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Research Facilities for Solar Astronomy at ARIES

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Abstract. The solar observational facilities at ARIES (erstwhile U.P. State Observatory, UPSO), Nainital, began in the sixties with the acquisition of two moderate sized (25 cm, f/66 off-axis Skew Cassegrain and 15 cm, f/15 refractor) telescopes. Both these systems receive sunlight through a 45 cm and 25 cm coelostat respectively. The backend instruments to these systems comprised of a single pass grating spectrograph for spectroscopic study of the Sun and a Bernhard–Halle $H\alpha$ filter, coupled with a Robot recorder camera for solar patrolling in $H\alpha$ respectively. With the advancement in solar observing techniques with high temporal and spatial resolution in $H\alpha$ and other wavelengths, it became inevitable to acquire sophisticated instrumentation for data acquisition. In view of that, the above facilities were upgraded, owing to which the conventional photographic techniques were replaced by the CCD camera systems attached with two 15 cm, f/15 Coude refractor telescopes. These CCD systems include the Peltier cooled CCD camera and photometrics PXL high speed modular CCD camera which provide high temporal and spatial resolution of $\sim$ 25 ms and $\sim$ 1.3 arcsec respectively.

Key words. Sun: telescope—coelostat—solar activity–CCD—V++.

1. Introduction

Over the years the principal research interests in solar astronomy at the observatory have been focused primarily on studies related to molecules in photosphere, sunspots and faculae on the Sun and solar activities. These studies were mainly related to solar spectroscopy using single pass grating spectrograph and observations of solar activities in $H\alpha$ through a Bernhard–Halle $H\alpha$ filter. Various interesting results were obtained by using these facilities, few of them were reported by Sinha *et al.* (1979); Pande *et al.* (1980); Bondal *et al.* (1982); Pant (1984).

With passing time it was realized that the $H\alpha$ observations and associated X-ray and radio emission measurements, with high temporal and spatial resolution, were crucial for evaluating the energy release processes in the solar flares (Kiplinger *et al.* 1988). In order to achieve these objectives the CCD technology was introduced for the solar observations, with a time resolution of $\sim$ 25 ms to 2 s and spatial resolution $\sim$ 1.3 to 2 arcsec (Verma *et al.* 1996). Multi-wavelength studies of solar flares and associated radio bursts, CMEs, coronal holes, etc. in recent years have yielded some interesting results about the solar activities (Anita Joshi *et al.* 2003; Uddin *et al.* 2004; Bhuwan Joshi *et al.* 2005). In the present paper we give a brief account of the telescopes, the backend instruments and methodology of data analysis in view of the solar observing facilities at ARIES, Nainital.

2. Chronology of solar observing facilities and methodology

The solar observational facilities at ARIES (erstwhile U.P. State Observatory, UPSO), Nainital were established in 1966 (Pande 1969). Then a 25-cm f/66 off-axis Skew Cassegrain telescope was acquired from Cox Hargreaves UK, attached with an observatory-made single pass grating horizontal solar spectrograph. The telescope forms an 18-cm solar image on the slit of the spectrograph. Except the grating, almost the whole of the spectrograph and the 46-cm coelostat (Fig. 1), were fabricated at optics and mechanical workshops of the observatory. The spectrograph was capable of providing a dispersion of 1.2 Å/mm in the first order at 2.5 micron. In addition to that, another system was acquired, consisting of a 25-cm coelostat and a 15-cm f/15 objective lens, forming an image of $\sim$ 22 mm at the focal plane. The backend instrument for this telescope was a Bernhard–Halle $H\alpha$ filter (0.5/0.7 Å pass band) coupled with a Robot Recorder 35-mm movie camera attached with a sequential timer, capable of providing a time resolution of ~ 0.15 second. The filter can be tuned to $+/-$ 1.0 Å of central wavelength in steps of 0.1 Å.

These units were operational till 1988, when two Coude refractors (15 cm, f/15), from Carl Zeiss, Jena were acquired in 1988 and 1992. In the mean time a few narrow pass band DayStar filters, central wavelength at $H\alpha$ (6562.8 Å pass band 0.5 Å), Ca II K (3933.7 Å pass band 1.2 Å) and CN (3883 Å pass band 1.0 Å), were also acquired. The Coude refractor forms about 21 mm diameter image of the Sun, which is enlarged to 42 mm using a Barlow lens when the Bernhard–Halle $H\alpha$ filter is used. One of these telescopes has been put atop a 30-feet tower (Fig. 2). The filtergrams can be obtained on the Kodak Tech pan 2415 film with the help of 35 mm DN22 Robot camera, capable of recording 4 frames/second. With the prevalent solar observing techniques,

Figure 1. The 45-cm coelostat for the 25-cm, f/66 off-axis Skew Cassegrain telescope at ARIES.

Figure 2. The 15-cm Coude refractor telescope (inset box) put atop a 30 feet tower (left), to the right is the Coude refractor telescope for observations of solar activities.

with high temporal and spatial resolution, the aforesaid facilities were drastically improved in 1993 by adopting the video and CCD technologies in the solar observing facilities. The CCD technology was introduced for achieving the following scientific objectives:

- To record the solar activities (solar flares and prominences) with high temporal and spatial resolutions of ~ 25 ms and ~ 1.3 arcsec respectively.
- To compare the $H\alpha$ emitting regions during solar activities with those of the simultaneously observed microwaves and HXR solar emission data at high temporal and spatial resolution for understanding the flare triggering mechanism.

The entire upgraded system consists of a CCD chip, its camera controllers, a Sun Spark station-20 computer, a GPS clock for accurate timing, etc. The various CCD camera systems for solar observations have been described as under:

2.1 *Peltier cooled CCD camera system*

This CCD imaging system has EEV 385×578 pixel CCD chip (type P86231) with a pixel size of 22×22 microns. Both full frame (8.47×12.7 mm $\sim 6.3 \times 9.5$ arcmin on the Sun with Bernhald–Halle $H\alpha$ filter) readout and frame transfer modes are possible. The CCD is controlled through a PC and the data acquisition is done using ATI software.

2.2 *Photometrics PXL high speed modular CCD camera system*

This system has two camera heads attached with entirely two different cooling systems. One of them can be used at a given time for observing the Sun.

2.2.1 *Fibre bound CCD camera system*

This system has thermoelectrically cooled FTS cold probe camera head (ambient temperature -42°C) and TK 1024, Class I, CCD chip (pixel size 24×24 microns). Each pixel of the chip is connected to a window by fibre optics in such a way that one pixel receives light from a 2.45 times larger area at the window. Thus the camera head window acts as 58.8-micron sized pixel with a spatial resolution of approximately 5 arcsec. The camera controller with a 12-bit digitizer has variable readout rates from 0.5 to 1 mega pixel per second. The system is controlled by a Sun Spark 20, 50 MHz computer having 7.3 GB disk capacity and 14 GB cartridge tape drive (Verma *et al.* 1996). A GPS clock connected to the computer records time with an accuracy of 1 ms in the header of solar image, using a Sun interface software available with the above system. An electro-mechanical shutter, through an interface card fabricated at the observatory is used for computer-controlled exposures at the chosen instants and at the desired time intervals.

2.2.2 *High speed CCD camera system for flare observations*

The camera head of this system has EEV37 CCD chip (512×512 pixels, pixel size 15×15 microns) with a facility of frame transfer mask. The same camera controller, Sun computer software, etc. are used to obtain Hα images of the solar flares. Liquid circulation unit is used for cooling the camera head up to $-25°$C. The solar images having 100×100 pixels area, can be obtained with a time resolution of about 25 milliseconds or at the rate of 40 frames per second. Full frame images can be obtained at the rate of 5 frames per second (Gaur *et al.* 1998). The system is capable of providing a spatial resolution of ~ 1.3 arcsec which is extremely good for the solar flare observations. The data recorded by these CCDs are analyzed using IRAF and IDL software. We also have a COHO camera, connected to GPS clock for accurate time display, which is used for video recording of the full disk $H\alpha$ and white light images of the Sun. More than 20 research papers have been published based on the observations taken with these facilities.

Due to some problem in the SCSI controller of the photometrics PXL CCD camera system, the repairing and upgradation work of existing hardware and data acquisition software of photometrics PXL camera systems have recently been carried out at ARIES. The SCSI controller was replaced by adding AIA and PCI interface cards in the camera controller and PC respectively, facilitating the direct communication of the controller with the computer. This interface is also compatible with any of the windows operating systems. This modified system consists of P4, 3.2 GHz system with windows XP and having 1 GB RAM and 160 GB HDD. The program module has been made in Visual Pascal and Microsoft Visual C++ and this module is run in V++ software (by Digital Optics). The images are stored in FIT format. Therefore images can either be analyzed using V++ itself or any other software.

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