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Intensified CCD Camera Based Remote Guiding Unit for VBT and Observation of Speckles with ICCD

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Abstract

For successful observations in any telescope, guiding becomes important. On 2.34 m Telescope at Vainu Bappu Observatory, Kavalur, a remote guiding system is assembled using Intensified CCD camera and a PC based image processing system. It is found that the camera reaches upto 14th magnitude at dark nights. The PC based image processing system eliminates noise in the picture and helps in integration of faint images, contrast enhancement and other related function. Though not ideally suited for speckle observations, the camera is used to record speckles at Vainu Bappu Telescope (VBT). Requirements for speckle observations are included.

Keywords: optical instrumentation, intensified CCD, speckles

Introduction

Optical Astronomers, working in the visible region have the advantage of monitoring the star field during the observation. This gives an assurance about the quality of the data they collect. Instrumental errors like improper tracking of telescope, obstruction in the light path of the main detector are easily noticed and corrective action taken immediately. Whenever there is a drift in the star position across the detector due to inaccurate tracking rate or an unbalanced telescope and shift in the star position due to disturbances to the telescope like a gust of wind or movement of observer at the prime cage has to be corrected immediately in order to get useful data. Some of the small sized telescopes do not have any co-ordinate display system. Guiding units become essential to acquire the object at these telescopes. When the electronics hardware became cheap during the last decade, efforts were made to use them. The single chip microcontroller based position display systems based on absolute encoders were mounted and tried (Chinnappan 1982). In bigger telescopes like

VBT more powerful microcomputer systems were designed and put into use for acquiring the object (Chinnappan & Bhattacharyya 1985). The telescope drive electronics has also become sophisticated (Chinnappan 1988). In the 1m Carl Zeiss telescope at Kavalur, a 20 cm telescope is used for guiding. An X,Y offset is provided in the guide telescope so that any star in the field can be centred for reference. Whenever there is a change in the image position, telescope control buttons are pressed and is brought back to the centre.

Instead of manual guiding, autoguiders are used at large telescopes. Autoguiders generate error information proportional to the change in image position and feeds this error in the feedback loop of the telescope drive electronics. Telescope tracks the objects accurately without manual interventions. In VBT presently only manual guiding is used. Since it is found that it is difficult to sit in the prime cage and guide throughout the night, a remote guiding unit was put into use during the last year. An autoguider based on the remote guiding unit is currently being undertaken.

Location for Guiding

The 1m telescope has a separate 20 cm guide telescope and is attached with the main telescope. This has the same *f* ratio as the main telescope and is accurately mounted so as to be parallel to the main telescope. Guide telescopes normally give very wide field coverage giving a couple of degrees. Limitation is that one may not see very faint objects. Stars upto 8th to 10th magnitude can be selected for guiding. As the field is wide, it is always possible to find a guide star. But the best performance can be achieved only if one guides from the star taken from the main field itself. The only limitation here is the limited field, typically in the order of a few tens of arc minutes. The probability of selecting a guide star which is bright enough for guiding becomes less. To overcome this difficulty, the incoming light can be magnified a few thousand times using image intensifiers or the photons may be collected by integration in the detectors like CCDs. In VBT, guide star is picked up from the main field itself. No separate guide telescope is used at present.

Guide cameras for remote guiding

Normally it becomes very inconvenient to guide at either prime focus or cassegrain focus, mainly because one has to move along with the telescope position. At low hour angle it becomes difficult. To overcome this difficulty, a television type camera is mounted in the guide star field and the display is provided in convenient location like console room. One sits in front of the TV monitor and keeps guiding the telescope by operating the telescope drive buttons. Manual operation can be replaced by autoguiders.

Earlier successful TV guiding cameras for telescope used secondary electron conduction tubes (SEC) preceded by an image intensifer devised by Wampler in 1972. Ditsler in 1979, used intensified silicon target videocon with an image intensifier tube (ISIT) for guiding. Now the trend is towards using solid state detectors like Charge Coupled Devices (CCD) or Charge Injection Devices (CIDs). Since CCDs are fabricated from silicon material, the thermal noise at room temperature is high. CCDs have to be cooled at about -120 deg C to effectively eliminate the dark noise. To avoid condensation problems, it requires high vacuum cryostats cooled with liquid nitrogen. Thermoelectric coolers which give 40 to 50 deg C differential with the ambient temperature can also be used. When CCDs are cooled, it is possible to integrate the signal in the chip itself before reading it. For guiding purpose, only a few seconds the signal can be integrated in the chip before reading it out.Other advantages of CCDs are accurate geometry of the device, large dynamic ratio and low operating voltages. They are not damaged by the intense light. The P8603 CCD device, marketed by English Electric Valve Co (EEV), has a matrix of 578 x 386 pixels. Each pixel is 22μ wide. A TV camera using this chip gives a signal to noise ratio of about 800: 1 for peak white noise. There is only one read amplifer, all the charges in the matrix have to pass through this read amplifier. The charge is converted to voltage, then in digital form and stored in the computer memory for further processing, or the output signal is converted to a composite video signal to be seen in a video monitor. At a TV camera, it has fixed integration time of 20 m sec per picture frame, the stars which can be seen through the camera is limited to less than 7th magnitude. To see fainter stars, longer integration time in the order of seconds are required. This necessiates cooling the CCD. Otherwise the incoming light has to be amplified. The 46936A type Intensified CCD camera available from M/S EEV has a microchannel plate attached with CCD. The microchannel plate has S-25 photocathode. The output is coupled to the CCD with fiber optic bundle. The 1 inch format of the Intensifier is matched to 2/3 inch of the CCD. The CCD is used in frame transfer mode in which one half of the CCD is covered with opaque material and is used to store the image. Shifting the image from image section to storage section and sending out the stored image outside the CCD occur at the end of the frame period. This avoids any smear in the image. The video output from camera can be displayed in any TV type monitor.

Image Processing System Based on PC

Low cost frame grabber cards for PCs are used to grab the image from the video signal at real time. The DT2851 frame grabber card has two 512 x 512 x 8 bit buffers. In normal operation, one of the buffer is filled with sky background, and the other buffer contains the star + sky information. By subtracting the sky background buffer, we get image frame corrected for sky background. Many such frames are added and the resultant is displayed. This incidentally removes the honey comb structure which is due to the fibre optic coupling between microchannel plate ànd CCD.

For selected image enhancements, the buffer values are transferred to an array processor (DT 7020) card. After the operation it is put back to the frame grabber card for display.

Software

Data Translation Inc.has provided function calls for controlling the buffers, acquisition of image, cursor movements etc. We have used C language to call these functions. The flow of the program is given below.

a. Clear the buffer A and B in frame grabber.
b. Acquire one image in the buffer A, display buffer A.

c. Place the X,Y cursor and manually find out the sky background value.
d. Fill this value in buffer B.
e. Subtract buffer B with buffer A. Resultant is in A.
f. Find out the brightest star position in the buffer. Give the operator for choice of the guide star.
g. If full width at Half Maximum (FWHM) is required to estimate the seeing, call that function.
h. Acquire n frames in A.(n is normally from 5 to 8).
i. Multiply sky buffer by n.
j. Subtract A-B, result is in A.
k. Display the buffer A.
l. Repeat steps h to k till the user wants to quit.

For contrast stretching, array processor was used. It is found that if the operations in array processor take longer time, then we can see a small flicker. With this operation, it is hoped to increase the limiting magnitude to 15.

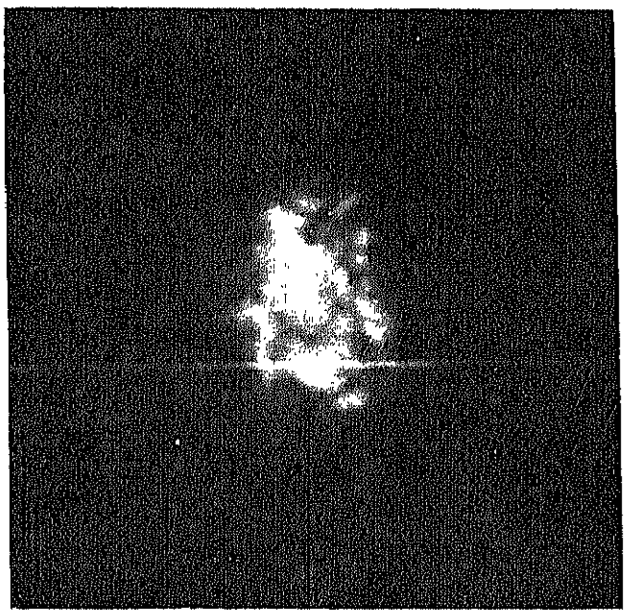

Figure 1. 20 m sec exposure of speckles of η Gem. obtained with f/13 beam of 2.34 meter VBT using ICCD as detector at Kavalur.

The ICCD camera is used for remote guiding both at prime and cassegrain foci of 2.34m VBT. We are able to get guide stars in the range 13 to 14 magnitude on dark nights. As the ICCD camera can be remotely controlled to scan the field, we always found one or two guide stars in the field for guiding. It is hoped that the PC based image enhancements will increase this limit by one or two magnitudes more. Instead of manual guiding, if proper error voltage is generated based on the image movement in CCD and fed back to the motor drive control, we can have automatic guiding. This is being tried out at present.

This concludes the discussion about ICCD for remote guiding. The next part deals with camera for speckle observations and recording at VBT. Cameras most suitable for speckle work is indicated.

Introduction to speckles

The resolution of conventional astro-photography is limited by the size of quasi-coherent areas (r_0) of the atmosphere. Random microfluctuations of the refractive index in the atmosphere due to variations of the temperature cause the fluctuation of phase in the incoming radiation field and thereby, produce two dimensional interferences at the focus of the telescope. These degraded images are the product of dark and bright spots, known as"speckles". The mean size of these speckle patterns is that of the Airy disc of the full aperature telescope and the life time of these patterns in the visible wavelength are 10-30 m sec. The method of speckle interferometry has been successfully applied to decode diffraction limited informations from short exposure astro-photographs, which essentially freezes the motion of the turbulent atmosphere. Recently, we have obtained speckles of various stars at the cassegrain focus ($f/13$) of the 2.34 meter Vainu Bappu Telescope at Vainu Bappu Observatory, Kavalur. In the following, salient features of the technique will be discussed.

Observations

To sample the size of the speckle on the intensified CCD, a Barlow lens was used (Saha et al. 1990) to slow down the focal ratio of the instrument to $\sim f/90$. A filter in the $H\alpha$ region $\Delta\lambda \sim 50\ A^0$, was utilised to enhance the contrast of the interference pattern. Since the atmospheric dispersion is much smaller than the Airy disc of the telescope in and around 30 degrees of zenith, our observations were confined within the said zenith distance. Several frames containing speckles of a few close binaries and of a few other point sources for the reference were recorded. Fig.1 shows the speckles of η Gem.taken with the $f/13$ beam of 2.34 meter VBT at VBO, Kavalur.

Discussion

The degradation of the image quality are primarily attributed to imperfections in the medium, as well as to aberrations of the instrument, which, in turn, can prevent the attainment of the diffraction limit of the telescope. The coherence time τ_0 of the atmosphere is a highly variable parameter. Depending on the velocity of the high altitude wind, it varies from $<< 1$ m sec to $\simeq 0.1$ sec. The exposure time is to be selected accordingly (usually, it is of the order of $\simeq 1$ to $3\ \tau_0$ for the two-dimensional detector while it is essential to be $<< \tau_0$ for scanning system) to maximise the S/N, as well as to freeze the speckle pattern. Advancements in detector technology enable one to detect photon events either in the mode of frame with a frame frequency of 50 Hz, or to detect each photon event at a rate upto $\simeq 1$ MHz.

Detectors with frame integration are subject to have limitation in detecting photon events and consequently, loose high frequency informations. If a pair of photons is not well separated, a hole, known as centreur hole appears in the centre of the autocorrelation (Foy 1988). Speckles are required to be oversampled to the image size of $f/400 - f/500$ on the detector. The photon counting camera (Blazit,1986) CP40, offers a very large number of pixels (3072 x 2304) and makes use of photon-centroiding to compute the photocenter of each event with an accuracy of 1/4 CCD pixels. While, on the other hand, the marked advantage of detectors vis., Precision Analogue Photon Address (Papaliolios, Nisenson,& Ebsstein 1985) (PAPA) or Renicon (Durand, Hardy & Couture,1987) (Resistive-anode) is that of enabling to record the photon arrival time, thereby, allows one to tune the value of τ_0 during the data treatment. However, the ICCD used in our observation would be utilised as a guiding tool for the object in our new camera and, therefore, the presence of observer can be avoided.

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