
Numbers 8 & 9 October 1991

# EVALUATION OF THE CCD SYSTEM AT VBT FOR ASTRONOMICAL APPLICATIONS

T.P. Prabhu
Indian Institute of Astrophysics, Bangalore.

Charge-coupled devices are being used at VBT since the last few years. The author commenced CCD observations at the prime focus of VBT in 1990 January using the Astromed CCD dewar of TIFR, with a GEC P8603/B chip (Bhat *et al.* 1990). The data acquisition system in operation was the one developed by IIA for a nearly identical system (Ananth *et al.* 1991). Due to a minor difference in the ADC cards in the two controllers, the data could be read only using the IIA controller. A 'TIFR' version of the software subsequently became available rendering the two CCD dewars and controllers fully interchangeable.

Since 1990 March, observations were made with the scientific grade GEC P8603 chip of IIA which was coated to enhance ultraviolet and blue response. TIFR, in collaboration with IUCAA, obtained a similar chip in 1990 December and this has also been used occasionally since then. The Boller & Chivens spectrograph with the CCD detector became available at the Cassegrain focus and this has been used since 1991 February.

An evaluation of the CCD system is reported here, based on the observations obtained at the prime focus (imaging), and at the Cassegrain focus (spectroscopy) during the observing seasons of 1990 and 1991. The observations were carried out in various collaborations with A.K.Kembhavi (IUCAA), P.N.Bhat and K.P.Singh (TIFR), F.Sahibov (Tajik Academy of Sciences) and G.C.Anupama and Y.D.Mayya (IIA).

*The system gain and the readout noise*

It was realized during the 1990 observing season that the dynamic range of the system was extremely limited since a high system gain was employed. The system gain was subsequently determined as ~ 1 count / electron (Bhat *et al.*1991). The preamplifier gain was hence reduced from the default 34 to 9.2 during the 1991 observing season. A laboratory check showed that the system gain at this setting corresponds to ~ 0.23 count/ electron (Prabhu and Anupama 1991a). There was a minor shortcoming in the analysis: since the same set of flats was used for preparing the master flat and for the analysis of noise, the memory of noise in individual flats was transmitted to the master flat and was hence partially corrected in the individual flats after flat-fielding. The system gain was hence underestimated. Better results have now been obtained. Further, a method has been evolved to determine the system gain and the readout noise easily and quickly using two nearly equally exposed spectroscopic flats (Prabhu, Mayya and Anupama 1991). Commands have been incorporated in the RESPECT software (Prabhu and Anupama 1991b) to effect this. Fig.1 shows a plot of noise counts versus signal counts, together with a least-squares model fit obtained using the GSTAT and GFIT commands of RESPECT. For the gain setting of 9.2 the best-fit values are:

System gain $G = 0.247 \pm 0.001$ count/electron,
$Q = 1/G = 4.05 \pm 0.02$ electron/count,
Readout noise $R = 7.62 \pm 0.07$ electron.

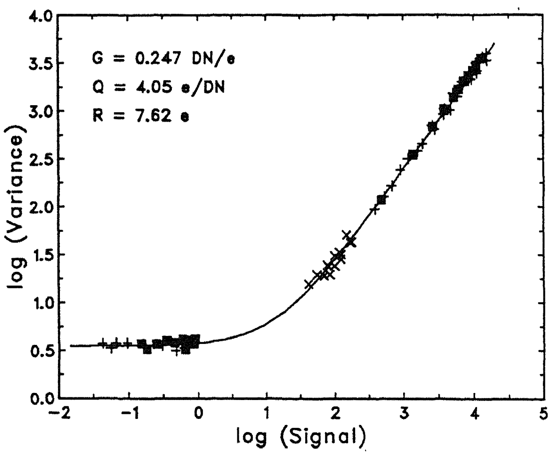


Fig 1. Noise as a function of signal and the theoretical fit (solid line) obtained with IIA's GEC P8603 coated chip and the TIFR controller with the pre-amplifier setting of 9.2. The data from spectroscopic flats (slit region and bias: + ; scattered light: x) and laboratory full-frame flats (filled squares) are separately shown. The fit is based on spectroscopic flat (+) data only.

The above set of values was obtained using two sets of spectroscopic flats obtained on 1991 March 10 and 11 using the IIA chip and the TIFR controller. Every fourth data point (+) is shown in the figure to avoid confusion. The theoretical fit is based on 137 points from these two sets of flats and two bias frames. Points obtained using scattered light incident outside the exposed region are shown as crosses. These points fall on the theoretical curve showing that (i) the scattered light can also be effectively used for calibration; and (ii) the threshold problem is not detectable up to the level of 60 counts (240 electrons). The filled squares denote the data points obtained using laboratory full-frame flats. Slight nonlinearity is evident at the high signal values. Ignoring this, one obtains $G = 0.266 \pm 0.002$ count/electron, a value higher by 8%. Allowing a quadratic term reduces the value to $G = 0.252 \pm 0.004$ count/electron, which agrees well with the spectroscopic determination. The ease and accuracy of the spectroscopic determination is evident.

*GEC P8603/B*.Chip

The B-grade chip of TIFR used during 1990 was of very poor quality. In addition to poor efficiency pixels scattered all over, which are possibly shadows of microscopic dust particles on the surface of the CCD (see McLean 1989), there were many defective columns. A defective column arises due to a bad pixel in a specific row that affects all the data passing through it. In the output image it appears as if the entire column were defective beyond the row in which the defective pixel lies. Fig. 2 shows a portion of a row of a flat image obtained in 1990 January. Three defective columns are seen at positions 114, 118 and 235. In the case of columns 114 and 118, the charge in the defective pixel appears to have diffused to a neighbouring pixel (113 and 117 respec

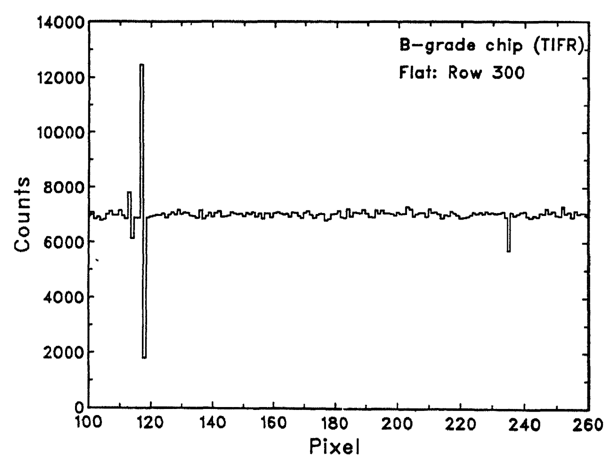


Fig 2. Counts in a portion of row 300 plotted against column number for a flat-field image obtained in 1990 January using the GEC P8603/B chip of TIFR. Bad columns of two different kind are evident near the beginning and end of the data.

tively). Column 235, on the other hand, is a charge trap. The charge passing through this pixel in a specific row is trapped and released temporarily, after a few star image is registered over such a column, it would appear to have a vertical trail. Both kinds of bad columns have very poor charge transfer properties. There were many such columns as seen in the column overscan obtained after all the rows are read. The average of column overscan is shown in Fig.3. Ideally the counts should have been those of bias (dark counts are negligible) - about 1670 counts. The high counts in the overscan may be compared with the average value of the flat which was about 9000 counts. All the columns showing high counts are defective beyond a specific row. Great care needs to be taken in analysing the data obtained with this chip.

*GEC P8603/A Chip*

The A-grade chips of IIA and TIFR/IUCAA have better performance. The vertical charge-transfer efficiency of the IIA chip is shown in Fig.4. It was computed as

$$\mathrm{CTE} = 1 - \frac{\text{row } 579}{\text{row } 578}$$

where row 578 is the last row read, and row 579 is the first row of column overscan. A single well exposed flat was used. The noise in the figure including occasional peaks and dips are due to statistical fluctuations in the counts–shot noise, in row 578 and readout noise in row 579. The average CTE is good (nearly 100% ) compared to the B grade chip for which it was as poor as 99% for the 'clean' columns. The above estimates are accurate to only two significant figures and can be improved by (i) averaging the estimates based on different flats and (ii) improving the bias estimate using an extended row overscan.

*The CCD Dewar*

Condensation used to appear on the windows of both the dewars as the relative humidity approached 70%, even after prolonged evacuation. The condensation would be noticed at first through a decrease in the counts. Soon

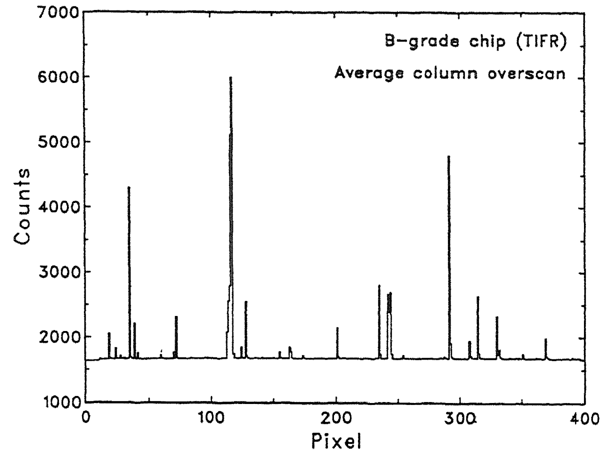


Fig 3. Average count per column in the column overscan region of the B grade chip. The high counts indicate unusually poor charge transfer efficiency in the corresponding columns.

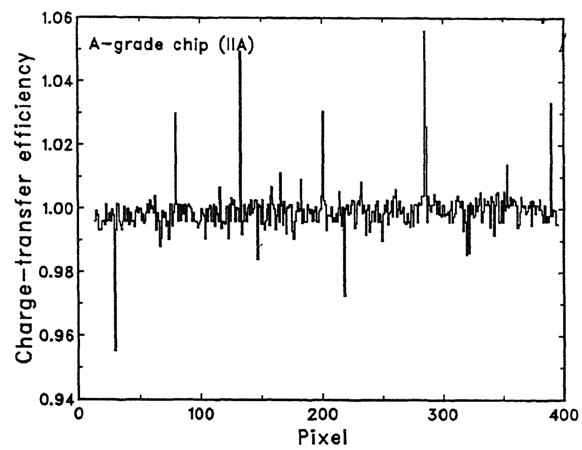


Fig 4. Charge-transfer efficiency of the IIA chip. Occasional dips and peaks are due to statistical fluctuations in the counts, and only the mean level is statistically significant.

halos would appear around stars. Finally, the star images would take on odd shapes as the droplets begin to form. Closer examination of spectroscopic flats revealed that during the earliest stages the counts in the central regions would fall appreciably whereas the noise remained high. It was not possible to notice this stage during observations.

A heater coil was fixed around the window to circumvent this problem. This introduced a non-uniform background in the image even though the glow of the heater was not perceptible to the eye. Subsequently an arrangement became available at the Cassegrain focus for periodic flushing of the region around the window by dry nitrogen. This arrangement is satisfactory.

*The output image*

A few problems were noticed in the images obtained while observing in 1990-91. They are listed below. Note that the images are described in the order of data transfer: the first serial transfer being shown at the left of a row and the first parallel transfer at the top of the image.

1. *Bias variations:* The bias frames obtained during 1991 showed gradation. The counts were high in the early pixels of rows and later pixels of columns (Fig.5). This appears similar to the 'luminescence' referred to by McLean (1989).

2. *The readout pattern:* The existing software reads out, the CCD image six rows at a time, stores and displays, before the next set of six rows are read. It was found that in between two transfers some negative charge used to build up on the output register. This was affecting particularly at low count levels in the spectroscopic data, narrowband images and short-exposure broadband images. Fig.6 shows that the problem is most severe in the left overscan area. Fig.7 shows that some effect is present even up to column 230. Modification done to the software by the electronics group at IIA has now reduced the problem to acceptable limits.

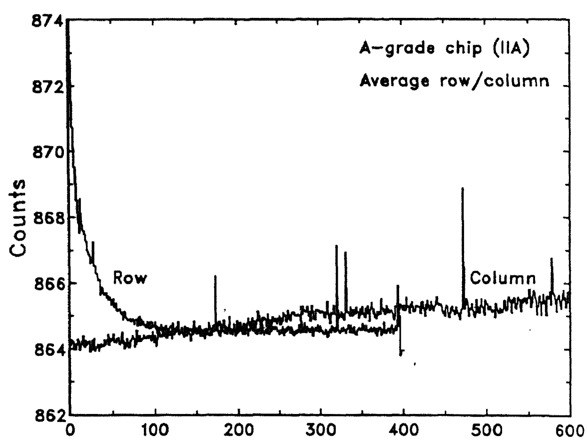


Fig 5. Counts in the bias frame obtained in 1991 April using IIA chip and TIFR controller. The averages of the over rows/columns are shown. Bias value is high during early rows and later columns. The superposed sharp peaks are due to cosmic ray events, which are registered in the bias frame since the frame transfer time is long.

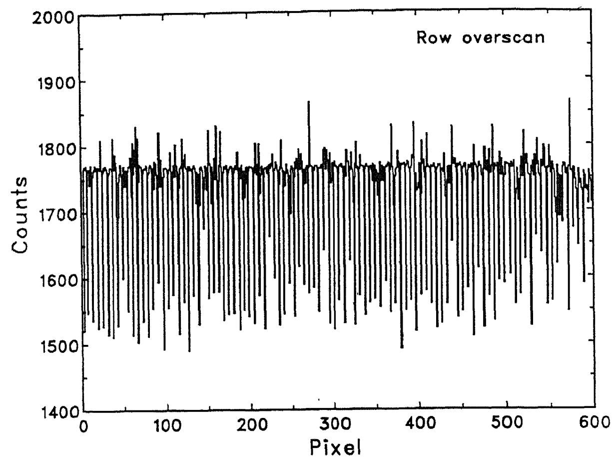


Fig 6. Row overscan (left) of an image obtained in 1991 March, averaged over 10 columns. Noticeably low counts appear in every sixth row.

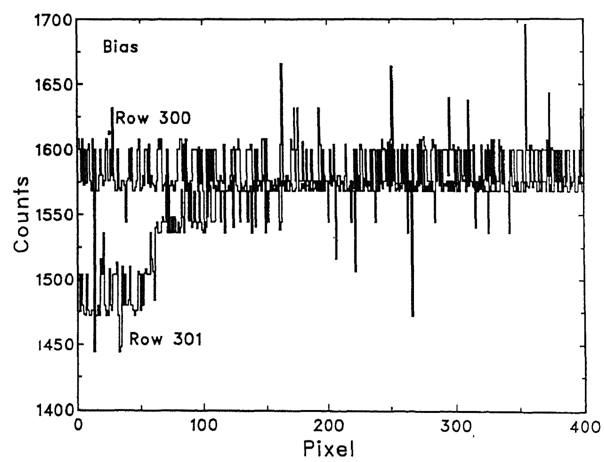


Fig 7. Row 301 of a bias frame obtained in 1991 March is compared with row 300. The former has noticeably low counts in the beginning.

3. *The binning bias:* The lack of a few of the last significant bits (LSBs) in the output image is called the 'binning bias'. This can be caused if the ADC is not a true digitiser over its total number of bits. An easy method of checking its presence is to construct a histogram of counts in different pixels of a flat image and to obtain a power spectrum of the histogram. If there is no loss of LSBs, the histogram should be continuous due to the Poisson noise in the signal

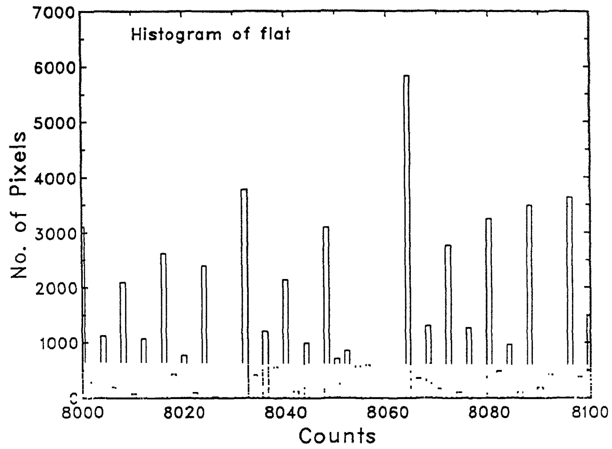


Fig 8. A portion of the histogram of counts in a flat image obtained in 1990 March using the IIA CCD and controller.

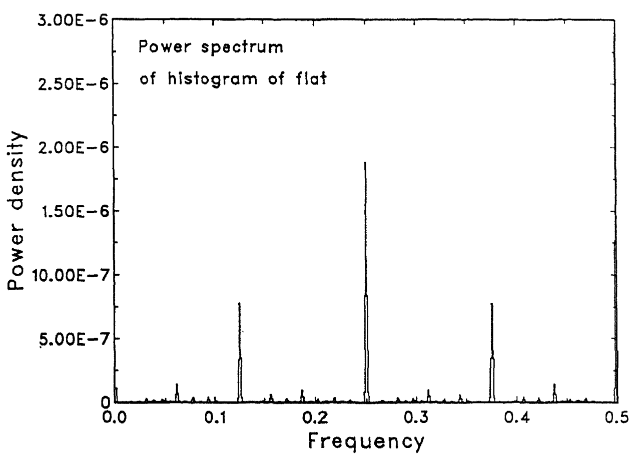


Fig 9. Power spectrum of the histogram shown in Figure 8. The strongest peak is at a period of 4 counts. Other peaks are due to harmonics and aliases.

counts (Djorgovski 1984). Fig.8 shows a portion of the histogram of a flat image obtained in 1990 March using the IIA CCD and controller. Fig.9 shows the power spectrum of a 1024 bin portion of the entire histogram. The peak at frequency 0.25 indicates that there is a high probability of the last two significant bits being affected. Thus the 16 bit ADC (a replacement of the original) is linear only over 14 bits. Other peaks in the figures are due to harmonics and aliases. The effect of the binning bias would be to introduce additional base-level noise and hence to reduce the sensitivity and dynamic range. The magnitude of the binning bias was found to be much less in the TIFR controller.

*Acknowledgements*

In addition to collaborators referred to in the text, I am grateful to Prof.J.C.Bhattacharyya for persuading me to observe with the VBT in collaboration with the TIFR group, to Prof.K.R.Sivaraman for inspiring me to analyse and understand the problems and to Dr.R.Srinivasan, Mr.A.V.Ananth and Mr.G.Srinivasulu for solving the problems. Useful observations with the VBT became possible through the efforts of Prof.N.K.Rao and the electronics, optics and mechanical divisions of IIA Bangalore and Kavalur. I also thank the observational assistants for their patience.

**References**

1. Ananth, A.V., Srinivasan, R., Srinivasulu, G and Chandramouli, S.S., 1991, *Indian J.Pure Appl.Phys.*, **29**, 529.
2. Bhat, P.N., Kembhavi, A.K., Patnaik, K., Patnaik, A.R. and Prabhu, T.P., 1990, *Indian J.Pure Appl.Phys.*, **28**, 649.
3. Bhat, P.N., Singh, K.P., Prabhu, T.P. and Kembhavi, A.K., 1991 (in preparation).
4. Djorgovski, S., 1984, in *Proc.Workshop Improvements to Photometry*, Eds. W.J.Borucki and A.Young, NASA CP-2350, p.152.
5. McLean, I.S., 1989, *Electronics and Computer aided Astronomy*, Ellis Horwood, Chichester.
6. Prabhu, T.P. and Anupama, G.C., 1991a, *VBT News*, No.**6** & **7**, p.5.
7. Prabhu, T.P. and Anupama, G.C., 1991b, *Bull.Astr.Soc.India*, **19** (in press).
8. Prabhu, T.P., Mayya, Y.D. and Anupama, G.C., 1991 (in preparation).

# CCD SURFACE PHOTOMETRY OF THE STANDARD ELLIPTICAL GALAXY NGC 3379

K.P. Singh [1], P.N. Bhat [1] T.P. Prabhu [2] and A.K. Kembhavi [3]

1. Tata Institute of Fundamental Research, Bombay.
2. Indian Institute of Astrophysics, Bangalore.
3. Inter University Centre for Astronomy and Astrophysics, Pune

The study of surface brightness of ellipticals using CCDs can be extremely useful in the understanding of their structural, evolutionary and physical properties The analysis of the surface brightness isophotes can be parameterised through the variation of ellipticity, twisting of the contours and departures from pure elliptical shapes. Any departure from symmetry would offer clues on the dynamics and structure of the galaxy and also on the possible merger history of the galaxy. One may also expect correlation between the photometric peculiarities and the radio and X-ray properties. The use of different colour filters in such studies can give clues to the presence of dust as well as of recent star formation in the galaxies.

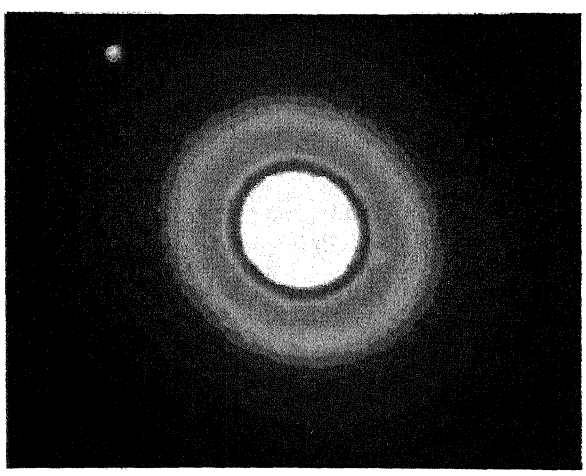

Fig 1. The CCD image of NGC 3379 in the V band. Two point sources in the field of the galaxy can be seen.

As a part of an ongoing project to study the surface brightness of ellipticals using a CCD at the prime focus of the VBT, we have carried out a detailed study of an elliptical galaxy, NGC 3379 which is a galaxy photometry standard (de Vaucouleurs and Capaccioli 1979). The observations were carried out in 1990 January 27-30 using the *V* and *I* filters and a GEC P8603B (B grade) chip. The image scale on the CCD is 0.6 arcsec pixel$^{-1}$ at the *f*/3.25 prime focus of the VBT. The field of view (foV) is 5.7 x 3.8 arcmin $^{2}$ . The read out noise of the CCD is ~ 9 electrons. The default amplifier setting used corresponds to a system gain ~ 1 electron per CCD count (ADU). The standard stars in M67 were used as the calibrators. For further details of the CCD camera and its standardization using the M67 star cluster, the reader is referred to Bhat et al. (1990, 1991). The seeing was typically about 2.5 arcsec (FWHM).

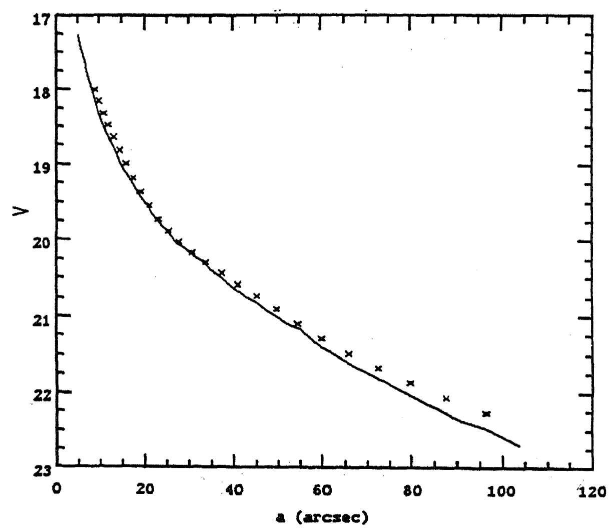


Fig 2. The V band surface brightness profile of NGC 3379 as a function of the semi-major axis. Measurements from VBT (x) are compared with the profile based on de Vaucouleurs and Capaccioli (1979: solid curve).

The images were bias subtracted and flat fielded using the best flat fields obtained from the twilight and the dawn skies. The cosmetic defects and the impact of cosmic rays were removed by applying the technique of median filtering to the images using an unweighted kernel of size 5 x 5 and the nearest neighbours. The resultant image of the galaxy is shown in Fig.1. The galaxy is bigger than what could be covered by the CCD foV. Two foreground stars in the galaxy, one of them as close as 26 arcsec from the centre of NGC 3379, were removed by substituting those areas with the surface brightness diametrically opposite to the stars, before

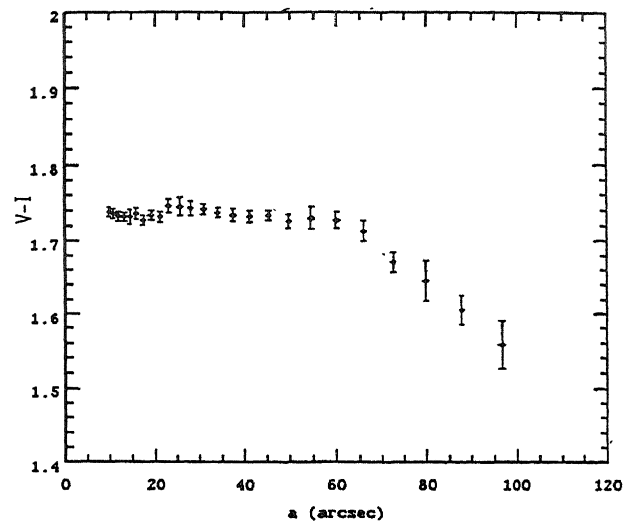


Fig 3. The observed (V − I) colour profile as a function of the semi-major axis of NGC 3379.

subjecting the data to isophotal analysis (see below). The sky was estimated from the empty areas of the exposed frames.

The shapes of the isophotes of the galaxies were analyzed by fitting ellipses to the intensity contours of the galaxy. The mean intensity of the ellipse, its ellipticity, position angle and ellipse centre were thus obtained for a given length of the semi-major axis. The Fourier components of the residual intensity from the best fitted ellipse were also evaluated by using the method of least squares. The procedure was repeated after increasing the semi-major axis length by 10%. The errors on all the parameters of the ellipse were also evaluated. The procedure was repeated for the data from both the filters. We excluded the saturated core regions of the galaxies from the above analysis. We note that the dynamic range was low due to the high system gain employed. The mean intensity of the galaxy was corrected for the average extinction appropriate for the zenith angle at the time of the observation. The extinction in the $V$ band were available from the same site during the nights of 1990 January 21, 24-26 (Mohin 1991, personal communication) and the $I$ band extinction was estimated using the $\lambda^{4}$ law. The transformations to standard $V$ band and $(V - I)$ colour were carried out using standard stars in M67.

In Fig.2, we present the measured surface brightness profile in the V band as a function of the semi-major axis. A detailed comparison of the profile with the work of de Vaucouleurs and Capaccioli (1979), who measured the B band surface brightness (as a function of the E-W radius), can be made by assuming a constant colour correction of $B - V = 1.0$ (solid curve in Fig.2). The agreement is good, the difference being $\simeq 0^{m}.05$.

In Fig.3 we present the $(V - I)$ colour profile of the galaxy. The increased reddening towards the centre is typical of the elliptical galaxies and indicates metal enrichment towards the centre.

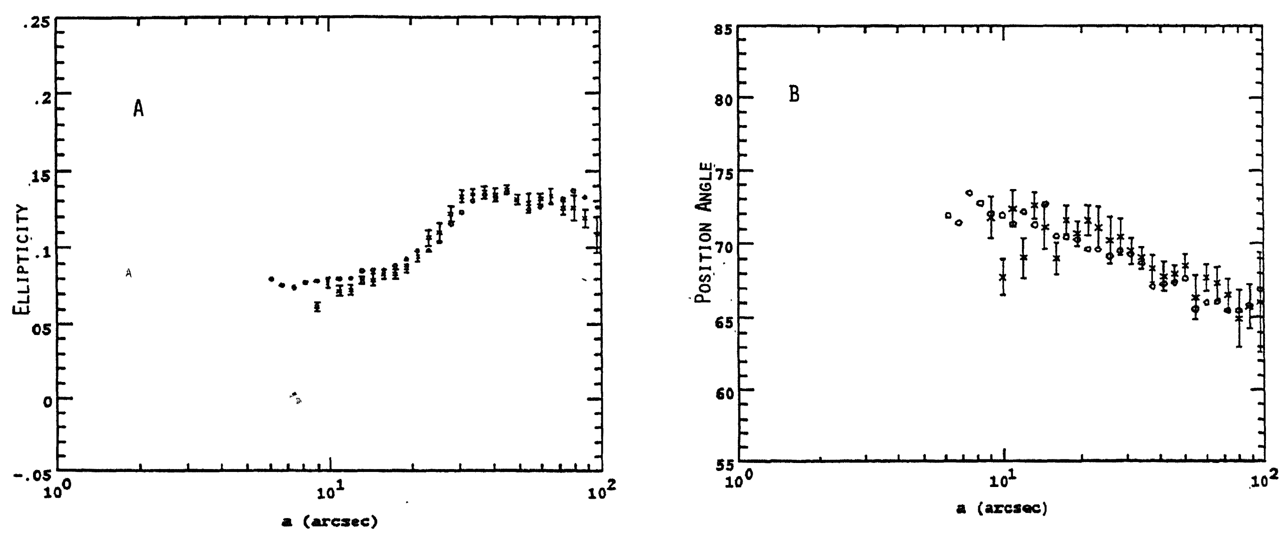


Fig 4. The ellipticity (a) and the position angle (b) profiles of NGC 3379 as a function of the semi-major axis. The circles represent the V band data and the crosses represent the I band data.

In Fig.4 we show the ellipticity and position angle profile of the galaxy as a function of the semi-major axis. The data from different filters are shown together. A comparison with the results of Bender et al.(1988) shows a good agreement. The outer ellipticity is consistent with the E1 classification for NGC 3379, whereas the inner regions are more circular. The position angle variation shows a twisting of the isophotes, perhaps a remnant of the merger process in the past or due to the triaxial nature of the galaxy.

*Acknowledgements*

We thank the staff at the VBT for assistance during the observations. The analysis was carried out using the IRAF software package recently installed on the Sun workstation at TIFR.

**References**

Bender, R., Dobereiner, S and Mollenhoff, C. 1988, *Astron. Astrophys. Suppl. Ser.*, **74**, 385.

Bhat, P.N., Kembhavi, A.K., Patnaik, K., Patnaik, A.R., and Prabhu, T.P., 1990, *Indian J.Pure Appl. Phys.* **28**, 649.

Bhat, P.N., Singh, K.P., Prabhu, T.P., Kembhavi, A.K., 1991, (in preparation)

de Vaucouleurs, G and Capaccioli, M., 1979, *Astrophys. J.Suppl. Ser.*, **40**, 699.

## SURFACE PHOTOMETRY OF GALAXIES

Ajit Kembhavi [1], T.P. Prabhu [2], P.N. Bhat [3] and K.P.Singh [3]

1. Inter University Centre for Astronomy and Astrophysics, Pune.
2. Indian Institute of Astrophysics, Bangalore.
3. Tata Institute of Fundamental Research, Bombay.

The linearity and dynamic range of CCD detectors make them ideally suited for surface photometry of galaxies which involves the mapping of the distribution of light from the relatively bright central regions of these objects to very faint regions which merge into the sky background. Such data are extremely difficult to obtain using traditional photographic methods and that is the reason why they are sparse relative to spectroscopic data. With the high quantum efficiency of CCDs, it is possible to make two dimensional model fits to the data and the progression of structural parameters like eccentricity, position angle etc., as well as the distribution of colours, H II regions and so on across a galaxy can be studied.

A collaborative programme on galaxy surface photometry has been in progress at the VBT. The sample consists of galaxies from the CfA redshift catalogue which have $m_B < 14.2$ and $cz \leq 4000$ km $s^{-1}$ . These limits have been chosen such that while providing candidates which are not already very well studied from the structural point of view, a good signal-to-noise ratio is obtained in wide band filters in about 600s of exposure at the prime focus of the VBT. There are now two nearly identical CCD camera and controller systems, supplied by Astromed Limited, available for use at the VBT. The CCD in either case is a GEC 385 x 576 phosphor–coated device. The two systems were interchangeably used during the observations in early 1991. A PC-AT based system developed at IIA was used for driving the camera and acquiring the data. The data were converted to the FITS format using the VAX 11/780 system at the VBO and later analysed at the VBO and IUCAA.

The primary aim of the program is to obtain surface photometric data on a complete set of galaxies, so that the distribution of properties as a function of galaxy type, environment etc. may be studied. Due to the slow rate at which data is acquired and the small number of dark nights available this will be a long term program and observations from the VBT will have to be supplemented by data acquired at other sites. It was thought desirable to begin with a subset of galaxies which would be interesting scientifically, and whsoe study will provide experience in observing techniques as well as in image processing. A sample of spiral galaxies of types Sb to Sc (and the barred variety) was identified and the aim is to exhaust this sample before others are taken. These types were selected because they are rich in star-forming regions and have also reasonably regular structures which are amenable to structural studies. Added to this sample were galaxies like the elliptical NGC 3379, which is used as a standard to "calibrate" surface photometric measurements with reference to data obtained by other observers and NGC 2903 which has a very interesting central region (T.P.Prabhu 1980, Astrophysics. Space sci. 68, 519).

The data being reported was obtained on the single night of 1991 April 16-17. The observations during other nights were plagued by bad weather or instrumental failures except for short spells during the night of April 15-16 when NGC 3379 was observed. Frames were taken in V and R filters with exposures in most cases lasting 600s. Two exposures of 600s each were taken with the B filter, the longer time being necessary in this case because of the lower efficiency of CCD and the lower luminosity of the galaxies at the shorter wavelengths. Data in all three filters were obtained for NGC 2903, 2997, 3379, 4273, 4643, 5600, 5846 and 6190.

A number of sky flats at dusk and dawn as well as dome flats were obtained. Accurate flat fielding is very important and several flats in each filter are required, so that master flats with good statistics may be generated. A large number of flats are required to determine the number of electrons per count and the readout noise. It has been found that this is best done in the laboratory rather than at the time of observation. The procedures adopted for determining these parameters generating master flats, the theoretical concepts underlying these procedures and the results obtained will be described elsewhere. The bias level was found to change somewhat through the night and it is therefore necessary to obtain bias frames periodically. We are presently determining the bias value using the overscan region in each frame.

Image processing of the 1991 April data is being done at IUCAA using the IRAF and VISTA packages on the SUN workstation. IRAF has excellent facilities for bias subtraction, flat fielding and so forth. It is possible to use these routines to rapidly clean a number of images though continuous user interaction becomes necessary until the characteristics of the instruments and data are well understood. IRAF also has packages like QPHOT and DAOPHOT for photometric calibration. There are no facilities in IRAF at present for surface photometry and here VISTA is to be used. The image formats used by IRAF and VISTA are different and application of the two packages simultaneously requires the use of FITS images on tape to pass from one package to another. Procedures for doing this conveniently are being evolved. The details will be described elsewhere.

## SPECKLE IMAGING

S.K.Saha
Indian Institute of Astrophysics, Bangalore.

The invention of speckle interferometry (A.Labeyrie 1970, Astron. Astrophys., 6, 85) has made a major break through in observational astronomy by counteracting the effect of atmospheric turbulence on the structure of stellar images. Details of the structure of a wide range of astronomical objects at scales of 15 to 30 milliarcseconds are routinely being observed by different active groups. The 2.34-m Vainu Bappu Telescope (VBT) provides us with an opportunity to study high-resolution features of interesting celestial objects using this technique.

On 1991 March 29-30, we obtained several frames containing speckles of 17 close binaries (separations < 1 arcsec) and of reference stars at the Cassegrain focus at the VBT. The camera comprising a Barlow lens, a filter in the Hα region (FWHM ~ 50A) and an intensified CCD (ICCD) was used to record these speckles. Specklegrams of these reference stars were obtained by shifting alternately between the programme star and the reference during the observing run to equalize seeing distributions. Slow wavering of speckles were also found for a brief period. Due to the finite exposure time (20msec) we could not exploit this situation to maximise S/N.

We also performed a series of experiments in the laboratory to study speckles by simulating seeing. This was done by introducing various static dielectric cells (SDC) of different sizes etched in glass plates. Several such glass plates with regular as well as random distribution of SDC's of known sizes were made and used in these experiments. The phase differences due to etching lie between $0.2\lambda$ and $0.7\lambda$. The wave fronts from an artificial point source was made to enter a telescope whose focal ratio is 3.25 same as that of the VBT at the prime focus. This focal ratio was slowed down considerably with a microscope objective to discern speckles. Two narrow band filters at 5577A, (FWHM = 100A) and at 6300A, (FWHM=100A) were used to record the speckles. It was found from a preliminary analysis that the source gets resolved in the 6300A filter enabling us to use speckles taken through the 5577A filter as reference.

Fig. 1 Speckles of the artificial star image obtained in the laboratory using a filter centered on 5577A (FWHM 100A).

Figure 1 shows the speckles obtained in the laboratory taken with a narrow band filter centered on 5577A (FWHM = 100A). The image was digitized with the PDS 1010M micro-densitometer and processed using the COMTAL image processing system of the VAX 11/780 computer at the VBO. The clipping technique was used to enhance the contrast in grey levels. The clipped image is superposed on the histogram-equalised original image.

We are now concentrating on fabrication of a newly designed speckle camera system. The optical components of this interferometer consist of (1) a magnifier (ii) a narrow band filter and (iii) a focal plane optical flat of low-expansion glass with a precision-made hole of aperture 356 $\mu$ on the surface which is equivalent to a field of ~ 9 arcsec at the prime focus of the VBT. This will also be used at the Cassegrain focus of the same telescope, in which case, the field covered by this aperture will be ~2.25 arcsec. The image of the object passes on to the microscope objective through this hole. The rear side of the flat is shaped suitably to enable the microscope objective to be brought very close to the focal plane (to a distance of nearly the focal length of the microscope objective). The surrounding star field of $\phi$ ~10 arcmim at the prime focus and $\phi$ ~ 2.5 arcmin at the Cassegrain focus is re-imaged on an intensified CCD for monitoring. The technical details of this optical set-up will be discussed elsewhere.

Since the intensity distribution in the focal plane in case of a quasi-monochromatic incoherent source is the convolution of the object intensity distribution and the telescope atmosphere point spread function, the estimation of transfer function of the latter is obtained by calculating Weiner spectrum of the instantaneous intensity from the unresolved star (reference star). Such a comparison is likely to introduce deviation in the statistics of speckles from the expected models based on the physics of the atmosphere. This, in turn, would result either in the suppression or in the enhancement of intermediate spatial frequencies which could lead to the artefacts. To cope with this situation, simultaneous observation of both the object and the reference star will be made at the prime focus by the present set-up if the latter is located in the isoplanatic domain around the object.

# M 4-18 : A LOW EXCITATION PN AROUND A WC 11 STAR

R.Surendiranath and N.Kameswara Rao
*Indian Institute of Astrophysics, Bangalore*

There is a class of very enigmatic objects classified under WC 11 group presently consisting of about six objects. Their place in stellar evolution is not clear. Their general properties have recently been reviewed by Rao, Giridhar and Nandy (1990).

They all exhibit low-excitation Wolf-Rayet stellar spectrum on which is superposed a low-excitation nebular spectrum. They have large amounts of excess emission in near IR to 100μ region. Radio continuum emission at cm wavelengths is seen in some of them. Strong CO (1-0) & (2-1) millimeter wave emission was also observed in a few of them. While some of these objects have been described as proto-planetary nebulae, others have been interpreted as transition objects between post planetary and born again AGB stars.

In elucidating the nature of these objects, the properties of the central star, their mass loss in particular and the abundances of the surrounding nebula might give clues for a better understanding of their evolutionary state. Observationally, one of the problems is to isolate (i.e. identify) the nebular lines from the crowded stellar (emission) lines before obtaining their fluxes to estimate the nebular abundances. Theoretically, the nebular emission spectrum has to be modelled with the effects of dust in the nebula taken into account. Our nebular model program developed in Fortran assumes i) spherical symmetry ii) steady state conditions and iii) OTS approximation for the diffuse radiation field. The physical processes considered are photoionization, radiative recombination, dielectronic recombination and charge exchange reactions. Filling factor values covering the range from fully clumped to uniform matter distribution have been used to take care of the effects of clumpiness of matter. The code has been well tested and calibrated. In a future version of the model we plan to include the effects of dust.

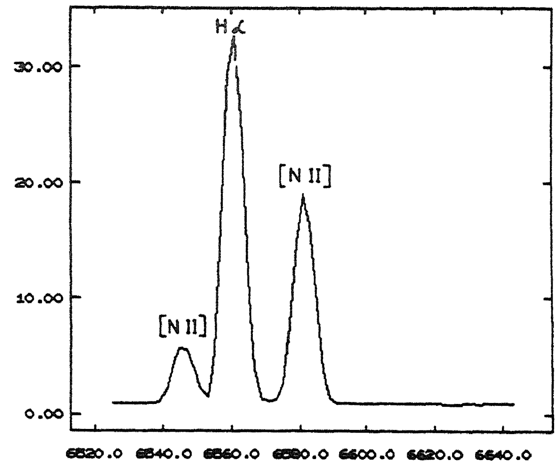


Fig. 1 Portion of the spectrum of M 4-18 showing the Hα line flanked by the well resolved [NII] lines.

M 4-18 is a prominent member of this group and had earlier been studied by Goodrich and Dahari (1985). They arrived at a very large abundance of oxygen and a low electron temperature ($T_e$ ~ 5000) in the nebula which looks anomalous and puzzling when compared to the central star which appears to be carbon rich. We attempted to do the observations as well as build a numerical model of the nebula to match the observations. One aspect which would give some clues about the metallicity of these objects is the abundance of sulphur which can be estimated.

The Boller and Chivens spectrograph at the VBT has been fitted with an Astromed CCD detector. In combination with the 6-inch camera and 600 line/mm grating it gives a resolution of ~ 3 Å, which would be sufficient for the study of nebular lines. Incidentally this is a better resolution than that employed by Goodrich and Dahari (6Å, IDS spectra). Thus, we hope to improve both the resolution and S/N ratio.

The observations obtained with the VBT on 1991 February 28 are shown below. The object acquisition and guiding were done from the console. A microchannel coupled CCD attached to the off-axis guiding unit was used to obtain the exposures. Although the bright moon was close-by, the contamination was not much and the contribution due to sky emission was subtracted.

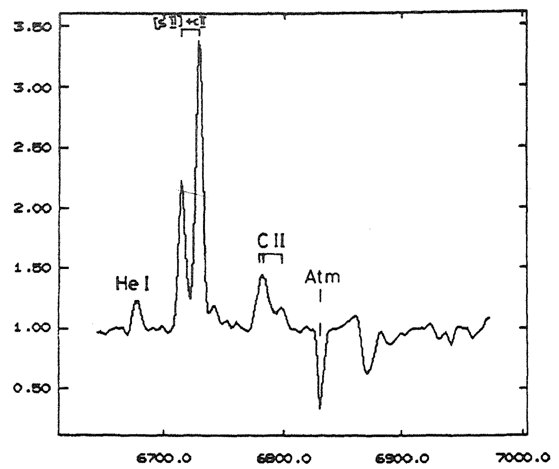


Fig. 2 Spectrum of M 4-18. The nebular lines of [SII] and the stellar lines of CII are indicated.

The seeing on that night was good (~1 to 1.5 arcsec). The long slit spectrum showed nebular lines extending to regions where stellar CII emission lines were not seen. This indicates that the nebula is about three to four arcsec across although it is listed as stellar in appearance in Acker's catalogue. The parts of the spectrum containing the nebular emission lines of nitrogen and sulphur are shown in figures 1 and 2. Further analysis is in progress.

## References


Goodrich, R.W., and Dahari, O., (1985), Astrophysics.J., **289**, 342-355.

Rao, N.K., Giridhar, S., and Nandy, K., (1990) Astron. Astrophys., **234**, 410-418.


VAINU BAPPU OBSERVATORY

Sky condition at Kavalur, April - September 1991.

| Month | Spectroscopic Hours | Photometric Hours |
|---|---|---|
| April | 134 | 21 |
| May | 129 | 21 |
| June | 13 | 00 |
| July | 18 | 02 |
| August | 27 | 02 |
| September | 25 | 00 |

*Photograph by R.C. Kapoor*

Bird of Paradise Flower (Strelitzia Reginae). This extoxic flower resembles a tropical bird hence called the Bird of Paradise Flower. It belongs to the banana family and is a very slow growing plant

*A Vagiswari*

Editor: R. Rajamohan, Editorial Assistant: S. Rajasekaran
Published by the Editor on behalf of the Director, Indian Institute of Astrophysics, Bangalore-560034, India