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Aryabhatta Research Institute of Observational Sciences : reincarnation of a 50 year old State Observatory of Nainital

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Abstract. The fifty year old State Observatory, well known as U.P. State Observatory till the formation of Uttaranchal in November 2000, was reincarnated on March 22, 2004 as Aryabhatta Research Institute of Observational Sciences with acronym ARIES, an autonomous institute, under the Department of Science & Technology, Government of India. The growth of academic and technical activities and new mandate of the Institute are briefly described. In early 60's, the Institute was one of the 12 centres established by the Smithsonian Astrophysical Observatory, USA, all over the globe but the only centre in India for imaging artificial earth satellites. Commensurating with its observing capabilities, the Institute started a number of front-line research programmes during the last decade, e.g., optical follow up observations of GRB afterglows, radio and space borne astronomical resources, intra-night optical variability in active galactic nuclei as well as gravitational microlensing and milli-magnitude variations in the rapidly oscillating peculiar A type stars. As a part of atmospheric studies, characterisation of aerosol at an altitude of about 2 km is going on since 2002. ARIES has plans for establishing modern observing facilities equipped with latest backend instruments in the area of both astrophysics and atmospheric science. Formation of ARIES, therefore augurs well for the overall development of astrophysics and atmospheric science in India.

Keywords : Optical Astronomy; Stellar and solar physics, Optical follow up observations, atmospheric science

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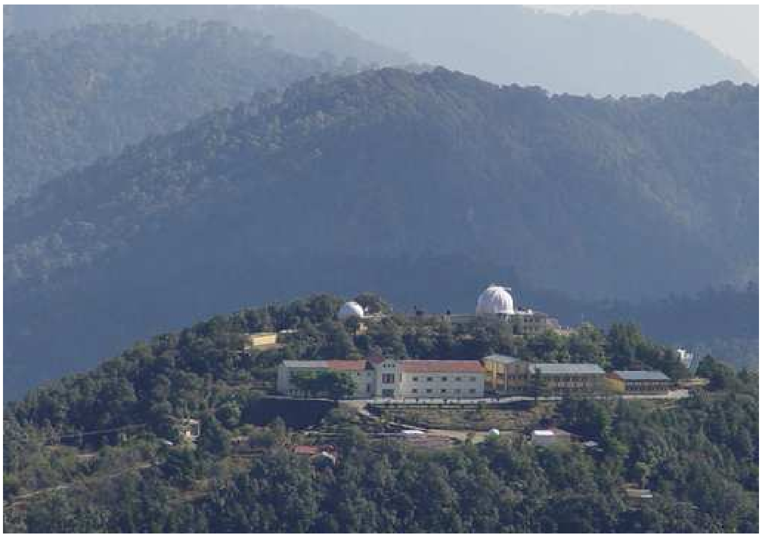

Figure 1. A panoramic view of ARIES located at Manora Peak, Nainital, Uttaranchal.

1. Introduction

On January 7, 2004, the Union Cabinet of the Government of India took a decision to convert the fifty year old State Observatory (historically known as Uttar Pradesh State Observatory (UPSO) till the formation of a new Uttaranchal State on November 9, 2000) into an autonomous institute devoted to basic scientific research in the frontier areas of astrophysics and atmospheric physics under the administrative control of Department of Science and Technology (DST), Government of India. A detailed account of this event has been given by Ramachandran (2004). The name of the new national institute **ARIES**, acronym for **Aryabhatta Research Institute of Observational Sciences**, incidentally signifies the zodiacal sign of Sun at two historically important epochs of the Institute separated by 50 years, the first one being its formation on April 20, 1954 under the Uttar Pradesh State Government while the second one is its reincarnation on March 22, 2004 under the Government of India. Figure 1 shows a panoramic view of the ARIES. The Institute came into existence in the holy city of Varanasi at the initiative of Dr. Sampurnanand, the then Education minister and later the Chief Minister of Uttar Pradesh and Prof. A.N. Singh, a Professor of Mathematics at Lucknow University. It was moved over in 1961 from dust and haze of the plains to the more transparent skies of the hills of Nainital in 1955 and to its present location at Manora Peak (longitude $79°27^{'}$E; latitude $29°22^{'}$N; altitude 1951m), a few km south of Nainital. A historical development of the UPSO has been chronicled by Sinvhal (2006).

A brief description of academic accomplishments and objectives of ARIES including

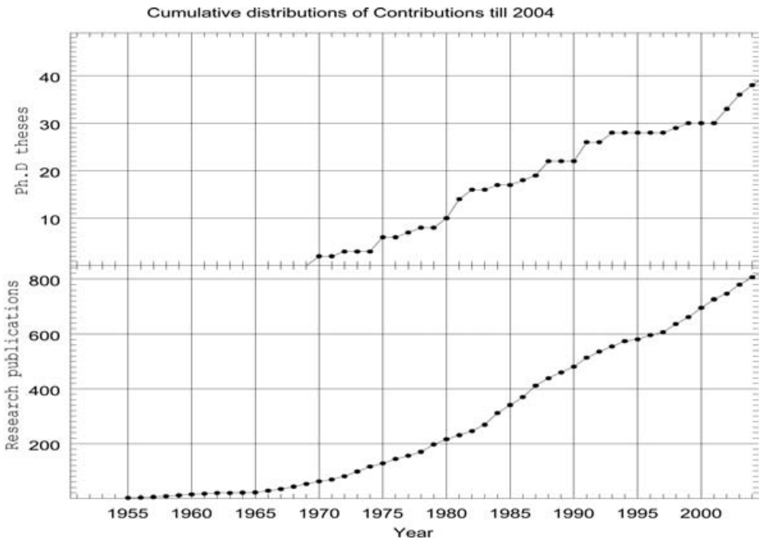

Figure 2. Cumulative yearly growth of research publications and Ph.D. theses.

its recent activities and existing observational facilities are given in the sections to follow. Towards the end, future plans of ARIES are summarized.

2. Academic accomplishments

In April 2004, the Institution completed 50 years of scientific research, discovery and training of manpower by maintaining a wide range of close collaboration with institutions and scientists from both within the country and abroad. During this period, the Institue contributed significantly in the studies of nearby galaxies, variability of Active Galactic Nuclei (AGN), optical follow-up of transient events like Novae, Supernovae and Gamma-Ray Bursts (GRBs), dark matter, stellar populations, stellar variability, stellar energy distributions, star clusters, planetary physics, solar activity, solar spectroscopy, airglow emission and aerosol content at high altitude in Himalayas. The contributions made by the Institute about a decade ago, along with new initiatives taken at that time are described by Sagar (1999b). The scientists from the Institute have published over 800 research papers so far. Out of these $\sim$ 75 % papers are published in well known journals, $\sim$ 15 % in proceedings of conferences/meetings/workshops and remaining in circulars. The Institute has also contributed to over 40 Ph.D. theses so far. The cumulative yearly growth of both research publications and Ph.D. theses is shown in Figure 2. They indicate that the Institute has contributed significantly to the development of scientific activities during last five decades with an acceleration towards the later years. Highlights of the work done so far are given.

- In the country, first photoelectric observations of stars and occultation of a star by a minor planet, near-IR and Fabry-Perot spectroscopic observations, optical data of a GRB afterglow and micro-lensing event have been taken at the Institute.
- The Institute actively participated in the discovery of rings around Neptune, Uranus and two additional rings around Saturn.
- The Institute's scientists have not only observed a large number of comets including Comet Halley, eclipsing binaries, variable stars, star clusters, high energy optical transients, nearby galaxies and AGN but also published many new results on them. For example, the slope of initial mass function (IMF) above one solar mass in young star clusters has been found to be similar to the Salpeter's value in the solar neighbourhood; the duration of star formation in a molecular cloud is several Myr and the plane defined by the interstellar dust is tilted with respect to the formal galactic plane. Many new variable stars and AGNs have also been discovered including a rare rapidly oscillating Ap star in the northern part of the sky.
- Out of many new molecular species predicted in the Sun's Photosphere and Sunspots by Institute's Scientists, the presence of SH, C_2 and SiO has been confirmed observationally.
- As a result of optical tracking of artificial earth satellites, the location of Manora Peak has been determined with a precision of 10 metres in the frame of reference of Standard Earth. This information is valuable for the geological survey.

Citations of the Institute's contributions in reputed scientific journals indicate that a good number of them are internationally recognised.

3. Advantage of the geographical location

The longitude (79° East) of ARIES locates it almost in the middle of about 180 degree wide longitude band having modern astronomical facilities between Canary Islands ($\sim$ 15° West) and Eastern Australia ($\sim$ 155° East). Therefore, the observations which are not possible in Canary Islands or Australia due to day light, can be obtained from ARIES. With its latitude of about 30° North, astronomical objects of both the Northern and Southern hemispheres are accessible from the place. Because of its geographical location and existence of good observing conditions for a good part of the year (September to June), ARIES has made unique contribution in many areas of astronomical research, particularly those involving time critical phenomena, despite having only small ($\leq$ 104-cm) size optical telescopes. Two best examples of this are the contribution in the discovery of Uranus rings in 1977 and the earliest optical observations of the GRB afterglows in 2001.

The location of the site is also suitable for carrying out certain unique aspects of atmospheric studies and can supplement the studies done on low altitude based stations. The possible research areas include the 'excess' atmospheric absorption at short wavelength by clear-sky atmospheres as predicted by radiative transfer models, aerosol-cloud interactions, gravity wave propagation, Mesospheric temperature variability and the role of black carbon in radiative forcing.

4. Existing observational and support facilities

The observational and support facilities available at ARIES are described in detail by Sagar (1999b) and Sinha (2005). Briefly, the Institute which started with a 25-cm refractor in 1955, installed other four telescopes namely 38-cm, 52-cm, 56-cm and 104-cm till 1972. The 104-cm Sampurnanand reflector telescope is the mainstay of the photometric, spectroscopic and polarimetric observations at ARIES. The focal plane instruments available for the telescope are Cassegrain plate holder, Meinel camera, photoelectric photometer, near-infrared JHK photometer, a laboratory spectrum scanner, modern cooled CCD cameras, imaging polarimeter, three channel fast photometer and an optical multichannel analyzer. ARIES also has two 15-cm reflectors equipped with H_α, Ca II K and CN filters and CCD cameras for carrying out observations of solar activities with a time resolution of up to 25 millisecond.

For optical tracking of man-made earth satellites using a 79/51-cm f/1 Baker-Nunn Satellite Camera, the Institute was the only centre in India but one of the 12 centers established by the Smithsonian Astrophysical Observatory, USA, all over the globe, during the International Geophysical year (1957-58). The first photograph of an artificial satellite was taken on 29 August 1958. The use of camera for optical tracking of the satellites was stopped in 1976 due to the advent of modern techniques in this area. It successfully photographed a total of over 45,700 satellite transits including that of the Apollo-11, Apollo-12 and Apollo-17 and the *Indian Satellite Aryabhatta*. Now, this camera is being converted into a wide field ($\sim 5 \times 5$ square degree) Schmidt-telescope for carrying out astronomical survey work.

For the studies related to atmospheric science, ARIES has a multi-wavelength radiometer (MWR); an optical particle counter (OPC, model 1.018 of Grimm Aerosol Technik, Gmbh, Germany); Aethalometer (Magee Scientific, USA model AE-21); a 5-channel Microtops Sun photometer (Solar Light Co., USA), and an automatic weather station (Campbell Scientific Inc., Canada). They are routinely used to characterise long term behaviour of aerosols and other related phenomena.

In order to meet the requirements for maintenance, design and fabrication of the instruments, ARIES has electronics and electrical workshop, a mechanical workshop, fine technics laboratory which includes aluminizing unit and optics workshop, a well maintained library with more than 11, 000 volumes of research journals and excellent collection of books and a modern computer center.

5. Proposed key research programmes

There is a plan to add a new dimension to the ARIES's research programmes. Besides expanding research in the key areas of it's past activities, a major programme of high-altitude ($\sim$ 2 km) atmospheric physics studies in the Central Himalayas as part of ISRO's Geosphere-Biosphere Programme (GBP) is proposed as the Institute has about 50 years of night atmospheric extinction data obtained during the photometric observations of stars.

ARIES would like to pursue front-line research programmes, both in house and collaboration, that commensurate with its capabilities. For example, programmes requiring long duration; multi-wavelength and multi-site observations using small size optical telescopes can be given priority. Such programmes are optical follow up observations of astronomical sources detected/discovered at millimetre, radio, infrared, UV, $X-$ray and $\gamma-$ray wavelengths as they are mandatory for establishing their identity and meaning in astrophysical terms. These along with recent significant results obtained in these areas are described and highlighted in the following subsections.

5.1 A High-altitude ($\sim$ 2 Km) atmospheric research site in Central Himalayas

A systematic and long-term characterization of aerosol properties at high altitude ($\sim$2 km) are very important for understanding global change, assessing the impact of human activities on free tropospheric aerosols and also for modelling boundary layer and free-troposphere mass exchanges. Such measurements are lacking, particularly in India. Taking the advantage of its geographical location, ARIES has therefore undertaken a major initiative in this direction. A MWR designed by Space Physics Laboratory of ISRO at Thiruvananthapuram has been set up at the Institute under ISRO-GBP ACE Project for spectral extinction measurements of directly transmitted solar radiation that reaches the ground. It has successfully been used for day-time aerosol optical depths (AODs) measurements since January 2002. Results based on analysis of these extensive (from January 2002 to December 2004) measurements are published by Sagar et al. (2004) and Dumka et al. (2006). They reveal mostly low values ($\leq$ 0.08) of AODs at 0.5 μm, comparable to the Antarctic environment, during winter (October, November, December, January and February) and a remarkable increase to higher values, up to 0.7 at 0.5μm, typical to continental regions during summer (March, April, May and June). The corresponding spectral variations of AODs are in the sense that increase is more at smaller wavelengths than the longer ones. These findings, for the first time, clearly indicate that in Indian high altitude ($\geq$ 2 km) Himalayan region, coarse/large size aerosols are more loaded during summer. These findings have important implications for weather and climatic studies. In order to understand both the short and long-term variations of aerosol characteristics, Aethalometer for aerosol black carbon measurements; Radiation sensors for surface solar radiation measurements and condensation nuclei counter to study aerosol-cloud interactions have recently been installed at ARIES. In fact they provided valuable data during the ISRO-GBP Land Campaign II over the North Indian Region using fixed stations during December 2004 and January 2005.

Recent studies suggest that the clear-sky atmosphere absorbs more short-wave radiation than predicted by radiative transfer models. They reported significant discrepancies at low altitude stations while showed good agreement at high altitude sites. These studies have led to a hypothesis that an unidentified absorber having optical properties similar to that of black carbon, may be present in the atmosphere. Several investigators, on the other hand, have found agreement between model and observations. ARIES would like to carry out observations and investigate this problem afresh.

5.2 Studies related to Sun, solar system and planet hosting stars

Under this programme, following research proposals are planned to be carried out by ARIES.

5.2.1 *Solar Physics*

A close relation of solar activity with the presence of convection and magnetic fields in the Sun is now well established. However, origin and evolution of various solar activities are not yet clearly known. In order to understand them, H_α and other narrow-band CCD optical observations with a time resolution up to 25 ms and spatial resolution 2-4 arc sec are being obtained by scientists from ARIES. They form integral part of the X-ray and UV observations taken by YOHKOH, SOHO, TRACE and HESSI space missions. Such multi-wavelength observations are extremely important to decipher the origin and evolution of solar active phenomena. ARIES is also participating in the first Indian Solar X-ray Spectrometer (SOXS) project.

A detailed multi-wavelength study of unusual impulsive solar flare of 1B/M6.7 class occurred on 10 March 2001 is published by Uddin et al. (2004). The two noticable unusual features of the flare are its compactness associated with a fast CME and Type II radio burts at all wavelengths and its rotation observed at hard $X-$ray wavelengths. They have also studied three small-to-medium size two-ribbon flares originated from the giant active region 9433 on 24 April 2001. These events occurred at the location of emerging flux and high sheer.

The temporal and spatial variations of the solar activity during the solar cycles 21, 22 and 23 have also been studied using $X-$ray data by Joshi & Joshi (2005) and Joshi & Pant (2005). They find not only several periodicities during this period but also a significant North-South asymmetry in the solar activity events which is maximum during the minimum phase of the cycle. The dominance of the activity in northern hemisphere during 1997-2000 shifted towards the southern hemisphere after the solar maximum in 2002.

5.2.2 *Solar System Studies*

Spectrophotometric observations of more than a dozen comets were carried out from ARIES at a large range of heliocentric distances using either spectrum scanner or optical multichannel analyser. 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. It was found that with heliocentric distance, gas production rate does not vary while C_2 and CN production rates show variation (Sanwal et al. 2004).

5.2.3 *Studies related to stars with planetary systems*

During last decade, one of the most significant astrophysical findings is the presence of planetary system around nearby stars. There are more than 130 stars which harbor about 160 extra solar-planets (cf. Espresate 2005). ARIES would like to actively participate in this new emerging field of research. The wide field of modified Backer-Nunn Schmidt camera will be an asset for this purpose.

5.3 Stellar variability and asteroseismology

Electromagnetic spectrum of static stars is emitted from the photosphere, its visible surface, and does not directly provide information on the internal structure. Oscillating stars, on the other hand, provide such opportunity, just as terrestrial seismology determine the internal structure of the earth. Asteroseismology is therefore the observational study of stellar structure using surface pulsations. For such studies, it is critical to have continuous coverage of the observations without gaps because of the day-night cycle; for this observatories spread around the world in longitude are needed. There are few observatories with good sites at the ARIES longitude. The 104-cm telescope of ARIES is therefore in high demand for many Whole Earth Telescope multisite photometric campaigns on asteroseismic targets, and some other such campaigns (Seetha et al. 2005). The ongoing activities in this area along with the future plan are briefly described below.

5.3.1 *Nainital-Cape survey of chemically peculiar stars*

In the spectral range B8-F0, some main sequence (MS) stars have over abundances and under abundances of a few heavy and light elements respectively. They are therefore called Chemically Peculiar (CP) stars. A group of CP stars having magnetic fields is termed as A-peculiar (Ap) stars. Some of them are rapidly oscillating Ap (roAp) stars. These roAp stars exhibit low-degree, high-overtone, non-radial p-mode pulsations with periods ranging from 5 to 21 minutes. The roAp stars thus pulsate in high-overtone acoustic modes similar to the Sun. However, contrary to the Sun, they have strong global magnetic fields. Asteroseismology of roAp stars therefore allows us to study the interaction of magnetic fields and pulsation under conditions much more extreme than those in the Sun. Out of the 31 roAp stars known till 1997, only 3 were located in the northern hemisphere's sky. This large difference between the numbers of known roAp stars in the two hemispheres was attributed to the fact that greater survey efforts had been made at the South African Astronomical Observatory (SAAO), in comparison to other astronomical sites. A survey programme named as **Nainital − Cape Survey** was therefore initiated in 1997 at ARIES in collaboration with ISRO Satellite Application Centre (ISAC), Bangalore; SAAO, South Africa and University of Central Lancashire, U.K. The aim of the programme is to apply the successful observational and data reduction techniques used in the Cape Survey project to a northern hemisphere observational site which has sky conditions similar to SAAO. The observational facilities along with detection limits imposed by the observing conditions (including atmospheric noise and telescope size) at ARIES are described by Sagar and Mary (2005). The scintillation noise on the best photometric nights is $\approx$ 0.1 to 0.2 mmag. This allows to detect few mmag variation in bright stars ($B \leq 12$ mag) from Manora Peak, Nainital. Fig. 3 shows the light curve of HD 13038 obtained from ARIES on 30 November 1998. These results show that Nainital is an excellent site to conduct the proposed survey work. We have obtained precise photometric observations for over 150 chemically peculiar stars during 1997 to 2004 on about 100 photometric nights using the 104-cm Sampurnanand telescope of ARIES. So far, discovery of pulsations in one roAp star, four δ Scuti like Am stars, and in a number of probable variables have been reported (see Joshi 2005; Girish 2005) .

The delta-Scuti stars are multi-mode pulsators with periods of 30 minutes to 6 hours. They also require extensive observations to unravel their pulsation behaviour. There are several large consortiums of observers including from ARIES, collaborating in world-wide networks to observe these stars in details for asteroseismological studies. We therefore propose to continue variability study of the above mentioned stars.

5.3.2 *Interacting binary systems*

Cataclysmic variables (CVs) are semi-detached binaries with one companion, usually a dwarf star, filling its Roche-lobe and second star, a degenerate white dwarf. Matter

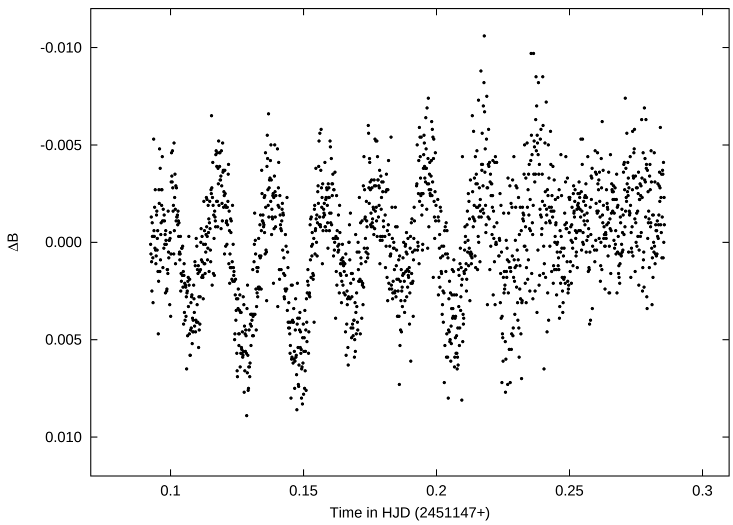

Figure 3. Light curve of the variable star HD 13038 obtained from Nainital on 30 November 1998.

is transferred from the lobe-filling star onto the white dwarf. Due to conservation of angular momentum this mass does not fall directly onto the degenerate component but forms an accretion disk around it. At the collision point between disk and mass stream an energetic shock front is created. The strength and the structure of the magnetic field of the white dwarf also strongly influence the nature of the accretion. The interacting binary systems play a crucial role in the study of the structure, evolution and instabilities of accretion discs because they (1) are nearby, (2) enable much more detailed study by virtue of being in a binary, and (3) in a few cases are eclipsing binaries which provide additional constraints on the geometry of the system and the structure of the accretion disc.

The interaction between different sources-mass-lobe filling star, accretion disk and shock front-results in a rather complicated observational picture: Quasi-periodic light fluctuations of several tenths of a magnitude on time scales of several minutes are superimposed on the orbital variation of the two components which ranges from about 1.5 to 10 hours. Optical and near-IR photometric and spectroscopic data allow us to derive essential physical parameters for these systems, such as orbital periods, masses and sizes of the components, mass transfer rates and temperature structure of the accretion disk and shock-front. This information can be put into a larger frame to examine the evolution of these systems, and to bring them into perspective with other semi-detached binaries and close binaries in general. We therefore plan to study the CVs using simultaneous optical and near-IR observations.

5.3.3 *Variability of blue stragglers in star clusters*

In some clusters a few stars are found on an extension of the MS above the turn-off point, and are referred to as blue stragglers. Their origin is still uncertain, though there is growing evidence that they are either binary stars or the result of a merger of two stars in the late stage of the development of close binary. A number of variable blue stragglers have been discovered so far but little is known of the characteristics of their variability. A close study of these stars could be expected to classify some aspects of the late stages of stellar evolution which are only imperfectly understood at present. A few galactic open and globular clusters have been studied by us keeping the above points in mind.

It is proposed to monitor selected galactic globular and open clusters for variability on time scales of a few tens of minutes to a few days. Spectroscopic studies of the confirmed and interesting variables can also be undertaken.

5.3.4 *Optical studies of variability in late type soft $X-$ray stars*

A significant fraction ($\sim$ 30 %) of the recently discovered soft $X-$ray sources in the Einstein and ROSAT surveys are late type stars (F, G, K, M) which exhibit a wide range of chromospheric activities that appear similar to those observed on the Sun. In such late-type of dwarfs, presence of starspots activities and their variability are often attributed to the formation of a magnetic dynamo mechanism within their convective envelopes. A detailed study of these type of stars will therefore help in understanding the formation and evolution of dynamos in late type stars.

While many active stars have been identified as such through their above-average X-ray and radio emission, it is only through detailed optical photometric and spectroscopic studies that their activity can be classified into known types, such as the RS CVn, BY Dra and FK Comae classes. The common characteristic of all these various classes of active stars, be they single stars or binaries, is rapid rotation: single, rapidly rotating stars are either young stars which have not yet lost most of their angular momentum or (in a few rare cases) are the results of the merger of a close binary system, while rapid rotation in close binaries is the natural result of spin-orbit tidal coupling and can occur even in middle-aged and/or old stars.

A multi-wavelength study of five chromospherically active stars, namely FR Cnc (= BD +16 1753 = 1ES 0829+15.9), HD 81032 (= 1ES 0920-13.6), HD 95559 (= 1ES 1737+61.2), HD 160934 (= 1ES0429+23.0) and LO Peg (=BD +22 4409) have been carried out by Pandey et al. (2005a,b). The extensive broad band BVR photometric and quasi-simultaneous low-resolution optical spectroscopic observations obtained during 2000–2004 are analysed along with the archival $X-$ray, IR and radio data. This has resulted in the discovery of two new active stars namely FR Cnc and HD 81032. A

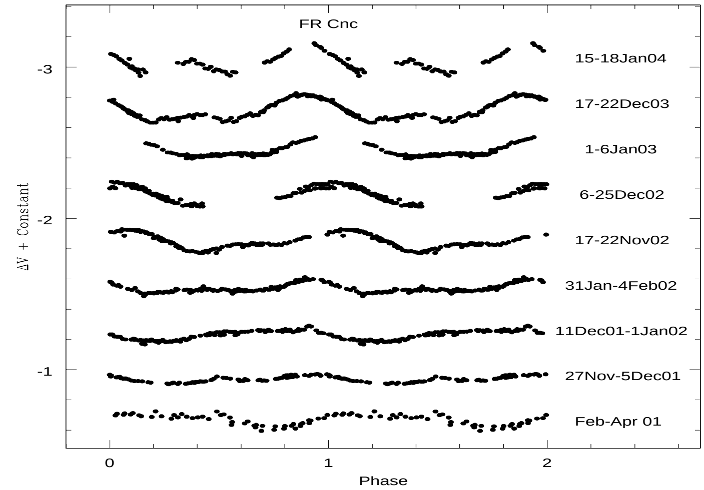

Figure 4. V band light curves of FR Cnc obtained from Nainital. It has a period of 0.8267 day. A constatnt offset has been applied to the light curve of each epoch for illustration purpose.

significant amount of photometric variability has been detected in all stars. For the first time, periods of their variability are established. The values are 0.8267 ± 0.0004 d and 18.802 ± 0.074 d for FR Cnc and HD 81032 respectively. Our observations suggest that HD 81032 is a new active star in an RS CVn binary system.

The shape and amplitude of the photometric light curves of FR Cnc, HD 81032, HD 95559 and LO Peg are observed to be changing from one epoch to another. As an example, Fig. 4 shows the folded V band light curves for FR Cnc. The change in the amplitude is mainly due to a change in the minimum of the light curve, and this may be due to a change in the spot coverage. This indicates the presence of variable dark spots on the surface of these dwarf systems. For both FR Cnc and LO Peg, two groups of spots are identified which have migration periods around 1 year. In the case of HD 81032, a single large group of spots seems to have a very large ($\sim$ 7.3 year) period of migration. Variabilities in colour and brightness are correlated for the stars FR Cnc, HD 81032, HD 160934 and LO Peg. This may indicate the presence of cool spots on their surface.

The spectral types of FR Cnc and LO Peg are determined to be K5V and K3V respectively. Variable H_α, H_β and Ca II H and K emissions in the spectra of the FR Cnc and HD 81032 indicate the presence of a high level of chromospheric activity. The chromospheric line emission is correlated with the photometric light curve. This again supports the presence of cool spots on the surface of these stars. The kinematics of FR Cnc, HD 95559, HD 160934 and LO Peg suggest that these stars are younger than 100 Myrs.

The X-ray observations carried out with the ROSAT observatory for FR Cnc, HD 81032, HD 95559, HD 160934 and LO Peg are analyzed. $X-$ray flares of moderate class were present in the light curves of HD 81032 and HD 160934. The best fit models to the X-ray spectra imply presence of two temperature coronal plasma components with sub-solar abundances in the HD 95559, HD 160934 and LO Peg while two coronal plasma components with solar abundance are in the case of HD 81032.

In order to achieve the goal of the project, we would like to continue the above mentioned type of studies for some more bright EUV and unusual soft X-ray sources. A large fraction of these objects are probable new accreting binaries, either magnetic CVs or low mass X-ray binaries. Our aim will be to identify the optical counter part and then to carry out detailed optical/near-IR photometric and spectroscopic studies. Experience gained in this area before the launch of ASTROSAT, will be valuable since we shall be ready to participate in the optical follow-up observations desired for the ASTROSAT sources.

5.4 Formation and evolution of Stars

Star formation is central to many branches of astrophysics, from the formation and evolution of galaxies to the presence of life on Earth, and yet there are serious gaps in our knowledge of the process and mechanism involved. It is known that in our galaxy stars form in dense molecular clouds where condensations collapse under gravity, increasing in density and temperature until nuclear reactions begin. In recent years, studies of star formation have shown that bipolar outflows and circumstellar disks are a frequent feature of the star formation process. However, the detailed physical process from the collapse of the molecular cloud to the end product of a MS star are not yet well understood. For example, it is still not known whether the formation of stars of different masses in a given molecular cloud begin at the same time or it continued over a span of time. Another very important and the most fundamental quantity in the study of star formation is the IMF, distribution of stellar mass in a star formation event. Theoretically, it is not clear whether the shape of IMF would depend on the chemical composition of the star forming gas, its physical state and environmental conditions etc. or not.

As the stars form in dense molecular clouds, the detailed processes are hidden from optical observations, and observations at infrared, millimetre and radio wavelengths are needed to penetrate the clouds. However, optical observations of young stellar clusters in combination with the near infrared provide valuable information about IR-excess which can be interpreted as circumstellar dust (Yadav and Sagar 2001; Kumar et al. 2004). The data would give us an insight into the nature of cocoon stars embedded in extremely young stellar clusters. The spatial distribution between them and visible O and B stars can throw light on the ongoing star formation. The HR-daigram of young stellar clusters can also be used to study the IMF.

One of the major impact of near infrared observations will be to probe giant molecular clouds and large dark clouds in search for low luminosity protostars, in order to derive the IMF and the star forming efficiency. The near-IR range is very sensitive to prostellar objects because of their high luminosity in this range, the low extinction of the surrounding interstellar dust (1/10 of A_v in K), and the absence of thermal noise that hampers high-sensitivity, mid-infrared survey, at least from the ground. The recent use of the new very sensitive near-IR 2-dimensional array detectors and the IRAS survey, have allowed statistical analyses of a few star-forming regions including the Orion Nebula, Rho Oph and Taurus-Auriga complexes. However, the existing observations cover only a small fraction (10-20%) of the total star forming regions of our galaxy. Given the high number of required surveying areas in the Galactic plane, we propose to obtain near infrared observations with its high sensitivity in J and K bands. This represents a unique possibility to undertake a complete statistical analysis of the stellar populations in star forming regions.

5.4.1 *Star clusters as a tool for stellar evolution*

A group of gravitationally bound stars formed nearly at the same time from the molecular cloud are known as star clusters. They are therefore located at the same distance and also considered to have same primordial chemical composition. Consequently, HR-diagram of a star cluster reflects the evolutionary dispersion of approximately equally old stars of different masses, after a lapse of time typified by the age of the cluster. Star clusters therefore provide a wealth of information against which the theory of stellar evolution can be tested.

Comparison between the theoretical and observed HR-diagrams leads to the determination of the age and chemical composition of stars in the cluster. Observed colour-colour and colour-magnitude diagrams are also used to determine interstellar reddening and distance to the cluster. The young star clusters are also excellent tools for tracing the evolution of the Galaxy and its present dynamical state. The 104-cm telescope has been optimally used for obtaining important observations of more than 50 open clusters and a few galactic globular clusters to fulfill the above goal. As an example, Fig. 5 shows the colour magnitude diagram of NGC 2099 obtained from ARIES. Such observations have led to the studies of open clusters pertaining to their star formation efficiency, age distribution, mass function and luminosity function. Spatial structure of clusters and interstellar extinction in young open star clusters have also been studied (Pandey et al. 2002, 2005; Nilakshi et al. 2002; Nilakshi and Sagar 2002). The slope of the mass function above 1 solar mass for young (age $<$ 100 Myr) star clusters is found to be not too different from that of Salpeter value (Sagar 2002; Lata 2005).

Most of the metal rich globular clusters in the galaxy are concentrated towards the Bulge and are severely affected by interestellar absorption. Consequently, few have been observed down to the magnitude of the turn-off point in the CMD, and hence their ages are unknown. Infrared photometry in the J, H and K bands is relatively little affected by interstellar reddening compared with the traditional optical bands used for colour-magnitude work. The long baseline offered by the combination of say the V and K

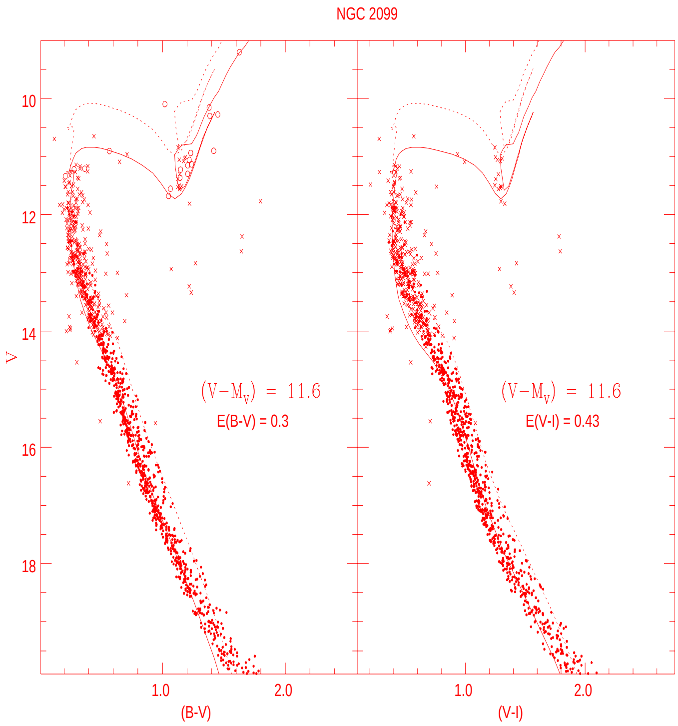

Figure 5. CMD of NGC 2099 obtained from Nainital (Nilakshi and Sagar 2002).

magnitudes should allow the temperatures of cluster stars to be accurately measured, especially as this colour is also insensitive to metallicity. Various combinations of colours would be used to determine the metal abundances. The use of infrared fluxes should allow a more precise conversion from observed to theoretical parameters and hence improved isochrone fitting to be made. It should thus be possible to determine the ages of the metal rich clusters with high precision and this will allow a comparison to be made with the ages of the metal poor clusters.

The above proposals aim to use the large infrared array and optical CCDs mounted on the 2-m HCT for CCD imaging.

5.5 Extragalactic studies

5.5.1 *Studies of galaxies*

Much progress in extragalactic research and cosmology rests on a detailed knowledge of the properties of nearby galaxies. This knowledge has been seriously lacking in the near infrared since the previous large-scale surveys are limited to a K magnitude of ~ 4. The

K band is particularly well suited to extragalactic studies for two reasons. First, the ratio M/L in K is almost independent of galaxy type, unlike the situation in the optical part of the spectrum or that in the far-infrared where the vagaries of star-formation can cause it to vary wildly from galaxy to galaxy. Second, the K band is only weakly affected by dust extinction or emission. For example, the extinction in K is less than 1 magnitude for galactic latitudes above 1 degree. We would therefore like to carry out near-infrared studies of nearby galaxies.

The discovery of large scale diffuse radio emission from what appears to be a large scale filamentary network of galaxies in the region of cluster ZwCl 2341.1+0000 which stretches over an area of several Mpc in diameter was reported by Bagchi et al. (2002). Photometric redshifts derived from multicolour CCD observations indicate that a significant fraction of the optical galaxies in this region is at redshift of z=0.3 which is supported by spectroscopic measurements of 4 galaxies in the Sloan Digitized Sky Survey at a mean z=0.27. The results are in agreement with the observed radio Synchrotron and $X-$ray thermal bremsstrahlung fluxes. Thus it can be concluded that the reported radio detection is the first evidence of cosmic-ray particle acceleration taking place at cosmic shocks in a magnetized intergalactic medium over scale of > 5 Mpc.

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. CCD Photometry of Wolf-Rayet (WR) galaxies using BVRI and H_α filters has been started at ARIES. These galaxies are thought to be undergoing present or very recent star formation that produces massive stars evolving to the WR stage. If WR stars in sufficient numbers are present in a galaxy, their integrated spectra could be viewed against galaxy continuum. More than 139 WR galaxies are now known but deep multicolour CCD photometry is available only for a few of them (Patil et al. 2001; Singh et al. 2001). Such observations provide direct evidence of various star forming regions and dust lanes in the galaxy and also gives evidence of merger or interaction of the companion galaxies. With these aims, broad-band BVRI CCD images of several bright WR galaxies will be obtained and studied in future also.

5.5.2 *Dark matter in the Galaxy*

One of the most important problems in cosmology is to identify dark matter in galactic halos as overwhelming evidences suggest that there is more gravitating mass in the universe than can be counted in the form of luminous stellar and interstellar matter. The nature of this dark matter remains a mystery. In order to detect and characterize this mass a stellar survey programme was initiated with French astronomers in 1998. If the dark matter exists in baryonic form then the mass of objects constituting this unseen component should correspond to cool white dwarfs. Assuming this to be the case, one should be able to detect nearby white dwarfs by studying the proper motion of faint objects from images taken even at an interval of one year. The observational material for this purpose consists of 3.6-metre Canada-France-Hawaii telescope deep images in two intermediate latitude galactic fields namely SA57 ($l = 69°, b = 85°$) and VIRMOS ($l = 173°, b = -57°$). Photometry and astrometry down to $I = 25$ have been carried out by Creze et al. (2004). This resulted in a catalogue of 20,000 and 100,000 objects for SA57 and VIRMOS fields respectively. The areas corresponding to the fields are 0.16 and 1.2 square degrees respectively.

By looking at differences in positions of stars detected on two epochs of observations, one can infer about their proper motions. However, no white dwarf candidate has been confirmed so far (Creze et al. 2004). This indicates that the dark matter is not baryonic in nature and even if exists in baryonic form it cannot account for all the unidentified missing mass.

5.5.3 *A search for dark matter towards M31*

In recent years, attention has also been centered on the possibility that the dark matter consists of some sort of astrophysical objects, generically termed as MACHOs and gravitational lensing technique is used to search them. To search for microlensing events in the far-off galaxies where most of the stars are unresolved, a technique called *pixel method* has been proposed and implemented by the AGAPE (Andromeda Gravitational Amplification Pixel Experiment) collaboration. With an aim to detect microlensing events towards M31, its broad band R and I CCD observations were obtained during 1998-2002 using 104-cm telescope of ARIES. The results derived from them are summarised below (Joshi et al. 2003, 2004, 2005):

1. Two possible microlensing events named as NMS-E1 and NMS-E2 have been detected. The data taken with 1.3-m MDM telescope at Kitt Peak, Arizona (USA) also confirm the events. The half time duration ($t_{1/2}$) of the NMS-E1 and NMS-E2 are estimated to be 63±2 and 105±11 days respectively. The pixel light curve of NMS-E1 is shown in Fig. 6. The event NMS-E1 is further confirmed with the 2.5 m-Isaac Newton Telescope's data taken at La Palma Canarie Island.

2. The long duration photometric study of $\sim$ 4,400 stars down to $\sim$ 21 mag in R band led to the detection of 359 variables, of which more than 300 are newly discovered. Out of the 359 variables, 26 are Cepheids, 115 are periodic variables, 2 are possible eclipsing binaries and remaining 215 stars are semi-regular or long-period variables. Of the 26 Cepheids, two are newly discovered, 11 are classified as Cepheids for the first time and 13 are confirmed as Cepheids in our study. Their precise period and amplitude of pulsation could be determined due to our long duration observations. The period-luminosity relation of Cepheids yields a distance of 790±45 kpc to M31. This is in agreement with those derived through other methods by different groups.

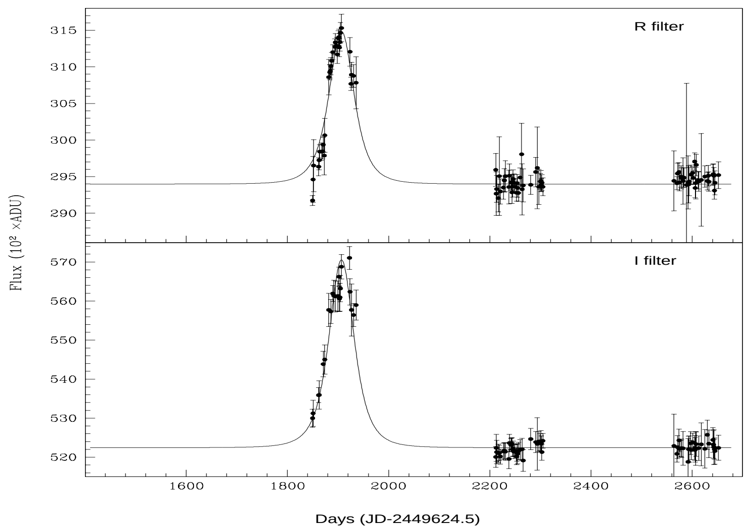

Figure 6. Pixel light curves of the microlensing event NMS-E1 in R and I bands. A theoretical light curve is also drawn with the observed one.

3. Two M31 novae named as NMS-1 and NMS-2 are also observed. Their photometric light curves indicate that the R band peak brightness of NMS-1 and NMS-2 are $\sim$ 17.2 and 17.7 mag respectively. While NMS-1 was a fast nova, NMS-2 could be a slow nova as it was observed after its peak brightness.

5.5.4 Optical follow up of GRB afterglows

One of the currently most active fields of astrophysics is the study of the dramatic events known as GRBs. Originating, not on the Earth, but far out in space, these short and intense flashes of high energetic $\gamma-$rays (10 KeV – 10 GeV) photons last from less than a second to several minutes. They have puzzled scientists since their accidental discovery in the late 1960's by sensitive instruments on-board orbiting military satellites, launched for the detection of nuclear tests. Precise localization of GRBs had been a major problem until the launch of recent satellites such as BeppoSAX, HETE-2, and INTEGRAL. Most GRBs have been found to be situated at extremely large (cosmological) distances. The energy released in such an event is larger than that of the Sun during its entire lifetime. The GRBs are therefore the most powerful events known in the Universe after the Big Bang. But their origin is still a mystery and they have been the subject of great interest and debate.

Recent studies suggest that the GRBs occur due to the conversion of the kinetic energy in ultra-relativistic outflowing ejection from the progenitor (i.e. central engine or so called fireball) to non-thermal $\gamma-$ray radiation via internal shocks. The subsequent interaction of the ejected material with the surrounding medium through external shocks produce afterglows visible in all bands from $X-$rays to radio wavelengths. Optical observations of GRB afterglows are indispensable as they provide valuable informations about GRB distances as well as its isotropic/no-isotropic nature of the emission. Consequently, they help in understanding the nature of their progenitor, environment and energetics. Optical observations at Nainital were therefore started in 1999 under a long term research programme in collaboration with astronomers from all over the globe. The first two successful observations of GRB afterglows from India were obtained from the ARIES (Sagar 1999a, 2000). Low resolution spectroscopic and/or broad band photometric CCD observations were obtained for over 20 long duration GRB afterglows so far. The results derived from these observations in combination with published multi-wavelength data are summarised recently by Sagar and Misra (2005). In general, early time flux decay constants (~ 1.1) are flatter than the value of ~ 2 at later times. Most of them are having relatively flat spectral index with its value ranges from about 0.7 to 1.0. The model of non-isotropic synchrotron emission from the centre of the GRBs is being supported by these observations. This reduces the energy budget to $< 10^{52}$ ergs from an isotropic value of $\geq 10^{53}$ ergs.

During the past couple of years mounting circumstantial evidence suggests that some GRBs signal the collapse of massive stars. This is based on the probable association of GRB with a supernova, e.g., SN 1998bw/GRB 980425 and GRB 030329/SN 2003dh. In fact, optical and radio observations of the latter clearly indicate not only association of the Supernova with the GRB event but also mutiple epoch of energy ejection from the progenitor (Resmi et al. 2005). Recently more clues have surfaced including the association of GRBs with regions of massive star-formation in distant galaxies and evidence of supernova-like light-curve **bumps** in the optical GRB afterglows of some earlier bursts. The afterglow observations support the jetted synchrotron emission from the central engine of the GRBs which explains the energy outcome in terms of massive stellar death models for the origin of GRBs. So far, afterglows are observed only for long duration GRBs. Origin of short duration GRB afterglows is still uncertain although the existence of a few of them have been confirmed during 2005. We would like to continue and strengthen this front-line research work in future also.

5.5.5 *Optical observations of blazars*

In order to understand the variability in blazars, in 1996, we obtained CCD optical observations of the BL Lac object S5 0716 + 71, which is an intra-day variable at radio and optical wavelengths as well as a $\gamma-$ray emitter. The data were obtained as a part of multi-wavelength monitoring campaign covering radio through $\gamma-$ray bands during a low brightness level of the blazar. In a similar campaign, it was again observed during March-April 1999, when the blazar was in active state. Intensity variations of more than

0.05 magnitude within a night were observed in half the cases and a good correlation between the light curves with different passbands was noticed. In all three prominent flaring events of intra-night variability (INV) were detected. No clear event of ultra-rapid fluctuations was detected (Sagar et al. 1999; Stalin et al. 2006).

Quasars (quasi-stellar objects) discovered in 1963 are extremely bright objects and believed to be powered by super-massive black holes. Only 10–20% of the quasars emit radio radiation while the remaining 80–90% barely emit any radio waves. However the intensity fluctuations of the radio-loud quasars at optical wavelengths on hour-like time scale is now a well established phenomenon. In contrast, it is not at all clear if similar INVs are also exhibited by radio-quiet quasars. Such observations can provide valuable clues to the question of radio dichotomy of quasars, currently among the most outstanding issues in extragalactic astrophysics. The significance of optical INV studies lies in the fact that they enable a probe of the innermost nuclear cores of AGN, on the scale of micro-arcsec which are totally beyond the reach of any imaging techniques in use currently. Multi-wavelength study of rapid intensity variations of AGN thus provides a uniquely powerful tool for investigating the process occurring in the vicinity of their central engines.

Although INV of blazars is an established phenomenon, several independent observational programmes have presented a rather confusing picture about the INV properties of other major classes of AGNs. An intensive optical monitoring programme of a carefully selected sample, representing major classes of luminous AGNs, was therefore undertaken at the ARIES to refine the understanding of the INV phenomenon. The observational strategy followed was to carry out densely sampled intra-night R band monitoring of one such object per night using CCD system, such that micro-variability of amplitude as low as 1% and time scales as short as $\sim$15 minute could be identified by differential photometry. Further, in order to minimize bias related to optical luminosity and/or redshift, a sample of 26 optically bright and intrinsically luminous quasars and BL Lacs was divided into 7 sets, each set belonging to a narrow redshift bin between $z = 0.18$ to 2.2 and containing one radio quiet quasar (RQQ), one lobe dominated quasar (LDQ) and one radio core dominated quasar (CDQ) and/or a BL Lac object. The typical duration of intra-night monitoring was between 5 to 8 hours and each object was monitored for 3 to 7 nights. The entire programme spanned 113 nights comprising 720 hours of observations (Stalin et al. 2004). Figure 7 shows the light curve of a few RLQs observed from ARIES. The main results are:

- BL Lac objects show high duty cycle of INV (75%) while LDQs, CDQs and RLQs show much smaller INV duty cycles ($\sim$ 20%). This indicates that there is a marked difference between the INV properties of BL Lacs and RQQs. It has also been found that amongst RLQs, only BL Lacs and possibly strongly polarized CDQs show high duty cycle of INV, weakly polarized CDQs have much lower INV duty cycle, no more than found by for LDQs and RQQs. Also LDQs and RQQs show small variability amplitudes ($<$ 3%), which is frequently not the case with CDQs and BL Lacs.

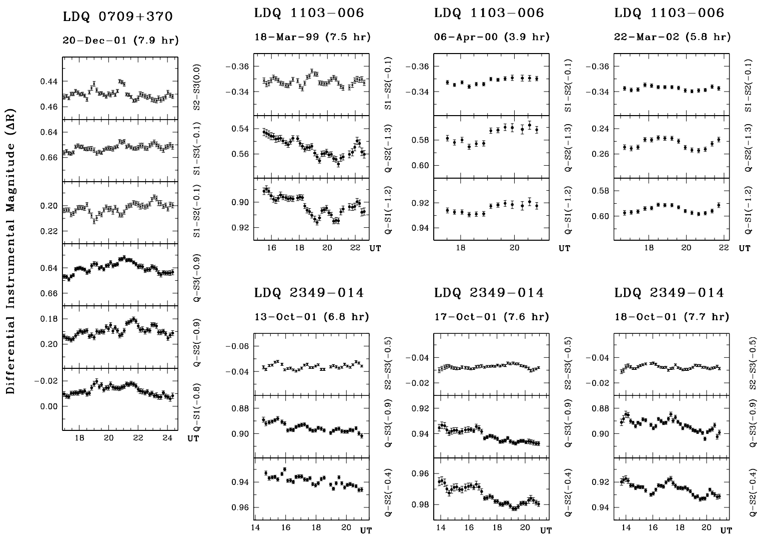

Figure 7. Differential light curves of radio loud quasars 0709+370, 1103-006 and 2349-014 obtained from Nainital. Epoch and duration of observations are marked.

- The high duty cycle shown by BL Lacs strongly suggests that relativistic beaming plays an important role in their observed micro-variability. The observed difference in micro-variability nature of LDQs and RQQs compared to BL Lacs can be accounted for in terms of their optically emitting nuclear jets undergoing different degrees of Doppler boosting in our direction.
- For blazars no correlation has been found between their INV amplitude and the apparent optical brightness. This suggests that the physical mechanisms of intra-night and long term optical variability do not have one to one relationship and different factors are involved.
- The micro-variability duty cycle of the AGNs studied in this program strongly suggest that the INV is associated predominantly with highly polarized optical component.

Our observations indicate that at least some RQQs do exhibit INV and usually less violently than do RLQs, particularly BL Lacs (Gopal-Krishna et al. 2003; Stalin et al. 2004). Given the widespread perception that most RQQs 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 optical INV characteristics are for RQQs and RLQs. In order to settle this major question which has a direct bearing on the issue of radio dichotomy of quasars, we have recently launched a systematic study using the 104-cm Sampurnanand telescope in collaboration with NCRA, Pune and IIA, Bangalore as the intra-night optical monitoring for Nainital and Hanle is supplemented with simultaneous radio monitoring, using GMRT at decimetre wavelengths. Such observations are capable of providing much needed vital clues on the radiation mechanism of quasars of different types.

5.6 Optical identifications of GMRT radio sources

GMRT, a world class radio telescope built by TIFR with indigenous effort, has the potential of detecting faint steep-spectrum radio sources. Finding the optical/near-infrared counterparts of these radio sources is going to be the first essential step in ascertaining their nature and isolating the most promising objects among them, which could then be taken to larger optical telescopes for a detailed study. Without these optical identifications, the science targets of GMRT would remain largely unfulfilled. We would therefore like to provide optical identification of GMRT radio sources using optical telescopes available in the country.

5.7 Other research programmes

In addition to the scientific programmes discussed above, in detail, there are a number of minor projects, few of them are highlighted below, which would be of interest to ARIES astronomers.

- Atomic line imaging of supernova remnants, to study their evolution and physical conditions in the shocked plasma; e.g. equilibrium conditions, elemental abundances, mixing of ejecta, etc.
- Near-IR imaging of Bok globules, Lynds clouds, Herbig-Haro objects, T-Tauri stars, YSO's etc;
- Study of various components of the interstellar medium from optical and near-infrared imaging (J, H, K bands) and spectroscopy of supernova remnants, planetary nebulae, HII regions, neutral HI clouds, etc. Imaging polarimetry to probe interstellar grain alignment and magnetic field structure in interstellar clouds.

6. New focal plane instruments commissioned with the 104-cm telescope

Recently, three channel fast photometer, Imaging polarimeter and a better CCD camera system have been developed and commissioned for regular use at the 104-cm Sampurnanand telescope of ARIES. They are described below:-

6.1 Three channel fast photometer

In order to carry out regular observations for the Nainital-Cape survey work at ARIES, a new high speed three channel photometer was developed and fabricated (Gupta et al. 2001; Ashoka et al. 2001). Such photometer is required for obtaining reliable and continuous time series data even under moderate sky conditions. The detector is a Hamamatsu R647-04 PMT made for photon counting applications at low light levels. The tube is blue sensitive with S–11 response with quantum efficiency peaking to 30 % around 400 nm. Further details of the instrumental parameters are published by Ashoka et al. (2001). This photometer has contributed significantly to the discovery of new variables in the survey (Joshi 2005; Girish 2005).

6.2 Imaging polarimeter

An Imaging Polarimeter has been commissioned for use with liquid-N_2 cooled CCD camera and is designed to suit 104-cm Sampurnanand telescope with f/13 focus at ARIES, Nainital (Rautel et al. 2004). A f/13 beam from the telescope falls on the field lens which in combination with camera lens makes image of the object at the CCD chip. In between the field lens and camera lens a rotatable half-wave plate (HWP) and a Wollaston prism are mounted. The rotatable HWP gives components of electric vector polarised orthogonally of varying intensities after emerging out of the Wollaston prism. The axis of the Wollaston prism is aligned to north - south axis of the telescope and the HWP is placed in such a way that the fast axis of the plate is aligned to the axis of the prism. Fast axis of the plate and axis of the prism are kept normal to the optical axis of the system.

The instrument measures the linear polarisation in broad B, V and R band and has a field of view $\sim 2'$ arcmin in diameter. The instrumental polarization is $\sim 0.04\%$. The instrument can therefore measure the linear polarization of different celestial objects having the polarization more than 0.1%. The instrument can be used to carry out all sky survey observations.

6.3 1k × 1k CCD Camera system

A high performance Liquid Nitrogen cooled 1k × 1k CCD camera system has recently been acquired to be used with 104-cm Sampurnanand telescope. The camera will cover a field of around 7 arcmin in diameter and has QE $>$ 90% at 500 nm, 30% at 350nm, 20% at 90nm and $>$ 80% between 480-750nm. The read out noise is 4 electron rms with full well capacity of around 200 kiloelectron. This camera with high quantum efficiency and low read out noise, ever acquired at ARIES, is likely to enhance the overall observing efficiency of the telescope by 10 to 20 %. The sensitivity of the detector in ultraviolet region would be most suitable for studying the star forming clusters and galaxies. Furthermore, its capability to take short continuous exposures of the order of tens of millisecond will be useful for monitoring the optical light variation in $X-$ray binaries and other short period variables.

7. Proposed observational facilities

Not only do the activities mentioned above demonstrate the range of new science that can be achieved but they also help to formulate the requirements for future instrumentations and facilities. Creation of a number of new observational activities has therefore been proposed at ARIES in both astrophysics and atmospheric science. They are briefly described below:-

7.1 Atmospheric science

Observational facilities to be installed at Manora Peak, Nainital for the studies of middle Earth atmosphere are atmosphere lower thermosphere airglow photometer; ST Radar; a Lower atmospheric wind profiler; millisecond pulsed LIDAR and a dual frequency GPS receiver. The objective of these facilities will be to study gravity wave propagation, mesospheric temperature variability, convection, tropopause variations, vertical wind velocities and the type of precipitating systems that prevail over the region. The data could also be used in atmospheric modelling studies.

As part of the climate studies initiative in India, ARIES is likely to be linked to a network of atmospheric radars being envisaged by ISRO, which would be linked to ISRO's Mesosphere, Stratosphere and Troposphere Radar facility at Gadanki, near Tirupati.

7.2 Optical astronomy

Existing 2-m class optical telescopes in the country are oversubscribed at least by a factor of 3. The number of academic staff and students at ARIES are growing continuously but slowly. In order to meet their need of optical observations, we would like to install a new 3.5-m class optical telescope and another 130-cm telescope at Devasthal site, described below.

7.2.1 *Devasthal: An excellent national site for optical astronomical observations*

The importance of good astronomical sites for locating any modern optical telescope can not be overemphasized. It is of paramount importance. The light pollution at Manora Peak, the existing site of ARIES, has increased significantly in recent times. Seeing at the

Figure 8. A view of 52-cm telescope installed at Devasthal for seeing and atmospheric extinction measurements

present site has also deteriorated. Therefore, a site survey work to select a suitable site in Kumaon and Garhwal regions of Shivalik Himalayas (Northern India) for setting up future observational facilities was initiated in 1980 and has continued over a decade. As a result of this extended survey, Devasthal was selected for further investigations. It has been found that Devasthal has over 200 spectroscopic nights in a year out of which about 80% are of photometric quality. The details of the site characterisation are published by Sagar et al. (2000) and Stalin et al. (2001). The median ground level seeing is about 1.1 arc sec and from the microthermal measurements it is found that the seeing will be sub-arc second for most of the time if the telescope is located at a height of about 12 metres from the ground. During night, relative humidity is generally below 60 % while wind speed is below 20 km/hour and temperature variation is within 2 degrees. 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 the peak is about 2500 metres, while longitude and latitude are 79°, $40^{'}$ $57^{''}$ E and 29°, $22^{'}$ $6^{''}$. Thus it is logistically simple and easy to manage from the present location of ARIES. At the same time sky is dark. For characterization of seeing and atmospheric extinction at Devasthal, the 52-cm telescope was installed. A view of the setup is shown in Fig. 8. About 4.5 hectares of land at Devasthal site has already been acquired by ARIES for installing modern optical telescopes.

Construction of a 6-m wide, 3.5 km long road leading to Devasthal is in progress. The place has already been connected with Manora Peak by a high speed 2.4 GHz Microwave link having a bandwidth of 14 Mbps. High tension power line is being installed at the Site.

In order to achieve the scientific goals of ARIES, both optical and near-IR observations are needed. Some time they are even required simultaneously. Considering the various factors like scientific need, (S/N) ratio for an object of given brightness for a particular exposure time, cost and time frame involved in installation, a telescope of about 3.5 metre diameter will be able to cater to our immediate needs. The telescope will be a state-of-art system. It will have relatively faster RC Cassegrain focus and an alt-azimuth mounting. It will be housed in a modern building designed to minimise the seeing degradation.

In addition to above, ARIES plans to install a 1.3 meter optical telescope at Devasthal by the end of 2007. This will not only cater to the immediate need of the Institute but also provide valuable experience for the proposed 3.5-m class optical telescope. Both the telescopes will be equipped with the state-of-art back-end focal plane instruments so that their observing capabilities can be optimized.

7.3 Space astronomy

India is entering space astronomy in a big way, with it's first muti-wavelength astronomical satellite ASTROSAT scheduled for launch in 2008. This satellite will carry instruments for optical, ultraviolet and X-ray astronomy. Prior to this, the Indo-Israeli ultraviolet astronomy experiment TAUVEX is to be launched by ISRO aboard the geostationary satellite GSAT-4. ARIES would like to make best use of the opportunities in space astronomy that will be opened up by the TAUVEX and ASTROSAT missions. We would therefore like to actively participate in these projects, help software development for data reduction and analysis, and undertake ground-based optical follow-up observations. This experience with space astronomy will enable us to use data also from missions launched by other nations, including optical telescopes in space, significantly expanding the scope of science problems that be addressed.

8. Conclusions

Together with other astronomical institutions in India and abroad, ARIES is playing a useful role in the promotion of pure scientific research. The optical observations carried out at ARIES are well recognised both nationally and internationally. Setting the agenda in astronomy, the decadal Vision Document 2004 published by the Indian Academy of Scienes, Bangalore states that the unique contributions that ARIES can make are in the area of studies of galactic and extragalactic variables, all sky polarisation survey, optical identifications of radio and space born sources, optical observations of high energy transient events and in the studies of star formation and stellar evolution. Scientists from ARIES have close interactions with other national observational facilities such as GMRT, the 2-m HCT at Hanle and the 2.34-m VBT at Kavalur. ARIES has already been invited/commissioned to carry out ground-based observations for the India-Israel satellite-based astronomy project called TAUVEX and the upcoming ASTROSAT, first Indian multi-wavelength astronomy satellite. The on-going aerosol characterization will contribute significantly to the ongoing ISRO-GBP Aerosol Climatology and Effects Project.

ARIES aims to play a major role in generating the much-needed highly skilled manpower by implementing appropriate research projects in the areas of astrophysics and atmospheric science. The Institute would therefore like to expand its ongoing collaborative programmes with universities and research institutions.

Thus with its dedicated staff and expanding research facilities, ARIES is expected to make an increasingly valuable contribution to the country's scientific and technological development by attracting young talented students and faculty. Research work in the experimental wing of ARIES is expected to lead to useful applied fallouts specially in the field of electronics, software and Information Technology.

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