ACOUSTIC WAVE DRIVEN MASS LOSS IN LATE-TYPE GIANT STARS

M.Cuntz[1], L.Hartmann[1,2] and P.Ulmschneider[1]
[1]Institut für Theoretische Astrophysik, Im Neuenheimer Feld 561
6900 Heidelberg, Federal Republic of Germany
[2]Harvard-Smithsonian Center for Astrophysics, 60 Garden Street
Cambridge, MA 02138, USA

ABSTRACT. Mass loss generated by radiatively damped acoustic waves is investigated. We find that a persistent wave energy flux leads to extended chromospheres. Mass loss is quite likely produced if the wave field retains a transient character and if large wave periods are used.

1. INTRODUCTION

Three facts suggest that acoustic waves may be important for the generation of mass loss in late-type giant stars: Pulsation appears to be a viable mechanism for driving mass loss from Mira stars. For late-type giant stars one expects nonradial oscillations of angular quantum number l lower than ten and large wave periods (compared with the acoustic cut-off period), approaching the pulsation period. Short-period acoustic wave calculations show that with increasing period more wave energy is fed into mass motion than into heating.

2. EXTENDED CHROMOSPHERES DUE TO DISSIPATION OF ACOUSTIC WAVE ENERGY

With an Eulerian spherical time-dependent hydrodynamic code which treats radiation losses with a Cox and Tucker type law we have computed models for α Boo. Our aim was to investigate the acoustic wave spectrum between the periods 0.1 P_{co}=1.4 10^4 s and the pulsation period 6 10^6 s, P_{co} being the acoustic cut-off period. In our first model we introduced a monochromatic acoustic shock wave with an initial amplitude of 0.2 Mach and a period of 0.1 P_{co} in an atmospheric shell of 20 percent of the stellar radius. The result was that the scale height greatly increased; at the upper boundary of the shell the pressure scale height is more than a factor of six higher than in the undisturbed atmosphere. This behaviour agrees well with the observation that the chromosphere in α Boo is extended (Carpenter and Brown 1985). The larger scale height is primarily due to the increased mean temperature caused by shock heating and to a lesser degree due to wave pressure caused by wave momentum dissipation in the shocks. As the dynamical steady state resulted in a very low mean flow velocity it was concluded that monochromatic short-period acoustic waves lead mainly to extended atmospheres and not to mass loss.

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3. GENERATION OF MASS LOSS BY ACOUSTIC WAVES

To satisfy the requirement for spatial resolution of the waves, and the boundary condition at infinity a compromise must be made as to the spatial extent of the atmosphere. For our preliminary results we consider three criteria to suggest the presence of mass loss in our finite atmospheric shell. The first criterion looks for the time-averaged flow velocity in the upper part of our model. After passage of the initial switch-on effect and after the damping of the atmospheric oscillation the mean flow velocity $v_m >> 0$ approaches a steady state. This steady mean flow we take as indication of mass loss. If (second criterion) in the upper parts our model the flow speed v becomes comparable or larger than the sound speed c mass loss is suggested. When in the upper parts of our atmosphere the mean flow speed becomes both larger than the sound speed and the escape speed v_{esc} we take this as our third criterion for mass loss. By various degree these criteria suffer from the unknown influence of the overlying atmosphere. In our second model we take a short-period Gaussian acoustic frequency spectrum of the same energy centered at the period of 1.4 10^4 s with a standard deviation of 2.0 10^4 s and cut off at 5 10^3 s to avoid negative periods. In the upper part of the model for a given time we now find mass loss after our first two criteria. At another time however we have $v<c$. Unlike to the monochromatic case the atmosphere is now unable to find a state with $v_m=0$. Long period waves from the spectrum or generated by overtaking shocks again and again lead to supersonic flows which suggests episodic mass loss. Our third model assumes long period (3.0 P_{co}) monochromatic adiabatic acoustic shock waves with an initial amplitude of 0.1 Mach in an atmosphere which extends over 11 stellar radii. We find $v_m > v_{esc}$, c which fulfills our third criterion and mass loss rates of about 10^{-11} M_o per year which are in rough agreement those by Drake and Linsky (1984). Yet it is known that adiabatic calculations overestimate the mass loss (Wood 1979).

4. CONCLUSIONS

We find that short-period acoustic waves are able to produce extended chromospheres. Monochromatic waves with periods much below the cut-off period do not lead to appreciable gas flows. Short-period acoustic wave spectra possibly generate episodic mass ejections. Adiabatic waves with periods of several times the cut-off period produce reasonable mass loss rates. We suggest that both long and short period waves are needed for an effective acoustic mass loss mechanism, the short period waves to produce extended chromospheres and the long period waves to push off the mass.

REFERENCES

Carpenter, K.G., Brown, A.: 1985, Astrophys. J. 289, 676

Drake, S.A., Linsky, J.L.: 1984, Proc. 3rd Cambridge Workshop on Cool Stars, Stellar Systems and the Sun, S.L. Baliunas, L. Hartmann Eds., Springer, Berlin, p. 350

Wood, P.R.: 1979 Astrophys. J. 227, 220

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