RADIAL VELOCITY OBSERVATIONS OF BARIUM, CH, AND R STARS

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The Ba II, CH, and R0-R3 carbon stars are related in that they are giant stars having about the same position in the HR diagram, and having enhancements of carbon features. The Ba II and CH stars are also noted for enhancements of s process elements. The Ba II stars normally don't exhibit C_2 bands that are characteristic of the CH and R stars, indicating that the Ba II stars have a C/O ratio close to but less than unity (Smith 1983). The Ba II and R stars are members of the old disk population (e.g. Eggen 1972), whereas the CH stars are high velocity, population II stars (Keenan 1942).

Radial velocity measurements of Ba II stars have been obtained during the last 4 years at the Dominion Astrophysical Observatory (DAO), and the conclusion has been reached that these stars are likely all members of binary systems. These observations, as of the end of 1982, have been published by McClure et al. (1980), and McClure (1983), and will not be discussed further. The connection between multiplicity and abundance peculiarities is uncertain, but two possibilities exist. Either a companion has evolved and exchanged enriched material onto the present Ba II star, or the companion has somehow affected the internal structure of the Ba II star making it mix. In the former case, a white dwarf companion might be expected, and some have been found (Böhm-Vitense 1983; Böhm-Vitense et al. 1983; Dominy and Lambert 1983) from IUE spectra. Dominy and Lambert (1983) argue that because the majority have no observed white dwarf companions, this hypothesis is ruled out, whereas Böhm-Vitense et al. (1983) argue in favour of mass exchange, feeling that there is a magnitude limit beyond which the white dwarf companions are just not observable.

The question arises: if all Ba II stars are binaries, are the related CH and R stars also members of binary systems? One might question this suggestion in the case of the CH stars since these are population II objects, and found in several globular clusters, populations normally thought to be deficient in binary systems (e.g. Abt and Levy 1969; Crampton and Hartwick 1972; Gunn and Griffin 1979). Figure 1 shows radial velocity data for CH stars, and subgiant CH stars (Bond

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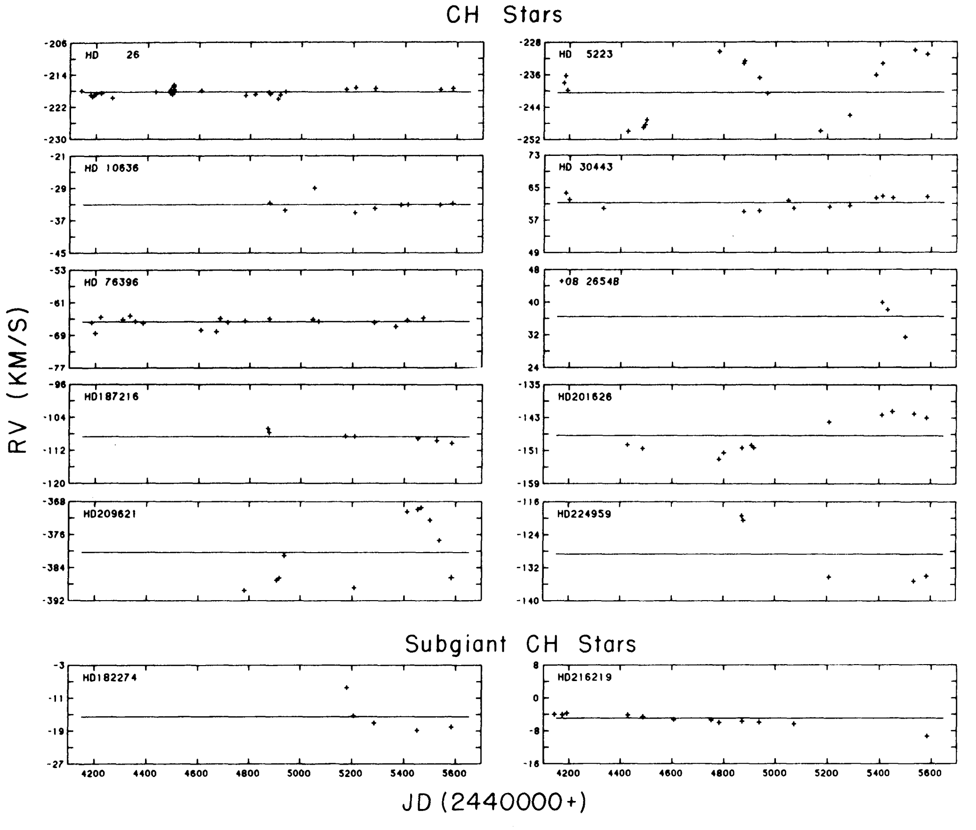

Figure 1. Radial velocities of CH stars versus Julian data. The solid lines represent the mean of the velocities.

1974), obtained with the DAO radial velocity coudé spectrometer during the last several years. Two effects are apparent. First, the majority of CH stars do indeed have long term velocity variations such as expected of a giant member of a binary system. Second, the scatter of the observations from night to night appears to be larger than the expected precision of the instrument, which is normally better than 0.5 km s^{-1}. The latter value is represented in the figure by the size of the symbols. Since these are population II giants, and must have very low surface gravities, perhaps turbulence in their atmospheres is adding scatter to the velocity curves.

Since the frequency of spectroscopic binaries among normal K giants has been found to be 25-30% (Gunn and Griffin 1979; Harris and McClure 1982), and since the frequency of binaries in population II is thought to be lower than in population I, the high frequency found here so far for CH stars (at least 65%) is highly significant. Experience has shown from our Ba II star observations, that increasing the number and time span of observations tend to turn up more binaries, so that the frequency determined from the present data will likely increase. It seems then that all CH stars are binaries as is the case for Ba II stars. In fact it perhaps strengthens the hypothesis that the CH stars are population II counterparts of the population I Ba II stars, and raises some doubts about binary frequency in population II being low.

Observations of R stars are much less advanced, but there are a significant number of members of this class for which the DAO data show long term velocity variations indicating multiplicity. About an equal number for which multiple observations have been obtained show no velocity variations. Although the frequency of binaries perhaps looks high (~ 50%), at this point, a much larger observational base is needed for the R stars.

Three areas for further observational study are: 1. continued observations of the R stars to tell us whether these too are multiple systems, and therefore related closely to the Ba II and CH stars, or predominantly single, in which case stellar evolution theory will have to account for the mixing which has occurred. 2. a thorough study of Yamashita's (1975) "CH-like" stars, which have spectra similar to the CH stars, with enhanced carbon and s process elements, but which have low space motions. Like the Ba II and R stars, these are probably members of the old disk population. Are these stars, therefore, a link between the Ba II and R stars? They have C_2 bands indicating a C/O ratio greater than unity, but they have enhanced s process elements not found among R0-R3 stars. 3. the "mild", "marginal", or "Ba0" barium stars need to be understood. These appear to have a high binary frequency, but not all are binaries (Griffin 1983; McClure 1983). Some have slightly enhanced Sr II and Ba II but no enhancement of CN (Sneden et al. 1981). Others have enhanced Sr II and CN, but no enhancement of Ba II (Bond 1983, private communication).

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DISCUSSION

Schatzman: What is the connection of the observational results, showing binarity of BaII stars with stellar evolution theory?

McClure: The next paper by Böhm-Vitense will discuss this. The abundance peculiarities of these stars must be connected in some way with binarity since this class of stars contains only binary systems. Either there was mass exchange from a higher mass companion, or else the companion has somehow caused the BaII star to mix. There is a great deal of debate now as to which of these has happened, and I am not able to answer this.

Richer: The inferred separations of the stars must be rather large. Does this worry you regarding the mass transfer?

McClure: If the companion was a reasonably massive star it could have become quite large by the time it reached the upper part of the AGB, large enough compared with the ~2 AU separations.

Wing: If all CH stars are binaries, can the fact that the CH stars in ω Cen lie within the cluster's giant branch be used to place a limit on the luminosities of their companions?

McClure: I don't think so. The companion is likely either a white dwarf or a main sequence dwarf, and therefore several magnitudes fainter so that it would not affect the magnitude of the CH star.