ON THE GRAVITY DETERMINATION FROM CARBON STAR SPECTRA

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ABSTRACT. Spectra of carbon dwarf and giant stars may look very similar, as is demonstrated, e. g., by TT CVn and G77-61. Model calculations show that the bands of C_2, CN and CO cannot be used in the range log g = 0... ...6 for log g determinations, since they are affected by abundance. If, moreover, lines of two ionization stages cannot be observed in any element, the only log g indicator would seem to be the ratio of the MgH band and the Mg I b lines. Simple analytic expressions are derived which demonstrate the relation between spectral appearance, abundances and gravity.

Generally, carbon stars are considered to be giants; the only exception up to now is G77-61 (Dearborn 1983), which has strong C_2 bands in its spectrum but should be a dwarf according to astrometric data (Dahn, Liebert and Hintzen 1977). In order to confirm this spectroscopically, and to determine the effective temperature, T_{eff}, and the element abundances, we perform a fine analysis mainly based on Lick IDS, MMT echelle and Palomar multichannel data, kindly provided by J. Liebert.

We calculate synthetic spectra for T = 4000 K and log g = 0 ....6. It turns out that by adjusting the C-abundance, the spectrum of G77-61 can be reproduced well by models in this whole range of gravity. This can be understood in the following way: Since the optical spectrum of G77-61 is completely dominated by the C_2 band, we approximate the absorption coefficient

$$\kappa = \kappa_o^C \, P_e P_g + \varepsilon_C^2 \kappa_o^L \, P_g^2 , \qquad (1)$$

where P_g and P_e are the total gas and the electron pressure; ε_C is the fractional carbon abundance; κ_o^C and κ_O^L are constants. In all models the first term of Eqn. (1) reduces to

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$$\kappa = \varepsilon_C^2 \kappa_o^L P_g^2 \quad (2)$$

Insertion of this expression into the hydrostatic equation

$$\frac{dP_g}{d\tau} = \frac{g m_H \mu P_g}{\kappa k T} \quad (3)$$

(g=gravity, m_H=mass of the H-atom, μ relative molecular weight, k=Boltzmann constant, T=temperature) gives

$$\frac{dP_g}{d\tau} = \frac{g m_H \mu}{\varepsilon_C^2 \kappa_o^L k T P_g} \quad (4)$$

and by integration

$$P_g^2 = \frac{2 g m_H \mu}{\kappa_o^L \varepsilon_C^2 k} \int \frac{d\tau}{T} \quad . \quad (5)$$

The monochromatic τ_λ-scale

$$\tau_\lambda = \int \kappa_\lambda(\tau)/\kappa(\tau)d\tau \quad . \quad (6)$$

(κ_λ=monochromatic absorption coefficient) is constructed by combination of Eqs. (2), (5) and (6)

$$\tau_\lambda = \frac{\kappa_o^\lambda}{\kappa_o} \tau \quad (7)$$

where κ_o^λ describes the wavelength dependence of the absorption coefficient.

If identical temperature distribution $T(\tau_\lambda)$ for all carbon stars with the same T_{eff} - but possibly quite different gravities - are assumed, then the flux emerging from the star

$$F_\lambda = 2 \int_0^\infty E_2(\tau_\lambda) \; B_\lambda(T(\tau_\lambda)) \; d\tau_\lambda \quad (8)$$

(E_2 is the second integral exponential function, B_λ=Kirchhoff-Planck-function) is independent of log g for all frequencies. Deviations in the temperature stratifications may be corrected to first order by changes of the abundances.

Similar arguments hold for CN and CO, so that they also cannot be used for the calculation of log g. If, moreover, atomic lines of two ionization stages cannot be observed for any element - as is the case for G77-61 - the only gravity indicator seems to be the ratio of the strength of the MgH band and the MgI b lines. The latter determines the Mg abundance. In a He-rich atmosphere a higher Mg abundance is needed to get the same line strength as in a normal atmosphere. As a consequence the MgH band is not dependent on the H-abundance. If the intensity of the Mg is kept constant in all models with different gravity, then the strength of the MgH band, which is due to the calculations comparable with the C_2-bands in the case of log g = 5 and vanishes at all if log g = 3.5, is a log g indicator. In G77-61 a very weak MgH feature leads in this way to a gravity of log g = 4.

We think that this is the only way to determine the gravity where independent data on the luminosity - as e. g., for field carbon stars, are not available.

Details of this investigation will be published in a forthcoming paper.

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