ON THE OBSERVABILITY OF CO AND CO^+ IN ETA AQUILAE

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The equivalent widths of $R(29)$ line belonging to 0—2 band of CO in η Aql are found to be 0·020 mÅ and 4·17 mÅ and of $R(31)$ 0·019 mÅ and 3·71 mÅ at maximum and minimum phases respectively. Thus, if Dawe's model atmospheres are realistic there is some chance of detecting the lines of the first overtone of CO near minimum phase of light variation in the star.

О наблюдаемости CO и CO^+ в η Aql

Вычисленна эквивалентная ширина линии $R(29)$ соответствующей полосе 0—2 молекулы CO в η Aql, равная 0,020 mÅ для минимальной и 4,17 mÅ для максимальной фазы. Ширина линии $R(31)$ равна 0,019 mÅ и 3,71 mÅ соответственно. Следовательно, если модель атмосферы по Dawe является реальной, имеется возможность детекции линий первого обертона CO вблизи минимума блеска этой звезды.

Introduction

Pande et al. (1971, 1972) have indicated the possibility of observing the molecules CO, C_2, OH and NH in the spectra of δ Cep and η Aql. This is based on the fact that under LTE for solar abundances, the abundances of the six molecules CO, CN, C_2, CH, NH and OH are in the order CO, OH, CH, NH, CN and C_2. Out of these, CH and CN have already been detected through their electronic transitions falling in the visible region of the spectrum of δ Cep. The abundance of CO is about four to five orders of magnitude larger than the less abundant already detected molecule CN. So it is likely that the first overtone of CO may show some observable lines in the region 2·3 to 2·5 microns. Using Dawe's (1968) models for maximum and minimum phases of light variation in η Aql, the equivalent widths of the $R(29)$ and $R(31)$ lines belonging to the first overtone of CO have been calculated. The details and the results of these calculations are reported here.

Some unpublished results of our group show that the lines belonging to the 0—3 band of $A^3\Pi_i - X^2\Sigma^+$ system of CO^+ will be absent in the photosphere, facula and sunspots. As the contribution function for the above lines is largest in the photosphere-chromosphere transition region, it appears that CO^+ may show up in supergiants. So, similar considerations were applied to the η Aql model atmospheres at maximum and minimum phases of light to find whether the mentioned CO^+ lines form in the star's spectrum or not.

Equivalent Width Calculations

The formulation of the problem is the same as given in Gaur et al. (1971). The assumptions involved are that LTE and solar abundances prevail, lines have pure absorption profiles broadened by thermal and turbulence Doppler effects and are unsaturated. Dawe (1968) has well emphasised the difficulties involved in assigning an average turbulence at each phase of the light variation in η Aql. Solar studies show, however, that a plausible form of depth dependence is given by

$$(1) \qquad \xi_t(\tau) = A \exp(-B\tau)$$

for the microturbulence velocity ξ_t where τ is the optical depth at 5000 Å. Assuming a turbulence velocity of 7 km/sec at $\tau = 0{\cdot}1$ and 30 km/sec at $\tau = 0{\cdot}001$ (Dawe, 1968) the turbulence velocity at maximum and minimum phases at various optical depths was obtained with the help of the relationship (1).

The dip $r(\Delta\lambda)$ at a distance $\Delta\lambda$ from the line centre is given by

$$(2) \qquad r(\Delta\lambda) = \int_0^\infty G(\tau') \frac{k\,\Delta\lambda}{k\lambda_0}\, d\tau' ,$$

where $G(\tau')$ is the absorption weighting function averaged over the disc, τ' the optical depth at 23007 Å, $k_{\Delta\lambda}$ is the selective absorption coefficient at distance $\Delta\lambda$ from the line centre and k_{λ_0} the continuous absorption coefficient in the vicinity of the line. For the $R(29)$ and $R(31)$ lines of the first overtone of CO, $k_{\Delta\lambda}$ was estimated in a manner similar to that given by Gaur et al. (1971).

The continuous opacity caused by H^- ion was taken from Tsuji (1966). The contribution of neutral hydrogen, electron scattering and Rayleigh scattering by neutral hydrogen atoms was estimated according to Stankiewicz (1969) and that of H_2^+ from Bates (1952). The weighting function $G(\tau')$ is given by the expression (Böhm, 1960):

$$(3) \quad G(\tau') = \frac{\int_{\tau'}^{\infty} B(\tau')\, E_1(\tau')\, d\tau' - B(\tau')\, E_2(\tau')}{\int_0^{\infty} B(\tau')\, E_2(\tau')\, d\tau'} .$$

Here $B(\tau')$ is the Planckian function at τ', which is obtained from the model optical depth. The functions $E_1(\tau')$ and $E_2(\tau')$ were taken from Stankiewicz (1968) and for $\tau' < 0{\cdot}01$ the values were calculated according to the formulation given by Kourganoff (1952). The values of $\Delta\lambda_D$ at various values of τ are obtained from the temperature structure of the model at the considered phases and the assumed turbulence velocity structure. The $p(\mathrm{CO})/p(\mathrm{H})$ values needed for determining $k_{\Delta\lambda}$ were obtained from the concentration-optical depth curves of Pande et al. (1972).

For each phase the $r(\Delta\lambda)$ values at various $\Delta\lambda$'s were obtained using (2) and (3) and numerical integration of these yielded the desired equivalent widths. The equivalent widths of the $R(29)$ and $R(31)$ lines for maximum phase of light variation in η Aql are 0·020 mÅ and 0.019 mÅ. For the minimum phase the equivalent widths of the two lines are 4·17 mÅ and 3·17 mÅ respectively.

The line to continuum ratio of absorption coefficients for the 7296·937 Å line (R_1, $K = 30$) of the 0 – 3 band of comet-tail system, was compared with the same ratio obtained for the solar photosphere by Pande and Gaur (unpublished) and we conclude that these lines will not show up in the η Aql spectrum.

Conclusions

From the above we conclude that under our assumptions, the lines belonging to the first overtone of CO are not observable near the maximum phase of light variation in η Aql. However, there are some chances of detecting these lines near the minimum phase if high resolution and high dispersion spectra of the star become available. If the lines of CO do not show up, then one may either have to alter the model used (a hotter model will then be more objective), or else the abundances assumed in our calculations.

Also, the lines belonging to the 0 – 3 band of the transition $A^2\Pi_i - X^2\Sigma^+$ should be absent in the star's spectrum.

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