Some new initiatives in optical astronomy at UPSO, Nainital

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The Uttar Pradesh State Observatory was established in 1954. Research and developmental activities at the Observatory have increasingly covered selected areas of astronomy and astrophysics. The Observatory is well known for its precise observations in the studies related to comets, ring formation in the planets, variabilities in stars, star clusters, stellar populations and photometry of galaxies. It has photographed about forty six thousand transits of artificial earth satellites during 1958 to 1975 and was one of the 12 centres identified by the Smithsonian Astrophysical Observatory, USA, all over the globe but the only centre in India for this purpose. Optical follow-up observations of radio and space-borne astronomical sources as well as gravitational microlensing and milli-magnitude variations in the rapidly oscillating peculiar A type stars have been started recently. The Observatory is thus one of the important research centres in India from where astronomers are making useful research contributions about the Universe and also opening up a number of new possibilities for study of exciting new astrophysics.

IN India, we have had a hoary tradition in astronomy. During the Vedic times, and again through the fifth to the twelfth century of the Christian era, astronomy attained respectable heights in the country. The works of Aryabhata I (*circa* 476 A.D.) and Bhaskara II (*circa* 1114 A.D.) are noteworthy in this context. A big effort towards a resurrection of that tradition was made in the early eighteenth century by Raja Sawai Jai Singh who set up a number of Jantar Mantars at Jaipur, Delhi and other places. The modern era of Indian astronomy started with the establishment of an astronomical observatory at Madras in 1786 which, a century later, in 1899, got shifted to Kodaikanal. In April 1971, the Kodaikanal Observatory was made an autonomous institution as the Indian Institute of Astrophysics which shifted to Bangalore in 1976. Another observatory was established in 1908 at Hyderabad. The Uttar Pradesh State Observatory (UPSO) was the third modern observatory to be established in India, in 1954.

It is largely through the initiatives of late Sampurnanand, the then minister of Education that the UPSO came into being at Varanasi in April 1954. The UPSO was started in the premises of the Government Sanskrit College (presently the Sampurnanand Sanskrit Vishwavidyalaya). The UPSO was moved over from dust and haze of the plains to the more transparent skies of the hills to Nainital in 1955 and to its present location at Manora Peak (longitude 79°27′E; latitude 29°22′N; altitude 1951 m), just south of Nainital in 1961. Figure 1 shows a view of the UPSO. The primary objective of the UPSO has been to develop a facility for modern astrophysical research and to carry out research in selected areas of astronomy and astrophysics.

The UPSO is under the administrative control of the Department of Science & Technology of the Uttar Pradesh Government. It has the distinction of being the only modern astronomical research institution run by a state government. A brief description of the available observational and ancillary facilities is given in the next two sections. Next we deal with the ongoing research programmes at UPSO. New initiatives in optical astronomy taken at the UPSO in the light of modern technological developments are then described.

Observational facilities at the UPSO

The principal equipments at an observatory are its telescopes. The UPSO which was started with a 25 cm f/15 (Cooke, UK) refractor, today has four telescopes of 104-cm, 56-cm, 52-cm and 38-cm apertures, for cometary, planetary, galactic and extra-galactic research and a few telescopes for solar research. The 25 cm telescope was very useful in the initial photographic and photoelectric programmes. Presently, the 15 cm, f/15 reflector (Ziess, Jena), acquired in 1960 and the 25-cm telescope is being used for acquainting the ever-curious visitors to the Observatory with heavenly bodies. A brief description of the other UPSO observing facilities is given below:

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Stellar telescopes and observing facilities

The 38-cm, f/15 reflector (Fecker, USA) telescope installed in 1961 at Manora Peak has German mounting. At its Cassegrain focus, the plate scale is 36 arcsec/mm. Till 1997, it was continously used for photoelectric and spectrophotoelectric observations. In early 1998, it was shifted to Devasthal for carrying out measurements of atmospheric turbulence (called seeing by astronomers) using modern technique of differential image motion monitor[1].

The 52-cm reflector telescope (Cox, Hargreaves and Thomson Ltd, UK) installed in 1961 at Manora Peak has an equatorial fork mounting. The telescope has f/13 folded Cassegrain (plate scale 31 arcsec/mm) and f/70 Coudé foci. Till 1995, it was used for stellar photoelectric and spectrophotoelectric observations. In December 1996, it was shifted to Devasthal for carrying out seeing[1] and atmospheric extinction measurements[2].

The optics and tube of the 56-cm reflector telescope were imported from Cox Hargreaves, UK. The mounting and the drive assembly for this telescope were made by UPSO. This is an f/15 folded Cassegrain on a fork mounting. The telescope was being used for photoelectric and spectrophotoelectric observations since 1968. The main mirror of the telescope was replaced by a new 56-cm Zerodur concave parabolic mirror by the UPSO optics shop a few years ago.

The 104-cm Sampurnanand reflector telescope was supplied and installed by Veb Carl Zeiss, Jena in 1972. It is a two-pier equatorial English mounting telescope and has f/13 Cassegrain and f/31 Coudé focii with plate scales 15.5 and 6.5 arcsec/mm respectively. Other details of the telescope are given elsewhere[3]. Till the late eighties, Cassegrain plate holder, Meinel camera, photoelectric photometer, near-infrared photometer and a laboratory spectrum scanner were the main instruments that were used with the telescope to carry out observations. A quantum jump, about 200-fold increase in the observing capability of the telescope was achieved with the acquisition of a CCD system of size 384×576 pixel^2 in 1989. In order to increase the throughput of the telescope, large size CCD chips 1024×1024 and 2048×2048 pixel^2 were acquired in 1993 and 1998 respectively. For guiding the telescope during long (≥ 20 min) exposures with the CCD systems, a compact ST4 CCD system was also acquired in 1991. For spectrophotometric observations, an optical multi-channel analyser with 1024 pixel reticon array as detector was acquired in 1991. The system is capable of medium resolution spectrophotometric work and is being used for studying energy distribution of stars and comets. In order to improve tracking of the telescope, a solid state drive system along with digital coordinate display system were acquired from Indian Institute of Astrophysics, Bangalore in 1995. Figure 2 shows a view of the telescope inside the dome.

Solar observing facilities

In 1966, steps were taken to establish solar observational facilities at the UPSO. Accordingly, a 25-cm f/66 off-axis Skew Cassegrain telescope acquired from Cox Hargreaves, UK along with a UPSO made single pass grating spectrograph became the basic observational facility by the early seventies. Excepting the gratings, almost the whole of the spectrograph and the 46-cm coelostat were made at UPSO optics and machine shops. The spectrograph is capable of providing a dispersion of 1.2 Å/mm in the first order and was used for observations till 1986.

A Bernhard–Halle 0.5 Å passband H_α filter coupled with a Robot Recorder 35-mm movie camera and its associated sequential timer with a time resolution of

Figure 1. A view of the Uttar Pradesh State Observatory, Manora Peak, Nainital.

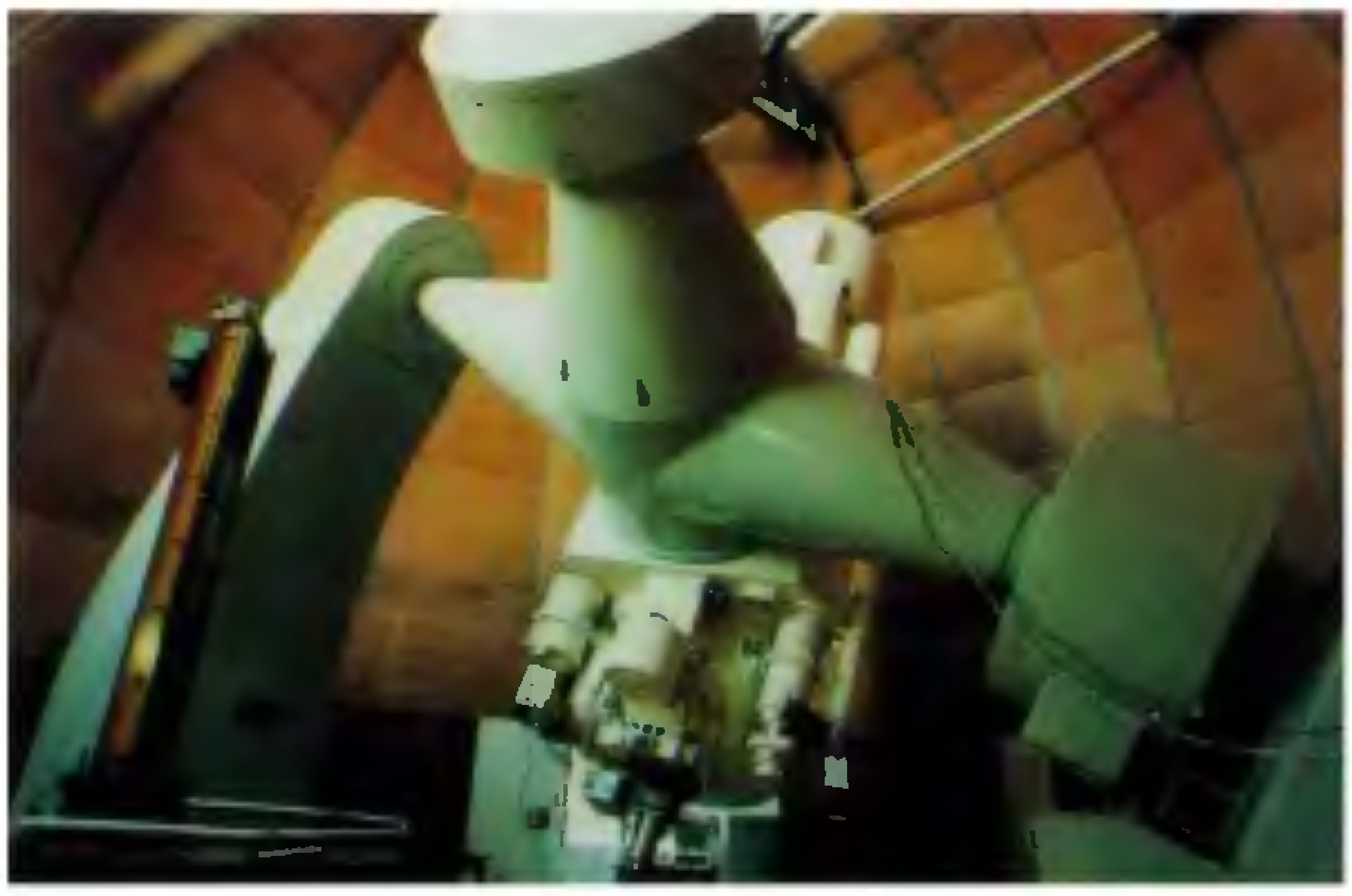

Figure 2. A view of the 104-cm Sampurnanand telescope of UP State Observatory, Nainital. CCD imaging unit is mounted at the Cassegrain focus of the telescope.

0.15 sec is used for an H_α patrol of the sun with either a 16-cm or a 24-cm solar image. The instrument became operational in 1975.

In addition, the UPSO has two telescopes of 15-cm aperture equipped with H_α, Ca II K and CN filters and CCD cameras for carrying out observations of solar activity phenomena namely sunspots, faculae, plages, flares, prominences, etc. with a time resolution of 25 ms. A detailed description of the solar observational facilities at the UPSO has been given elsewhere[4].

Satellite tracking facility

Since the International Geophysical year (1957–58), the UPSO was the only centre in India for optical tracking of man-made earth satellites for about two decades using a 79/51-cm Baker–Nunn Satellite Camera along with a precision timing. The camera is a f/1 Schmidt type telescope coupled with a dual channel timing system built by the Electronic Engineering Company of California, USA. This programme was in collaboration with the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, USA. The first photograph of an artificial satellite was taken from the UPSO on 29 August 1958. Till 1976, a total of 45,714 satellite transits including that of the Indian Satellite Aryabhata were successfully photographed with this facility.

As a result of optical tracking of artificial earth satellites, the position of the centre of the location of the Baker–Nunn camera at the UPSO is determined with a precision of ± 10 m and can, therefore, be used as reference point for geological survey work. Due to the advent of modern techniques in this area, the camera is not used anymore for optical tracking of the satellites. However, it has occasionally been used for wide field photography of comets, etc.

Workshops and other facilities at the UPSO

In order to meet the requirements for maintenance, design and fabrication of astronomical instrumentation as well as for research, the UPSO has an electronics workshop, a machine workshop, fine technics laboratory which includes aluminizing unit and optics workshop, a fairly well-equipped library, a computer section and a small photographic section.

Aluminizing unit

Since mirrors used in the telescope lose their reflectivity due to weathering etc., their realuminization is a must. Keeping this in view, an UPSO-made aluminizing plant, capable of taking jobs up to 60 cm diameter was the first unit to become operational in 1972 and was in regular use till the mid-eighties when another indigenous 124-cm diameter aluminizing unit became operational[5]. This unit was designed to realuminize the primary mirror of the 104-cm Sampurnanand telescope which was successfully done in 1997. Another small 30-cm diameter unit has also been designed and fabricated at the UPSO itself. Both units are regularly used for aluminizing mirrors under a vacuum of ~ 15 μtorr. The smaller unit is also used for evacuating the CCD and near-IR detectors.

Computer centre

The UPSO has a modern computer centre. In 1979, the UPSO acquired an ECIL Micro-78 microcomputer system. The centre was upgraded with acquisition of a multi-user Micro-Vax II system in 1989. In order to meet the fast growing needs of the UPSO, a VAX 3100, a SUN Sparc I, a VAX 4000 and a DEC Alpha workstation were acquired in the early nineties. Five UNIX-based Alpha workstations and 10 PCs were procured in 1998. Image processing software packages MIDAS, IRAF, STSDAS, IDL, SM and other general utility packages have been installed on these computer systems. All these systems have been networked together. For fast communication, a VSAT facility has been installed which has linked the UPSO with the rest of the world through web, internet and e-mail services.

Electronics workshop

The Electronics workshop supplemented by an electrical wing looks after the routine maintenance, testing, modifications, design and fabrication of electronics/electrical equipments. The major instruments developed at the UPSO include frequency drives for telescopes, photometric data acquisition systems, a thermal monitor to record microthermal fluctuations with an accuracy of ± 0.01°C, a remotely controlled filter disc rotator device for the 104-cm telescope[6] and a control consol system for the 124-cm aluminizing unit.

Machine workshop

The fabrication, maintenance and modifications of various equipments, telescope houses and other miscellaneous jobs are carried out by the machine workshop. Its major achievements have been the mounting of the 56-cm telescope along with its drive assembly, and fabrication of the mechanical components of the horizontal solar telescope and its associated double pass spectrograph, a Cassegrain spectrograph, a number of photometers, three optical grinding and polishing machines, a glass slitting machine, 30-cm and 60-cm vacuum aluminizing units and many components of the 124-cm aluminizing unit and a 16-cm solar coelostat.

Optics workshop

The optics workshop has an automatic grinding and polishing machine capable of taking jobs up to 75 cm diameter, two rotating spindles for manual work on jobs up to 25 cm diameter, a drilling assembly for scooping holes, a glass slitting machine and a grinding machine capable of taking jobs up to 20 cm. The major components made by this unit include a 56-cm Zerodur concave parabolic primary mirror of the 56-cm telescope, a few medium sized (up to 46 cm diameter) $\lambda/10$ plane surfaces, plane parallel (within 3″) plates up to 8-cm diameter, $\lambda/10$ concave spherical surfaces up to 25-cm diameter and a number of small optical slits, telescopes, prisms, achromates and Fabry lenses.

Growth of research activities at the UPSO

Over the years the principal research interests at the UPSO have been mainly in the fields of photometric studies of galaxies, stellar populations, stellar variability, stellar energy distribution, star clusters, planetary physics, solar activity and studies related to molecular lines in the Sun. In India, the first optical observations of an afterglow of a γ-ray burst, the first photoelectric observations of stars, cometary light and occultation of a star by a minor planet as well as the first near-infrared JHK photometric and Fabry–Pero spectroscopic observations have been made at the UPSO. Some of the research achievements are described briefly.

Solar physics

The solar studies have basically been theoretical but after the commissioning of 35-cm DN 22 Robot recording camera and CCD imaging systems, observational studies of the solar activity namely sunspots, faculae, plages, flares and prominences are also being carried out.

Molecules in the Sun: Theoretical studies of diatomic and triatomic molecular lines have not only refined the existing sunspot and facular models of the Sun but also predicted many new molecular species in the Sun's photosphere, sunspots and faculae[7]. Some of them have been identified spectroscopically later on. Studies carried out at the UPSO establish that simultaneous observations of molecular lines in the photosphere and sunspots could model the sunspot as a function of size, magnetic field and solar activity.

Solar activity: It is now well recognized that most or all aspects of solar activity namely sunspots, plages, faculae, surges, solar flares, prominences and coronal mass ejections including acceleration of non-thermal particles, high speed wind stream and other mass ejection, radio, hard X-ray and γ-ray emissions are intimately related to convection and magnetic fields. But their origin is still poorly understood. In order to investigate them, the observations have been carried out in H_α and other narrow-band filters using photographic, video and CCD imaging techniques with a time resolution up to 25 ms and spatial resolutions 2–4 arcsec. Time evolution of the morphological changes taking place in the solar active features has been used to understand their origin. Study of flares at different wavelengths, coronal mass ejections, radio burts, coronal holes, etc. during the last few solar cycles have yielded some interesting results about the solar active phenomena[8,9]. It has been found that there are about 5 zones in each hemisphere which are most prolific in producing solar activity. A useful relation between onset times of solar flares at different wavelengths has been observed. Periodicity and asymmetry have also been observed in some of the solar active phenomena[10].

Total solar eclipse: While still at Varanasi, the UPSO participated for the first time in the total solar eclipse expedition of 20 June 1955 in Sri Lanka to carry out the photographic polarimetric observations of solar corona. Though the expedition was unsuccessful because of cloudy weather prevailing during totality at Hingurakgoda, Sri Lanka, useful experience was gained. The total solar eclipse observations of 16 February 1980 and of 24 October 1995 were carried out successfully from Mahboobnagar in Andhra Pradesh and Mejakhas, in Uttar Pradesh respectively. Observations of flash spectrum sequence just before and after totality and polarimetry of corona were carried out in 1980 while the narrow band line (Fe X, 6374 Å) CCD imaging of the solar corona was done in 1995. Useful information about the solar corona was obtained from these observations[11].

Solar system studies

Comets: The nucleus of a comet head is made up of a conglomerate of silicate dust, water ice and frozen volatiles that are mostly made up of organic compounds. As the comet approaches the Sun, due to solar radiation pressure, a tail is formed. Spectrophotometric observations of about 12 comets were carried out from the UPSO at a large range of heliocentric distances using either spectrum scanner or optical multichannel analyser[12]. These observations were used to study variation of production rates of observed species with heliocentric distance. Emission bands of NH, CN, CH, C_2, C_3 and NaI were studied in these comets, if they were detected. It was found that gas production rate did not vary with heliocentric distance while C_2 and CN production rates showed variation.

Occultations of stars by planets: Photoelectric observations of the occultations of stars by Uranus[13,14], the ring system of Saturn[15,16], Neptune[17,18] and several minor planets were observed from the UPSO. These observations played a key role in the discovery of the rings of Uranus, two additional rings around Saturn and indication of rings around Neptune.

Stellar and galactic studies

Be stars: The Be stars are non-supergiant B stars with emission episodes signifying mass loss. The Be star has a fast rotating central star surrounded by a circumstellar envelope which exhibits more or less irregular variations with time. A wide range of phenomena, therefore, take place in Be stars such as photometric variations, variation in the strength of line and continuum, mass loss due to radiatively driven stellar wind and change in Balmer jump. About 50 Be stars have been observed spectrophotometrically in order to study their continuum energy distribution, variable nature and evolutionary status[12]. On the basis of measured H_α emission equivalent widths, an estimate of the dimension of the extended envelope of a few stars has been made.

Intrinsic variables: About 15 classical cepheids have been observed spectrophotometrically[12]. A temperature scale for cepheids was obtained. The pulsation masses and the evolutionary masses of the cepheids were discussed. Further, UBV photometric light curves of several Cataclysmic variables[19], RR Lyrae and δ Scuti stars have been obtained. These have been used to determine their new period and to study multiple periodicities, peculiarities in the light curves and cause of pulsation in these stars. The effects of metallicity have also been studied in the period–luminosity–colour relation of RR Lyrae and δ Scuti stars.

Eclipsing binaries: The stars forming a binary pair eclipse each other during their orbital cycle if their plane of orbit lies in the line of sight. Such binary stars are known as eclipsing binaries and provide an opportunity for a complete determination of fundamental parameters such as mass, radius and temperature of the component stars. About 15 eclipsing binary stars have been observed in standard UBV system[20]. New periods and photometric elements of many of them have been determined. In some cases, mass transfer rates have also been estimated. The Roche-lobe of the secondary component in Algol-type binaries is found to be shrinking as mass transfer proceeds and the orbital angular momentum is not conserved during mass transfer[21]. Spectrophotometric observations obtained for 8 close binary systems have been used to discuss their peculiarities.

Star clusters: The galactic star clusters have been forming and dissolving since the formation of galactic disc some 10 Gyr ago. The open (or galactic) star clusters are, therefore, good tools for tracing the evolution of the Galaxy and its present dynamical state. These can also be used to test the theories of stellar and galactic evolution as well as to study the galactic structure[22]. To obtain fundamental information for such studies, a knowledge of the cluster's distance, age and interstellar extinction in the direction of the star cluster is essential which can be obtained from colour–magnitude and colour–colour diagrams of the star cluster. The UPSO 104-cm Sampurnanand telescope has been optimally used for obtaining important observations of about 35 open clusters to fulfill the above goal[23].

The observations have led to the studies of open clusters pertaining to their star formation efficiency, age distribution, mass function and luminosity function[24]. Spatial structure of clusters and interstellar extinction in young open star clusters have also been studied[25].

Galactic stellar populations: A photometric and astrometric survey programme of a few selected fields at intermediate galactic latitudes and galactic plane was undertaken under an Indo-French collaborative programme in order to study the galactic stellar populations with a view to having a good model of the Galaxy. The observational material included the Schmidt plates of French, ESO, Tautenburg and Palomar Schmidt telescopes coupled with a few very deep CCD frames taken at the 3.6 m Canada–France–Hawaii Telescope. To calibrate Schmidt plates photometrically, CCD observations with a view to generating secondary standards were made at UPSO[26,27]. The most striking results of the work are the estimation of the cut-off of the galactic disc around 14 kpc from the centre and accurate characterization of the thick disc with a scale length of 2.8 kpc and a scale height of 760 kpc.

Infrared astronomy: Measurements with a Westphal photometer have shown that during winter months the water content at the UPSO is less than 4 mm of precipitable water, thus making the place suitable for work in the near infra-red at J, H and K passband corresponding to wavelengths of 1.2, 1.65 and 2.2 μm respectively. Observations of 26 unassociated IRAS sources have been carried out in these passbands[28]. One hundred and three nearby bright main sequence stars of spectral type F and G were searched for infrared excess from IRAS Catalogue. It was found that none of G-type stars show infrared excess and only 4 out of 28 F-type showed 'Vega-like' characteristics.

Extragalactic studies

Most of the known galaxies are classified according to the Hubble sequence depending on their morphology. There are galaxies that contain multiple nuclei, have irregular shapes, show the presence of plumes, tails, jets, hot spots, etc. The study of such peculiar galaxies helps us to understand the role of mergers and galaxy–galaxy interaction leading to intense stellar activity. With the above aim, several bright galaxies have been imaged in broadband BVRI filters using the CCD systems on the UPSO 104-cm telescope.

New initiatives at the UPSO

With the advent of modern optical detectors like CCDs, advancement in technology and computer facilities, availability of new technology for optical telescopes and need of multi-wavelength astronomical observations, the UPSO has taken up some new initiatives in optical astronomy both in research as well as in installation of modern observational facilities.

Optical follow-up as a part of multi-wavelength astronomy

During the past few decades, the advent of new observational astronomy at millimetre, radio, infrared, UV, X-ray and γ-ray wavelengths has enabled discovery of a number of new celestial objects and phenomena. In order to establish their identity and meaning in astrophysical terms, optical observations are indispensable, as the extraordinarily rich concentration of diagnostics of the physical conditions is available in the optical band. We have, therefore, started following research programmes as optical follow-up of astronomical observations carried out at other wavelengths.

Optical follow-up of gamma-ray bursts: Gamma-ray bursts (GRBs) are short and intense flashes of cosmic high energy (~ 100 KeV–1 MeV) photons. They release ~ 10^{51}–10^{54} ergs or more in a few seconds and thus become the most (electromagnetically) luminous objects in the Universe. The origin of GRBs is still a mystery. After the launching of many space-borne instruments, and in particular, the Italian–Dutch X-ray satellite BeppoSAX in mid-1996, it became possible to obtain position of GRB with an accuracy better than 3–5 arcmin within hours of occurrence and also carry out observations of relatively long-lasting afterglows in X-ray, optical and radio regions. The first Indian optical observations of an afterglow of a GRB were made at the UPSO on 23 January 1999 in B, V and R photometric passbands using a modern CCD camera mounted at the Cassegrain focus of the 104-cm Sampurnanand telescope[29,30]. These in combination with other optical observations of GRB 990123 indicate that the flux decay constants are independent of λ at least in the range 0.4 to 2.4 μm (ref. 30). However, different values of constants are required for different duration of the light decay curve[31]. Multi-wavelength including our optical observations of this GRB indicate that the initial and afterglow emissions are associated with three distinct regions in the fireball[31,32].

Optical/IR follow-up of ISOGAL survey: The ISOGAL is a ISOCAM survey at 15 and 7 microns with 6″ pixels and sensitivity below 10 mJy. The survey covers ~ 20 deg^2 in selected areas of the central $l = \pm 30$ deg of the galactic plane, all complemented by 0.8 and 2.2 microns DENIS (DEep Near-Infrared Southern) sky survey data. There are a number of known heavily reddened young star clusters and intermediate mass young stars within the ISOGAL and DENIS fields. In order to carry out a detailed study of these objects, a systematic optical follow-up programme has been started at the UPSO using CCD camera and JHK photometer mounted at the Cassegrain focus of the UPSO 104-cm Sampurnanand telescope. This project has been supported financially by the Indo-French Centre, New Delhi under a scientific collaborative programme between French and Indian astronomers.

Optical follow-up of interesting X-ray objects: Many new soft X-ray sources recently discovered in surveys with the Einstein and ROSAT (ROentgen SATellite) are found to be associated with bright late-type stars. The optical, X-ray and radio observations indicate that these systems may be RS CVn-like objects. However, evidence for binarity and also the optical photometric properties of these objects are lacking. About twenty such northern hemisphere objects are being monitored with the UPSO 104-cm Sampurnanand telescope using CCD camera in collaboration with Tata Institute of Fundamental Research (TIFR), Mumbai. Optical variability has been detected in three of the seven objects observed so far.

Optical observations of blazars: Study of rapid intensity variations of active galactic nuclei (AGN) provides a uniquely powerful tool for investigating the process occurring in the vicinity of their central engines. This strategy is further sharpened when the variability is monitored simultaneously in different frequency bands. We used the UPSO 104-cm Sampurnanand telescope and CCD camera for BVRI photometric observation of the blazars S5 0716 + 71 and 3C345 in 1994 and 1996 as a part of multi-wavelength monitoring campaign covering radio through γ-ray bands. The present optical observations[33,34] have been carried out during a low brightness level of the blazars. In the different passbands, the blazar S5 0716 + 71 showed correlated night to night intensity variations of ≥ 0.05 mag while no such variations were observed in the optically violent variable quasar 3C345. Intra-night variability with a rate of ≥ 0.1 mag per hour was also observed in S5 0716 + 71 on a few occasions.

There were no large (≥ 1 mag) amplitude variabililty events during our observations.

Optical micro-variability of powerful AGN: The intra-night optical variability studies enable one to probe the innermost nuclear cores of active galaxies, on the scale of micro-arcseconds which are beyond the reach of any imaging techniques in use currently. Though the first systematic search for intra-night optical variability of radio-quiet quasars was launched by us in early nineties[35], a number of other groups have also joined us recently. The results obtained from our own observations and by some others indicate that at least some radio-quiet quasars do exhibit microvariability, albeit somewhat less often, typically for shorter times, and usually less violently than do radio-loud quasars and blazars. Given the widespread perception that most radio-quiet objects lack relativistic jets, the likely sources of these small fluctuations are the accretion disks that almost certainly exist around central supermassive black holes. However, no consensus has been reached about how similar the intra-night optical variability characteristics are for radio-quiet and radio-loud quasars[36]. In order to settle this major question which has a direct bearing on the issue of radio dichotomy of quasars, we are obtaining optical light curves of 7 sets of optically bright and intrinsically luminous AGNs using the CCD camera and 104-cm Sampurnanand telescope at the UPSO on at least 6 to 8 epochs. Each set consists of (a) one radio-quiet quasar, (b) one radio-loud quasar, and (c) a blazar, all matched in redshift and optical luminosity. Light curves of some programme objects have been obtained recently.

Some new research programmes in optical astronomy

Here we give a description of the new research areas started recently at the UPSO.

Astroseismology and the Nainital roAp star survey: The rapidly oscillating Ap (roAp) stars located in the classical instability strip of the HR diagram are cool, magnetic, chemically peculiar A–F IV–V stars which exhibit low-degree, high-overtone, non-radial p-mode pulsations with low oscillation amplitude and periods ranging from 5 to 15 min. The multi-periodic p-mode oscillations in roAp stars are of considerable significance because they allow the use of astroseismology as a tool in the study of the chemically peculiar stars of the upper main sequence. The extremely low oscillation amplitudes (often < 1 milli magnitude) demand high photometric precision. There are two main sources of atmospheric noise that the roAp star observer has to contend with. First, there are sky transparency variations that occur on a time-scale of 20 min or longer. The other source of atmospheric noise is scintillation which sets the lower limit of detectability of oscillation amplitudes in roAp stars. For single-channel observations, the effect of these variations is to introduce peaks at low frequencies $\nu \leq 1.0$ MHz in the Fourier transform of the data. On good nights, these sky transparency peaks are well resolved from the frequencies of interest ($\nu \geq 1.0$ MHz) and the roAp oscillations can be detected without difficulty. On poor nights, the sky transparency noise can extend above 2.0 MHz, making the detection of the roAp oscillations impossible. The level at which the sky transparency noise reaches the scintillation noise sets the lower frequency limit at which oscillations can be detected and studied. Figure 3 shows a schematic amplitude spectrum of atmospheric noise attainable within 5 h of observations on a photometric night at Nainital with the 104-cm telescope. The level of the sky transparency noise drops down to the level of the scintillation noise somewhere between 1 and 2 MHz. Nainital is thus an excellent site to conduct a northern hemisphere roAp star survey. The raw single-channel data are shown in the lower panel of Figure 4 where one can notice gradual variations caused by sky transparency as well as oscillations due to the star. Application of a constant value of atmospheric extinction (0.26 mag/airmass) makes the star's oscillations clearly visible on a steady intensity level (see upper panel in Figure 4). This indicates photometric stability of the sky conditions which makes detection of a few milli magnitude variations in bright stars ($V \leq 10.0$) possible from Nainital.

During the observations in November 1997 and in November–December 1998, we have discovered oscillations in a few stars with amplitudes of several milli magnitudes. Preliminary results based on these observations have been published elsewhere[37–39]. Presently, the high speed photometric observations are being carried out occasionally using the ISRO Satellite Centre high speed photometer attached to the UPSO 104-cm telescope. In order to carry out regular observations at the UPSO, a new high speed photometer is under fabrication under a project financed by Department of Science and Technology, Govt of India, New Delhi. This work is being carried out in collaboration with scientists from ISRO, Bangalore and SAAO, Cape Town, South Africa.

Search for dark matter towards M 31 by microlensing effects: One of the most important problems in cosmo-

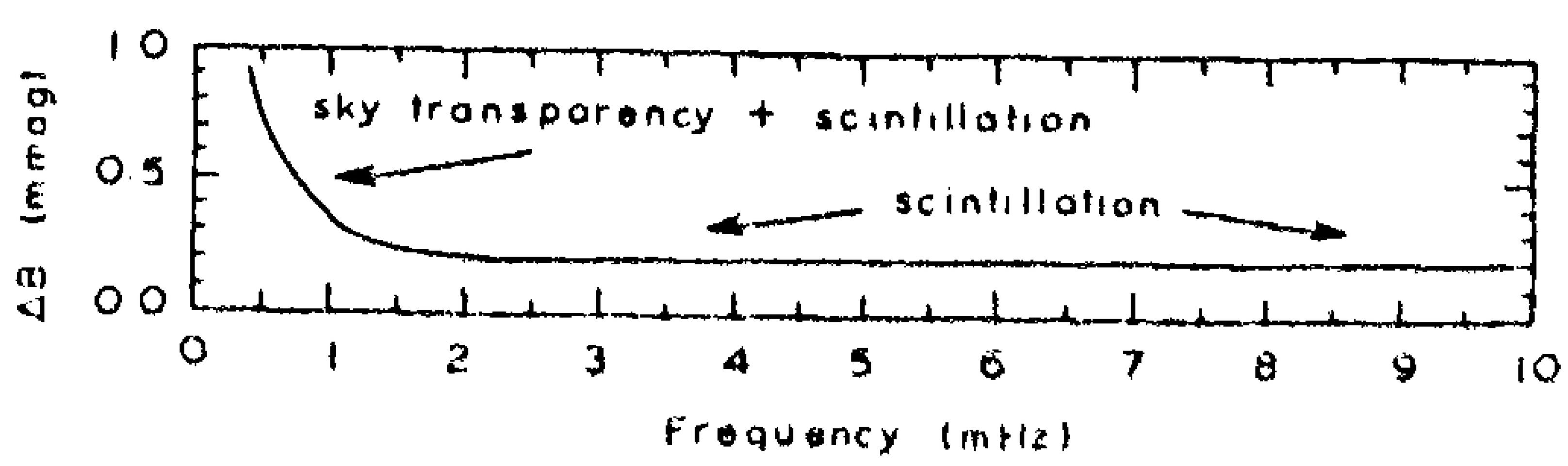

Figure 3. Amplitude spectrum of atmospheric noise in Johnson B passband at the UPSO 104-cm Sampurnanand telescope.

logy is to identify the dark matter in galactic halos. In recent years, much attention has been centred on the possibility that this consists of some sort of astrophysical objects, generically termed as MACHO (MAssive Compact Halo Objects). These could be either brown dwarfs or the dark remnants of *Population III* stars which formed relatively early in the life of the Universe. In 1986, Paczyński[40] suggested that gravitational lensing could be used to search them.

To search for microlensing events towards M 31, a technique called the Pixel Method has been developed under a collaborative programme AGAPE (Andromeda Gravitational Amplification Pixel Experiment). The aim of this project is to probe the halos of the Milky Way in a direction very different from that of Magellanic Clouds and also to make a map of the halo of M 31 Galaxy which is a large spiral galaxy, very similar to our own, but easier to look at.

As the observations are required for a short duration each night but over a long period, we started observations using 1024 × 1024 pixel^2 CCD chip mounted at the f/13 Cassegrain focus of the UPSO 104-cm Sampurnanand telescope under a collaborative programme between French and UPSO astronomers. During the observing seasons in 1998, we could obtain data for about 45 nights spread over 2 months. Recently, we have aquired a large size 2048 × 2048 CCD camera which will cover 4 times larger field on the sky than the present CCD camera. It will be used extensively in future for this programme.

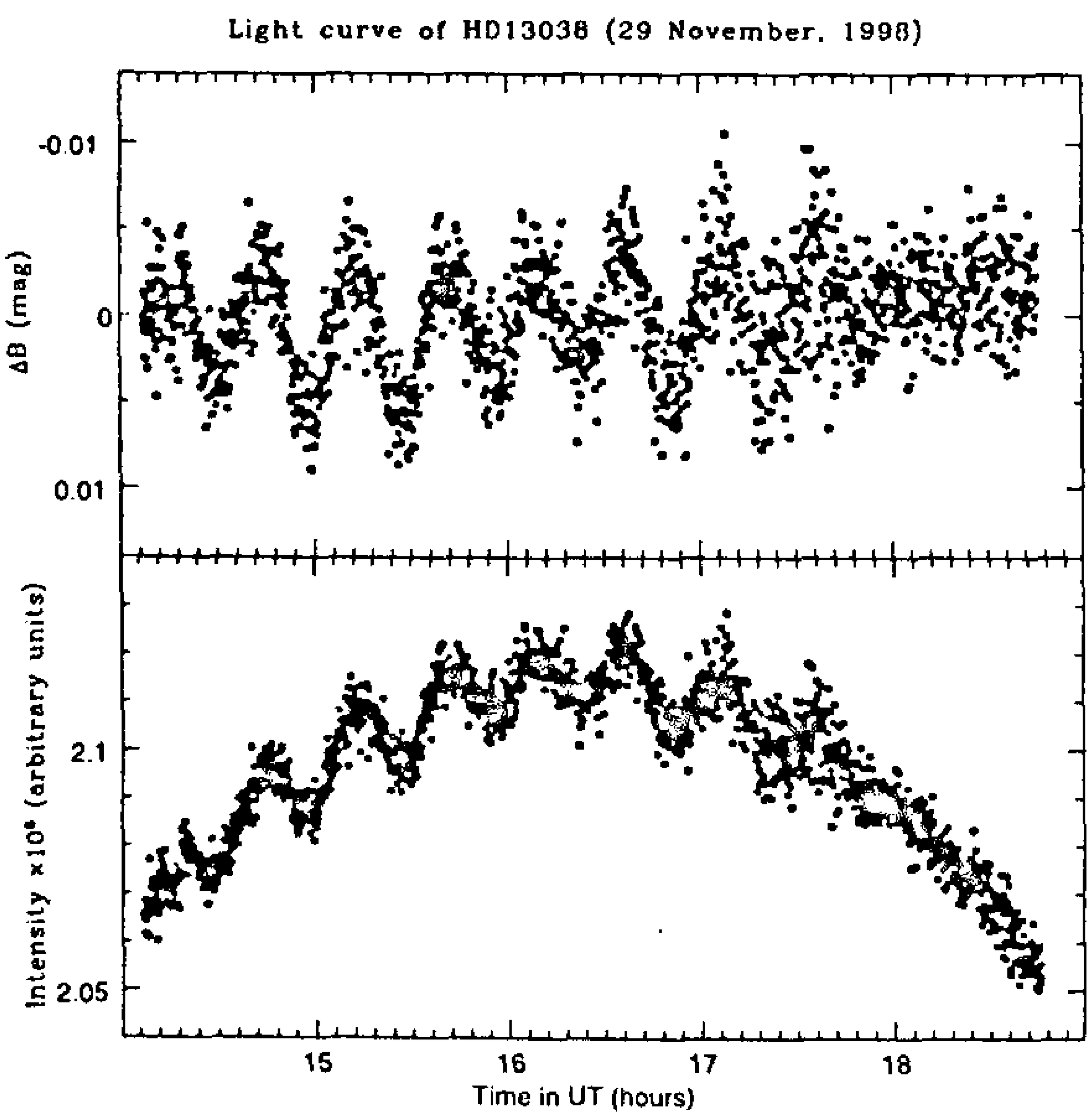

Figure 4. Light curve of the newly discovered variable star HD 13038 obtained from Nainital on 29 November 1998. Lower panel displays the raw-data while the upper panel shows variations of few milli-magnitudes in the star obtained after an atmospheric correction of 0.26 mag/airmass in the raw-data. The light curve clearly shows the beat phenomenon of the two pulsation periods present in the star.

Application of spatial-coherence spectroscopy in astronomy: The first experiment showing the application of spatial coherence spectroscopy in astronomy has been carried out recently at the UPSO in collaboration with the scientists from National Physical Laboratory, Delhi[41]. It is a new technique for determining the angular size of a star. The experiment was performed with the UPSO 104-cm Sampurnanand optical telescope. For making spectral measurements, a monochromator with a holographic grating with 600 l/mm and having dispersion 5 nm/mm was used. The detector used to record the spectra was a liquid nitrogen cooled 1024 × 1024 pixel^2 tektronix CCD camera system. The size of a pixel is 24 micron and one pixel corresponds to 0.38 arcsec on the sky. The spectra of the stars α-Bootis and α-Scorpio were measured from 360 nm to 660 nm. The spectral degree of coherence was measured by probing the spectral changes that occur on interference of the star light from the Young's double slits separated by 56 cm. The value of spectral degree of coherence obtained experimentally for these stars is in close agreement with the value that is expected theoretically from the known parameters of the stars.

Encouraged by the above results, we plan to use two telescopes which will provide large base line length. This proposed set up will provide us excellent opportunities for determining the angular diameters of the relatively distant stars and may become unique.

Installation of modern optical facilities at Devasthal

The importance of good astronomical sites for locating a moderate size telescope cannot be overemphasized. After a survey extending for about a decade, a suitable site, Devasthal, has been identified. The location of Devasthal is such that logistics of access and transportation are not too difficult and at the same time, it is far from any urban development. Devasthal is about 50 km by road from Nainital. The altitude of Devasthal peak is 2420 ± 5 m, while longitude and latitude are 79°40′57″ and 29°22′6″. The results obtained using the 56-cm telescope installed at Devasthal are shown in Figure 5. The measurements have not been corrected for instrumental noise due to finite exposure time and ST 4 CCD, etc. In the figure, one can notice hours of stability in seeing at Devasthal. Details of the site survey work have been published recently[1,2,42,43]. Briefly, the site has more than 200 astronomically useful nights, dark sky, low atmospheric extinction and most importantly, seeing better than 1 arcsec for about 40% of the time.

The last major observational facility funded for the UPSO was in 1972 when its 104-cm Sampurnanand telescope was commissioned. For solar observations, the UPSO has merely two 15-cm telescopes which are being used to monitor solar activity. The number of meaningful

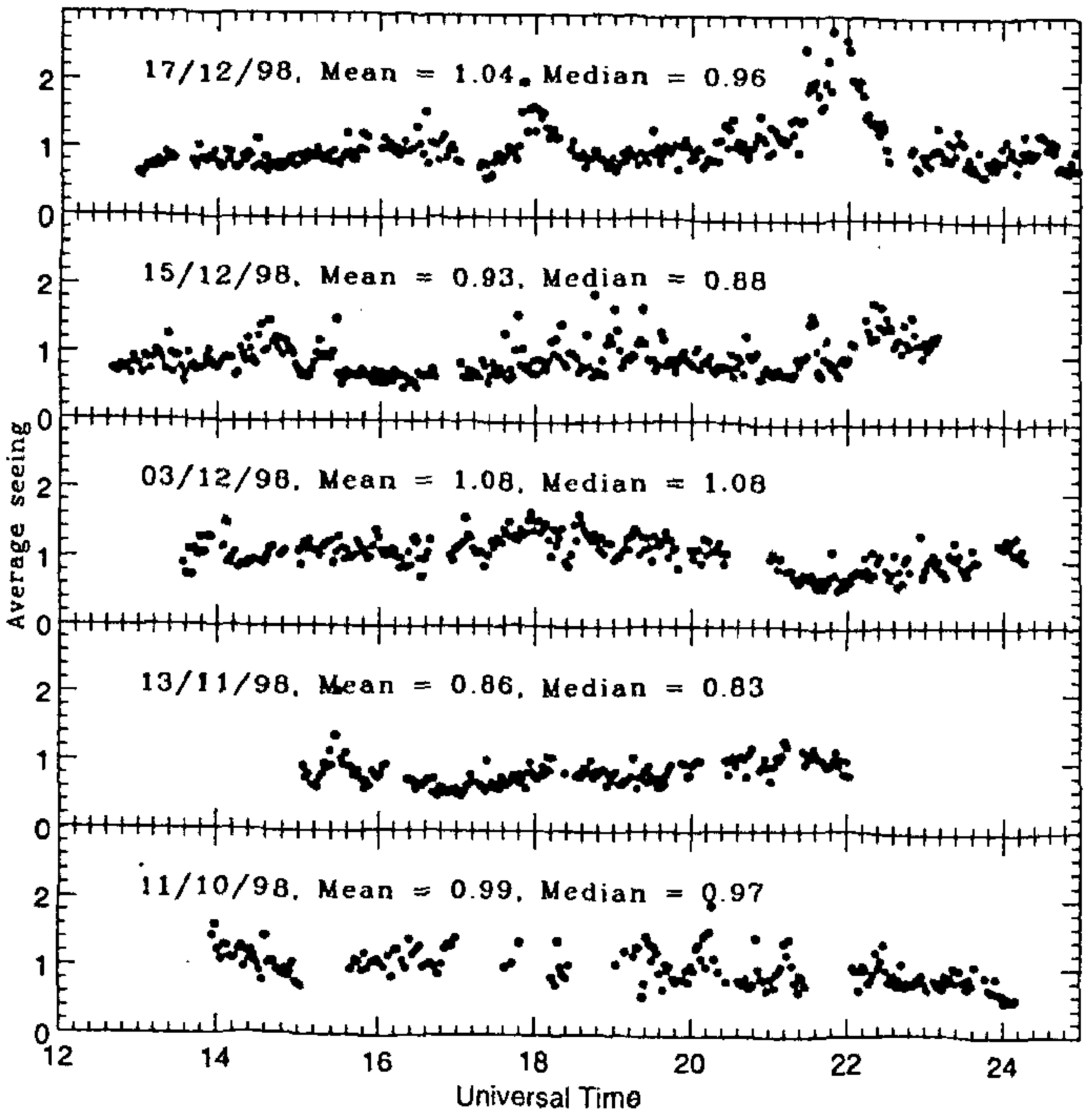

Figure 5. Seeing measurements carried out at Devasthal peak using differential image motion monitor and 38-cm telescope. One can notice that on several occasions, good seeing (better than 1 arcsec) is present for few hours in a stretch.

research programmes that can be undertaken with these telescopes has now become limited mainly because of its limiting sensitivity and the greatly increased international competition. Considering the factors like cost etc. on one hand and to remain as an important international centre of optical astronomy well into the 21st century on the other hand, the UPSO plans to set up a modern optical telescope of about 3-m aperture[44] and a 60-cm Solar Vacuum Telescope (SVT)[45]. These sizes, although small when compared to many other large telescopes in the world, are adequate to justify the use of modern instruments (like high resolution spectrographs, multi-object spectrographs, mosaic CCDs, etc.) capable of yielding front-line scientific results, thus supporting a variety of solar, galactic and extragalactic research programmes.

As scientists of TIFR were anxious to have a medium size modern optical telescope to complement their research being carried out at other wavelengths, in particular with the GMRT, the UPSO and TIFR decided to install a 3-m size modern optical telescope jointly while the SVT will be installed by the UPSO alone.

Conclusions

Together with other astronomical institutions in India and abroad, the UPSO is playing a useful role in the promotion of scientific research. The optical observations carried out at the UPSO are well recognized both nationally and internationally. The new initiative taken up recently at the UPSO will play a major role in ensuring the long-term survival and competitiveness of the UPSO scientists on the international scene. Thus, one can say that with dedicated staff and expanding facilities for research, the UPSO may be expected to make an increasingly valuable contribution to the country's scientific and technological development.

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ACKNOWLEDGEMENTS. I thank Prof. Harish C. Bhatt and Dr A. K. Pandey for going through the manuscript critically. Comments and suggestions of referee and review editor have improved the presentation considerably.

Received 4 March 1999; revised accepted 27 July 1999

Towards a hunger-free century

Jacques Diouf

The issue

Let me say from the outset that it is my conviction that there is no reason not to have a hunger-free world some time next century. The world will be able to produce enough food for everyone. It already does so, and it could produce more. However, unless deliberate action is taken at all levels, the chances are that the early years, perhaps even the early decades of the next century, will not be hunger-free and undernutrition will likely continue in the foreseeable future. This perspective is exactly the reason why the World Food Summit had been convened in 1996. The Summit agreed on a very concrete Plan of Action which, if implemented, should make it possible to reduce the numbers of undernourished by at least one-half by no later then the year 2015. We cannot make hunger disappear overnight. The key issue is what we must do in order to make the vision of a hunger-free century come true the soonest possible.

Before discussing this issue in more detail, I would like to make two points: finding sustainable solutions to the problem of hunger requires that we move beyond the traditional, often simplistic, concepts concerning the causes and consequences of hunger. First, it is now a well-accepted perception that increasing the amount of food available is a necessary but not sufficient condition for eliminating hunger. What is equally important is people's ability to secure food and in particular how to achieve the poor's access to food. Second, hunger is not a question of energy (calorie) deficits only. Hunger is a problem because of the human suffering it represents and because of the destructive health effects of malnutrition. Accordingly, if our efforts to eliminate hunger focus on filling stomachs without regard to the nutritional quality of the food consumed, we will not have accomplished much in the way of reducing the effects of hunger and of improving human welfare. The World Food Summit recognized this and the signatories committed themselves to improving year-round access by all 'to sufficient, nutritionally adequate and safe food . . .'[1].

Past and present

Let us start with a brief review of where we stand at present and how we got here. World population has just passed the 6 billion mark. This is twice the population of 1960. It is a remarkable achievement of the global food and agriculture system that this huge increase in world population in a relatively short period went hand in hand with significant progress in food security for most parts of the world. The share of the growing world population with adequate access to food has continued to rise. As a world average, the per-person food availability for direct human consumption grew 19% to 2720 kilocalories per day in the three and a half decades to the mid-nineties, while that of the developing countries grew 32% to 2580 kilocalories per day. Over the same period, India

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*Millennium lecture delivered at M.S. Swaminathan Research Foundation, Chennai 600 113 on 29 April 1999.