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Spectroscopic and infrared properties of Type II Cepheids in the LMC and the Galaxy

Tom Lloyd Evans[1] **and Karen R. Pollard**[2]

[1]SUPA, School of Physics and Astronomy, University of St Andrews, North Haugh, St Andrews, KY16 9SS, UK
email: `thhle@st-andrews.ac.uk`

[2]Dept. of Physics and Astronomy, University of Canterbury, Private Bag 4800, Christchurch 8020, New Zealand
email: `karen.pollard@canterbury.ac.nz`

Abstract. The evolutionary origin of the Type II Cepheids and of the subset with extensive circumstellar material, the RV Tauri stars, is still obscure. Recent surveys have provided infrared and visible light photometry and spectral classifications for a substantial fraction of those known in both the Galaxy and the LMC. We use these data to investigate the relationship between the two types of star and in particular the occurrence of disks around many of them.

Keywords. Magellanic Clouds, stars: AGB and post-AGB, stars: variable: other, stars: winds, outflows

1. Introduction

The Type II Cepheids in the Large Magellanic Cloud are of particular importance in the systematic study of these stars because they are all at the same distance and the period-luminosity relationship may be obtained directly. CWA and RVA stars have been studied by Alcock et al. (1998) and many more stars of CWA type have been observed by Udalski et al. (1999). The sharpness of the P-L relation enables stars with known periods but without adequate visual light photometry, and especially galactic stars of unknown distance, to be placed in the correct relative position. The LMC examples are also of importance in that infrared photometry is available for all stars of sufficient luminosity from the 2MASS survey and from the Spitzer-SAGE survey data provided by Meixner et al. (2006). $JHKL$ photometry of a sample of galactic stars is available from work by Lloyd Evans (1985) and by Goldsmith et al. (1987). Spectral classifications of the LMC sample are available from work by Lloyd Evans & Pollard (2004) and of galactic stars from unpublished work by Lloyd Evans.

2. Infrared two-colour diagrams

This material enables us to plot various infrared colours against period, as well as constructing a variety of two-colour diagrams. The recent study of the light curves of galactic stars, using ASAS-3 photometry, by Wils & Otero (2007) allows an improved classification of these stars into CWA and RVA or RVB as an alternative to the GCVS classification, which uses photometry from a variety of sources of differing quality. There is JHK photometry, at a single epoch, for all these stars from 2MASS. We obtain a colour excess in $H-K$ relative to a fiducial line as a function of $J-H$. This has been plotted against period. The border between CWA and RV types is fuzzy, in that there is overlap between stars with or without alternate deep and shallow minima, as well as between stars with or without a near infrared excess. The occurrence of infrared excesses in a few stars classified as CW was noted before by Lloyd Evans (1985). This plot, as well as that of $K - L$ also plotted against period, confirms the picture seen earlier in the two-colour plots by Lloyd Evans (1985) and, especially, by Goldsmith et al. (1987). There is a marked split between stars with and without substantial infrared excesses. Those without large excesses grade from small excesses to colours appropriate to a normal stellar photosphere. A substantial proportion of RVA and even RVB stars, especially at the longest periods, have little or no infrared excess. The largest excesses are found in stars classed as RVB, while a few, such as the RVA stars AC Her and RU Cen, which have only small excesses at K, have large excesses at longer wavelengths, as found by Lloyd Evans (1985).

A study of the 2MASS JHK data for the LMC stars by Lloyd Evans & Pollard (2004) showed that few have large infrared excesses and that several have no appreciable excess. The Spitzer-SAGE photometry by Meixner et al. (2006) allows us to construct several colour indices, of which $J - [4.5]$ has the longest baseline, as these stars are generally too faint to have reliable photometry at 5.6 and 8.0 μm. The plot of $J - [4.5]$ against log period shows exactly the same pattern as was found for the galactic stars: there is an even sharper discontinuity between stars with and without significant infrared excess, and this is confirmed by the exclusive possession of a measurable flux at 24 μm by stars which have large excesses at 4.5 μm. A few stars, which did not appear to have significant excesses at K, do have excesses at 4.5 μm. One CWA star of shorter period has an excess at 4.5 μm. The break between stars classified as CWA or as RV on the basis of light curve occurs at log P = 1.6, but the difference from the longer period of log P = 1.8 found in the Galaxy may not be significant, as the quality of the visible light photometry for LMC stars is higher than that available for galactic stars. None of the LMC stars is known to belong to the RVB group, with variable mean light: such stars were not included in the search specification for the MACHO sample by Alcock et al. (1998), nor in other samples studied to date. There must be a strong selection against the inclusion of such stars in an LMC sample, as they will suffer substantial extinction in the presumed edge-on disk.

3. Circumstellar disks as remnants of AGB dust formation

Similar excesses at K and L in the case of young T Tauri stars are regarded, e.g. by Hartmann et al. (2005), as resulting from the presence of dusty disks, for which there is much independent evidence. Stars with such excesses follow a different locus in the respective two-colour diagrams to AGB stars with circumstellar shells, which lie close to the interstellar reddening line of the stellar photosphere. The disks of post-AGB stars, including many of RV Tauri type, are studied by De Ruyter et al. (2006). It was suggested by Lloyd Evans (1999), following ideas put forward by Morris (1987), that stars which produced dust on the AGB might retain it in a disk rather than allow it to expand freely, if they were in binary systems, so that the RV Tauri stars were those binaries in which the primary happened to lie in the Cepheid instability strip. However this scheme is not well supported by observations, as cooler stars which were supposed to occupy the temperature range between the AGB and the Cepheid instability strip have turned out to be of other types, such as massive supergiants.

4. Circumstellar disks maintained by continuous dust formation

An alternative explanation of the disks is that they are only formed when the star reaches the instability strip, where pulsation drives off material which then condenses to produce dust. The presence of a companion is still required to permit the formation of a disk. Hα emission is an indicator of the presence of shock waves in the atmosphere of a pulsating star, and such emission is found in Miras and Type II Cepheids, but does not occur with significant strength in classical Cepheids. The data obtained by Lloyd Evans & Pollard (2004) for the RV Tauri stars in the LMC and by Lloyd Evans (unpublished) for galactic CWA and RV stars may be used to investigate this possibility. There should be a correlation between the Hα emission strength and the size of the IR excess, in this case. Plots of Hα intensity against pulsation period show the well-known decline of intensity with increasing period among the CW stars, with no indication of greater intensity at a given period in the case of RV Tauri stars or of CW stars with an infrared excess. Indeed, some of the RVB stars with the strongest infrared excesses have especially weak or no Hα emission. There is thus no support for this hypothesis.

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