system uses a Thomson CSF Th7882 CCD chip coated to enhance its blue sensitivity. Two different techniques were employed, one using the flat fields obtained during the imaging observations and another using the spectroscopic flat fields. The system gain G in counts per detected electron was estimated from the noise statistics:

$$\sigma_{\rm T}^2 = G^2 R_e^2 + GS + f^2 S^2, \qquad (1)$$

where $\sigma_{\rm T}$ is the observed standard deviation in counts, and the three terms on the right-hand side of the equation denote contributions due to the read-out noise, signal, and flat-field variations, respectively. R_e is the read-out noise in electrons, and S is the signal in counts. The system gain G is the conversion factor from counts to electrons, and hence a signal of S counts corresponds to S/G electrons which will have $\sqrt{S/G}$ shot noise in electrons. The last term in the equation, which has the constant f relating the signal to the flat-field noise, dominates the noise in the raw frames. Hence, an accurate estimate of G requires that its effect be minimized.

The bias and flat field images were first examined carefully and the following features were noticed.

(1) The first 2–3 rows have lower counts, and the first 2–3 columns have higher counts compared to the mean value in the frame. One is hence advised to trim these rows and columns away.

(2) The mean bias value reduced monotonically from a value of 334.5 early in the evening to 328.5 early in the morning even though the indicated temperature of the chip was constant at $(-120.2 \pm 0.2)^\circ$C. No reason could be ascribed to this; one is advised to monitor bias during the night and take the nearest value of bias while reducing the images.

(3) The efficiency of the system decreases slowly from 100% at row 200 to about 80% at the early rows. This may be partly due to vignetting. Increasing the size of the filters to more than the present 1-inch diameter may reduce this effect. Regular flat-fielding procedure eliminates this to an accuracy of 2%.

(4) Dark rings of diameter 30–50 pixels and annulus width 7 pixels are seen scattered on the images. The efficiency of dark area is 3–4% lower than average. These are possibly caused by the scattering off the dust particles settled on the window, and are corrected well by the procedure of flat-fielding.

(5) There are 10 highly inefficient pixels that are not corrected well by the procedure of flat-fielding.

Some of the flat-field images obtained through filters were stacked to obtain a master flat that is accurate to 0.1%. Remaining flats were corrected for vignetting and pixel-to-pixel variations of sensitivity using the master flat. This should eliminate the last term in Equation (1). In practice it was found that a small residual remained, and a second-order fit was necessary to obtain an accurate evaluation of G. Furthermore, an estimation of R_e using a least-squares polynomial fit turned out to be inaccurate since the second term is highly dominant in the data.

The initial estimates were hence improved by a nonlinear least-squares technique using the Marquardt algorithm. It was found that the best results were obtained when the fit was made in the log-log domain, *i.e.*, when the equation fitted was logarithm of Equation (1).

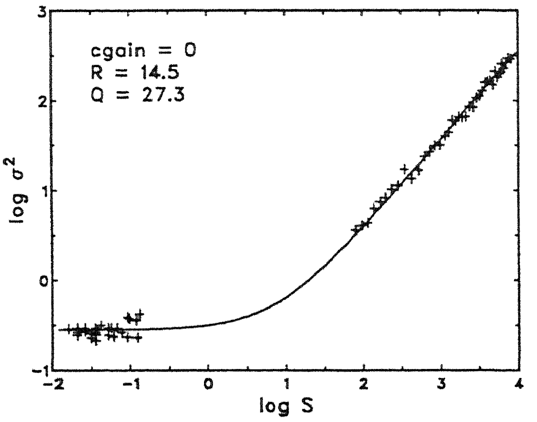

Fig. 1. The statistics of variance against signal obtained using two spectroscopy flats and a bias frame using GSTAT command (+). Different signal levels correspond to different wavelengths. The very low 'signal' values are values of local bias above the global mean, and have been plotted only to show the mean bias level and the variance. The smooth curve is the fit derived using GFIT command.

An alternate method of reducing the contribution of flat-field variations involves taking two nearly equally exposed flats and examining their difference or ratio. The observed variance for such an image would be

$$\sigma_{\mathrm{T}}^2(S_1 - S_2) = \sigma_{\mathrm{T}}^2(S_1) + \sigma_{\mathrm{T}}^2(S_2), \tag{2}$$

$$\sigma_{\mathrm{T}}^2(S_1/S_2) = [S_2^2\sigma_{\mathrm{T}}^2(S_1) + S_1^2\sigma_{\mathrm{T}}^2(S_2)]/S_2^2. \tag{3}$$

This method is particularly suitable for spectroscopic flats since there is better control over the level of exposure. Further, if one neglects the second-order effects due to wavelength dependence of system gain, it is possible to obtain a range of exposure levels from a set of only two spectroscopic flats due to the combined effect of the chromatic response of the instrument, energy distribution of the source, and vignetting in the instrument. Commands have been introduced in the RESPECT software package to estimate the noise statistics (GSTAT command) and then to determine the system gain and readout noise using the method outlined above (GFIT command). Though both subtraction and division options are available in the GSTAT command, it was found that in practice the method of division yields better results since the nonlinear term cancels more effectively. Fig. 1 shows the variance–signal plot obtained using spectroscopic flats together with the derived fit.

The system gain of a CCD system depends directly on the pre-amplifier gain. The pre-amplifier gain in the Photometrics CCD system is software-selectable through the 'cgain' command in steps of one in the range 0–4095. The default value at the system at VBO is 0. The system gain was calibrated using both the image and spectroscopy flats for cgain = 0 and 33, and using only spectroscopy flats for cgain = 66. The two methods agreed to within a per cent in the case of the first two sets. The results are presented in Table 1. The value of $Q = 1/G$ in electrons per count is also given since it is more common to express the system gain in this way. Note that the derived value of readout noise is higher than specified for the chip (7-8 electrons). This is due to the fact that one digital unit corresponds to many more electrons than the read-out noise. In addition, it was noticed at higher gain that there is some external interference in the form of a fixed pattern of high counts. This adds to the noise even in the absence of signal. Efforts are on to isolate and remove this interference.

Table 1. System gain and read-out noise at different values of pre-amplifier gain.

cgain	G count e^{-1}	Q e count^{-1}	R_e electrons
0	0.0366	27.3	14.5
33	0.0757	13.2	11.7
66	0.1120	8.9	10.4

Nimisha Kantharia, Joint Astronomy Programme, Indian Institute of Science, Bangalore, participated in the calibration using spectroscopic flats, as a part of her project work.

Y. D. Mayya has added a new set of broadband filters that are more efficient than the ones in use, and also yield better transformation equations. The combination is shown in Table 2. At an image scale of 0.357 arcsec per pixel, and a total field of 137 arcsec × 206 arcsec at the $f/13$ Cassegrain focus of the 1-m reflector, the 'dipper asterism' of M 67 (NGC 2682) was observed during 1991 January – April for calibrating the system photometrically at the default gain (cgain = 0). Instrumental magnitudes were extracted from the images using the growth curve technique, the software for which is developed by Mayya under STARLINK environment.

Table 2. Glass filter combinations.

Band	Components	Thickness (mm)
	GG 13	2
B	BG 12	1
	BG 18	1
V	GG 14	2
	BG 18	2
R	RG 610	2
	KG 3	2

The atmospheric extinction measurements were made on each night using images observed at different air-masses.

The first-order extinction coefficients are listed in Table 3. Mean values of second-order coefficients were $k''_b = 0.036$, $k''_v = 0.010$ and $k''_r = 0.00$.

Following photometric transformation coefficients were obtained.

$$B - V = (-1.037 \pm 0.006) + (1.056 \pm 0.004)(b - v)_0, \quad (4)$$

$$V - R = (0.094 \pm 0.003) + (0.868 \pm 0.007)(v - r)_0, \quad (5)$$

$$V - v_0 = (18.292 \pm 0.004) + (0.018 \pm 0.003)(b - v)_0, \quad (6)$$

$$B - b_0 = (17.256 \pm 0.007) + (0.073 \pm 0.005)(b - v)_0, \quad (7)$$

$$R - r_0 = (18.217 \pm 0.003) + (0.160 \pm 0.007)(v - r)_0. \quad (8)$$

Standard errors of the fits were typically 0.006 mag.

Mayya carried out also the calibration of a narrowband Hα filter of width 160Å centred at 6563Å. Defining an instrumental magnitude h he obtained the transformation

$$(r - h)_0 = (-2.114 \pm 0.004) + (0.023 \pm 0.011)(v - r)_0, \quad (9)$$

with a standard error of 0.011 mag. Neglecting the small colour term, this implies that the ratio of broadband R to the narrowband h fluxes is 7.09. One can hence estimate the continuum near 6563Å by scaling R fluxes by this factor, instead of obtaining long integrations in narrow off-band filters.

Table 3. Atmospheric extinction coefficients.

Date	k'_b	k'_v	k'_r
1991			
Jan 13	0.341	0.166	0.090
Feb 13	0.407	0.214	0.113
Feb 14	0.385	0.206	0.119
Feb 15	0.472	0.295	0.212
Mar 16	0.397	0.187	0.102
Mar 17	0.430	0.224	0.133
Mar 18	0.478	0.259	0.145
Apr 14	0.418	0.237	0.153

The calibration results can also be used to estimate the efficiency of the telescope, filter and CCD combination. The derived values are 2.2% in B, 8.5% in V, and 10.0% in R and Hα bands. The count rates (per second) for a 15 mag star at an air-mass of 1 are 5.6 in B, 17.2 in V, 17.5 in R and 2.5 in Hα. For extended objects, a count rate of 1 count per second implies a surface brightness of 15.0, 16.1 and 16.0 mag arcsec^{-1}, respectively, in B, V, and R bands. For the Hα filter, it implies a flux of 10^{-13} erg cm^{-2} s^{-1}. The observed sky brightness near zenith during the early part of the night on 1991 March 16 was 21.4, 20.6 and 19.6 mag arcsec^{-1}, respectively in the BVR bands, and 2.0×10^{-15} erg cm^{-2} s^{-1} in the Hα band.

T. P. Prabhu

Total solar eclipse of 1991 July 11

A five member team (K.R. Sivaraman, Jagdev Singh, R. Srinivasan, K.K. Scaria & F. Gabriel) set up the eclipse camp at Waikoloa on the north west tip of Kohala-Kona coast of the big island of Hawaii for observing the total solar eclipse of 1991 July 11. Three experiments planned to be conducted were (i) spectroscopy of the corona in the two emission lines; 5303Å [Fe XIV] and 6374Å [Fe X]; (ii) imaging in five coronal emission lines, in Hα and in the electron-scattered continuum with narrowband filters using a Peltier-cooled CCD as the prime detector; and (iii) broadband photography. The telescope and the spectrograph were set up and aligned by July 2 at the camp site and in the following days, all the telescopes were tested by obtaining test exposures. The coelestats and the associated electronic drive system functioned very well and the tracking was excellent. The Peltier-cooled CCD system functioned most satisfactorily and the images could be obtained through all the narrowband filters within four minutes (which was the duration of totality) in a pre-arranged sequence with the software developed and installed specifically for the eclipse observations. Pre-eclipse calibrations were done between July 5 and 7 and the following days were spent in further rehearsals. On July 9, the sky became more thick (with thin cirrus clouds) than on the previous two days. However the sky improved as the day progressed. On July 10 there was thin cirrus all around. At 1 a.m. of July 11, the eclipse day, the clear sky indicated good viewing during the eclipse. By 4 a.m. clouds started forming all over which caused a great anxiety. At 5 a.m. it did not look better. The clouds seemed to move fast one hour after sunrise and even after the first contact. It was possible to obtain a few images of the partially eclipsed sun using the CCD system as well as the broadband camera through passing clouds. But soon, the clouds thickened which made the view of the eclipse impossible. The skies remained cloudy ever through the day. Waikoloa coast is well-known for its clear skies and good atmospheric transparency; but the eclipse day was destined to be one of the two days with cloudy skies during our entire stay of 25 days there.

Members of the eclipse team

Supernova Spectroscopy from VBO

Extragalactic supernovae are being observed spectroscopically from VBO since 1980. Of 10 supernovae observed so far, the bright supernova in the LMC was followed in great detail using the 1m and 0.75m reflectors despite its low elevation over the southern sky. Others were observed sparsely close to the maximum light: SN 1980K in NGC 6946, SN 1980N in NGC 1316, SN 1983G in NGC 4753,

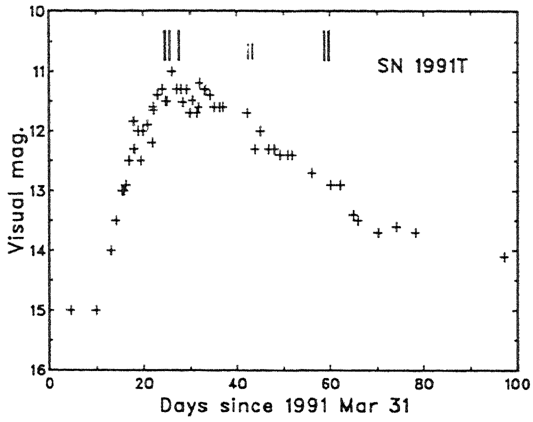

Fig. 1. Light curve of SN 1991T based on visual estimates (+) published in IAU Circulars. Vertical lines indicate the times of spectroscopic observations from VBO. The longer lines refer to observations from 2.3m VBT, whereas the shorter ones refer to observations from 1m reflector.

SN 1983N in NGC 5236, SN 1984A in NGC 4419, SN 1986G in NGC 5128, and SN 1989B in NGC 3627.

The detectors and telescopes used have shown substantial improvements during the period of these observations. The availability of the Universal Astronomical Grating Spectrograph at the 1m reflector, of the Boller & Chivens Spectrograph at the 2.3m VBT, and of the CCD detectors at both these telescopes, has made it possible to reach fainter limits, and also to obtain better signal-to-noise ratio at a given brightness. It was thus exciting to observe SN 1991T and 1991AA at both these telescopes during 1991 April-May.

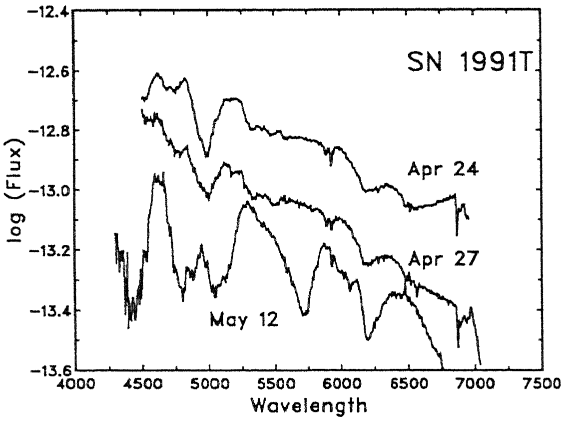

Fig. 2. Spectra of SN 1991T in NGC 4527 observed from 2.3m VBT on 1991 April 24 and 27, and from 1m reflector on May 12.

The light curve of SN 1991T is shown in Fig. 1, based on visual estimates published in IAU Circulars. The epochs of observations from VBO are also indicated in the figure. The reduced spectra observed on 1991 April 24, 27 and May 12 are shown in Fig. 2. The early spectra obtained just before maximum appear different from typical SN Ia spectra though Balmer lines are absent and the 6150Å feature characteristic of SN Ia spectra is weakly present. The strongest absorption feature is at 4960Å. The spectrum on May 12 resembles post-maximum type Ia spectra better. The interstellar Na I D absorption due to the host galaxy NGC 4527 is seen in the spectra at a redshift of 1700 km s^{-1}. The spectra shown in the figure are averages of 3 half-hour exposures in the case of VBT data and of 2 half-hour exposures in the case of 1m reflector. Longer exposures were needed in the case of the 2.3m reflector to achieve desired signal-to-noise ratio due to the presence of strong moonlight background.

SN 1991AA was a much fainter supernova in an anonymous galaxy with a redshift of 3300 km s^{-1}. It was discovered at magnitude ~ 16 on May 7, but brightened by about 1.5 mag by June 1. Spectra of the supernova were recorded with 1m reflector on May 12, and with the 2.3m VBT on May 28 and 29. The raw spectrum obtained with the 1m reflector is shown in Fig. 3. The signal-to-noise ratio is very poor, and the spectrum is contaminated by the night sky emission lines (to be subtracted during further reductions). The prominent feature is the '6150' dip which is considerably blue-shifted compared to typical SN Ia. The strength of this feature in the pre-maximum spectrum of SN 1991AA contrasts with its weakness in SN 1991T at similar epoch.

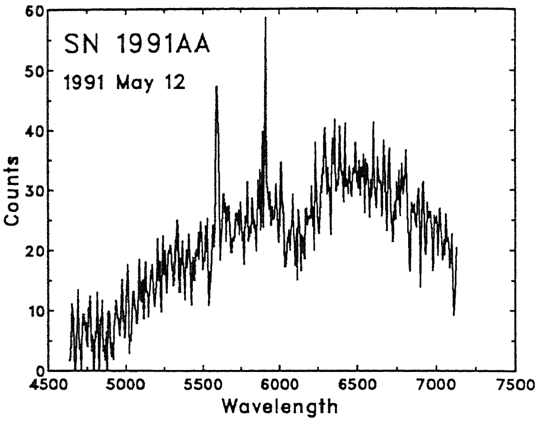

Fig. 3. Raw spectrum of SN 1991AA in an anonymous galaxy. The spectrum was recorded with the 1m reflector in an integration time of 30 min. The magnitude of the supernova was ~15. The sky spectrum has not been subtracted.

T. P. Prabhu & G. C. Anupama

Flare-related Changes in Magnetic Stresses

Solar flares are deemed to be the manifestations of the traumatic conversion of magnetic energy into thermal energy. The amount of energy available for such conversion is limited to the excess of magnetic energy over that in a corresponding potential field that has the same distribution of magnetic flux as the observed field. One parameter that is an index for the non-potential nature of the field is the angular deviation of the observed transverse field from the transverse field of the equivalent potential field (magnetic shear). Another parameter is the angle between the observed transverse field and the lateral gradient of the vertical component of the field (magnetic tension). The 'holy grail' of solar flare mhd research is to detect flare related changes in magnetic stresses.

Four vector magnetograms of the active region NOAA AR 4474 obtained by the MSFC group in 1984 April were analyzed to look for changes in both parameters, *viz.*, magnetic shear and magnetic tension associated with a 2B/C6 flare that occurred in the south-eastern portion of the active region at 20:17 UT on 1984 April 28. Fortunately, two of the four magnetograms spanned the event; one was obtained at 19:53 UT and the other at 20:31 UT. Neither magnetogram showed evidence for detectable amounts of magnetic stresses at the site of the flare, leave alone changes in stresses. Since non-potentiality is necessary for supplying the flare energy, this is indeed a curious result. The puzzle was somewhat resolved when we looked at the Hα pictures of the flare site before the event and found moderately sheared fibrils.

There was however evidence for flux emergence in that period as seen in the increase of transverse field strength and magnetic shear near the flare site. The Hα pictures showed further emergence of the loop and its subsequent evolution into a pore. Thus there is enough circumstantial evidence that new flux emerging beneath an existing field that was moderately sheared at chromospheric heights set off the flare. An useful lesson that we learnt from the whole exercise was that one should not confine the search for flare-related changes in magnetic stresses to the photosphere but must look at the chromosphere as well.

P. Venkatakrishnan & R. S. Narayanan

newsline

J. H. Sastri has been promoted as Professor with effect from 1990 April 1. N. K. Rao has been promoted as professor, and P. Venkatakrishnan and T. P. Prabhu as Associate Professors with effect from 1990 October 1. R. K. Kochhar and Vinod Krishan have been promoted as Professors, and Ram Sagar as Associate Professor with effect from 1991 April 1.

* * *

The council members of Indian National Science Academy visited the Kodaikanal Observatory on 1991 May 18.

* * *

Eleven graduate students of physics from different universities and IITs undertook summer projects at the Instiute and its field stations at Kavalur and Kodaikanal, during 1991 June–July. Two students of computer applications have undertaken a full-term project in the electronics laboratories since May.

* * *

B. Datta and P. Venkatakrishnan taught at the Summer School in Astronomy and Astrophysics, Joint Astronomy Programme, IISc, 1991 June. R. K. Kochhar, Vinod Krishan, D. C. V. Mallik, B. Datta and Ram Sagar also gave seminars at the school. The summer school participants visited IIA and VBO.

* * *

R. T. Gangadhara attended the Spring College on Plasma Physics, ICTP, Trieste, May 27 – June 21. He also delivered a talk on the 'Role of Compton and Raman Scattering in AGN Continuum' at the College. R. Rajamohan participated in the First NASA Workshop on the Detection of Near-Earth Asteroids, California, June 30 – July 3. Ram Sagar and G. C. Anupama participated in the Mini-workshop on Image Processing, IUCAA, Pune, July 22–26. They delivered invited talks on 'Stellar Photometry in Crowded Regions', and 'RESPECT Software', respectively.

* * *

An essay titled 'Torsion, Minimum Time, String Tension and its Physical Implications' by C. Sivaram received Honorable Mention at the 1991 Gravity Research Foundation competition.

* * *

Prof. Paul J. Wiita, Georgian State University, USA, visited the Institute during 1991 July 6–12. He collaborated with Vinod Krishan and R. T. Gangadhara on the problem of fast time variability in active galactic nuclei.

* * *

Profs. Ralph Pudritz and Patricia Monger of McMaster University, Canada, and J. W. Sulentic, University of Alabama, USA, visited the IIA and VBO during 1991 July. They delivered colloquia and also had discussions with many astronomers at the Institute.

* * *

Prof. K. M. Ghosh of Calcutta University (now retired) spent two weeks at the Institute in July. He delivered a series of lectures and held extensive discussions on problems related to turbulence in earth's atmosphere, solar atmosphere, and large-scale structure of the universe. He also arranged a visit to the department of aeronautical sciences of IISc for a demonstration of experiments in the subsonic wind tunnel, and the measurement of quantities characterizing hydrodynamic turbulence.

* * *

K. R. Sivaraman and G. A. Shah retired as professors at IIA on 1991 July 31. K. R. Sivaraman continues with the Institute as an Emeritus Professor. Ch. V. Sastry has assumed charge as acting director.

Colloquia

The following lectures were given at IIA between 1991 April 1 to July 31:

1. Line formation in the outer layers of stars : (a) Geometrical and physical aspects. (b) Dynamical effects (A. Peraiah, IIA, Bangalore).
2. Post AGB stars and protoplanetary nebulae (M. Parthasarathy, IIA, Bangalore).
3. Accretion discs around compact stars (P. Bhaskaran, PRL, Ahmedabad).
4. Relativistic Rheology (L. Radhakrishnan, Shivaji University, Kolhapur).
4. Plasma instabilities in the ionosphere (S. P. Gupta, PRL, Ahmedabad).
5. Relativistic Rheology (L. Radhakrishnan, Shivaji University, Kolhapur).
6. An empirical model of pulsar radiation mechanism (Joanna Rankin, University of Vermont, USA).
7. Astroseismology of DOV white dwarf PG $1159-035$ (S. Seetha, ISRO, Bangalore).
8. CCD observations of $\mathrm{H}\alpha$ in cool supergiants (Sushma V. Mallik, IIA, Bangalore).
9. Trends in workstation hardware and software (Patricia Monger, McMaster University, Canada).
10. Hydromagnetic disc winds in young stellar objects and active galactic nuclei (R. E. Pudritz, McMaster University, Canada).
11. Optical interferometry (M. Vivekanand, RRI, Bangalore).
12. (a) Properties of broad-line profiles in active galactic nuclei. (b) The amazing story of compact group of galaxies (J. W. Sulentic, University of Alabama, USA).
13. Statistical physics and modern theory of turbulence (Lecture Series) (K. M. Ghosh, Fellow, Indian Physical society, Calcutta).
14. CCDs and cooling requirements (V. Chinnappan, IIA, Bangalore).
15. Design and fabrication of the liquid-nitrogen-cooled cryostat (S. Jacob, IISc, Bangalore).

Editors: T.P. Prabhu & A.K. Pati
Editorial Assistant: Sandra Rajiva
Published by the editors on behalf of the Director, Indian Institute of Astrophysics, Bangalore 560034.

Newsletter
Quarterly Newsletter of the Indian Institute of Astrophysics
Vol. 6, No. 3, July 1991

To:

____

____

____

Indian Institute of Astrophysics
Bangalore 560034