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A BRIEF REPORT ON WET OBSERVATIONS FROM INDIA

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Abstract. WET observations from the Vainu Bappu Observatory at Kavalur made in 1988–1993 are described. They include the following stars: AM CVn, G 29–38, PG 1159–035, GD 358, V471 Tau, BG CMi and RXJ 2117+34.

Key words: methods: observational – techniques: photometric – stars: white dwarfs – stars: oscillations – stars: individual: AM CVn, G 29–38, PG 1159–35, GD 358, V 471 Tau, BG CMi, RXJ 2117+34

1. Introduction

Our participation in the WET network had an unexpected beginning. Sheer fortune played an important role. In late 1984, we saw a paper by Patterson et al. (1979) in which the 1051 s period of AM CVn was stated to be increasing at a rate of 0.012 s per year. And more importantly, we did not see the later analysis of Solheim et al. (1984) in which the results of Patterson et al. were shown to be wrong and that the 1051 s period was in fact decreasing rather than increasing! Thanks to our poor literature awareness (!) and hoping (beyond hope!) that we might indeed be able to contribute towards a determination of the period derivative, as well as for the sheer pleasure of witnessing oneself the light variations from two interacting white dwarfs, we decided to include AM CVn into our list of targets for observations in 1985.

Besides, since the object is not too faint for our 1 meter telescope ($V \sim 14.1$) and because its RA ($\sim 12^{\,h}$) allowed us to observe it continuously for several hours during the "so-called" good observing season at Kavalur, which allowed us to observe several cycles of its oscillations on a single night, we were quite happy to start observations in February 1985. Because the object is helium-rich and hydrogen poor, we also dreamed to present the results in the meeting on hydrogen-deficient stars in Mysore in late 1985.

In our February 1985 observations, we detected some flaring activity on the star and were obviously thrilled by it. When we started the Discrete Fourier Transform analysis to search for the periods in the system, we had a number of doubts to get clarified. Then at the IAU meeting in Delhi, we had our first encounter with some of the pioneers of AM CVn observations and analysis of time series data: Jan-Erik Solheim, Don Winget, Kepler and Don Kurtz. In a corridor meeting, we were shown the WET plans and proposals. At that time, we were perhaps the only people in India having some experience and interest in time series photometry.

So we were given an option to join the network. However, since Dr. Parthasarathy of the Indian Institute of Astrophysics, a former Texas student, was more closely known to the WET team, we really postponed our decision for a later date, not wanting to deprive him of the first option. We were convinced that if we wanted other colleagues to believe the flares, dips, eclipses and oscillations in our light curves, we must have simultaneous recording of the light curve of a nonvariable star, close to the target star. Therefore, we started designing our two-star photometer.

Ashoka joined our team in early 1988 and Jan-Erik Solheim visited our center around the same time. During the discussions that followed, it became clear to us that we should join the WET team, because Parthasarathy was too busy with his spectroscopic work, and time series photometry was clearly an area more to our liking. Jan-Erik Solheim wrote the minutes of our meeting and told us that he would persuade Ed Nather to come to India and tell us how to use the interface card and his famous QUILT program.

Fortunately by the time Ed Nather and Chris Clemens came to India in September 1988, the fabrication of our own two-star photometer was nearing completion. It had actually not been tested completely. We were indeed very scared to assemble the photometer in front of strangers but we had no option. The sky was clear for hardly an hour in the evening, and in his characteristic encouraging style, Ed Nather gave us a certificate of "pass" after his "Fabry check" of the two channels separately. By that time clouds rushed in. All of us waited till midnight. The clouds wouldn't go unless Ed and Chris took some rest, which they badly needed after the long journey to India and the hard work in our lab in Bangalore. So they retired soon after midnight. And by early morning, the clouds disappeared for about an hour again, and at that time we could get one star in each channel and record the data simultaneously using the interface card and the QUILT software – everything worked. We were very thrilled, indeed.

In November 1988, we applied for time for our first WET run on V471 Tau and G 29–38 and got some real two-channel data for the collaboration. We were "adopted" by this time as members of the WET family.

In retrospect, we like to think that the stellar connection through AM CVn brought us into the WET collaboration – who can say anymore that "the stars do not decide our future"!

Seetha received an opportunity to work with the WET team at the University of Texas for nine months from May 1989 onwards. This visit allowed her to concentrate on a single topic (which is often not the case here) and learn several new ideas which could be passed on to her colleagues here after her return. She analyzed the data on G 29–38, PG 1159–035 and GD 358 and their respective second channel stars. The second channel data were used to eliminate the background from the main star data.

From a comparison of the total power contained in each of the above stars, it was estimated that if the driving mechanism is assumed to be due to partial ionisation of hydrogen for DAVs, then the results indicated that the driving in DBVs is due to helium partial ionisation and that in DOVs it is due to partial ionisation of carbon/oxygen rather than to nuclear reactions. Also, the limits of amplitude in the power spectrum indicated that the driving occurred in the top layers of the above three stars. The highest and lowest observed period limits in the power spectrum were used as an estimate of the thermal timescales of the boundary layers of the driving region.

These layers can be specified in terms of mass layers of the star, i.e., a layer n is identified by M_n, where M_n is the total mass contained above this layer. With this definition, the position of the outer layer and inner layer of the driving region are respectively as follows in the units of stellar mass: for G 29–38 (DAV) it is between 7×10^{-14} and 4×10^{-12}, for GD 358 (DBV) it is between 6×10^{-12} and 2×10^{-10} and for PG 1159–035 (DOV) it is between 4×10^{-8} and 10^{-7}. The values for G 29–38 are commensurate with the theoretical models of DAVs and that for GD 358 agree with the models which indicate that a thickness of the helium layer for this star is $10^{-6}\, M_{\odot}$.

The above analysis was later used for her Ph.D. thesis, entitled "White dwarf pulsators – a study with the Whole Earth Telescope" (1991), the first thesis from the WET program.

Table 1. A log of Kavalur observations in the WET campaigns during the past 5 years

WET campaign	Telescope	Allocated nights	Objects	No. of hours of data collecting
Nov 1988	102 cm, VBO*	Nov 8–20	G 29–38	0.7
			V471 Tau	17.0
Mar 1989	102 cm, VBO	Mar 5–7	PG 1159–035	5.0
Mar 1990	234 cm, VBO	Mar 22–24	AM CVn	4.0
	102 cm, VBO	Mar 25–26	AM CVn	4.0
May 1990	102 cm, VBO	May 19–21	GD 358	—
	234 cm, VBO	May 22–27	GD 358	—
Feb, Mar 1992	234 cm, VBO	Feb 26–28	BG CMi	20.0
	102 cm, VBO	Feb 29–Mar 03	G 226–29	10.0
Sep 1992	102 cm, VBO	Sep 24–25	RXJ 2117+34	—
Mar 1993	102 cm, VBO	Mar 21–24	PG 1159–035	10.0
	234 cm, VBO	Mar 23–24	PG 1159–035	10.0

* VBO: Vainu Bappu Observatory, Kavalur.

2. The two-star photometer

Fig. 1 shows a schematic diagram of the photometer (Venkat Rao et al. 1990). The main channel employs a conventional design. It consists of a 45° flip mirror M1 that reflects the incoming beam to a wide angle eyepiece of 50 mm aperture. The latter provides an 8 arcmin field of view at the $f/13$ Cassegrain focus of the 102 cm telescope at the Vainu Bappu Observatory, Kavalur. A set of selectable diaphragms of diameter 10.1, 13.6, 17.5, 24.0, 32.5 and 79.0 arcsec are provided on a diaphragm wheel. A retractable prism-microscope arrangement is used for verification and centering of the program star. A set of six selectable filters of 22 mm diameter each is placed on a filter wheel below the diaphragm. At present, the wheel carries filters which are equivalent of Johnson's U, B, V, R and I filter system. The U filter used by us has no red-leak. A detachable photomultiplier tube (PMT) housing carries a Fabry lens and an uncooled RCA 31000M tube in the main channel.

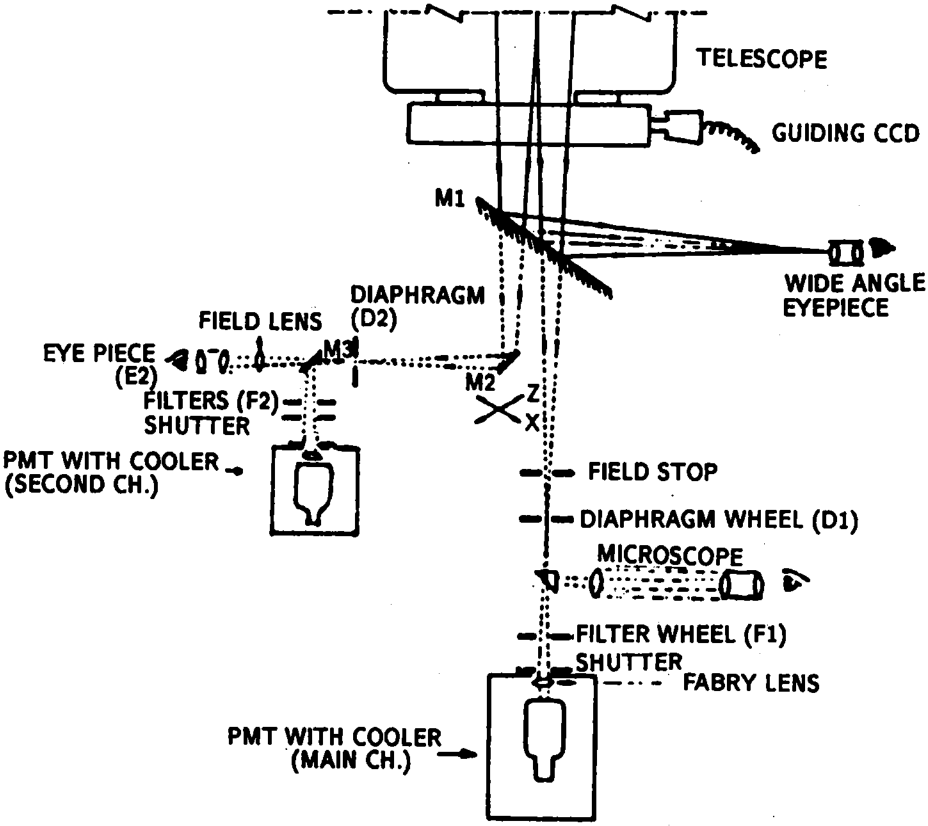

Fig. 1. A schematic diagram of the photometer.

The second channel consists of a cylindrical tube that carries a tiny mirror M2 at one end placed at 45° to the incoming light from the telescope, a flippable semicircular plate D2 having two diaphragms of 14.5 and 24.5 arcsec diameters, another retractable mirror M3 kept at 45° to the light beam reflected by the mirror M2, a field lens and an eyepiece E2 at the other end of the tube. The whole cylinder is mounted on a movable bench that provides X and Z motions such that a field of 8×4 square arcmin may be scanned in the focal plane to pick up the second star. The mirror M3, when pushed in, deflects the beam through a set of filters F2 onto the fixed PMT housing that carries the Fabry lens and an uncooled RCA 8850 tube. When the diaphragm is flipped out, an unvignetted field of 2.5×2.5 square arcmin in the eyepiece E2 enables us to pick up the second star easily and to center it within the diaphragm in this channel. The PMT housing is permanently fixed and hence the differential flexure between the main and the second channel is negligible in our novel design. The PMT outputs are fed to interface through EG&G PARC (discriminator/amplifier) model 1182.

We have recently modified our photometer by attaching a CCD guiding unit which uses an EEV intensified CCD. The CCD is mounted on a movable X/Y tube to pick up a suitable guide star whose image can be seen on a PC monitor, with which the guiding can be done very accurately and comfortably.

3. Future plans

Having talked so much on the past let us look a little into the future. On the analysis front we would like to analyze some of the future data on white dwarf pulsators to confirm the driving mechanism and the region of driving. We might in the process also improve on the analysis techniques used in Seetha's thesis.

We also have plans to apply the cleaning techniques to power spectra of single site data and to compare it with the overall WET resolved spectral data to evaluate the capability of these techniques. For this purpose, a few of the methods to be tried would be prewhitening, clean algorithm, etc.

On the instrumentation side, we have been working on the fabrication of a three-channel photometer. This has, however, not been moving as fast as we would like it to be (as is usually the case). We would, however, very much like to lay our hands on the "PHATPHOT" which must have undergone finer/longer quality control checks under the watchful eye of Ed.

A 1.2 meter IR/optical telescope is currently being installed at Gurushikhar (Mount Abu) in Rajasthan, where the number of photometric nights per year is estimated to be at least twice than that at Kavalur. When this telescope becomes operational (in 1994), we hope to get more nights for WET campaigns from there.

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