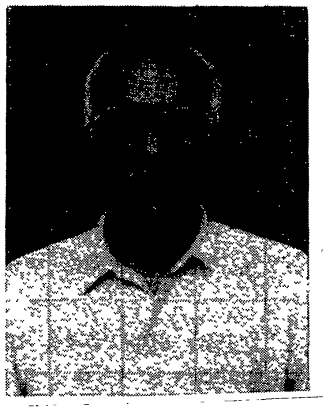
Bull. Astr. Soc. India (1997) **25**, 301–307

Silver Jubilee Article



My experiences as an astronomer and a survey of binary star research carried out at CASA

M.B.K. Sarma

Department of Astronomy, Osmania University, Hyderabad 500 007, India

I was introduced to the field of Astronomy and Astrophysics by my Ph.D guide, Prof. R. Satyanarayan, Head of the Department of Physics, Osmania University. He worked for his Ph.D degree at the Royal College of Science, London, under the guidance of Prof. R.W.B. Pearse, who introduced him to the astrophysical applications of the work suggested to him. I continued his work wherein the effect of pressure on the broadening of spectral lines was studied. Heavily condensed discharges were passed through different metal / gas electrodes situated in a vacuum chamber. The enclosed pressure was increased systematically upto one atmosphere by admitting air / gas into the chamber. As the pressure was increased it was noticed that sharp spectral lines became broad and finally at some pressure, all the lines were broadened to such an extent that they merged with each other and into the continuum. Since the spectra of Wolf - Rayet stars contains very wide spectral lines and intense continuum, our idea was to explain this wide spectrum of the W-R stars as mainly due to pressure and not due to high velocities of ejection. Once Dr. C.D. Deshmukh, former central Finance Minister and the then U.G.C. Chairman visited the Physics Department of the Osmania University and showed interest in our experiment. When my guide explained to him the main aim of the experiment and its possible application to W-R spectra, Dr. Deshmukh reasoned that since it was known that the pressure of stellar atmospheres was not as high as we were using in the laboratory, how one could apply these results to stellar spectra! Such was the inquisitive nature of Dr. Deshmukh! My thesis on "Selective pressure broadening of lines of ionized atoms" was sent to Prof. L.H. Aller, as the foreign examiner in 1958 and I was awarded the Ph.D degree in 1959. I met Prof. Aller at the IAU meeting at Berkeley during 1960. When he saw my name on a card on my shirt pocket, he immediately remembered my thesis and discussed the results. What a remembrance!

I worked as a guide to the visitors of IAU - 1960 to the MT Hamilton (Lick Observatory) and it was during this time that I first met Prof. Vainu Bappu. He took more interest on the 36 inch Crossley reflector and asked me to obtain the drawings (or draw myself) of the Crossley dome and its working mechanism. He suggested that our telescope (48 inch) at Rangapur might be provided with a similar dome. From that time onwards, Prof. Bappu remained as my

friend and advisor. Once I worked with him for one month at Kodaikanal, with the new Photo Electric Spectrum Scanner, on A type stars. After IIA was established, he expressed his wish for a close collaboration between our Department and IIA. He was very happy when the Ph.D thesis of Dr. M. Parthasarathy turned out to be one such project. The photometry of HU Tau, which formed a part of Dr. Parthasarathy's thesis was carried out by me and Dr. Parthasarathy at Nizamiah Observatory and the spectroscopy was carried out by Dr. Parthasarathy at Kavalur.

I was appointed as Assistant Astronomer in 1958 and was deputed by the Osmania University to visit USA, under the Wheat Loan Programme, and get training on the reflector telescopes so that our new 48 inch telescope would be used better. This telescope was also gifted to Osmania University under the Wheat Loan programme. I first worked with Dr. Seyfert and Dr. Hardie at the Arther Dyer Observatory of Vanderbuilt University, Nashville, Tennesse. Here, I faced some unsavoury problems (connected with the colour of my skin) and the Department of State, USA, under whose invitation I had visited that country, shifted me to Lick Observatory. At that time Dr. Whitford was the Director of the Observatory. Once every year, in summer, the Whitfords gave, 'at home' to the new-comers on the mountain and I attended, the 'at home' during the summer of 1960. My stay of one year there was very fruitful. I worked with Drs. Wallerstein (Berkeley campus), Walker and Herbig and published three papers in ApJ and PASP. During my visit to Sydney, Australia in 1972, for attending the IAU meeting, I met the Whitfords again, after a gap of about 12 years but the moment they saw me they recognised me and remembered the names of all the others who had attended the get-together party on the mountain in the summer of 1960!

After returning to the Astronomy Department from USA, I started teaching B.Sc. and M.Sc classes. At one time, Prof. Abhyankar and I were the only teachers for six batches of students (3 B.Sc and 3 M.Sc). The teaching load was so heavy that the University was prepared to pay us an extra allowance. We declined this offer and instead requested the University to appoint two M.Sc final year students as part-time lecturers to teach B.Sc practical classes. This was agreed to and appointments were made accordingly. This might have been the first and last time for the university to appoint M.Sc students, as part-time lecturers!

The site survery for the 48 inch telescope had started before my departure to USA, with Prof. Abhyankar's and my visits to many prospective sites around Hyderabad. By the time I returned, after two years, the survey was over and the present observatory site was chosen. Prof. Abhyankar and I along with a few students and staff, completed the necessary final tests. By the time, the installation of the 48-inch telescope had started in 1965, the construction of the buildings, guest house and staff quarters were ready for occupation. Prof. R.V. Karandikar took over as the Head of the Department and Director of the Observatories and got the installation of the 48-inch telescope completed by 1968. The Fecker Engineers, who had supplied the 48 inch telescope, had come from USA to install the telescope.

Even though the installation was over, it was after Prof. Abhyankar had taken over charge from Prof. Karandikar in 1973, that regular observations started with the 48-inch telescope. In the process of observations it was noticed that the telescope drive was not perfect and that the motion of the dome which was constructed by a local firm, was very tardy. Moving the

telescope and dome from one direction to the other was found to be very time consuming. Hence it was felt necessary to choose observational projects that needed limited motion for both the dome and the telescope. Since study of binary stars was of great astrophysical importance and by chance such projects satisfied the above condition, it was decided to observe binary stars.

Prof. Abhyankar, Prof. Sanwal and I alongwith some students worked together, initially, for getting the telescope in working condition and once the tricks of the trade were known and research scholars joined the Ph.D courses, we selected individual programmes.

Even though we had our own students, Prof. Abhyankar and I along with our students used to work together as one single unit and even today the same practice is continuing. Prof. Abhyankar was always helpful and gave many helpful suggestions during the course of my research career. He still continues to do so. I will always remain grateful to him for his benevolence.

We shall now survey the studies of binary stars conducted at CAS in Astronomy. The 15-inch Grubb refractor at the Nizamiah Observatory campus, Begumpet, Hyderabad and the 48 inch reflector telescope at Japal-Rangapur Observatory, 60 km south-east of the Osmania University Campus, were used by the staff and students of the department for training and research purposes. These telescopes were provided with photoelectric photometers having 1P21, EMI 9502B and EMI 6256B photo multipliers, GR 1230 A DC amplifiers and Honeywell Brown chart recorders. After 1983, an EG and G ortec photon counter was provided for the 48 inch telescope. Standard UBVRI filters were used at the telescopes. Research scholars and Sri B.D. Ausekar, Research Assistant, had participated in the observational and reduction programmes. Our study of the binary systems can be divided into the following 5 categories.

A. Study of RSCVn Systems

V 711 – Tau = HR 1099 : This non-eclipsing RSCVn type binary was studied during the observing seasons of 1978 - 82. A migration period of the spots of about 10.5 years was derived from these observations. An unusual active period during 1981 - 82 was noticed. (*AJ*, **83**, 1510, 1978; *Acta. Astr.*, **30**, 101, 1980; *Acta. Astr.*, **31**, 103, 1981; *PASJ.*, **37**, 107, 1985).

SZ Psc : Under an international collaborative programme this RSCVn eclipsing binary was observed during 1980. The combined effort of four institutes made it possible to derive reliable elements of the system.

UX Ari : This non-eclipsing RSCVn system was observed during three seasons of 1975-76, 1981-82 and 1982-83.

From these observations spot-free brightness of the photo-sphere could be derived and the variation of the mean V brightness was found to be due to spot activity and not due to intrinsic variation. (*JAA*, **5**, 159, 1984).

AYCET : The international campaign for observing this long period RSCVn system from fifteen observatories, all over the world, could find multiple periods and amplitudes for the variations of this system. Its complex photometric behaviour was explained in terms of spots, chromospheric activity and a possible activity cycle. (*A&A*, **157**, 1, 1986).

TYPYX : This system was observed during three observing seasons of 1976-79. From these observations new ephemeris were derived. These observations did not show any variation in the depths of the minima or any wave-like distortion outside eclipses which are characteristics of the RSCVn systems. Using Russell-Merrill method the light curves were solved and absolute elements were derived. These observations and analysis formed a part of Dr. Vivekananda Rao's Ph.D thesis. (*Acta Astr.*, **28**, 231, 1978; *Acta. Astr.*, **31**, 107, 1988).

RZEri : Observations of this RSCVn eclipsing binary were obtained in UBV passbands during 1976-79. The analysis of these light curves using Wilson-Devinney method yielded improved absolute elements. From the position of the components on the evolutionary tracks of Maeder and Meynet, for Pop I composition, it was concluded that the evolution of the components of RZ Eri was abnormal. This study formed a part of the Ph.D thesis of Dr. B.V.N.S. Prakash Rao. (*JAA*, **15**, 165, 1994).

UVPSC : This interesting system was observed during 1976-79. By removing the effect of 'RSCVn wave' on the observations, an improved period and absolute elements were derived. Large intrinsic variations of the hotter component were detected. These analyses formed a part of the Ph.D thesis of Dr. P. Vivekananda Rao. (*JAA*, **4**, 161, 1983; *Bull. Astr. Soc. India*, **11**, 75, 1983; *Ap. Sp. Sci.* **99**, 239, 1984).

WYCnc : This system was observed in UBV colours during 1973-74 and 1976-79 and in UBVRI colours during 1984-86. After the observations were corrected for the RSCVn wave, improved period and elements were derived. From the uncorrected light curves, spot modelling was done. Three of the four spot groups detected were found to have direct migration of periods 1.01, 1.01 and 2.51 years and the fourth spot group showed retrograde motion of 3.01 years. This study formed a part of the Ph.D Thesis of Dr. B.V.N.S. Prakash Rao. (*Bull. Astr. Inst. Zech*, **27**, 335, 1976; *Bull. Astr. Soc. India*, **18**, 249, 1990; *JAA* **12**, 225, 1991).

B. Study of algol systems

HUTAU : This bright eclipsing binary was observed during 1970-72. The light curves were solved using Wilson-Devinney method and improved absolute elements were derived. The secondary component which had filled the Roche Lobe was found to be overluminous for its mass of 1.3 $m_{\odot}$. The luminosity of the primary component with a mass of 4.7 m_{O} was found to be equal to that of a star of 3.0 $m_{\odot}$. These studies formed a part of the Ph.D Thesis of Dr. M. Parthasarathy. Ap. Sp. Sci., 72, 477, 1980; *Bull. Astr. Soc. India*, **21**, 601, 1993; A&A, **297**, 359, 1995.

TT Hya : This system was observed during 1973-77 in UBV passbands. The light curves were solved by Kulkarni and Abhyankar using Russel - Merrill method and making a few

assumptions on the mass-ratio, absolute elements were derived. After the spectroscopic mass ratio was published by Popper, the above light curves were reanalysed using Wilson - Devinney method and reliable absolute elements were derived. It was noticed that the secondary component was overluminous and the primary component was underluminous for their masses. This study formed a part of the Ph.D thesis of Dr. A.G. Kulkarni. (*Ap. Sp. Sci.*, **67**, 205, 1980; *JAA*, **2**, 119, 1981; *Bull. Astr. Soc. India*, **22**, 451, 1994).

RCMa : This important binary system was observed during the 1980-81 and 1981-82 observing seasons, both spectroscopically and photometrically. From the observed primary minimal times the elements of a third body orbit were found. From the spectroscopy, the mass function f (m) was derived. Using Russell - Merrill method, absolute elements were derived. These studies were presented in the Ph.D thesis of Dr. K.R. Radha Krishnan. After the mass ratio was available from Tomkin's spectroscopic study, these light curves were re-analysed using Wilson-Devinney method and reliable absolute elements were derived. It was noticed that both the components of RCMa were overluminous, oversized and hotter for their masses. Assuming that the overluminosity of the primary component was due to over-abundance of He ($28\% < y < 100\%$), we derived the masses of the original primary and secondary components of this system as 1.4 $m_\odot$ and 0.73 $m_\odot$ respectively. (*Ap. Sp. Sci.*, **99**, 229, 1984; *Bull. Astr. Soc. India*, **12**, 182, 1984; *Bull. Astr. Soc. India*, **12**, 411, 1984; *Bull. Astr. Soc. India*, **13**, 261, 1985; *ApJ*, **458**, 371, 1996).

EU Hya : This system was observed during 1973-74 and 1977. The analysis of the B and V light curves with Russell - Merrill method by Kulkarni and Abhyankar suggested it to be a detached system while a solution with Wilson - Devinney method suggested it to be a semi-detached system with a photometric mass - ratio of 0.212. The primary component was found to be an F 2 V and the secondary component to be an evolved star of KO - 4 IV spectral types. These observations and analysis with R - M method formed a part of the Ph.D thesis of Dr. A.G. Kulkarni. (*PASP*, **108**, 967, 1996).

RXHya : This system was observed during 1983-87. The light curves were solved by Wilson - Devinney method. Using the mass function and assuming a few properties of the primary component, absolute elements were derived. This study formed a part of the Ph.D thesis of Dr. Motilal. (*A&AS*, **81**, 67, 1989).

RRLep : This system was observed during 1982-87. The light curves were solved by Wilson-Devinney method and assuming a few properties for the primary component, absolute elements were derived. This study formed a part of the Ph.D Thesis of Dr. Motilal. (*A&AS*, **81**, 81, 1989).

RUEri : This system was observed during 1974-76. An improved period of 0.6321995 days, was derived. Using Russell-Merrill method new elements were derived. (*Ap. Sp. Sci.*, **74**, 41, 1981).

C. Other systems

RVCrv : This system was observed during 1971 and from the analysis of the light curves tentative photometric elements were derived. The system was found to be a contact-system. (*A&AS*, **13**, 101, 1974).

WXEri : Observations of this system were made during 1973-1975 seasons. The analysis with Russell - Merrill method yielded photometric elements. The system was tentatively classified as detached with the primary component being an F3 star, pulsating like a delta scuti variable. (*Ap. Sp. Sci.* **65**, 443, 1979).

VCrt : Observations of this system were carried out during 1973-76 seasons. (*IBVS* No. 719, 1972).

TTAur : This system was observed during 1973-77 seasons. Solution of the light curves with Russell - Merrill method yielded improved elements. The system was found to be detached. This study was presented in the M. Phil dissertation of Dr. N. Raja Sekhar Rao. (*Bull. Astr. Soc. India*, **10**, 323, 1982).

D. Analysis of light curves of eclipsing binaries whose data was published by other observers

SVCam : This interesting RSCVn system was observed for seven years by Patkos and these observations were analysed for elements. After removing the effect of the 'RSCVn wave' from the observations, improved elements were obtained using Woods WINK programme. The uncorrected light curves were analysed for spot parameters. The study was presented in the Ph.D Thesis of Dr. C.V.S.R. Sarma. (*Bull. Astr. Soc. India*, **13**, 346, 1985; *JAA*, **10**, 307, 1989; *JAA*, **12**, 49, 1991).

TWAnd : V & B light curves of this Algol type binary made by Ammann and Walter were analysed using Wilson - Devinney method and improved absolute elements were derived. The primary component having a mass of 1.7 m_O appeared to be evolving in a manner similar to a single star of the same mass suggesting that the mass accrued by it, if any, from the Roche Lobe filling secondary had no effect on its evolution. (*Bull. Astr. Soc. India*, **25**, 93, 1997).

AUMon : The yellow light curve of this Algol system, obtained by Lorenzi was analysed using Wilson - Devinney method and improved absolute elements were derived. The primary component, having a mass of 6.0 $m_\odot$ appears to be evolving in a manner similar to a single star of the same mass suggesting that the mass accrued by it, if any, from the Roche Lobe filling secondary component, had no effect on its evolution. (*A&A*, 1996, Communicated).

VVOri : The UBV light curves of this detached eclipsing binary obtained by Duerbeck and Hα (wide) Hα (narrow) light curves obtained by Chambliss and Davan were analysed using Wilson - Devinney method and improved absolute elements were derived. The secondary component was found to have a UV Excess of $0^m.3$. It was also found that while the primary component

had slightly evolved along the main sequence, the secondary component was still un-evolved. (*JAA*, **16**, 407, 1997).

E. Modification and application of synthetic light curve methods (other than Wilson - Devinney)

Eventhough the Wilson - Devinney method was being widely used for solving eclipsing binary light curves, Kopal's frequency domain method and Wood's WINK method were also tried for comparison.

1. The light curves of TT Hya and TT Aur in UBV colours observed by Kulkarni and Abhyankar were analysed using Kopal's frequency domain method with slight modification. This work formed a part of the Ph.D thesis of Dr. Jawahar Kaul. (*JAA*, **3**, 93, 1982).

2. Modifications and improvements to Wood's WINK programme as updated by Wood and Etzel in their "Status Report – 10" of 1983 were made and applied to a few eclipsing binary systems observed at JRO. Also a new computer programme based on Roche model for solving light curves was developed and this programme was christened "Ganesh". While Wood's WINK programme adopted "ellipsoidal model", in Ganesh, 'Roche model' was adopted. Using the above two programmes the light curves of the eclipsing binaries TT Hya, RCMa, TT Aur, and RVCrv were analysed and the derived elements compared. The results illustrate the effect of the differences in "Models", on the solutions. This study was presented in the Ph.D thesis of Dr. M. Kameswara Sarma.

Acknowledgements

Most of the work on RSCVn and Algol systems was carried out with the active participation of Prof. P. Vivekananda Rao. His dedication and determination helped us to successfully complete many projects of the Department. I am thankful to him for his help.

Part of the work on the Algol systems was carried out with the financial assistance from the Council of Scientific and Industrial Research (CSIR), New Delhi, through their Emeritus Scientists scheme. I gratefully acknowledge this help.