Accuracy of stellar parameters of exoplanet-host stars determined from asteroseismology

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Introduction

The successful launching of Corot produces data for transiting exoplanets with unprecedented accuracy compared to ground-based observations. The measure of planetary mass and radius provides priceless information on the mean density and bulk composition of exoplanets. Unfortunately, a remaining source of uncertainty on the planetary parameters (mass and radius) is due to uncertainties on the stellar parameters.

Our goal is to examine the accuracy on the latter parameters that could be obtained using asteroseismology with the expected accuracy on oscillation frequencies of COROT. We explore the space of stellar parameters, in terms of mass, effective temperature, luminosity, metallicity and mixing length parameter and we analyse the sensitivity of predicted spectrum of oscillation frequencies to these parameters. Adopting various levels of stellar and white noises, we analyse the frequency uncertainty for oscillation modes of given amplitude and lifetime. This analysis is done taking into account the performances of COROT in the Asteroseismology and Planet Finder channels (Auvergne et al. 2008).

Accuracy of frequency determination

The stellar variability and the lifetime of an oscillation mode alter the accuracy of the frequency determination. Figure 1 shows the power spectrum density and the error on mode frequency taking into account various effect.
Top plot: Background power spectrum densities for various levels of stellar and white noise.
Bottom plot : Resulting frequency uncertainty for modes with amplitude 10 ppm and lifetime 5 days.
Green curve : typical background for a giant (from Kallinger *et al* 2008) and photon noise for a bright star in the CoRoT planet finding channel.
Red curves: solar background (as estimated from a 6 month VIRGO/PMO6 time-series around solar activity maximum) plus white noise at the level of 0.65 ppm/sqrt(muHz) (as expected for the brightest stars in the CoRoT asteroseismology channel).
Orange curves: solar background multiplied by 10 plus photon noise at the level of 1.95 ppm/sqrt(muHz) (as expected for a V~8 star in the CoRoT asteroseismology channel).
Blue curves: mean observed background for 119 stars with 12<V<12.5 and 0.5<B-V<1.5observed with time sampling 32s in the CoRoT planet finding channel during run Ira01.
Dashed lines in top panel: white noise alone (estimates taken from Auvergne et al. 2008, A&A, in press).
Solid grey line in top panel: peak signal for modes with amplitude 10 ppm and lifetime 5 days.
Solid grey line in bottom panel: minimum uncertainty due to the mode lifetime Dashed grey line in bottom panel: minimum uncertainty for a mode with infinite lifetime (Nyquist sampling)

Aigrain *et al*, 2004, 414,1139
Kallinger *et al* 2008, A&A, 481, 571

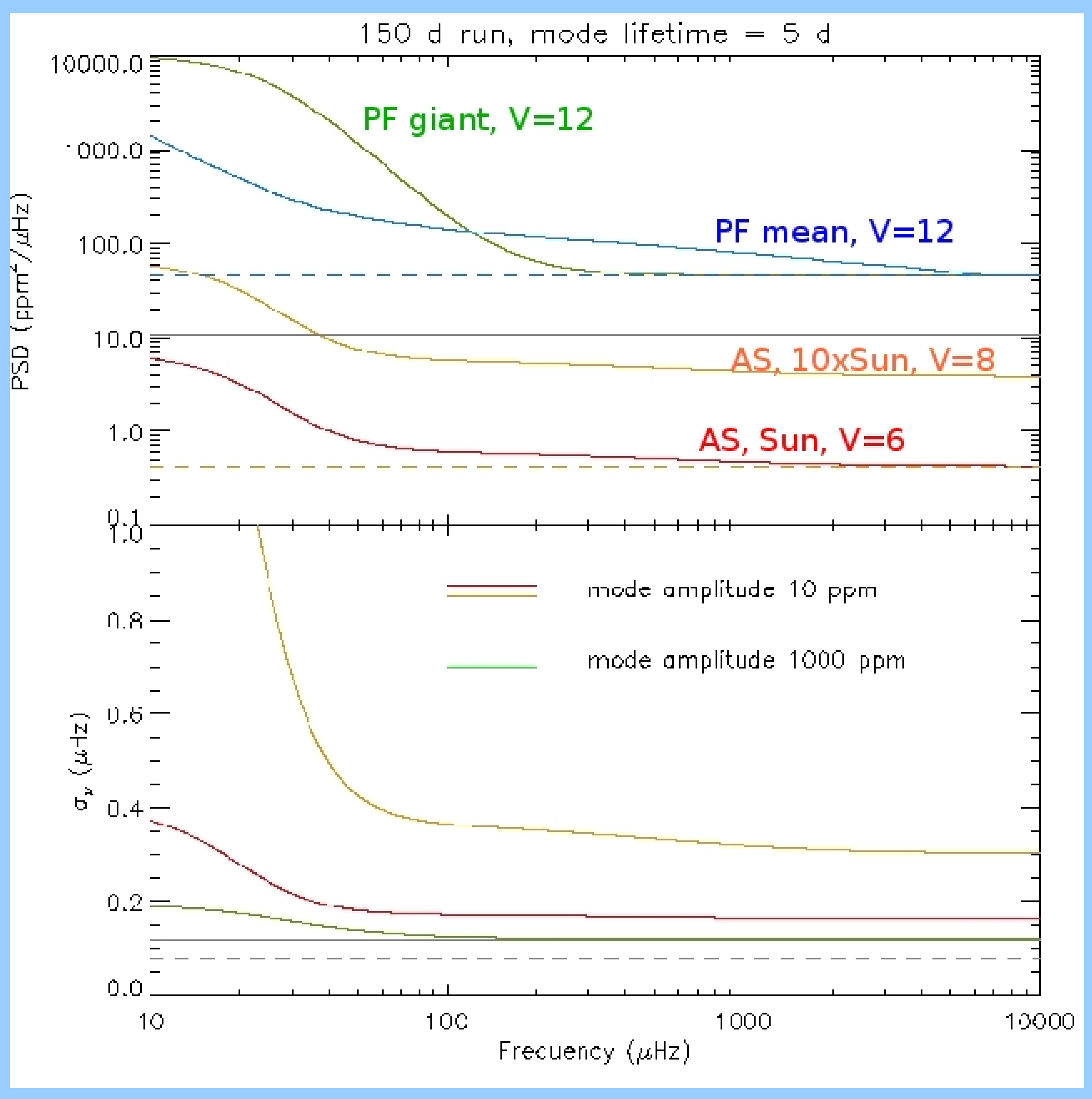

Figure 1 : accuracy of frequencey determination

Method

The pulsation calculations are performed with a nonradial nonadiabatic code originally developed by Lee (1985) and Mulet-Marquis *et al*, 2007.
The equations are linearised around hydrostatic equilibrium, and eigenfunctions are expressed with spherical harmonics Y_{lm}.
The opacities used are the Livermore ones.
The system of equations is solved with Henyey-type relaxation method. A linear non-adiabatic stability analysis gives the eigenfunctions expressed with spherical harmonics Y_{lm}, and the eigenfrequencies $\sigma = \sigma_r + i\sigma_i$. (Mulet-Marquis *et al*, 2007)

Lee, U., 1985, PASJ, 37, 279
Mulet-Marquis *et al*, 2007, A&A 465,937

Stars studied

The large difference between the fundamental parameters of XO-3 of Johns-Krull *et al* 2008 ($M=1.41\pm0.08\ M_{sun}$; $R=2.13\pm0.21\ R_{sun}$) and of Winn *et al* 2008 ($M=1.213\pm0.066\ M_{sun}$;$R=1.377\pm0.083\ R_{sun}$) was a strong motivation to study how accurately the fundamental parameters of a star (mass, radius, luminosity) can be determined with asteroseismology alone. This difference yields large uncertainty on the fundamental parameters of the planet XO-3b.
We concentrate on stars with characteristics close to those of the planet-host star XO-3 (M~1.4 Msun, R~1.5 R_{sun}, T_{eff}~6400 K, planet XO-3b $M=11.79\pm0.59\ M_J$, $R=1.217\pm0.073\ R_J$, Winn et al 2008)
We focus on modes with low value of l ($0 \leq l \leq 3$) and radial order n between 5 and 15.

Johns-Krull *et al*, 2008,ApJ 677-657
Winn *et al*, 2008, ApJ 683, 1076

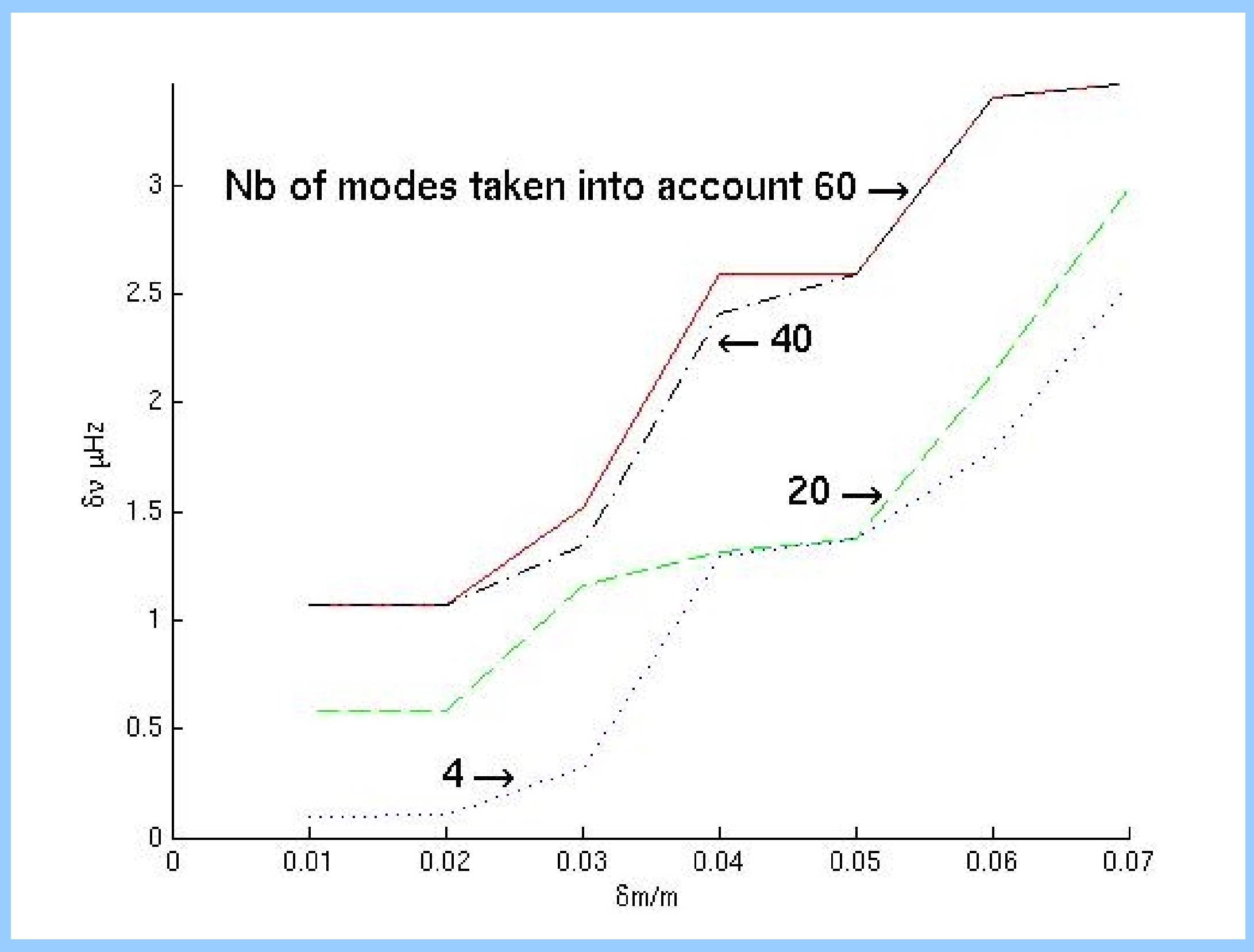

Figure 2 : difference between spectra of two stars as a function of the mass difference (coarse grid of stellar parameters)

Results

Comparing two spectra generated for two sets of stellar parameters, $\delta\nu$ is defined as the largest difference between frequencies of a mode with given radial order n and degree l.
We produce a first coarse grid of stellar models with different values of M, L, T_{eff}, and determine the minimu value $\delta\nu_{min}$ of $\delta\nu$ within a mass range m±δm. The variation of $\delta\nu_{min}$ with δm is plotted for a coarse grid of parameters on figure 2.
For a given mass difference, we analyse the effect of the number N of modes taken into account to compute $\delta\nu_{min}$. A refined grid is generated around stellar parameters which produce similar mode spectra. The variation of $\delta\nu_{min}$ with N for a mass difference of 2%, 4% and 6% is shown on figure 3.

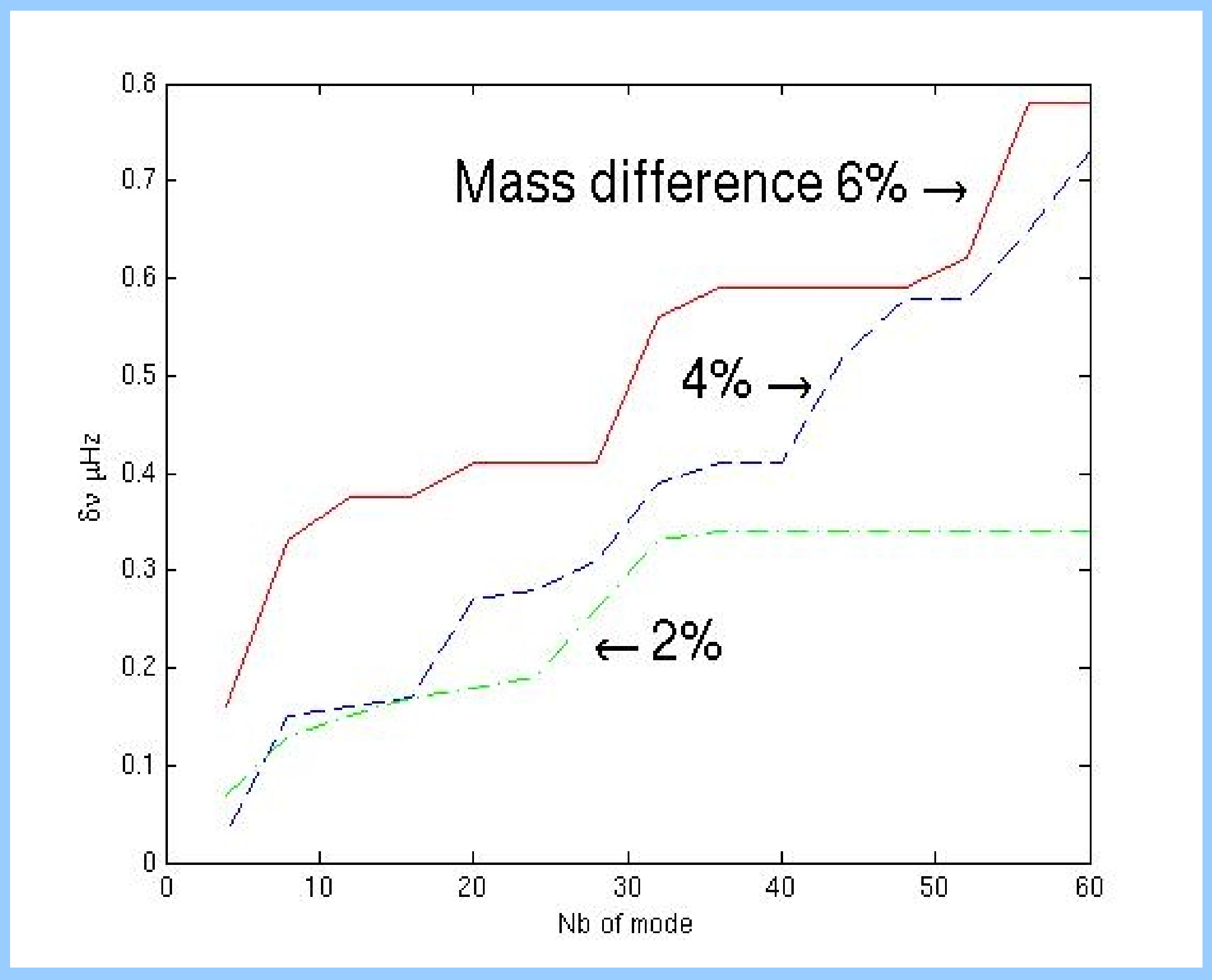

Figure 3 : difference between spectra of two stars as a function of the number of modes taken into account (refined grid of stellar parameters)

Conclusions

The refinment of the grid used to compare the spectra of stars has a huge influence. For a mass difference of 6%, the closest spectra with 40 modes taken into account differ by 3.4 μHz on the coarse grid and only 0.59 μHz on the refined grid. As one can expect, the larger the mass difference, the larger the spectra difference, also the larger the number of modes taken into account, the larger the spectra difference.
With an accuracy of 0.3 μHz on the frequency determination by Corot from figure 1, we find a spectra degeneracy. As an example, two stars with a mass difference of 4% may have the same observed spectra with up to 30 modes taken into account.
For asteroseismological analysis of stars in the planet channels of Corot, amplitudes of modes need to be significantly larger than expected in solar type stars.
We plan to extend this analysis to stars with different spectral types (from M to F).