INFLUENCE OF THE PERTURBATION OF THE REYNOLDS TENSOR ON THE STABILITY OF THE SOLAR 5 MINUTE OSCILLATIONS

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I. INTRODUCTION.

The excitation mechanism of the 5 min. oscillations is not yet understood. So far two mechanisms have been discussed. The first one is the linear vibrational instability. The second one is the non linear coupling between convection and pulsation discussed by Goldreich and Keeley (1977) and Goldreich and Kumar (1986).

The vibrational stability was studied by several groups (Ando and Osaki 1975, 1977, Berthomieu et al. 1980, Antia et al 1982, Christensen-Dalsgaard and Frandsen 1983, Antia et al. 1986). Some of them neglected the perturbation of the convective flux, some took it into account. However there are two more terms in the expression of the coefficient of vibrational stability which have been ignored so far. They are both connected to the perturbation of the Reynold tensor and therefore depend of the interaction between convection and pulsation.

The aim of this paper is to investigate the influence of the two terms on the vibrational stability of the solar 5 min. oscillations.

II. COMPUTATION OF THE PERTURBATION OF THE REYNOLD TENSOR.

The two terms of the coefficient of vibrational stability discussed here can be found in Ledoux and Walraven (1957). However, we write them in such a way that their connection with the Reynold tensor ($\overline{\rho V^i V^j}$) appears clearly. They write:

$$\sigma_2' + \sigma_3' = - \frac{\frac{3}{2}\int (\Gamma_3 - \frac{5}{3})(\frac{\delta\rho}{\rho}) \ I(\delta p_t) dV}{2 \ \sigma_a \int |\delta r|^2 \ \rho dV} + \frac{\int I(\beta^i_j) \ \nabla_i \ \delta r^{*j} \ dV}{2 \ \sigma_a \int |\delta r|^2 \ \rho dV}$$

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where
$$\beta^{ij} + \delta p_t \delta^{ij} = \delta(\overline{\rho V^i V^j})$$
$$\delta p_t = \frac{1}{3}\,\mathrm{Tr}\;\delta(\overline{\rho V^i V^j})$$

To compute the perturbation of the Reynold Tensor, we follow the same procedure and the same theory as Gabriel et al. (1975). Some care must be taken in averaging over the convective wave vector $\vec{k}$. We suppose that its horizontal component k_H is randomly distributed and that $(k_r/k_H)^2 = R$ where R is a free parameter (k_r is the vertical component of $\vec{k}$ and R = 2 for isotropic convection).

As we perturb a convection described by the mixing length theory, we also have to decide of an expression for the perturbation of the mixing length ℓ. After Cowling (1935) we take

$$\delta\ell/\ell = \delta r/r$$

For comparison, the calculations were also done supposing $\delta\tau = 0$ where $\tau = \ell/V_r$ is the live-time of the convective eddies.

III. NUMERICAL RESULTS.

σ'_2 and σ'_3 have been computed for modes in the 5 min. range of degree l equal to 2, 10, 20, 200, 400 and 600 and for values of the parameter R equal to 0.5, 1, 2, 4 and 8. It is found that:

1) For $\delta\tau = 0$ the modes are slightly more unstable than for $\delta\tau \neq 0$;
2) The strongest instabilities are found for R = 2 and 4;
3) For a given degree the most unstable mode has the same order n for R = 2 and 4 and the e-folding times τ_e have the same order of magnitude.

In the following, we consider the results for R = 2 and 4 and $\delta\tau = 0$.

4) For l = 2, 10 and 20 all the modes considered (P > 3.7 min) are unstable. The e-folding time and the order of the most unstable modes are given in table 1. It is interesting to notice that for l= 2, the modes of order 20, 21 and 22 are those which have the largest observed amplitudes.

Table 1
most unstable modes of low degree

l	n	τ_e(years)
2	21	0.22
10	16< n <21	0.24
20	16	0.15

Table 2
most unstable modes of high degree

l	n	τ_e	n^*
200	3	.076	8
400	2	.073	4
600	1	.014	2 if R = 4 3 if R = 2

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5) for l = 200, 400 and 600 only the modes with $n \leq n^*$ are unstable. n^* is given in table 2 together with the order n and the e-folding time τ_e of the most unstable modes. In Deubner et al. (1979) power spectrum the power drops sharply for $n > n^*$ and the most unstable modes among those which have the largest energies.

IV. CONCLUSION

The e-folding times we find are of the same order of magnitude as these found y other authors for the flux term. Therefore when the interaction between convection and pulsation is discussed, one cannot just consider the perturbation of the convective flux and the two terms discussed here must also be taken into account. We also find the results encouraging as they fit well the few observational results we have.

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