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Infrared Radial Velocity Results for Long Period Variables

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Abstract. High-resolution time-series infrared spectra have been observed for a total of 20 Long Period Variables. The stars can be placed in four groups with distinct kinematic behaviour.

1. Introduction

In a series of papers (Hinkle 1978; Hinkle et al. 1982; Hinkle et al. 1984, Hinkle & Barnbaum 1995; Hinkle et al. 1995) we have explored the photospheric kinematics of long period variables (LPVs) measured in the infrared. It is difficult to observe the kinematics of LPV stellar pulsation using visible spectra. The 1.5-2.5 μm infrared has been used because it spans the opacity minimum, is relatively unblended, and offers a variety of molecular bands (especially the CO overtone bands) which make wonderful probes of the atmospheric structure.

2. Discussion

The 1.6-2.5 μm infrared spectra were obtained using the KPNO 4 meter telescope and Fourier transform spectrometer (FTS). The sky subtraction of this instrument (Hall et al. 1979) allows daytime observations of bright objects unaffected by the sky spectrum. As a result of being able to use daytime, a large amount of telescope time was available for monitoring projects. Nearly all observations discussed here were obtained during daylight. High-resolution time-series infrared spectra have now been observed for a total of 20 LPVs, 14 of which are Miras, 5 SRa, and 1 SRb, spanning the M, S and C abundance types.

All the Mira velocities when plotted against visual phase show good velocity repeatability from cycle-to-cycle. However, cyclic differences of up to ~2 km s^{-1} from the mean occur, with the degree of scatter from the mean apparently being a function of phase. Maximum visual light roughly corresponds to the time of most negative (largest outward) radial velocity. The apparent deceleration from approximately phase 0.2 to 0.8 is approximately constant and similar in all Miras studied with periods spanning about about a factor of two in length. Comparing velocity versus phase plots for the Miras, an obvious feature that differs from star-to-star is the phase when the hot expanding material is

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first visible. In the spectrum this corresponds to doubling of the lines. In the prototypical Miras (o Cet, χ Cyg) infrared line doubling is observable at phase 0.9 or shortly after. The velocity curves of R And, R Aql, R Cas, S Cep, R Leo, U Ori, and IK Tau are similar to the prototype stars. The velocity amplitude of these stars is $\sim$25 km s^{-1}.

In some Miras line doubling can occur as early as 0.3 of a period before visual maximum. The appearance of the expanding gas at an early phase seems to be correlated with the conspicuous premaximum bump in the light curve. An excellent example is T Cep. Interestingly, while the lines double at an early phase they persist double until about the same phase as for the prototype Miras, i.e., doubled lines disappear shortly after maximum light. The appearance of the expanding gas must depend on the opacity of the overlying, infalling material. We have been unable to ascertain if this opacity is the result of simply a different amount of material above the shock or results from the effect of different abundances of metals or CNO. We have now identified three Miras in this group, R Aur, T Cep, and R Hya.

The third group of stars that can be discerned from the velocity measurements are Miras that have visual amplitudes near 2.5 magnitudes. SV Cas, W Hya, and X Oph are in this category. These stars have velocity curves which are essentially identical to the above Miras with the expanding gas visible at 0.3 of a period before maximum. However, line doubling is detectable only briefly with the result that infalling material disappears from the spectrum shortly after minimum light.

The SRa variables, while long considered a rather arbitrary division of the Miras by amplitude of the light curve, can be shown from the velocity results to be a separate group of variables. We have observed three members of this group, V450 Aql, RU Cyg, and SV Peg. These stars never show line doubling. The largest amplitude system we have observed, RU Cyg, has an 8 km s^{-1} velocity amplitude, similar to the velocity range of the low amplitude Miras. We have also observed in some detail one SRb variable, W Cyg. W Cyg similarly does not show line doubling, has a velocity amplitude of 3.5 km s^{-1}, and, as might be expected, has rather irregular velocity variations. As in the Miras, in addition to regular pulsations the SR star velocities undergo non-repeatable velocity variations of a few km s^{-1} amplitude. For small amplitude SR variables the non-cyclic velocities can mask the stellar pulsation.

References

Hall, D. N. B., Ridgway, S. T., Bell, E. A., & Yarborough, J. M. 1979, Proc. Soc. Photo-Opt. Instr. Eng., 172, 121

Hinkle, K. H. 1978, ApJ, 220, 210

Hinkle, K. H., & Barnbaum, C. 1995, in preparation

Hinkle, K. H., Hall, D. N. B., & Ridgway, S. T. 1982, ApJ, 252, 697

Hinkle, K. H., Scharlach, W. W. G., & Hall, D. N. B. 1984, ApJS, 56, 1

Hinkle, K. H., Scharlach, W. W. G., & Johnson, D. 1995, in preparation.