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A DIFFUSION MASS-LOSS MODEL FOR THE AP STAR 53 CAM

J. BABEL
Institut d'Astronomie de l'Université de Lausanne, CH-1290 Chavannes-des-Bois, Switzerland

ABSTRACT The mechanism and properties of mass loss are poorly known for Ap stars. Present upper limits on the mass loss rate are of 10^{-10} $M_\odot yr^{-1}$, a value which does not permit any element separation. Abundance maps could be a very powerful tool to constrain the mass loss rate and the wind geometry of Ap stars, as surface abundances are sensitive to rates as small as 10^{-15} $M_\odot yr^{-1}$. We here propose a diffusion-mass loss model for 53 Cam and compute abundance distributions in the photosphere of 53 Cam. The mass loss geometry is determined from the Ca II K line profile and its time variation. We obtain that the diffusion-mass loss model explains many spectral features of 53 Cam, both in the UV and visible domains.

DIFFUSION AND MASS LOSS

In Babel & Michaud (1991a,b,c), it was shown that the parameter free diffusion model could explain the "mean" abundances observed on 53 Cam (Landstreet 1988), but not the abundance maps. We assume the presence of a weak stationary wind, which is inhomogeneous on the stellar surface. For 53 Cam, we obtain that most chemical elements rapidly reach (in about 10^6 yrs) an equilibrium solution with $V_{tot} = 0$. In contrast, some elements tend towards a stationary solution with constant positive outwards flux.

Equilibrium and stationary abundance distributions were calculated in detail for the atmosphere of 53 Cam, for Cr, Sr, Ca, Mn and Ti (see Fig. 1) and for mass loss rates lower than 4 10^{-15} $M_\odot yr^{-1}$ (see Babel 1992). We obtained that: 1) Over the mass loss range considered, chemical abundances of the considered trace elements in the convection zone raise with the mass loss rate. 2) Abundance distributions are strongly stratified in the atmosphere.

COMPARISON WITH OBSERVATION

The very large abundance stratification obtained and its effect on line profiles led us both to reanalyse the data on 53 Cam obtained by Landstreet (1988) (Babel 1992) and to perform abundance analysis on *IUE* high-resolution spectra (Babel & Lanz 1992)

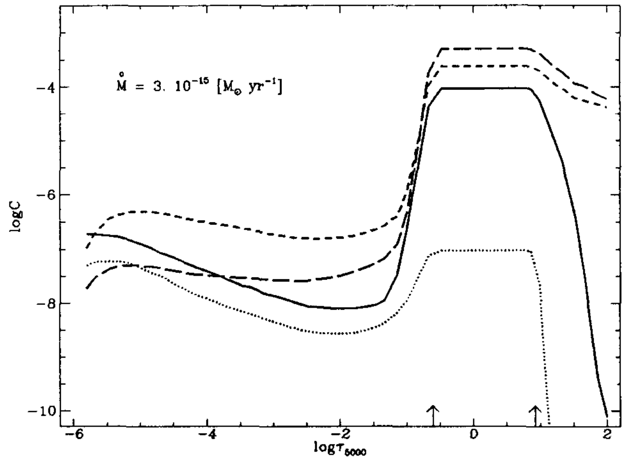

FIGURE I Equilibrium abundance distribution in 53 Cam, for a mass loss rate of $\dot{M} = 3\ 10^{-15}\ M_\odot yr^{-1}$ (Ca:solid line, Sr:dots, Mn:long dashes, Cr:short dashes, Ti:dot-long dashes). The arrows indicate the borders of the H I convection zone.

Visible: The Ca II K line, was used to determine the wind geometry of 53 Cam, as the photospheric calcium abundance distribution varies strongly with the mass loss rate and as the K line is very sensitive to abundance stratification.

We obtain that the peculiar spectral profile of the K line and its time variation are very well reproduced by the diffusion-mass loss model, if a wind of $\dot{M} = 3\ 10^{-15}\ M_\odot yr^{-1}$ is present in the two caps around the magnetic poles. The line profiles of other elements like Cr and Sr are also very well reproduced by this model. Elements like Ti and Mn are yet not well accounted (see Babel 1992).

UV: We investigated the UV domain (2500-3100 Å) with *IUE* spectra of 53 Cam (Babel & Lanz 1992) and obtained abundances of Cr, Fe, Mn, Ti and Ca for two rotation phases. The most striking result of our UV analysis is the considerably lower Cr and Fe abundances deduced (about 0.8 dex) from the UV domain than obtained by Landstreet (1988) from the visible. We obtained simultaneously a very good agreement between the predictions of the diffusion-mass loss model for chromium and both visible and UV Cr II line intensities. These results clearly show, in accordance with the diffusion model, that chemical elements have strongly stratified abundance distributions in the photosphere of 53 Cam.

CONCLUSION

We have developed a simple diffusion-mass loss model for 53 Cam. We assumed that H II convection was not affected by the magnetic field and introduced a

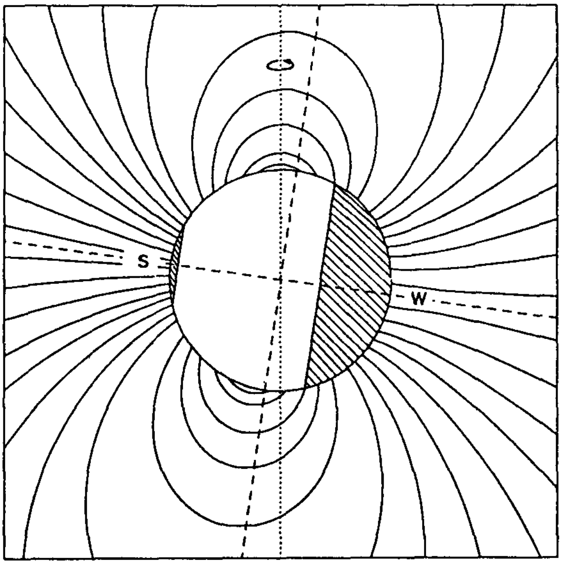

FIGURE II Mass outflow distribution on the surface of 53 Cam deduced from the profile and variation of the Ca II K line and from the diffusion-mass loss model ($\dot{M} = 3\ 10^{-15}\ M_{\odot} yr^{-1}$: hatched areas; $\dot{M} \simeq 0.0$, elsewhere). The magnetic geometry is from Landstreet (1988). Labels S and W indicate respectively the strong pole (-18000 G) and the weak pole (4100 G). The size of the mass loss caps are quite well constrained by the large phase coverage of the observations of Landstreet (1988).

small inhomogeneous wind as a free parameter. The diffusion-mass loss model explains simultaneously visible abundance maps, UV abundances of Cr and the profile of the Ca II K line. It gives the first evidence of a magnetically confined wind on the surface of a cold Ap star. It fails yet, in explaining the map of elements like Ti, which are sensitive to the transition region with the wind (see Babel 1992).

Our results finally show that the conjunction of detailed abundance maps and diffusion calculations could permit to reveal hydrodynamics phenomena which can not be detected at present by direct observation.

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