CIRCUMSTELLAR SHELLS OF A-K LUMINOUS SUPERGIANTS

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ABSTRACT. Infrared vibration-rotation bands of CO are ideal probes of the circumstellar environment of yellow supergiants. Results for a sample of stars are reviewed.

1. INTRODUCTION

The most luminous stars of all spectral types appear to be losing mass. Theoretical calculations (Choisi, Nasi, and Sreenivasan 1978) indicate that the yellow supergiants form an interesting subset of the most luminous stars with mass loss rates that can exceed $10^{-3} M_{\odot} yr^{-1}$. The spectra of some yellow supergiants have conspicuous spectral features indicating the presence of thick circumstellar shells (Sargent 1961). Interestingly, the circumstellar environment of yellow supergiants is not conducive to the formation of dust. A survey of IRAS measurements of infrared excesses of G supergiants found that only 4% have detectable circumstellar emission (Odenwald 1986). Stothers (1975) has suggested that these dust shells are "fossils" left from when the stars were on other portions of the H-R diagram.

A program of observing the infrared spectra of yellow supergiants at high resolution was begun a few years ago using the Kitt Peak 4 meter telescope and Fourier transform spectrometer. Of particular interest to this program are spectral lines which originate entirely in the circumstellar shell and are not contaminated by an underlying photospheric profile. For some yellow supergiants we have discovered that CO $\Delta v=2$ bands are present in the 2.3μm spectrum. CO is formed entirely in the circumstellar envelopes of yellow supergiants since it cannot exist in warm photospheres. CO vibration-rotation lines are formed in LTE under the low density conditions expected in a circumstellar shell (Hinkle and Lambert 1975). The entire CO $\Delta v=2$ band, consisting of dozens of lines, may be observed in a single spectrogram and simply modeled to produce excitation temperatures and column densities.

[1]Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

I. Appenzeller and C. Jordan (eds.), Circumstellar Matter, 327–328.

2. VARIABLE CIRCUMSTELLAR SHELLS

Two yellow supergiants studied in detail are V509 Cas and ρ Cas. Lambert, Hinkle and Hall (1981) give first results from infrared spectroscopy of these stars. Both stars are massive and have no infrared excess but large mass loss rates. Time series near-infrared spectroscopy (Sheffer 1985; Sheffer and Lambert 1986) has revealed that both stars are pulsating with periods of 500 to 600 days. This pulsation is of large amplitude with a shock travelling outwards through the atmosphere during each cycle. Both stars have strong 2.3μm CO lines. The CO samples a region of excitation temperature ∿1500 K, implying a distance of about 2 R_* above the photosphere. New results show that the CO line profiles undergo large changes during the pulsation cycle, indicating that the circumstellar CO line forming region is not decoupled kinematically from the photosphere. Such an association between the circumstellar shell and the photosphere may result in discrete mass loss events tied to the pulsation cycle. Discrete mass loss events complicate measurements of the time averaged mass loss rate (Hinkle 1983) and could reconcile the very large mass loss rates derived by Lambert, Hinkle, and Hall with more canonical values.

3. BINARY SYSTEMS WITH DUST

ε Aur and 3 Pup are both yellow supergiants with infrared excesses. Both of these systems are binaries. In the case of ε Aur the dust is associated with the companion to the F Ia primary (Backman et al. 1984); 3 Pup may be a similar system (Lambert, Tomkin and Hinkle 1986). Both 3 Pup and ε Aur (when eclipsed) have weak CO Δv=2 lines present. The CO in ε Aur is formed in a gas torus surrounding the dust-enshrouded companion. Hinkle and Simon (1986) find that the CO spectrum demands the yellow supergiant in the ε Aur system have a mass $\lesssim 7 M_\odot$, implying it is a low mass, post asymptotic giant branch star.

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