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CCD imaging camera and CCD based guiding system at the 1 meter UPSO telescope

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Abstract. Two CCD imaging camera systems acquired from Photometrics USA have been installed at the Cassegrain focus of 1 meter UPSO telescope. A 384 × 576 pixels Thomson CCD based camera system has been working since November 1989 and 1024 × 1024 pixels Tektronic CCD chip based camera system has been installed in February 1993. The details of their configuration for image acquisition, display and processing are described. The facilities of image processing available at UPSO are also described. A CCD based star tracker/imaging camera has also been acquired and installed in the eyepiece hole of 20 cm guiding telescope, which is an auxiliary telescope of 1 meter reflector.The working of this instrument as star tracker is described.

Key words : CCD imaging—guiding—image processing

1. Introduction

The principle of CCD was invented in 1969 and the first Astronomical application of a CCD system was done in 1976. Since then CCDs have become one of the most popular detectors in Astronomy. CCD detector combines, the advantage of photographic plate and photomultiplier tube, namely : two dimensional detection in an integrating mode, good linear response, high quantum efficiency and large dynamic range. Because of its bi-dimensional property a number of stars can be observed simultaneously, which results in saving a lot of telescope time, which has become a rare commodity these days.

A CCD is an optical detector. When photons fall on the CCD, electrons are generated, all these electrons are suitably collected. The charge collected is linearly proportional to the amount of incident photons. The resulting electronic charge is collected into a two dimensional imaging area called the parallel register. To transfer the charge from individual pixels to the output register a clocking sequence is used which is as follows :

(1) A vertical shift of entire image by one pixel. This delivers a row of charge to the output register.

(2) A horizontal shift through all the pixels in the output register. This delivers each charge in that row to the output amplifier, one pixel at a time.

This process is repeated until all the rows in the CCD have been delivered to the output amplifier.

2. CCD imaging cameras

We have acquired and installed two CCD imaging cameras. The Photometrics 3000 CCD imaging system has been operational since November 1989. The complete system was acquired from Photometrics Ltd., Tucson, Arizona, U.S.A. The system consists of a camera head, camera electronics unit and computer system.

(i) *Camera head* : The camera head is composed of a sealed CCD enclosure, a CCD detector, a shutter assembly and the electronics directly associated with CCD operation. The CCD detector is a Thomson chip having 384 × 576 pixels and metachrome coating for UV sensitivity and is operated at –120 C. At the *f*/13 Cassegrain focus of the 1 meter reflector, each CCD pixel having 23 × 23 micron size, corresponds to 0.36 arcsec of the sky, thus providing a total field of 140 × 210 square arcsec.

(ii) *Camera electronic unit* : The unit provides power for camera electronics and cooling control system and provides the required CCD clocking signals. It also contains signal processing circuitry to amplify the image signals from the CCD and provides noise filtering. The A/D converter changes the processed analogue signals to digital format. The digital transmitter sends the converted image data to the computer, which is kept in the observing room. The shutter control circuitry which responds to commands from computer is also located in the camera electronic unit.

(iii) *Computer system* : The Photometrics 3000 computer system is based around a 68020 microprocessor, and a camera controller provides all commands. The system consists of;

- a RS 170 Compatible Video Display.
- a floppy disk drive and a Winchester hard disk of 55 MB capacity.
- a graphic terminal.
- 1/4 inch cartridge tape drive.
- 1/2 inch streamer tape drive.
- FORTH and UNIX operating systems.
- necessary software for operating the CCD and processing the image.

The new CCD imaging camera system configuration also consists of a camera head, camera electronics unit and a computer. The block diagram of the system is shown in figure 1.

The camera head encloses a 1024 × 1024 pixel Tektronix chip in a cryocooled Dewar. The CCD chip is having metachrome II coating for UV sensitivity and is operated at –110 C. Quantum efficiency curve of the detector is show in figure 2. At the *f*/13 Cassegrain focus of 1 meter telescope, it covers a field of 6 × 6 arcmin. The Dewar is equipped with an electromechanical shutter having 7ms open time and 10ms close time. Cryogen hold time is about 10 hours if filled with 0.5 litre of liquid nitrogen. The Dewar can be used in vertical as well as horizontal orientation. The camera electronics unit is similar to the previous system.

Host computer for this system consists of a PCL PC/AT 80386 having main memory 640 Kb, 8 Mb extended memory, 200 Mb hard disk, 5.25 inch and 3.25 inch floppy disk drives, 40 Mb cartridge tape drive, super VGA display and Epson 1050 dot matrix printer. The operating system is MS dos version 5.0. Microsoft window version 3.1 and microsoft mouse are also there. For acquiring and processing CCD images, PMIS and IMAGE 200 softwares from Photometrics have been installed.

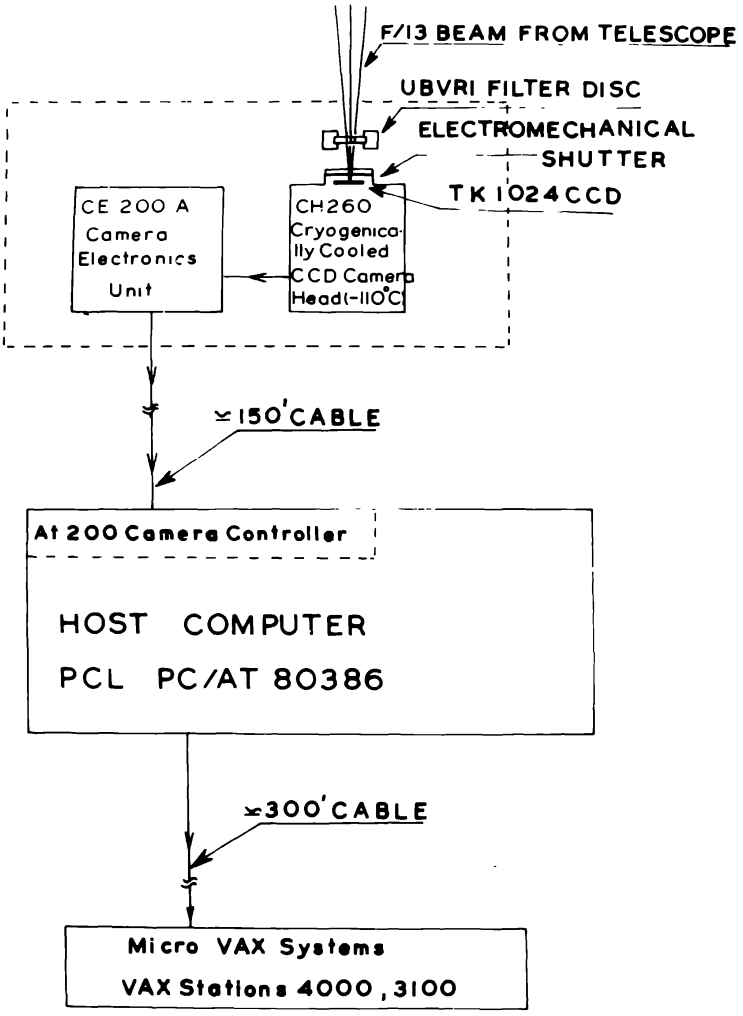

Figure 1. New CCD imaging camera system at 1 meter UPSO telescope.

3. Image processing facilities

CCD data as received from the imaging camera system is raw data, which has to be processed to extract useful information. The output of a CCD is a matrix of numbers which are related to the incident flux. Image processing can be considered as data reduction and involves mathematical manipulations of the two dimensional array of numbers. During the past decade image processing softwares have become available i.e., STARLINK, IHAP, MIDAS, IRAF, VISTA, FIGARO etc.

MIDAS image processing system is being widely used by the astronomical community. We at UPSO have also installed MIDAS package along with DAOPHOT to carryout stellar photometry. MIDAS was earlier running on VAX machines but now new version runs on UNIX also. The facilities for image processing at UPSO are :

- Microvax II with
- 16 MB memory.
- 2 × 159 MB disks.

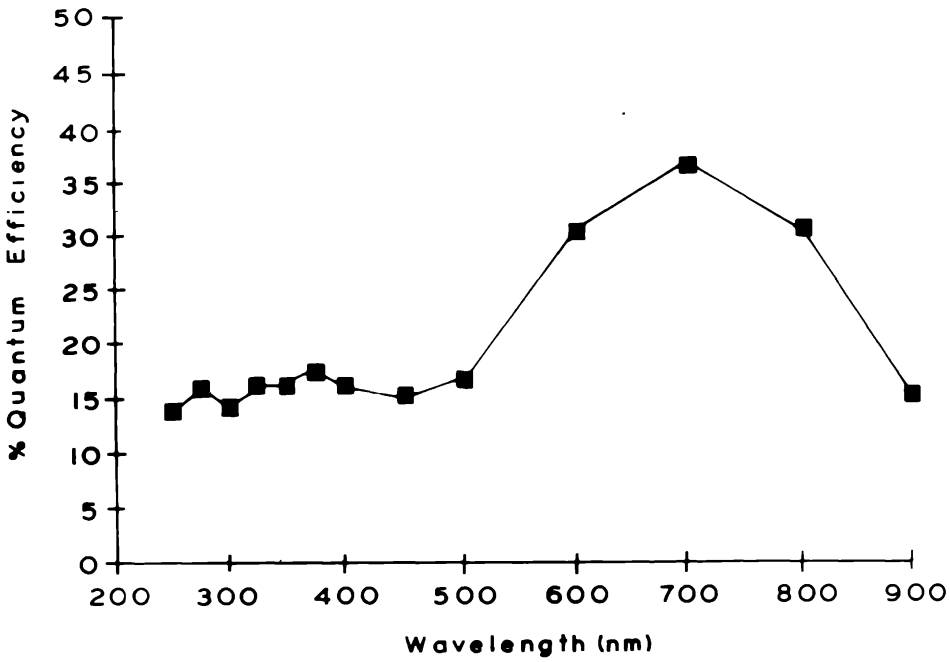

Figure 2. Quantum efficiency curve.

- 622 MB disk.
- TK 50 cartridge tape drive.
- Streamer magnetic tape drive.
- 4 VT320 terminals.
- 4 VT340 terminals.
- 1 Tektronix 4209 colour graphic terminals.
- dot matrix printer.
- 400 LPM Line printer
- laser printer.
- colour inkjet printer.
- 16 user VMS lincence.
- FORTRAN compiler.
- Vax station 3100, 8 MB, having TK 50 cartridge tape drive.
- Vax station 4000, 16 MB, having TK 50 cartridge tape drive.
- Sun sparc station.

4. CCD photometry

The main research programs taken up using CCD and the available image processing facilities are UBVRI, CCD photometry of galactic open clusters, surface photometry of galaxies, stellar populations and galactic evolution studies using photometric and astrometric survey (A Franco-Indian cooperation project). Photometric performance of the previous CCD system has been evaluated (Mohan *et al.* 1991) and the photometric performance of new CCD system is currently being evaluated.

5. CCD based guiding system

A CCD based guiding system at the eye end of the 20 cm guiding refractor, which is an auxiliary telescope of 1 meter telescope, is installed. The instrument was acquired from Santa Barabara Instrument group USA. The eyepiece of the guiding telescope is taken out and the CCD head of the tracker is installed in place of the eyepiece.

The tracker can be used as an automatic star tracker to take long guided exposures or in conjunction with a PC as an imaging camera also. It consists of a 192 × 165 pixels CCD head and microcontroller. The microcontroller activates four relays to operate $\pm\alpha$ and $\pm\delta$ pushbutton motions of the telescope for a calculated interval of time depending upon the correction required. We are using the wiring provided in the telescope for the guiding speed of 1′/min to connect the relays.

The main steps involved in using star tracker are, adjustment of various parameters, taking dark frame, finding and focusing the guide star, calibrating drive and tracking.

Pressing the calibrate drive button causes the star tracker to activate the $\pm\alpha$ and $\pm\delta$ relays one by one for a preset time and measures the telescope speed in terms of pixels per second. Knowing that, it can then determine the amount of time to activate a relay (engaging the drive) to correct for an error in terms of number of pixels. This mode determines CCD orientation also.

In the tracking mode when track button is first pressed it takes an initial image and find and records the X and Y position of the brightest object in the field of view. It uses that initial position as the zero error position and then cycles repeatedly, taking images, measuring the brightest objects position, calculating a tracking error which is the star's current position minus the zero error position, and making corrections to drive the star back to zero error position. It also checks to make sure the star's brightness has not fallen to one half its initial value. If it has, it activates an alarm.

Reference

Mohan V., Paliwal D. C., Mahra H. S., 1991, Bull. Astr. Soc India 19, 235.