THE EFFECT OF METALLICITY AND PULSATION ON THE INFRARED COLORS OF LUMINOUS M GIANTS

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The temperature calibration for cool stars and in particular the Miras continues to be contentious. Lunar occultations have provided radii for many K and M stars and a good temperature calibration has been derived for the hotter non-variable M stars (Ridgway et al. 1980). The situation for the Miras and carbon stars and the metal-rich and metal-poor M stars is, however, not so clear cut. Observations are generally made in some broad-band color such as (R-I), (V-K) or (J-K) and a temperature derived using either the Ridgway et al. (1980) empirical scale or a black-body scale; differences can amount to several hundred degrees. We decided to theoretically explore the effects that extension, metallicity and pulsation could have on colors.

Using the code of Scholz and Tsuji (1984) we have computed spherically extended model atmospheres for two sets of luminosity and mass ($L = 4 \times 10^4 L_\odot$, $M = 4\ M_\odot$; $10^4\ L_\odot$, $1\ M_\odot$) at three different stellar radii ($R = 273\ R_\odot$ [$T_{eff} = 3500°K$], $371\ R_\odot$ [3000°K], $535\ R_\odot$ [2500°K] and three different metal abundances [Z/H] = +0.5, 0, -1. These models should be relevant to the oxygen-rich asymptotic giant branch stars in the galactic center, the solar neighborhood, the Magellanic Clouds and the dwarf spheroidals. In addition, for 4 $M_\odot$, 6 models with modified CN abundances were computed to investigate how the dredge-up of nitrogen rich material in upper AGB stars, as suggested by Wood, Bessell and Fox (1983), could affect the spectrum. Finally, we have commenced the investigaton of Mira-type atmospheres by computing the structure and flux of several atmospheres with $L = 10^4\ L_\odot$, $M = 1\ M_\odot$, $R = 371\ R_\odot$ but imposing density-radius profiles with two discontinuities, to simulate the presence of shock fronts in the atmosphere. Such a profile was produced with pulsation

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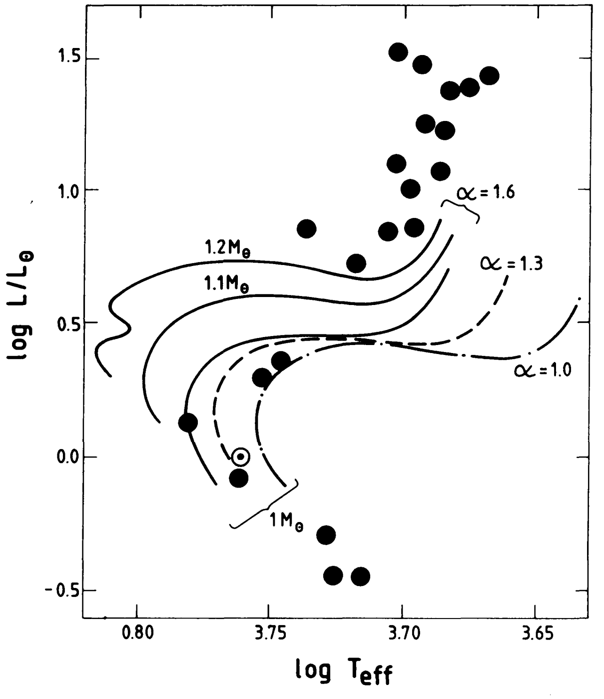

Fig. 1. The position of the program stars in a temperature-luminosity diagram. For comparison calculated evolutionary tracks for stars of solar composition (VandenBerg 1983) have been included.

However, the stars were not selected to cluster, and on the contrary an attempt was made to sample a range both in temperature and luminosity. If we believe that the mass of a red giant is close to solar then we get a reasonable agreement with our determination for a value of the mixing length parameter l/H_p close to 1.6.

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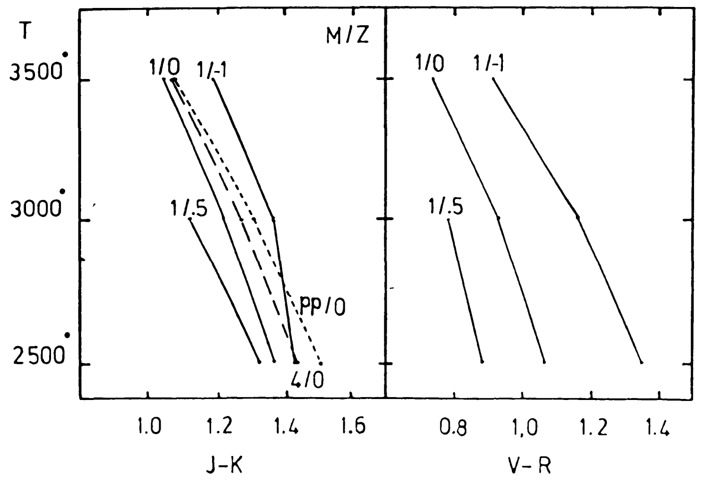

Fig. 2. Continuum colors for the models.

Hot H_2O absorption is a feature of the spectra of the cooler normal stars, but in a Mira it seems that regions favorable to the formation of polyatomic molecules exist in a higher temperature atmosphere. Carbon-Miras also show this phenomenon, their spectra differing from those of non-mira carbon stars in the occurrence of strong HCN or C_2H_2 bands. We hope to extend this preliminary work to different temperatures, phases and possibly different C/O abundances.

In Fig. 2 are plotted the (J-K) and (V-R) continuum colors for the various models. It can be clearly seen that color differences due to extension and metallicity are quite large and would result in significantly different temperatures being derived from an inappropriate color-temperature relation. For example, the extended model for $1M_\odot$ and 3000 K has the same (J-K) color as the extended model for $4M_\odot$ and 3100 K, and the plane-parallel model for 3220 K. Metallicity effects are even larger, models with (T,[Z]) = (3500,-1), (3100,0) and (2850,+.5) having the same (J-K) color. Similar color differences occur in other spectral regions such as (V-R) and (V-K), although the plane-parallel and extended model colors are much closer in VRI. Clearly, to obtain accurate temperatures from fitting observed and theoretical colors it is necessary to compute more realistically blanketed colors or observe in band-free windows, and to have some knowledge as to the mass, luminosity and abundance of the stars. A further complication in such cool stars is whether or not the star is a Mira (or Long-Period) variable as will be discussed in the next section.

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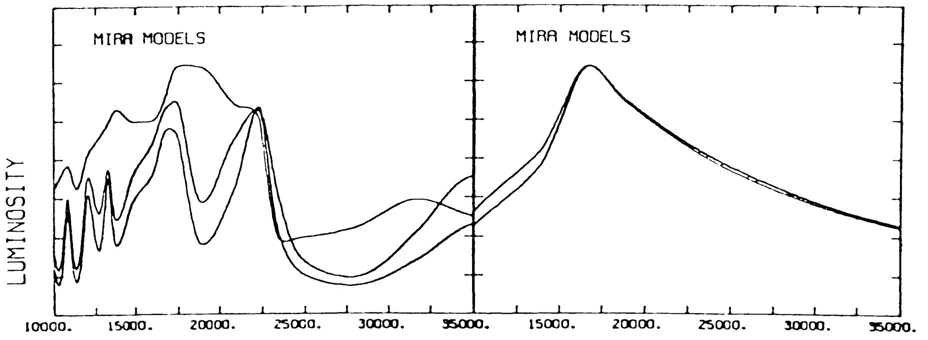

Fig. 3. Luminosity vs. wavelength for mira-models.

Fig. 3 shows the resultant fluxes for the two mira-models and for comparison, the flux for the normal model of the same temperature and mass. The very obvious difference is the occurrence of strong H_2O bands in the mira-models (a well noted feature of all M-type Mira variables), which change with phase, although there was little change in continuum color. The H_2O absorption occurs most strongly in the K-band, causing the (J-K) colors to be redder.

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