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Multiplicity in 5 $M_\odot$ stars

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Abstract. Binary/multiple status can affect stars at all stages of their lifetimes: evolution onto the main sequence, properties on the main sequence, and subsequent evolution. 5 $M_\odot$ stars have provided a wealth of information about the binary properties fairly massive stars. The combination of cool evolved primaries and hot secondaries in Cepheids (geriatric B stars) have yielded detailed information about the distribution of mass ratios. and have also provided a surprisingly high fraction of triple systems. Ground-based radial velocity orbits combined with satellite data from Hubble, FUSE, IUE, and Chandra are needed to provide full information about the systems, including the masses. As a recent example, X-ray observations can identify low mass companions which are young enough to be physical companions. Typically binary status and properties (separation, eccentricity, mass ratio) determine whether any stage of evolution takes an exotic form.

Keywords. binaries: general, stars: variables: Cepheids

1. Introduction

Understanding the configurations involving massive stars, the processes which shape them, and the objects they evolve into is formidable–though being undertaken with equally formidable observing and computing resources. In the interplay of rotation, winds, and magnetic fields binary/multiple status sometimes take on a leading role, sometimes plays a relatively passive role. It is, however, frequently a significant factor and progress is being made in determining binary/multiple properties. This contribution discusses two aspects for $5M_\odot$ stars, the frequency of higher multiplicity systems and the identification of low mass companions.

2. Multiplicity

Cepheids (post-main sequence He burning stars of typically 5 $M_\odot$) have provided some new insights into system multiplicity. Frequently they have hot companions which can be studied uncontaminated by the light of the primary. This has lead to the identification of triple systems in a number of ways. For the best studied sample (18 stars with orbits and ultraviolet spectra of the companions), 44% (possibly 50%) are actually triple systems (Evans *et al.* 2005).

3. Low Mass Companions

A second important area where we are obtaining new information about $5M_\odot$ systems is in the identification of low mass companions. These are the most difficult companions to detect, either in photometric or spectroscopic (radial velocity) studies. We are exploring the use of X-ray data to determine the fraction of late B (B3-A0) stars which have low

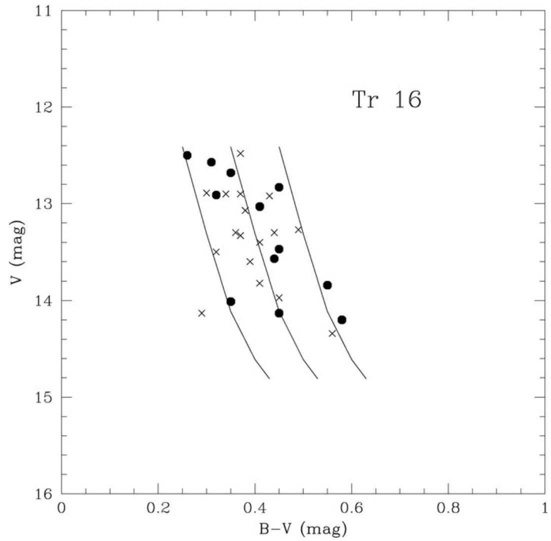

Figure 1. The sample of late B stars in Tr 16. Lines show the ZAMS (center) with a range of E(B-V) = ± 0.1 mag. Dots are X-ray sources; x's are not detected.

mass companions. Late B do not in general produce X-rays themselves. However, low mass stars (mid-F through K spectral types) at the same age ($\simeq$ 50 Myr) are strong X-ray producers, much stronger than field stars of the same temperature. Fig 1 shows data from the Chandra ACIS image of Tr 16 (Evans *et al.* 2011; Townsley *et al.* 2011, Albacete-Colombo *et al.* 2008). With many exciting more massive stars in Tr 16, little attention has been paid to late B stars, so the first step was to establish a sample. A list was compiled of stars within 3' of η Car (the center of Tr 16), with an appropriate combination of V and B-V for the ZAMS (distance of 2.3 kpc, E(B-V) = 0.55 mag ±0.1 mag), and proper motions consistent with cluster membership (Cudworth *et al.* 1993). 39% of the stars are detected, spread through the luminosity range as would be expected for a random occurrence. These are identified as having low mass companions. This approach is complementary to photometric or interferometric surveys such as the O/B survey of Mason *et al.* (2009) and the IUE survey of Cepheids (Evans 1992) and probes new parameter space.

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