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PRL Mt. Abu Observatory: New initiatives

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Abstract. We discuss some of the science goals with two new facilities being created by PRL at the Mt. Abu Observatory. The first one is a wide-field near-infrared camera and spectrograph (NICS) that uses a HAWAII-1 1kx1k detector array. With its improved sensitivity and spectrographic capabilities, NICS appears to be well suited for studying star forming clusters to determine the ages and the low mass end of the initial mass function. Investigations will be continued on the photometric and spectrographic evolution of recurrent novae and on AGB/Post-AGB stars using this new instrument. The second facility being created is a high-precision, high-resolution spectrograph for detecting extra-solar planets by monitoring radial velocity variations in nearby stars. A velocity resolution of $\sim$ 3 - 5 m/s is expected to be achieved, which may be sufficient to detect 10 M_{Earth} planets and a number of Jupiter-mass planets. We describe both the instruments and discuss science programmes that we intend to take up at Mt. Abu.

Keywords : instrumentation: photometers, instrumentation: spectrographs, techniques: radial velocities, novae, stars: AGB and post-AGB, planetary systems

1. Introduction

The 1.2 m Infrared Telescope at Mt. Abu is situated at the geographic location of Lat.: 24.65 N; Long.: 72.78 E; and Alt.:1680 m with an astronomical seeing of $\sim$ 0.9 arc sec (best); and a median of $\sim$ 1.2 arc sec. Instruments built at PRL and currently operational are as follows:

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1. Two Channel Fast IR Photometer for lunar occultation;
2. Fibre-linked Astronomical Grating Spectrograph;
3. Scanning of IFPS for velocity fields using optical and infrared emission lines;
4. Optical Polarimeter;
5. A near infrared camera and spectrograph (NICMOS) 256x256 MCT Array Imaging with 0.5/1.0 arc sec per pixel in a FOV of 2/4 arcmin R = 1000 spectroscopy.

Using these instruments we have been studying Near-Infrared Photometry of Star forming regions; Near-IR Photometric and Spectroscopic light curves of novae; Spectroscopy of AGB and Post-AGB stars; velocity mapping of galactic planetary nebulae and HII regions, polarimetry of comets, high angular resolution studies of giants using lunar occultation technique in the infrared region, and Extragalactic Astronomy. We list below some of the highlights of Mt Abu results (see for details and references, Anandarao & Banerjee 2005)

2. Highlights of science from Mt Abu observatory

- Detection of a helium nova;
- Understanding Peculiar Novae V838 Mon / V4332 Sgr;
- Dust and Molecular Formation in Novae;
- Detection of structure and asymmetry in the carbon star IRC10216;
- Detection of H2 outflows from the low mass YSO RNO 91;
- Detection of H2 in massive star forming regions IRAS 06061+2151;
- Detection of Quadrupolar Lobes in Planetary Nebula NGC 4361;
- Velocity Field Mapping in the HII region in M8;
- Detection of dust features in Elliptical Galaxies;
- Dust properties from polarimetry of Comets.

In sections 2.1 and 2.2, we discuss in some detail, some of the important contributions from NICMOS camera at Mt. Abu.

2.1 Studies on Novae: V445 Puppis, A Helium Nova and RS Ophiuchi

An unusual and enigmatic nova, V445 Pup was discovered on 30 Dec 2000, at the Mt. Abu Observatory. The striking feature of this nova was the absence of hydrogen lines. Theoretically, it is possible that in the nova binary the mass accreted on the wite dwarf (WD) becomes Helium-rich by several cycles of mass loss; eventually causing a He-shell flash. This may give rise to a Helium Nova that is devoid of Hydrogen lines; but rich in Helium and Carbon lines. The WD may accrete sufficient mass to trigger a collapse to become a neutron star and eventually a Type Ia Supernova. Near Infrared Spectra from Mt. Abu Observatory confirmed Hydrogen deficiency. This is the first observed helium nova (Ashok & Banerjee 2003 and references therein).

Another very important result in novae research done at PRL was the detection of a shock wave in a Recurrent Nova (RN) called RS Ophiuchi. This RN underwent five previous outbursts; the latest outburst being on 12 Feb 2006 which was studied extensively from Mt Abu. Shocks are generated from the interaction of the ejecta from the white dwarf with the wind of the red giant companion. Theory predicts two distinct phases in the time evolution of shock velocity, (i) the free-expansion phase during which the V_s = constant and (ii) the decelerative cooling phase during which $V_s \propto t^{0.5}$. A shock wave was detected in RS Oph, as inferred through the narrowing of emission lines, with the velocity evolution consistent with shock models. The observations show that the mass of the white dwarf in RS Oph is close to the Chandrasekhar limit, indicating that it could be a potential supernova candidate in the future. This is the first report on infrared signatures of shock waves in RNe (Das, Banerjee & Ashok, 2006).

2.2 Infrared Spectroscopic Study of AGB and Post-AGB Stars

A sample of over 80 stars was observed in spectroscopy in the H and K bands (and for some in J band too), using the NICMOS Camera at Mt Abu 1.2 m Telescope. A correlation was found between the equivalent widths (EW) of the CO (3-0) line (in H band) arising in photospheres and the [H-K] or [K-12] colours, indicating massloss due to pulsation process in M type AGB stars. The EW of CO (3-0) is thus a new massloss index. Variability in spectral lines was found in some PAGB stars indicating on-going episodic mass loss with as small intervals as a month; cooler PAGB stars showed variability in CO first overtone bands, while hotter stars showed in HI lines. Modelling of Circumstellar Shells in AGB/PAGB stars showed evolution of massloss rates as the AGB stars approach the PAGB phase (Venkataraman and Anandarao, 2008).

3. A new wide-field near-infrared camera and spectrograph (NICS)

Science Goals:

Photometric Imaging of Star Forming Regions for low mass, initial mass functions;

Light Curves of Novae, FU Ori/EX Ori type objects;

Spectroscopy of Novae, AGB/PAGB Stars, FU Ori/EX Ori type objects.

Configuration of NICS:

- Field of View (FoV) is 8 x 8 sq.arcmin (unvignetted); Pixel Scale of 0.5 arcsec/px;
- Broad-band filters Y, J, H, K, Ks (Mauna Kea standard) and narrow-band filters for Br γ and H_2 1-0S(1) lines and very broad-band filters IJ, JH and HK for combined extended spectroscopy;
- Rotatable Grating/Mirror assembly for spectroscopy and imaging: Grating 150 l/mm; Blazed at 2 mum;
- Spectral Resolving power R > 1000;
- Lenses are of different materials with ARC for entire range of wavelengths: R > 90-95 %;
- A Pupil Mask is used for reduction of extraneous noise especially in K band.

HAWAII-1 focal plane array of 1024x1024:

- Pixel Size = 18.5 μm;
- Detection range $\lambda\lambda$ 0.85 - 2.50 μm;
- Quantum Efficiency at 77K, 2 μm is 65;
- Dark current (at 77 K) < 1.0 e^-/s;
- Read Noise = 15-20 e^-;
- Full Well Capacity = 1.3×10^5 e^-;
- Electron Gain = 5.

The details of optical design are given in Anandarao et al. (2008).

From observations of photometric standard stars at Mt Abu, we obtain a photometric accuracy < 0.1 mag in all 3 bands; Zero Point Mags: J = 19.87; H = 20.06; K = 19.50. The sensitivity limit is found to be 11.3 mag in K band in 1 sec with S/N = 3.

Spectroscopy can be done at a dispersion of $\sim$ 9-10 A/pxl and 2 bands can be recorded simultaneously.

4. PRL Advanced Radial Velocity All-sky Search (PARAS)

Rationale: Exoplanet science, and more generally the search for life on other worlds, is a recent field, yet one that corresponds to one of the most ancient quests of humanity, and one which has perhaps a very strong visibility (a positive image) among the general public. Till today astronomers have found more than 300 planets around stars and it is very clear that the goal of spectroscopic characterization of the atmosphere of habitable planets, in search of biomarkers, will ultimately require one or more very ambitious and innovative missions. Direct imaging of planets is the greatest challenge astronomers face today and is an extremely difficult task. The Radial Velocity (RV) technique (the most successful indirect planet detection technique and the only one that gives all the orbital parameters)

The salient features of PARAS are as follows (Chakraborty et al. 2008):

- Fiber-Fed Spectrograph with R $\sim$ 70000;
- Wavelength coverage 370 - 850 nm;
- Built to be very stable against environmental variations (under vacuum $\sim 10^{-2}$ mbar with temperature control up to $\pm$ 0.02 C);
- Star and Th-Ar on two different fibers;
- Scramblers will be used for ensuring spectrograph slit illumination to be very stable;
- Fibre accepts a sky angle of 2.35 arcsec with a seeing disk of 1.1 arcsec;
- Data Pipe line software being tested (in collaboration with Suvrat Mahadevan of Penn State U.)

Main Science Goals for PARAS are

(i) to search for planets around a sample of $\sim$ 1000 Dwarf main-sequence stars of G, K, M type within a radius of 50 pc (in 5 yrs). This includes the search for Neptunes ($\sim$ 20-Earth Masses) in the Habitable zone;

(ii) RV detection of non-transiting planets in KEPLER field (105 sq. deg.) and follow-up confirmation and science for Kepler space mission and Marvels (Sloan 2.5m telescope - 10-20 m/s);

(iii) determining the direction of the planet orbit w.r.t. the stellar rotation axis for transiting planets using the Rossiter-McLaughlin effect; and

(iv) to search for planets around bright A & F dwarfs and G,K giants

Other Relevant Sciences include: High resolution variability studies of young stars to detect transient events like comet/asteroid in-fall etc (Chakraborty et al. 2004) and to determine metallicity of Planet Candidate Stars.

The proposed PRL radial velocity Survey from 1.2m at Mt. Abu is expected to give 3-5 m/s on 10th mag stars. First light is expected early 2010. A RV accuracy of 1 m/s is possible on a 10th mag star with Telescope of aperture $\sim$ 1.8m. In comparison HARPS has RV detection capability < 1 m/s at present.

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References

Anandarao B.G., & Banerjee D.P.K., 2005, in Proc. Symp. "Infrared and Optical Astronomy at Mt Abu Observatory: the past decade and the future", PRL, Ahmedabad, 2004, BASI, 34, 75

Anandarao B.G., Richardson E.H., Chakraborty A., & Epps H., 2008, SPIE 7014, 70142Y-70142Y-8

Ashok N.M., & Banerjee D.P.K., 2003, A&A, 409, 1007

Chakraborty A., Ge J., & Mahadevan S., 2004, ApJ, 606, L69

Chakraborty A., Richardson E.H., & Mahadevan S., 2008, SPIE, 7014, 70144G-70144G-6

Das R.K., Banerjee D.P.K., & Ashok N.M., 2006, ApJ, 653, L141

Venkataraman V., & Anandarao B.G., 2008, MNRAS, 409, 1007