NON-ADIABATIC STUDY OF THE *KEPLER* SUBGIANT KIC 6442183

M.GROSJEAN[1], M.A. DUPRET[1], K.BELKACEM[2], R.SAMADI[2], S.DEHEUVELS[3], O.BENOMAR[4]

mail : grosjean@astro.ulg.ac.be

1 : Institut d'Astrophysique, Géophysique et Océanographie, Université de Liège, BELGIUM
2 : LESIA, Observatoire de Paris-Meudon, FRANCE
3 : UPS-OMP, IRAP, Université de Toulous, FRANCE
4 : Sydney Institut for Astronomy, University of Sydney, AUSTRALIA // Departement of Astronomy, University of Tokyo, JAPAN

ABSTRACT

Due to the precision of *Kepler* observations, we have now access all the characteristics of the modes (frequency, linewidth, height) in the power spectrum of solar-like oscillations. Benomar et al. (2013) have measured the linewidth and amplitude of individual modes (including mixed modes) in several subgiants. Comparison between the theoretical predictions using our non-adiabatic code with observations give important constraints on red-giants models. Lifetimes and amplitudes of modes trapped in the envelope (e.g. radial modes) constrain the characteristics of the convective envelope and its time-dependent interaction with oscillations. Lifetimes and amplitudes of mixed-modes (mainly dipole modes) strongly depend on mode trapping, allowing us to probe the core of red-giants.

We first model Kepler subgiants based on forward modelling of surface properties and observed frequencies. Non-adiabatic computations including a time-dependent treatment of convection give the lifetimes of radial and non-radial modes (including mixed-modes). Next, combining the lifetimes and inertias with a stochastic excitation model gives the amplitudes of the modes. We can now directly compare theoretical and observed linewidths and amplitudes of mixed-modes.

BEST FITTING MODEL

Observations :
- Kepler Q 5-7 (9 months)
- Frequencies, linewidth and amplitudes : [1]
- Spectroscopic constraints : [2]

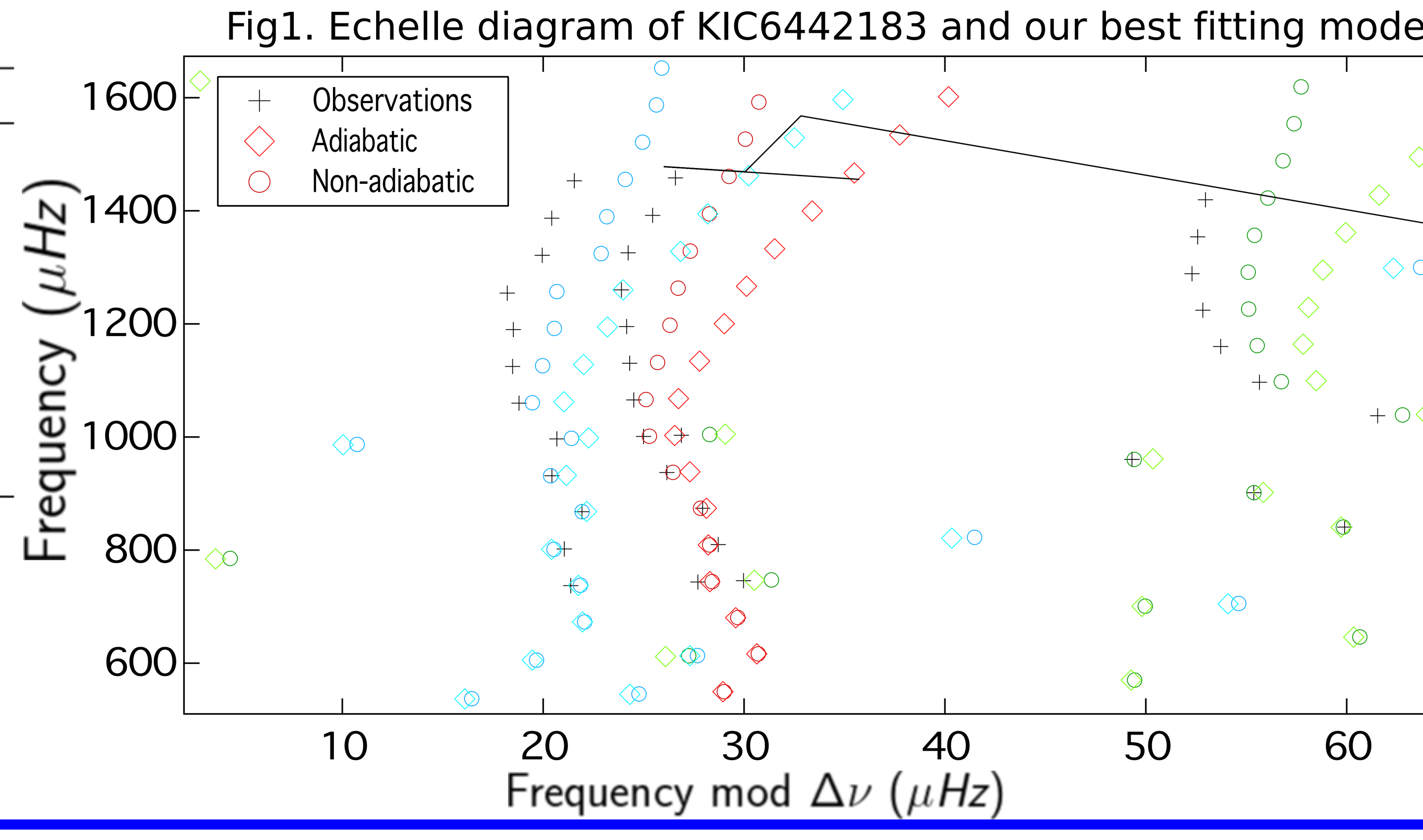
Model :
- structure model with CESTAM [3]
- Input physic : MLT, OPAL, GN93
- **Non-adiabatic oscillations [4] with Time-Dependent Convection [5]**

TABLE 1. MAIN PARAMETERS

	KIC 6442183	Model
M ($M_\odot$)		1.02
R ($R_\odot$)		1.65
T_{eff} (K)	5738 ± 62	5624
log g	4.14 ± 0.10	4.01
[Fe/H]	-0.120 ± 0.050	-0.120
$\Delta\nu (\mu Hz)$	65.07 ± 0.09	65.03
$\nu_{max} (\mu Hz)$	1160± 4	

We fit the spectroscopic constraints and low frequencies modes. **The final model is the one for which the non-adiabatic frequencies are the closest to the observed ones** ([1] have not fitted l=2 mixed-modes in the observed spectra).
With this model, we find inertia ratios, compatible with observations and previous theoretical modelling [9]

Fig1. Echelle diagram of KIC6442183 and our best fitting model

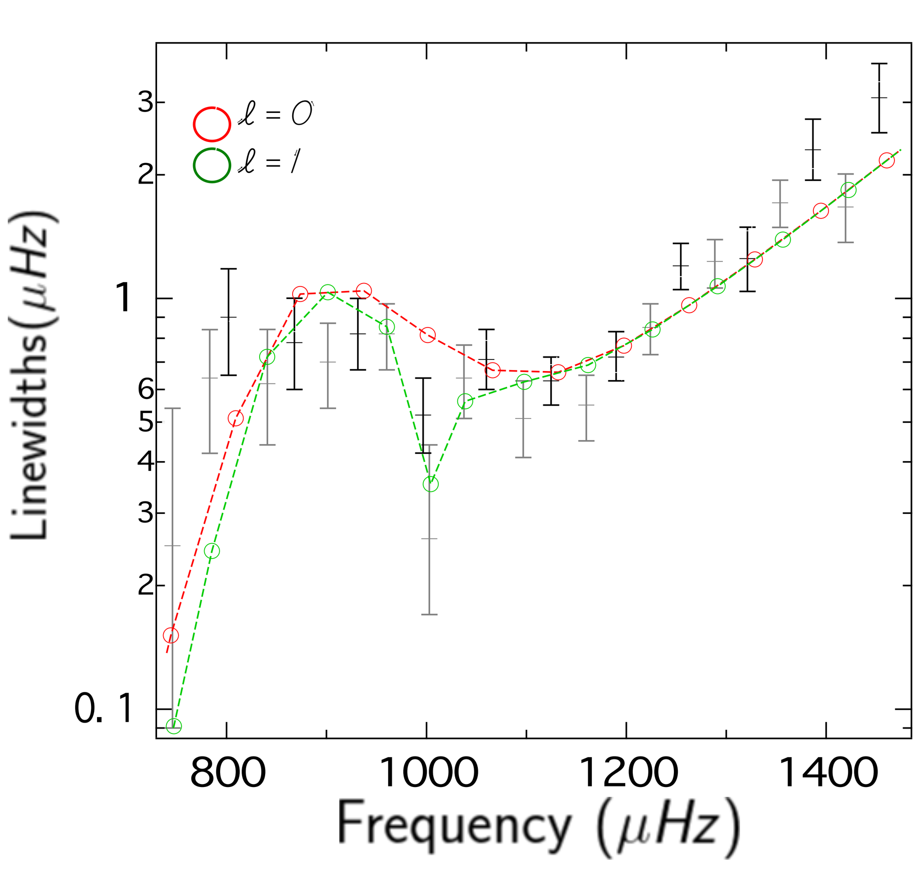


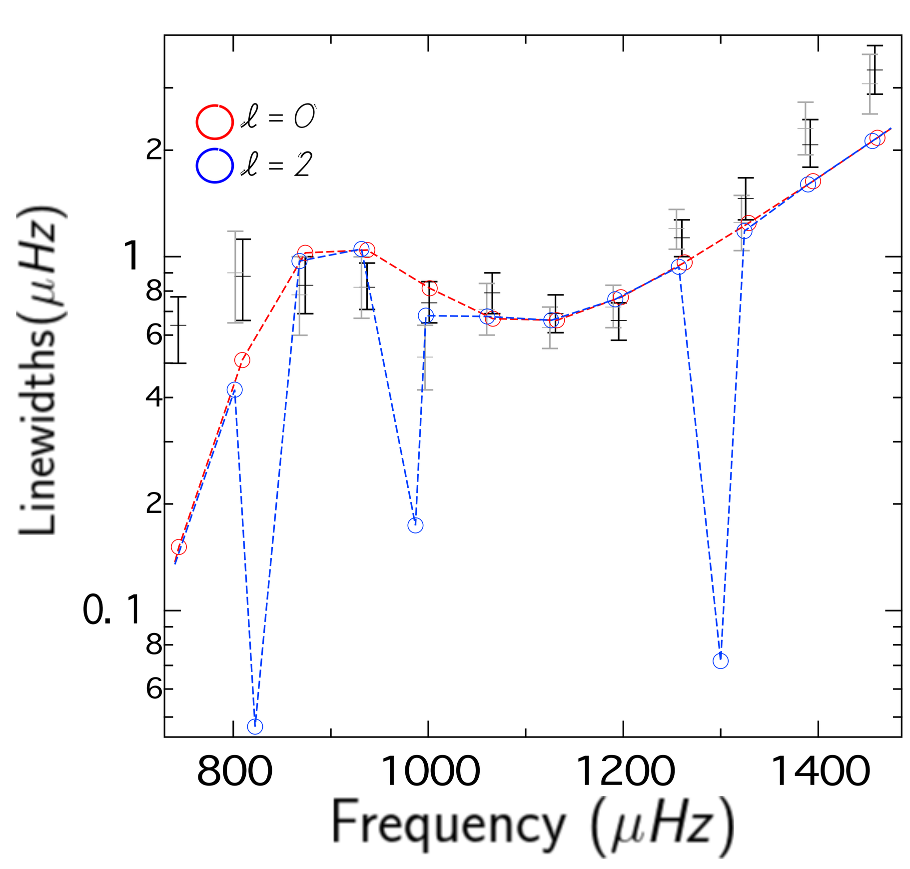
At high frequency :
- Adiabatic frequencies drives away from observed ones due to surface effects.
- **Non-adiabatic calculations allow us to strongly reduce this difference.**

LINEWIDTHS

Linewidth (Γ) related to lifetimes of the mode (τ) : $\Gamma = 1/\pi\tau$
Main incertitude source in TDC : closure term of the pertubed energy equations β [5]

=> β adjusted to obtain a plateau of the damping rates at $\nu_{max} \propto \frac{g}{g_\odot}\left(\frac{T_{eff}}{T_{eff\odot}}\right)^{-1/2}$ and lifetimes of the order of the observed ones [6].





- Theoretical linewidths globaly reproduce the observed ones, including dipole mixed modes.
- Away from ν_{max}, we predict linewidths slightly smaller than the observed ones (difference lower than 2σ)
We notice the presence of 3 quadripole mixed-modes with small linewidhts in our theoretical computations that do not appear in the observations.
=> Analysis on the entire duration of observation will lead to a better resolution (around 10x the predicted linewidth of these modes) that should be enough to detect these l=2 mixed modes and verify our predictions for their linewidth.

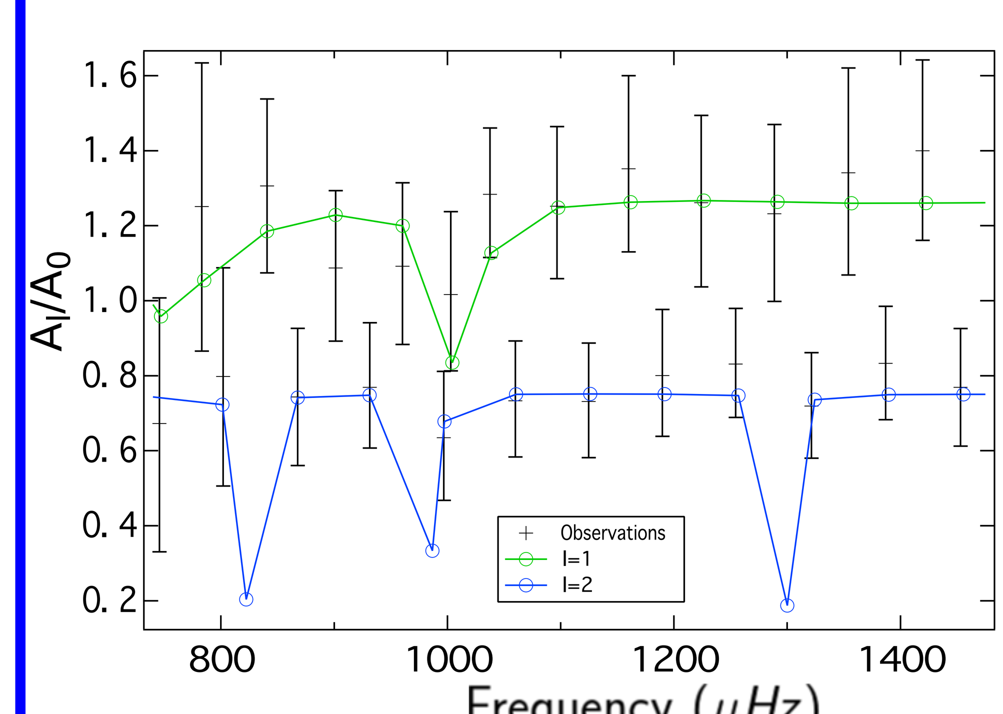
AMPLITUDES

Since linewidth and heights are strongy correlated we present here the results on the amplitudes of the modes. Radial velocity amplitudes are given by

$$V^2 = \frac{P_R}{2\eta M I}$$

where PR is the reynolds stress contribution given by the stochastic excitation code [7]. We neglect the entropy contirbutions.

- For individual amplitudes :
The conversion from radial velocity to bolometric amplitudes introduce more uncertainties. In addition, measured amplitudes may not be accurate because of the complex Kepler instrumental response and of the necessary data preprocessing, prior to the power spectrum analysis.
- Theoretical amplitudes (in ppm) of the order of observed ones



Amplitudes ratios :
- Independent of the radial velocity to bolometric amplitude conversion and of the instrumental response
- **Theoretical predictions are in the error bars.**
- The error bars are too large to provide additional constraints on the models.
+with these amplitudes and lifetimes, l=2 mixed modes should havedetectable heights.

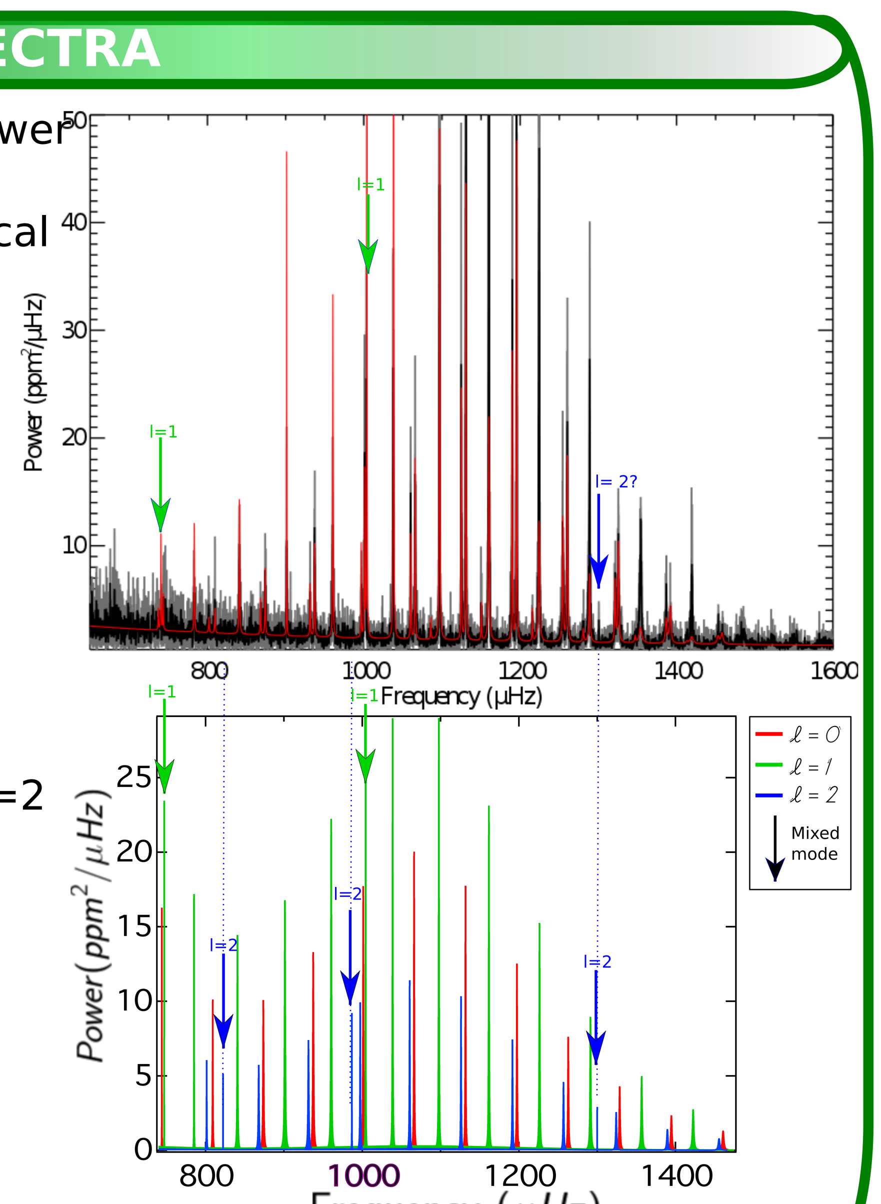
More precise amplitudes ratios, i.e. for a longer duration of observations (only 9 months here), will help to
- Test quadripole mixed-modes amplitudes
- **Provide additional constraints on the models**
- Additional mixed-modes for the seismic modelling.
- More precise linewidth and amplitudes to test our TDC treatment

POWER SPECTRA

Top : observed power spectra
Bottom : theoretical power spectra simulated for 9 months of observations

Theoretical power spectra globaly reproduced the observed one.

We predict three l=2 mixed-modes that should become detectable with a higher resolution spectra (i.e. with a longer duration of observations).



CONCLUSIONS

We perform a fully non-adiabatic modeling of an observed sub giant star to model not only the frequencies but also the linewidths of radial and non-radial mixed-modes.
In the search of the equilibirum model, the use of non-adiabatic frequencies, instead of adiabatic ones, allow us to strongly improve the agreement between observed and theoretical frequencies in the high frequency range.
The predicted linewidths are in good agreement with the observed ones. Remaining discrepencies away from ν_{max} could help us to better constrain our modelisation of the TDC in future works. Since the theoretical linewidth ratios between radial and non-radial mixed-modes reproduce well the observed ones over the entire frequency range, we are confident that such theoretical ratios can be used to draw conclusions on the detectability of mixed modes in theoretical works. Given the uncertainties on the observed amplitude ratios, we are not able to firmly conlude about the origin of differences between predicted and observed mode amplitudes. Longer duration af observations will certainly help to obtain more constraints on the models.
This work is a first step to improve our modeling of the convection-oscillation interaction. There is still some improvements to do on the modeling : using 3D Large Eddies Simulations (see e.g. [10]), improving the closure equation of our TDC model, ... Finally, we plan to extend such work to other observed evolved stars.

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