Hydrodynamical, 3D simulations of the outer layers of the Sun and α Cen A are used to obtain constraints on the properties of turbulent convection in such stars. These constraints enable us to compute — on the base of a theoretical model of stochastic excitation — the rate \( P \) at which \( p \) modes are excited by turbulent convection in those two stars. Results are then compared with solar seismic observations and recent observations of \( \alpha \) Cen A. For the Sun, a good agreement between observations and recent observations of \( \alpha \) Cen A. From those observations Bedding et al. (2004) have derived oscillation amplitudes and also averaged estimates of the oscillation life-times.

The stochastic excitation mechanism has been modeled by several authors (e.g. Goldreich & Keeley 1977; Goldreich et al. 1994; Samadi & Goupil 2001). On the base of Samadi & Goupil (2001)’s theoretical model of stochastic excitation and constraints from a 3D simulation of the Sun, Samadi et al. (2003a) succeeded in modeling the rates \( P \) at which the solar \( p \)-modes are excited by using a Lorentzian function as a model for the eddy-time correlation \( \chi_k \), instead of using the Gaussian function. This result is summarized in Sect. 4.

An open question is then whether or not such non-Gaussian model for \( \chi \), is also appropriate for other solar-like oscillating stars and whether the present model of stochastic excitation is valid for other stars? This question is addressed on the basis of the recent seismic observations of \( \alpha \) Cen A.

2. THE THEORETICAL MODEL OF STOCHASTIC EXCITATION

The model of stochastic excitation we consider in this work is basically that of Samadi & Goupil (2001). This model provides an expression for the rate \( P \) at which a given mode with frequency \( \nu_0 \) is excited. This expression can be written in a schematic form as:

\[
P(\nu_0) \propto \int dm \int d\tau \int d\tau' \langle \xi \rangle \langle \xi \rangle \langle SS \rangle \cdot \xi
\]

(1)

The calculation of the rate \( P(\nu_0) \) at which a given \( p \)-mode of frequency \( \nu_0 \) is excited, then results from an integration over the stellar mass \( m \) and local integrations over distance \( \tau \) and time \( \tau' \) (of the mode eigenfunction \( \xi \) and the correlation product of the excitation sources \( \langle SS \rangle \)).
The excitation sources, $S$, are: the turbulent Reynolds stress and the advection of the turbulent entropy fluctuations by the turbulent motions. $<SS>$ is expressed in term of the turbulent kinetic energy spectrum $E(k,\nu)$ where $k$ is the wavenumber of a given turbulent element (see [Samadi & Goupil 2001]). Following [Stein 1967], $E(k,\nu)$ is split into a spatial component, $E(k)$, and a frequency component — $\chi_k(\nu)$, also designed as the eddy-time correlation function — so that

$$E(k,\nu) = E(k) \chi_k(\nu). \quad (2)$$

3. COMPUTATION OF THE EXCITATION RATES $\chi$.

We consider a 3D simulation of $\alpha$ Cen A computed with [Stein & Nordlund 1998]'s 3D numerical code which models only the upper part of the convective zones. The grid of mesh points of the simulation is 50 x 50 x 82 large. The simulation has a solar metalicity while the real star has a metallicity [Fe/H] $\sim$ 0.2.

We compute the rate $P(\nu)$ at which p modes are excited in $\alpha$ Cen A according to Eq. (1) in the manner of [Samadi et al. 2003b]: The 1D stellar model consistent with the simulations of stars is computed with [Christensen-Dalsgaard & Frandsen 1983]'s stellar code and assumes the classical mixing-length formulation of convection. The mixing-length parameter of the 1D model is adjusted in order that the 1D model matches the simulation. The eigenfunctions ($\xi$) and their associated frequencies ($\nu$) are computed with [Christensen-Dalsgaard & Berthomieu 1991]’s adiabatic code. The total kinetic energy contained in the turbulent kinetic spectrum, $E(k,\nu)$, its depth dependence, and its $k$-dependency are obtained directly from the 3D simulation. For the eddy time-correlation function $\chi_k$, a Gaussian function is usually assumed, i.e. it is assumed that two distant points in the turbulent medium are un-correlated (e.g. [Goldreich & Keeley 1977; Balmforth 1992]). Here, we investigate both a Gaussian and a Lorentzian form for $\chi_k$.

For the Sun (see Fig. 1): the rate $P(\nu)$ at which solar p modes are excited $P(\nu)$, was already computed in [Samadi et al. 2003b] on the basis of a 3D simulation of the Sun with a higher spatial resolution (253x253x163) than that of the present simulation of $\alpha$ Cen A.

4. EXCITATION OF SOLAR P MODES.

It is shown — on the base of a 3D simulation of the Sun — that the Gaussian function usually used for modeling the eddy-time correlation function, $\chi_k$, is inadequate [Samadi et al. 2003b]. Furthermore the use of the Gaussian form under-estimates $P$ as shown in Fig. 1 with the blue curve.

On the other hand, a Lorentzian form fits best the frequency dependence of $\nu$ as inferred from a 3D simulation of the Sun. Computed values of $P$ based on the present model of stochastic excitation and on a Lorentzian function for $\chi_k$ reproduce better the solar seismic observations by [Chaplin et al. 1998] as shown in Fig. 1 with the red curve.

This result then shows that, provided that such non-Gaussian model is assumed, the model of stochastic excitation is — for the Sun — rather satisfactory without adjustment of free parameters in contrast with previous approaches ([Christensen-Dalsgaard 1982; Balmforth 1992; Goldreich et al. 1994; Samadi et al. 2001]).

5. $\alpha$ CEN A: THE OBSERVATIONS BY BEDDING ET AL. (2004)

Solar-like oscillations have recently been detected in $\alpha$ Cen A by [Butler et al. 2004] with the UCLES spectrograph. The identification of the modes and the determination of the mode amplitudes have been recently performed by [Bedding et al. 2004]. Fig. 2 presents the mode amplitudes in Doppler velocity for the $l$=0,1,2,3 modes which have been detected.

The authors have also derived — on the basis of the method proposed by [Stello et al. 2004] — an estimation of the mode life-times for two different frequency ranges (see Table 1).

Table 1. Life-time of the modes as derived by Bedding et al. (2004) for two different frequency ranges.

| Frequency range (µHz) | 1700-2400 | 2400-3000 |
|----------------------|-----------|-----------|
| Mode life-time (days) | 1.4       | 1.3       |
Figure 2. Amplitudes in Doppler velocity of the modes detected in α Cen A by Bedding et al. (2004). The green filled dots correspond to the l=0 modes, the black ones to the l=1 modes, the red ones to the l=2 modes and the orange one to the l=3 modes. Here the observed amplitudes have not been corrected for the mode visibility.

6. α CEN A: INFERRING THE INTRINSIC AMPLITUDES OF THE MODES FROM OBSERVATIONS

As can be seen in Fig. 2, the measured amplitudes are very scattered. Due to visibility effects, intrinsic amplitudes of l=3 modes ($I_3$) are expected to be much smaller than those of l=1 ($I_1$) i.e. $I_3 \ll I_1$.

However some observed amplitudes of l=3 ($O_3$) are found as large as those of l=1 ($O_1$) but for a given radial order, amplitudes for l=1, l=3 modes are clearly ant correlated as shown in Fig. 2. This suggests that the observed amplitude of a given mode l=3 can be strongly biased by the presence of a neighborhood l=1 mode. In contrast, the pollution of the l=1 amplitude by that of a l=3 one is expected to be quite small. Neglecting this pollution effect, we sum the amplitudes of l=3 and l=1 neighboring modes of a given radial order and attribute this amplitude to l=1 mode i.e.: Since $I_3 \ll I_1$, then $O_3 + O_1 = I_3 + I_1 \sim I_1$. We next correct for the mode visibility.

We perform the same with the l=0 modes: we sum the amplitude of l=0 mode and the l=2 mode. However this determination of the amplitudes of the l=0 modes must be more biased than for the l=1 modes as the amplitudes of the l=2 modes are not so small compared with those of the l=0 modes.

Results of this determination of the intrinsic mode amplitudes are presented in Fig. 3.

7. α CEN A: COMPARISON OF THE PREDICTED EXCITATION RATES $P$ WITH THOSE INFERRED FROM THE OBSERVATIONS

We derive the 'observed' excitation rates $P$ from the intrinsic mode amplitudes (Fig. 3) and the mode life-times (Table 1) inferred from the observations according to the relation:

$$P = 2\pi M \Gamma V^2$$  \hspace{1cm} (3)

where $\Gamma$ is the mode line-width related to the mode lifetime $\tau$ (Table 1) as $\Gamma = 1/\pi/\tau$, $M$ is the mode mass calculated from the mode eigenfunctions associated with the 1D stellar model of α Cen A and finally $V$ is the intrinsic mode amplitude (Fig. 3).

Theoretical $P$ are calculated according to Eq. (1) and as explained in Sects. 2 and 3.

Inferred and predicted mode excitation rates of α Cen A are presented in Fig. 4.
8. CONCLUSION

For α Cen A as for the Sun, \( P \) computed assuming the Lorentzian function for the eddy-time correlation function \( \chi_k \) tend to be closer to the observations than those assuming the Gaussian function, however the quality of the data does not allow to conclude firmly about the best function for \( \chi_k \).

In this first tentative comparison, the predictions and the observations of α Cen A disagree by a large amount (the inferred \( P \) are very scattered: the disagreement varies by a factor 2 to 7 approximatively). This large discrepancy can either be caused by the present data quality which is not sufficient for our purpose, by the way the intrinsic amplitudes and the life-times of the modes are determined or finally attributed to the present modelling. Data of higher quality or/and more adapted data reductions are really welcome for deriving precise constraints on the p-mode excitation in α Cen A.

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