An observer who cut her big toe
Needed blood to make up for the flow
When the nurse asked "what type"
She replied without hype
"If you're working for Conti its O".

SESSION 5

a) THEORY AND MASS LOSS RATES
b) BINARY STARS
c) MISCELLANEOUS TOPICS

Chairman: J.M. MARLBOROUGH

a) 1. D.C. ABBOTT: The domain of radiatively driven mass loss in the HR diagram.
2. A.G. HEARN and I.M. VARDAVAS: Stellar corona models.
3. P.B. KUNASZ: Synthetic line profiles in early-type stellar winds. I. H and He^+.
4. D. VAN BLERKOM: The Hα profile in Zeta Puppis.
5. P.D. NOERDLINGER: The mass loss rate of γ Velorum.
6. G. OLSON: Wind models for ζ Orionis.

b) 1. C.D. GARMANY: Binary frequency among the O-type stars.
2. K.C. LEUNG and D.P. SCHNEIDER: Contact binaries of spectral type O.
3. P.C. MASSEY and P.S. CONTI: The O-type spectroscopic binary system HD 149404.
4. N.D. MORRISON and P.S. CONTI: The O-type spectroscopic binary system HD 93206.
5. Y. KONDO, G.E. McCLUSKEY, Jr. and J. RAHE: Mass flow and evolution of UW Canis Majoris.
6. V.S. NIEMELA and J. SAHADE: The spectroscopic binary γ^2 Velorum.
7. V.S. NIEMELA: The binary orbit of HD 92740.
8. C.T. BOLTON: Results from the 1977 coordinated observing campaign on HD 226868=Cygnus X-1.

c) 1. L. CARRASCO, G.F. BISIACCHI, R. COSTERO and C. FIRMANI: The nature of the runaways: old disk population OB stars?
2. G.F. BISIACCHI, L. CARRASCO, R. COSTERO, C. FIRMANI and J. RAYO: The distribution in luminosity of OB stars and evolutionary time scales.
3. W.P. BIDELMAN: H-deficiency and mass loss.

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THE DOMAIN OF RADIATIVELY DRIVEN MASS LOSS IN THE H-R DIAGRAM

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INTRODUCTION

Previous work by Castor, Abbott, and Klein (1975) presented a self-consistent model of a steady-state stellar wind. They also showed qualitatively that for O stars at least a static atmosphere could not exist. This paper extends that result by calculating in detail the minimum luminosity as a function of effective temperature required for the line radiation force to exceed gravity. Within the observational and theoretical uncertainty there is a one-to-one correspondence between a star's calculated ability to self-initiate a stellar wind by radiation pressure alone and the observed presence of outflowing material in the UV resonance lines.

COMPUTATIONS

Two cases were considered: (i) static stars and (ii) stars which were assumed to have a wind initially. The line list used for both cases was a synthesis of the extensive tabulations of Kurucz and Peytremann (1975) and Abbott (1977, 1978), supplemented by more accurate experimental and theoretical oscillator strengths for the resonance lines of the important ions (e.g., Morton, 1978). The radiation force was calculated for each line and then summed over all lines in the list to give the total force.

Static Case

In the static case the force was calculated using the two level atom plus overlapping hydrogen continuum approximation. Castor (1974) has given expressions for the line radiation force in terms of the line source function for this case. The line source function was calculated following the prescription of Hummer (1968). The ionization balance was calculated using the Saha equation at density and temperature (n,T). ($n = n_e$, T = gas temperature) was used for points where the overlapping hydrogen or helium continua were optically thick, while ($n = n_e/W = 2n_e$, T = radiation temperature) was used for optically thin points. The run of density

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and temperature with depth and the radiation temperature with frequency were taken from model atmospheres of Mihalas (1972). The maximum radiation force occurs when all lines are optically thin. However, the force continued to increase with decreasing density even beyond this point because of ionization effects. The calculations were therefore truncated at the density at which the drift velocity of the predominant ion equaled the proton thermal velocity, on the assumption that at smaller densities the ion could not transfer its absorbed radiative momentum to the rest of the gas.

Wind Case

For each effective temperature stellar wind models were calculated as described in Caster, et al. (1975), except for the use of the line list described above. The core photospheric fluxes were taken from models of Kurucz, Peytremann, and Avrett (1974). The maximum radiation force occurs when all lines are optically thin, however, a steady-state solution does not exist unless at least one important line is optically thick through the critical point. Since the density of the wind decreases with decreasing luminosity, the minimum luminosity or "wind limit" is defined uniquely by the condition that all lines become optically thin exterior to the critical point.

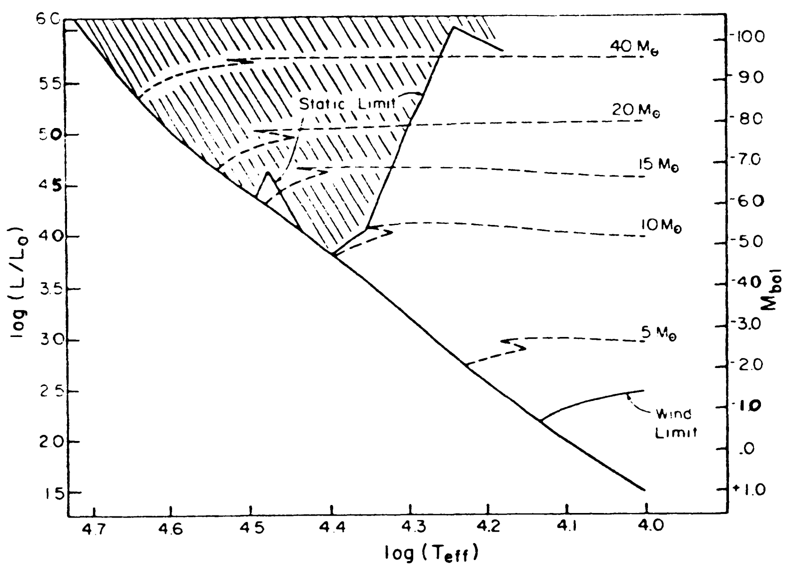

Figure 1 - Minimum luminosity required to initiate (static limit) and to sustain (wind limit) a radiatively driven wind.

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RESULTS

The results are shown in Figure 1. Three regions are delineated. (i) The shaded region indicates luminosities greater than the "static limit". For these stars a static atmosphere is dynamically unstable, i.e., a radiatively driven wind is self-initiating. (ii) For stars whose luminosity lies between the "static" and "wind" limit both a hydrostatic atmosphere and a stellar wind are possible equilibrium solutions. In this region radiation pressure can sustain an existing wind but cannot initiate a wind. (iii) For stars beneath the "wind limit" a stellar wind can neither be initiated nor maintained by a line radiation force.

Region (i) agrees with the observed distribution of stars having winds which Lamers and Snow (1978) found was bounded by $M_{bol} \sim -6$. This correspondence also seems to indicate that in region (ii) stars have chosen to remain static. This could be either because there is no other mechanism which can initiate a wind or because in this region the wind is an unstable equilibrium solution. Of particular interest for discriminating between these possibilities are stars whose evolutionary tracks have crossed the "static limit".

On the other hand, region (ii) has not been carefully observed in the UV. Since the rates of mass loss are small, winds in these stars may not be obvious. As an example, in the Copernicus U2 scans of 20 Tau and ζ Dra the C II λ1335 and C III λ1176 lines appear to have very weak, violet-shifted absorption extending several Angstroms beyond the photospheric profile, which may indicate outflow. Also, since even these low rates of mass loss would overwhelm diffusion, the coincidence of the "wind limit" with the onset of the peculiar B_p stars may indicate that winds exist for stars in region (ii).

A paper in preparation will describe more fully these results and their implications for peculiar Ap stars and Be stars. This work was supported by NSF grant No. AST76-15448 to the University of Wisconsin.

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DISCUSSION FOLLOWING ABBOTT

Underhill: Saul Adelman and I have identified ultra-violet lines in ζ Dra, B6III and τ Her, B5IV (Ap.J.Suppl. 1977). We found no need to hypothesize faint extended shortward wings in CII 1335 or CIII 1176 in these stars. Stalio has done identifications for types near B8. The presence of possible neighbouring lines must be carefully evaluated before concluding a shortward extended absorption wing is present.

Wolff : The Hg Mn stars increase both in frequency and in the conspiciousness of their peculiarities up to a sharp boundary somewhere between 15000 and 16000 K. This boundary coincides fairly well with your lower limit for radiation supported winds. However, there are certainly a few - but a very few - peculiar stars, particularly those with enhanced lines of phosphorus and gallium, that are hotter than your boundary. Regrettably, 20 Tau itself shows a marginal enhancement in its manganese line strengths.

Stalio: I want to mention that the Hg Mn star α And seems to have displaced resonance line components for SiII (from U1 Copernicus data). The terminal velocity of the displaced components is of the order of -100 km/s.

de Loore: Concerning the Ap stars, the Si-Eu-Cr stars are not included in your comments. Do they fit also in this picture or not?

Abbott: These are stars observed to have magnetic fields. Magnetic fields are effective in inhibiting a wind, which means this picture probably does not apply to these stars.

Vreux: Could you comment on the influence of a corona on your results?

Abbott: To the extent that a corona raises the state of ionization it will sharply decrease the force. To my knowledge there is as of yet no observational evidence that main sequence late B and early A stars have coronae.

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