A REDDENING AND METALLICITY-FREE TEMPERATURE ESTIMATOR FOR LATE M GIANTS

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ABSTRACT. Lockwood's measurements in five-color narrow-band photometry of spectroscopic standard M stars is used to define an estimator of temperature. The TiO and VO indices deduced from this photometry depend in the same way on the metallicity but vary in a different way with the temperature: their ratio is only influenced by the temperature. A relation between T/V and the temperature is calibrated for M giants between 2000 and 3000° K. Both the T and V indices are indicators of metallicity and gravity which allow us to check that the relation (T/V)/temperature is independent of the metallicity. This relation leads to a precise determination of the temperature and can be applied to a wide variety of M giants, independently of their reddening and chemical composition.

1. INTRODUCTION

M giants are generally distant stars, most are variable, and a great number of them have an extended dust envelope; thus many are affected by interstellar or circumstellar reddening. Their kinematics show that they are mainly old stars; a large dispersion in their metallicity and surface gravity may then be expected.

The search for a reddening and metallicity-free temperature estimator is fully justified for these stars. Such an estimator can be derived from the near-infrared molecular band intensities. The method is based on the fact that the TiO and VO bands vary in a distinct way with the temperature but depend in the same way on the metallicity and gravity. An application of this method to Lockwood's narrow-band photometry is presented here.

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2. NEAR INFRARED NARROW-BAND PHOTOMETRY

Wing(1967) established a 27-color photometric system which measured continuum magnitudes and the strengths of molecular absorptions in late-type stars in the spectral region 0.75 - 1.11μm. For M stars, only TiO and VO band strengths have to be measured, and, on the basis of Wing's scanner study, Lockwood (1972) reduced the number of band passes to five: two continuum regions (filters 87 and 104), one VO band (filter 105) and two TiO bands (filters 78 and 88). Then color-free indices of TiO and VO strengths are defined:

$$T_1 = (78-87) - 0.6(87-104) \text{ and } V_1 = (105-104) + 0.1(87-104).$$

The effect of reddening on these indices is very small (0.03 mag. for T_1 and 0.003 mag. for V_1 per magnitude of visual absorption): they may be considered as free from reddening effects. Filter 104 is blanketing-free, but filter 87 is affected by TiO blanketing after M5. T_1 is a function of metallicity and gravity (Mould 1976). T_1 and V_1 depend in the same way on the metallicity and gravity but vary in a different way with the temperature. T_1/V_1 is influenced only by the temperature (Grenon 1981) and can be used to estimate it in the range where both the indices are well defined (M5-M9).

3. BLANKETING-FREE INDICES

For most of the standard stars measured by Lockwood (1972) we know a V magnitude, which is affected by a TiO absorption δ_V estimated by Smak and Wing (1979). A black-body fit between V + δ_V and 104 leads to an estimate of 87 + δ_{87}. The normalization of V - 104 = 0 for α Lyr was used. The comparison of the calculated 87 + δ_{87} and the measured 87 magnitudes gives an estimate of the TiO blanketing δ_{87} in the filter 87 as a function of the spectral type. This estimate of δ_{87} is quite consistent with the measurement of TiO absorption at 7540 Å by Piccirillo et al. (1981).

Then we can define blanketing free indices:

- two in the continuum region: $(87)_c = 87 + \delta_{87}$ and 104
- one of TiO strength $(T_1)_c = T_1 + 1.6\ \delta_{87}$
- one of VO strength $(V_1)_c = V_1 - 0.1\ \delta_{87}$

4. REDDENING AND METALLICITY-FREE TEMPERATURE ESTIMATOR FOR M GIANTS.

The spectral-type standard stars selected by Lockwood are small amplitude variable late-type stars from Keenan's (1963) list supplemented by few semi-regular small-range variables later than M6. To define spectral class M10, the mira, R Cas, at its minimum, is

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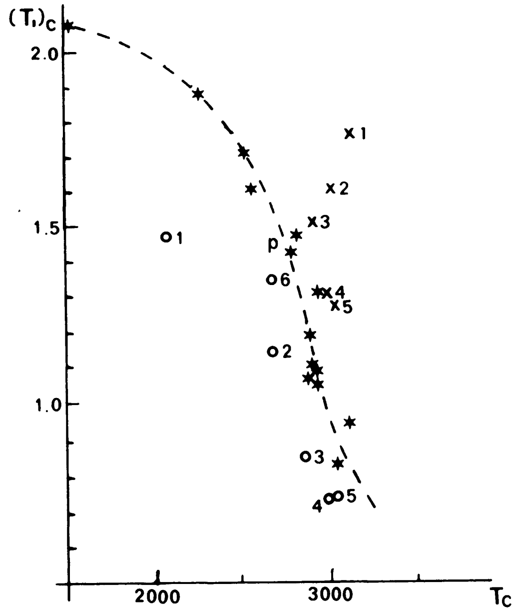

Fig. 1. Relation between the corrected TiO strength and the color temperature. The probable metal rich or lower gravity stars are noted x and the deficient or larger gravity stars by o.

used as adopted by Lockwood (1970), so the results concerning this spectral type has to be taken with caution.

From $(87)_c$ and 104 we can deduce a color temperature T_c. The indices $(T_1)_c$ and $(V_1)_c$ are mainly functions of metallicity and temperature. Fig. 1 shows the relation $(T_1)_c/T_c$. At a given T_c, the stars above and below the mean relation are probably metal rich or lower gravity stars and metal deficient or greater gravity stars respectively. The stars occupy the same relative location in the $(V_1)_c/T_c$, diagram and in the $(T_1)_c/T_c$ diagram. This confirms our interpretation of the specific nature of these stars. Only one star, denoted "p" on the figures, is not located similarly in both diagrams: it is likely a vanadium-poor star (TY Dra).

Fig. 2 gives the relation of the ratio $(T_1)_c/(V_1)_c$ versus the temperature T_c. This relation is somewhat noisy but the noise is lower than when no blanketing correction is made. The noticeable property is that no systematic effect is seen with abundance or gravity.

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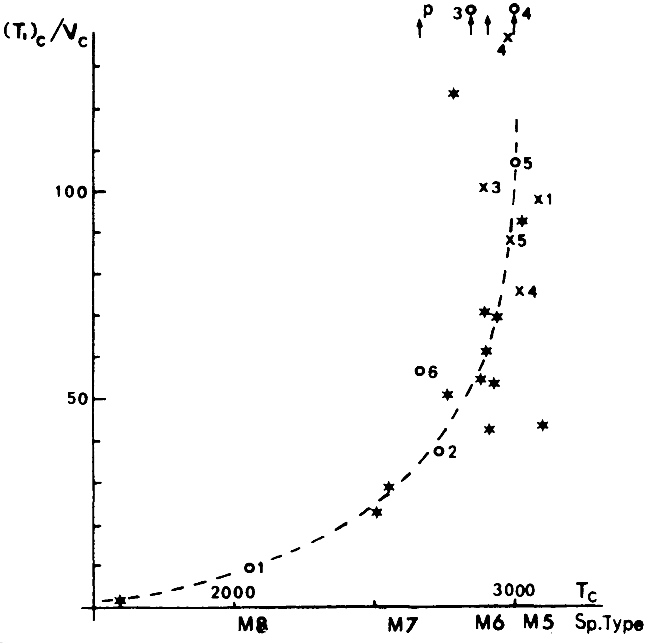

Fig. 2. Relation between the temperature T_c and the ratio of molecular TiO and VO strengths for spectral type standard stars measured by Lockwood (1972). The symbols are the same as in Fig. 1.

5. CONCLUSION

The ratio of the indices T_1 and V_1 of TiO and VO strengths leads to a precise determination of color temperature in the range 1900 - 2900°K. This T_c may also be transformed into T_{eff} using stars with known apparent diameters. The deduced relation can be applied to a wide variety of late M giants independently of their reddening, chemical composition or mass.

6. REFERENCES

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