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Close binary stars with moderate size optical telescope

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Abstract. We discuss here the role of moderate size optical telescope in the studies of the evolution of close binary stars. The informations about the structure and evolution of the close binary star DI Pegasi, extracted from its photometric observations, taken with 104 cm UPSO telescope are described in brief. Also, discussed are some meritorious research programmes with MSOT for binary star research which may lead to a better understanding of our knowledge about the stellar evolution of single as well as double stars.

1. Introduction

Our knowledge about the evolution of close binary stars is based primarily in our understanding of the structure and evolution of single stars. A combination of observational results obtained from photometry and spectroscopy of eclipsing binaries are used to get relevant stellar parameters such as mass, radius, luminosity, age, chemical composition, apsidal motion rate, etc. These stellar data play a key role in the development of stellar structure and stellar evolution of single as well as double stars. Also, a comparison of these parameters with theoretical models allows us to verify the evolutionary tracks of the star on H-R diagram point by point. The purpose of this paper is to discuss what we have and what we expect from moderate size optical telescope, MSOT, for a better understaning of our knowledge about the evolution of close binary stars.

2. Observational status

Although majority of stars, about 80%, in the solar neighbourhood, within 100 Lyr radius, are members of binary or multiple systems, only 0.2% are the eclipsing binary systems. At present, nearly 10000 eclipsing binary stars have been discovered in our Galaxy and also nearly 300 eclipsing binaries in other nearby galaxies mainly in LMC, SMC and M31. Nearly every type of stars, namely, main-sequence stars, subgiants, giants, supergiants with entire range of spectral types and masses, are observed as the member of the close binary systems. Also, white dwarfs, neutron stars and possibly black holes have been found as the components of the close binary stars.

The compilations of the stellar data derived from the close binaries have been published by several authors such as Popper (1980), Harmanec (1988) Andersen (1991), Webbink (1994) and etc. Accurate data till 1996 with accuracy better than ± 1% in mass, ± 2% in radius and ±10% in luminosity are not available for more than two hundred binary stars. Also, they cover satisfactorily only a range of spectral types between B6 and G5. A distribution of binary components, having absolute dimensions with such accuracy, in mass-radius plane is given in Figure 1. The photometric observations, for example, taken by us with 104-cm telescope and the informations extracted from those observations, for a semi-detached binary system D1 Peg are discussed, in Sections 3.

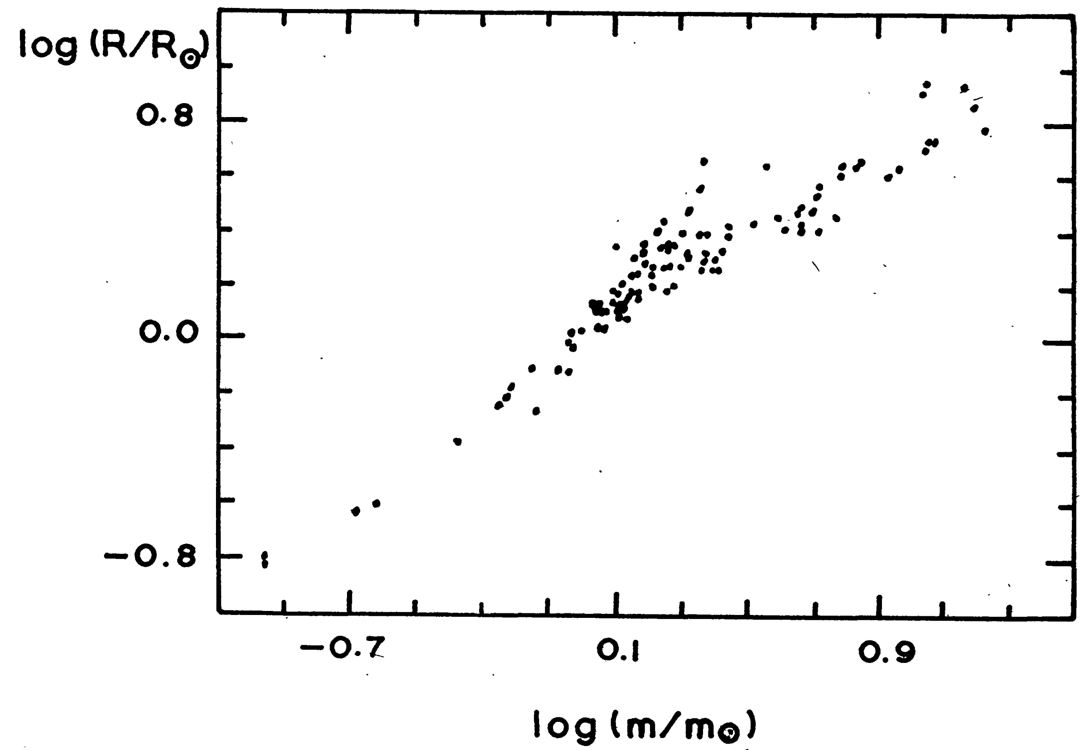

Figure 1. Distributions of close binary stars with well determined stellar parameters in mass-radius plane.

3. Binary system DI Pegasi

DI Pegasi is an interesting eclipsing binary system in which at primary minimum light, a brighter but smaller star is eclipsed by a fainter but larger star. The system was observed by us with 104-cm UPSO telescope to obtain its light curves in U, B and V filters. The details of our findings about the system are, already, given in our earlier papers (Chaubey, 1982; 1993). In brief, the most interesting feature that can be seen in the U, B and V light curves of the system is that the shoulders of the primary minimum are depressed. This phenomenon shows that the hotter component of DI Peg is surrounded by a disk of circumsteller material which is luminous by scattered light and lies in the plane of the orbit. The reduction of light is due to the eclipse of disk by the subgiant cooler star before and after the hotter star is eclipsed.

The O-C values of the times of primary minimum light of DI Pegasi against the cycles show that orbital period of the system is not constant. This O-C curve can be explained very well in terms of alternate period change model (B-H model) proposed by Biermann and Hall (1973). According to the B-H model, a dynamical instability causes a sudden out flow of mass from cooler star, which has already filled its Roche-lobe. This may cause some mass transfer to the hotter star (alongwith the loss of systemic angular momentum). In either case, orbital angular momentum decreases and the orbital period shortens. If the period subsquently increases, this increase indicates that mass was accreted by the hotter star and orbital angular momentum returned to the orbit. One such possibility is when O-C diagram is represented by a series of upward curving parabolas intersecting at the moments of sudden period decrease. Using the observed increase in orbital period, it is found that 3.94×10^{-7} $M_{\odot}$ of mass is transferred from the secondary to the primary star in one year. A model for the semi-detached binary systems DI Peg, thus extracted from our photometric observations, taken with 104-cm UPSO telescope, is given in Fig. 2.

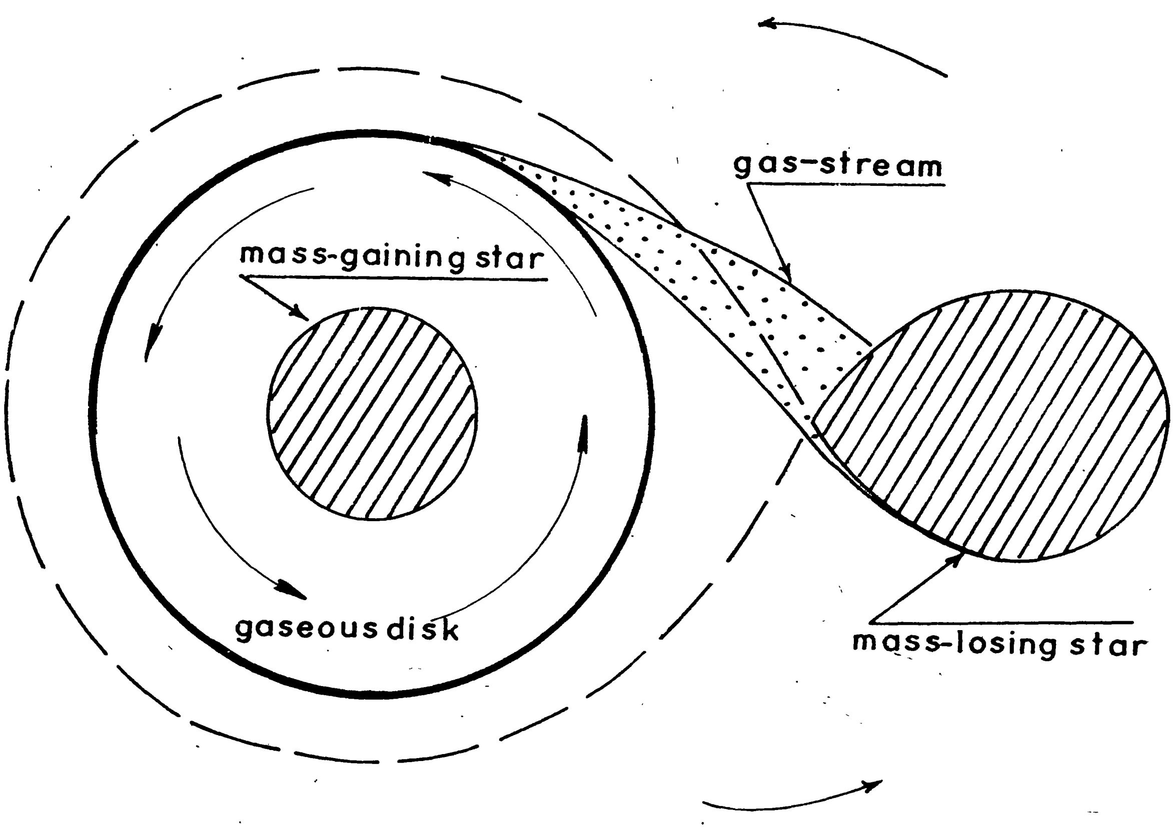

Figure 2. A model for the semi-detached binary system DI Peg.

4. Future research programmes

Although during the last decade, bigger and faster computers and their increasing availability make it possible to construct more realistic models, with few approximations, for the binary systems and the evolutionary processes taking place in them, yet still more observational and theoretical attention is needed for eclipsing binaries and close binaries in general. Concerning the coverage of the H-R diagram (Fig. 1), the stellar data for the systems having less massive components (masses below the sun) as well as systems having massive components ($m > 15\ M_\odot$) are needed. It would be possible to obtain such stellar data in the next few years by studying the faint binaries of special interest in our Galaxy, like the lower end of main-sequence band as well as of other nearby galaxies with CCD detectors.

Recently, several (≈ 300) new contact binary systems have been discovered in several old open and globular clusters (Hut et al., 1992; Kaluzny et al., 1997; 1996; Kaluzny and Rucinski 1993; Yan and Reid 1996). Some of the binaries of these clusters exhibit small light variations (amplitudes $\approx 0^m.1$). This may indicate that some of them are of extremely small mass ratio. Also, the high space velocities of W UMa binaries $< s > \approx 61$ kms^{-1} (relative to the Local Standard of Rest) found by Guinan and Bradstreet (1988) suggest that most of these systems are intermediate to old disk population objects with age 5-10 Gyr. Thus in our opinion, the F and G stars, in solar neighbourhood, having high space velocity would be the excellent candidates for photometric and spectroscopic studies to search for an additional low mass contact binary systems and product of stellar mergers. Although many of high velocity stars are probably evolved single stars such as horizontal branch of giants / subgiants, yet it may be possible that significant fractions are low mass ratio contact binaries and products of stellar mergers. Their photometric observations could reveal periodic light variations due to ellipsoidal and /or eclipse effects, while spectroscopic reveal Doppler shifts arising from orbital and rotational motion.

As discussed by Koch (1990), the study of eclipsing binaries in other galaxies is important for several reasons; it should be possible to establish emperical mass-luminosity relation for stars of chemical histories significantly different from the solar neighbourhood and also binaries with well determined parameters may be used in determination of accurate distance of the galaxy in which they reside. With the use of moderate size (D$\approx$ 3m) optical telescope having large focal ratio and larger format CCDs (2K $\times$ 2K pixel arrays) having quantum efficiency (> 80%) at optical wavelengths and low read-out noise (< 10 eV) it would be possible to carry out moderate precision ($\pm 0^m.02$) photometry of eclipsing binary stars up to 25 magnitudes and spectroscopy up to 20 magnitude stars in Galactic open and globular clusters as well as in M31, LMC, SMC and also some other nearby galaxies. The CCDs photometry and the MOSs spectroscopy may be the efficient means to accomplish this.

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