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ATMOSPHERIC PULSATIONS AND MASS LOSS DRIVEN BY OVERTAKING ACOUSTIC SHOCKS.

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ABSTRACT A new pulsation mechanism was found which uses short period acoustic waves as energy source and is triggered by shock overtaking. This mechanism together with the well-known κ–mechanism could be an important mass loss driver for late-type giant stars.

Keywords: Acoustic waves; shocks; pulsation; late-type stars; mass loss

INTRODUCTION

From the analogy with the combustion engine one learns that a stellar pulsation mechanism needs an *energy source* which balances the large radiation losses of the atmosphere resulting from the pulsation and a *trigger* which releases the driving energy at the right phase in the pulsation cycle. In the *combustion engine* the spark ignites the gasoline at the moment of highest compression. The *κ–mechanism* which drives the Cepheid and Mira pulsations works by converting radiation energy into heat at the moment of highest compression, where the opacity at the highest temperature and pressure is largest. In the newly found *shock overtaking pulsation mechanism* (Rammacher and Ulmschneider 1991) short period acoustic shock waves by the process of overtaking are converted into strong shocks at the moment of largest compression. We investigate the possible significance of this mechanism for mass loss in late-type giant stars.

THE SHOCK OVERTAKING PULSATION MECHANISM

From their solar acoustic wave calculations Rammacher and Ulmschneider (1991) conclude: 1. That a single strong acoustic pulse creates pulsational oscillations in the atmosphere. These oscillations decay rapidly due to the large radiation losses (see Fig. 1). 2. Excitation by monochromatic acoustic waves with periods less than the acoustic cut-off period $P_A \approx 180$ s and greater than a period $P_O \approx P_A/5 \approx 40$ s eventually leads to atmospheric oscillations with a period forced by the wave. When these wave calculations are started, transients with periods near P_A are superposed over the shorter period waves. These transients decay rapidly similarly as in the calculation with an acoustic pulse. 3. For an excitation with monochromatic waves with periods less than $P_O \approx P_A/5 \approx 40$ s the wavelength is small enough that shock overtaking occurs in the chromosphere in regions where the temperature (and sound speed) decreases outwardly. This shock overtaking produces a strong shock which generates pulsations with periods $P_P \approx 165$ s near the cut-off period. These pulsations persist as long

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as the acoustic wave is present (see Fig. 1). 4. The *shock overtaking pulsation mechanism* produces first overtone pulsations (outer atmosphere expansion and inner atmosphere contraction followed by the reverse situation) P_P which are more rapid than the fundamental oscillations (expansion everywhere followed by contraction everywhere) P_A.

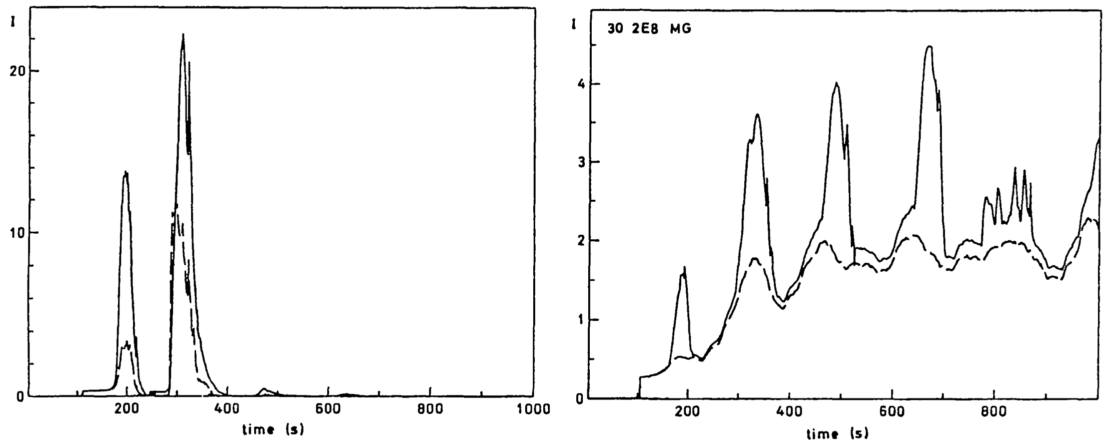

Fig. 1: The intensity of the violet (drawn) and red (dashed) emission peaks of the Mg II k-line for a single acoustic pulse (left) and a short period acoustic wave with $P = 30s$ (right) after Rammacher and Ulmschneider (1991).

MASS LOSS BY THE SHOCK OVERTAKING PULSATION MECHANISM

Fig. 2 shows empirical mass loss rates of stars in the HR-diagram as reported by Cassinelli (1979). Superposed we have indicated various mass loss mechanisms which are currently discussed in the literature. It is widely accepted that early-type stars have mass-loss by *radiation driven winds* and that late-type giants and supergiants above and to the right of a line recently given by Gail and Sedlmayr (1987) as well as Dominik *et al.* (1990) have *dust-driven winds.* Mass loss in Mira-stars is due to *pulsation driven winds.* At the main sequence, stars like the sun have weak mass loss rates due to *thermal winds.* As shown by Hammer (1981) the observed mass loss rates higher in the HR-diagram can not be explained by thermal winds. *Alfvén wave driven winds* possibly exist only below and near the Linsky-Haisch dividing line, above which, due to the very low rotation rates the dynamo action ceases and the stars are not expected to have significant magnetic fields. *Acoustic wave driven winds*, due to shock overtaking of waves of different periods in a spectrum, have been demonstrated to lead to episodic mass loss (Cuntz 1990). However, it has not been shown that this latter process can drive the large observed mass loss rates below the Dominik *et al.* line. We therefore feel that a significant mass loss process is missing to drive mass loss of red giants below the Dominik *et al.* and above the Linsky-Haisch line. Moreover near the Dominik *et al.* line for the dust driven wind mechanism to work an additional mechanism is needed to bring a lot of mass to the dust formation radius.

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We propose that this missing mechanism could be the shock overtaking pulsation mechanism which produces and self-starts nonradial pulsations depending on the available short period acoustic wave power and its distribution over the stellar surface. Rammacher and Ulmschneider (1991) find that a large fraction of the short period acoustic wave energy flux is converted into pulsational wave energy. These pulsations would then be assisted and amplified by the κ–mechanism such that both the strong radiation field and the large acoustic wave flux (Bohn 1984) may be tapped for driving the wind loss. This scenario agrees strikingly well with the observational fact that these late-type giants exhibit a wide range of irregular variability. However, a final verdict over this picture can only be given when detailed computations involving the excited atmospheric and envelope oscillations have been made.

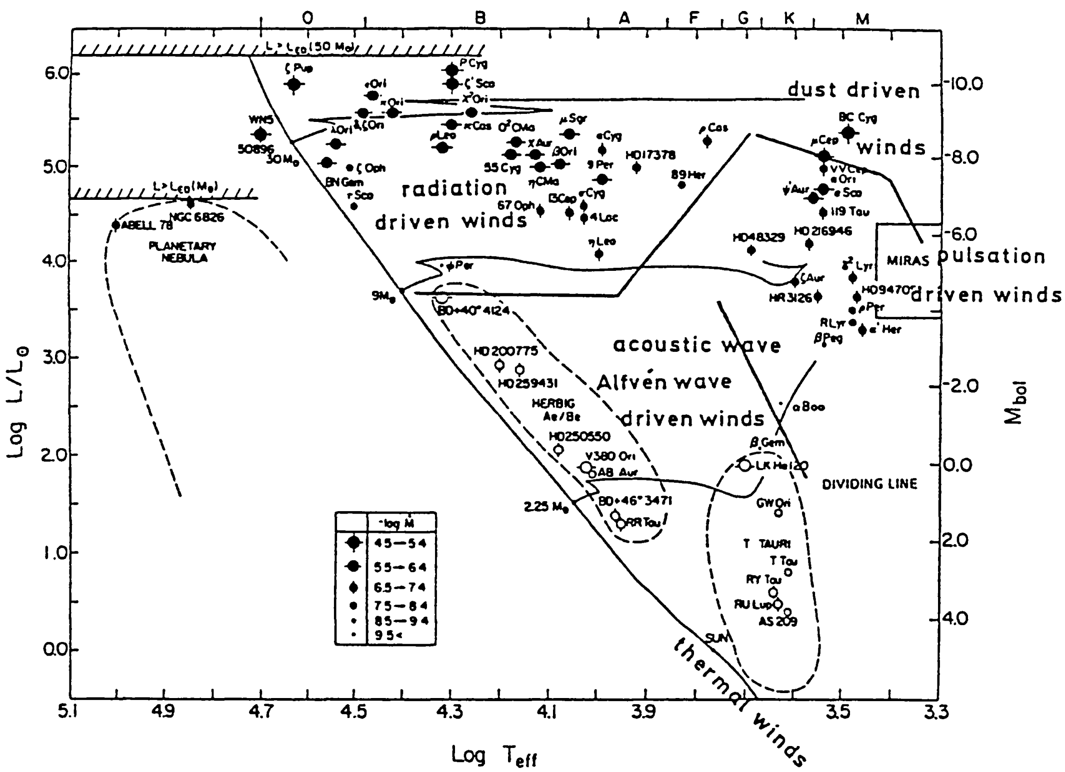

Fig. 2: Mass loss rates together with proposed and confirmed mass loss mechanisms in the HR-Diagram after Cassinelli (1979).

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