Results on the HH exercise: how did I fit the data?

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1 Goal

The goal of this document is to report on what one of the data fitter of the team B (Meudon-Appourchaux-Nice and consort) have done.

2 The approach

There are few simple steps that are used to reduce the data such as:

- timeseries plot
- histogram of the time series (gap detection)
- interpolation of the gaps (if possible)
- compute the fft of the timeseries
- echelle diagramme of the power spectra (looking for a credible $\Delta\nu$)
- identifying degrees in the echelle diagramme
- run a statistical test to check for peaks to be fitted
- fit the power spectra

For this latter step, we usually assume the following:

- the mode of a multiplet are excited with the same amplitude modulated by the visibility for each (l, m)
- the visibility for each (l, m) is a function of the angle of inclination of the star onto the line of sight (i ?)
- the visibilities are computed neglecting the limb darkening

- the mode splitting for a multiplet is fitted using a_i using Clebsh-Gordan coefficients (see associated report), the maximum i depends on the number of multiplet in a mode ($2l$+1 components)
- the statistics of the spectra is assumed to be a χ^2 with 2 d.o.f
- spectra are fitted using Maximum Likelihood Estimators
- other details depend on the spectrum analysed

3 Results

3.1 Nice-Toutain spectrum

The timeseries seems to have no peculiar problem. Figure 1 shows the power spectrum. The modes are clearly visible from 250 μHz to 1800 μHz. Figure 2 shows the echelle diagramme with a spacing adjusted by hand of 57 μHz. The ridges are easily identified and we can proceed to fitting the data.

The $l = 0$ and $l = 2$ modes are fitted in pair assuming a common linewidth, 2 different amplitudes (one for $l = 0$, a common one for the $l = 2$ multiplet), an angle of star inclination, a common flat noise and a single splitting a_1.

The $l = 1$ and $l = 3$ are fitted in the same manner, except that a test for the presence of $l = 3$ check whether the spectrum should be fitted for a pair $l = 1 - 3$ or simply just for $l = 1$. Although, most of the time the test did not detect the presence of the $l = 3$, it happens that the $l = 3$ could be seen by eye, at least one component of the multiplet. Unfortunately, this may not be enough to properly derive the characteristics of the $l = 3$ modes.

Given the fact, that the $l = 1$ gave a rather consistent splitting, the $l = 0-2$ was fitted again by giving as a starting parameter a value close to that of $l = 1$, but free nevertheless. Likely the same approach may be used to refit $l = 3$.

3.2 Roxburgh-Barban spectrum

Figure 3 shows a subsection of the timeseries and its associated histtogram. Some zeros put at regular places (and a large one somewhere else) give obviously problems. Figure 4 shows the effect of the 20-min periodic gap as a 833-μHz modulation. After finding the gaps, those are corrected by simply interpolating with data before and after the gap. Figure 5 shows the same chunk of the timeseries after the correction. Figure 6 shows the power spectrum after correction. The modulation has dropped by more than a factor 100. A small peak appear at around 164.12 μHz, still pondering about whether it is an artifact or a g mode... Finally Figure 7 shows the echelle diagramme with a spacing of 52 μHz. This echelle diagramme is not easy to read at all. It required lots of thinking before we could do somthing about it. Finally, we come to a solution where the brightest ridge is due to the $l = 0$, and the other ridge are due to

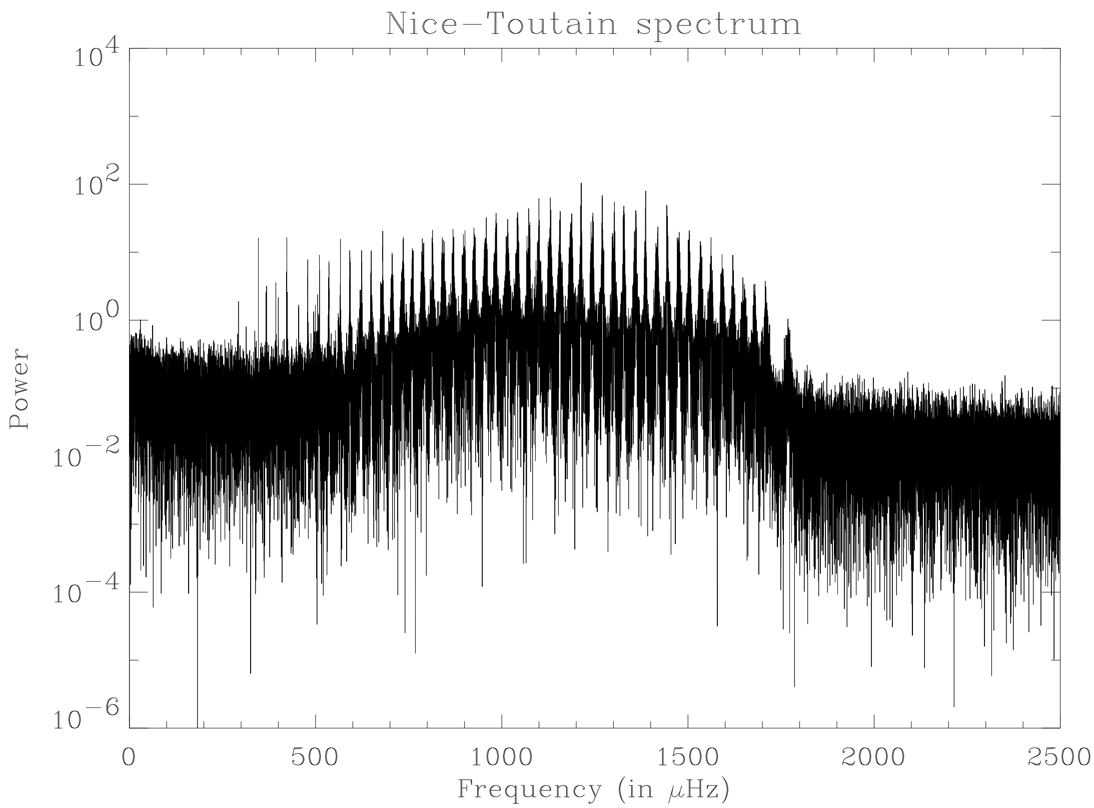

Figure 1: Power spectrum as a function of frequency

$l = 2$ and $l = 1$ split by 10 μHz, giving in total 1+3+5=9 ridges. The trouble is that some ridges appear to be fainter for m=-2 than for $m = +2$. For regular stars, this is unlikely but given the fact that the star rotates about 25 times faster than the Sun, we can expect other peculiarities. In addition, it seemed that the ridges of a given l were not equally spaced, which is not unlikely because the star is squashed and the spherically symmetric structure of the star does not exist anymore. But if it were the only problem that woudl have been simple. Unfortunately, the ridges for $l = 2, m = +2$ alias into the ridge for $l = 1, m = -1$, and vice-versa. The solution I chose for fitting the data was the following:

- fit spectrum over 70 μHz or so
- assume a common linewidth for all degree
- fit simultaneously $l = 0, 1, 2$

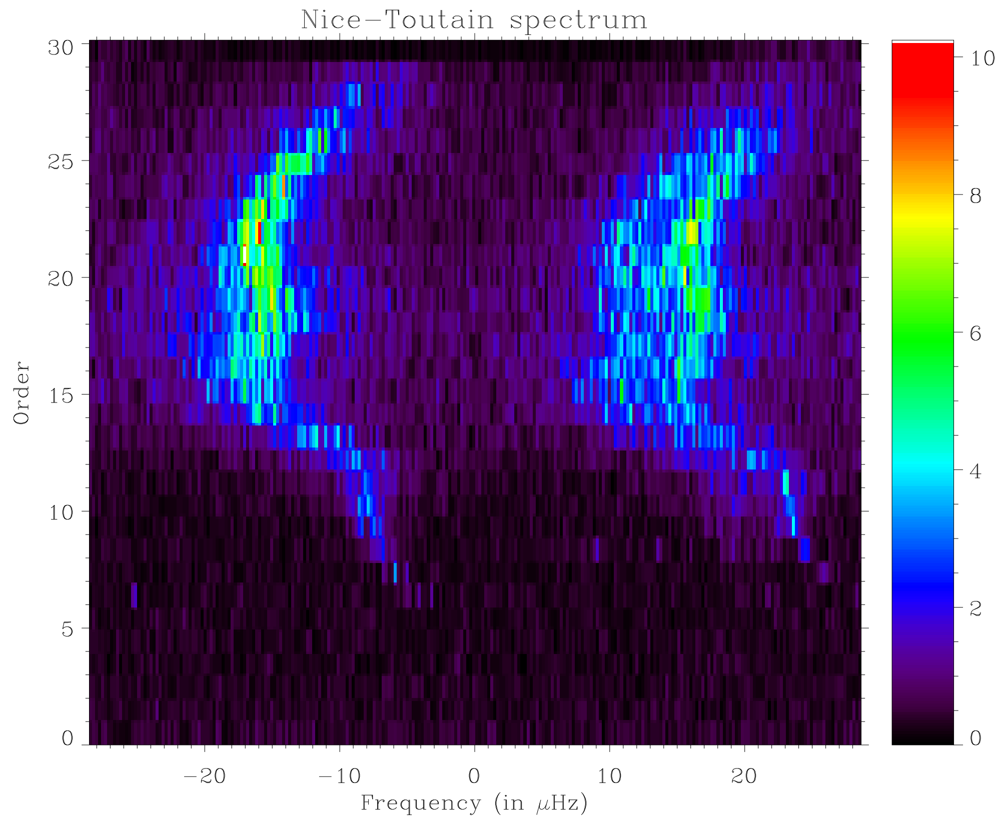

Figure 2: Echelle diagramme with a spacing of 57 μHz. Given the structure of the ridges, we assumed that the left-hand side ridge is due to the $l = 1$ and $l = 3$ modes, and the right-hand side ridge to the $l = 0$ and $l = 2$ modes.

- fit with a fixed frequency the two spurious peak (alias of $l = 2, m = 2$ and alias of $l = 1, m - 1$
- assume a splitting of 10 μHz
- fit l=1 and l=2 with a_i coefficient up to i=2, i=4 respectively
- and a flat noise

The fit works properly and return good results, whether they reflect what was out inside is an other story (comme dirait Kipling...).

Please forgive me for misspelling, lack of accuracy and details..., time is running out...

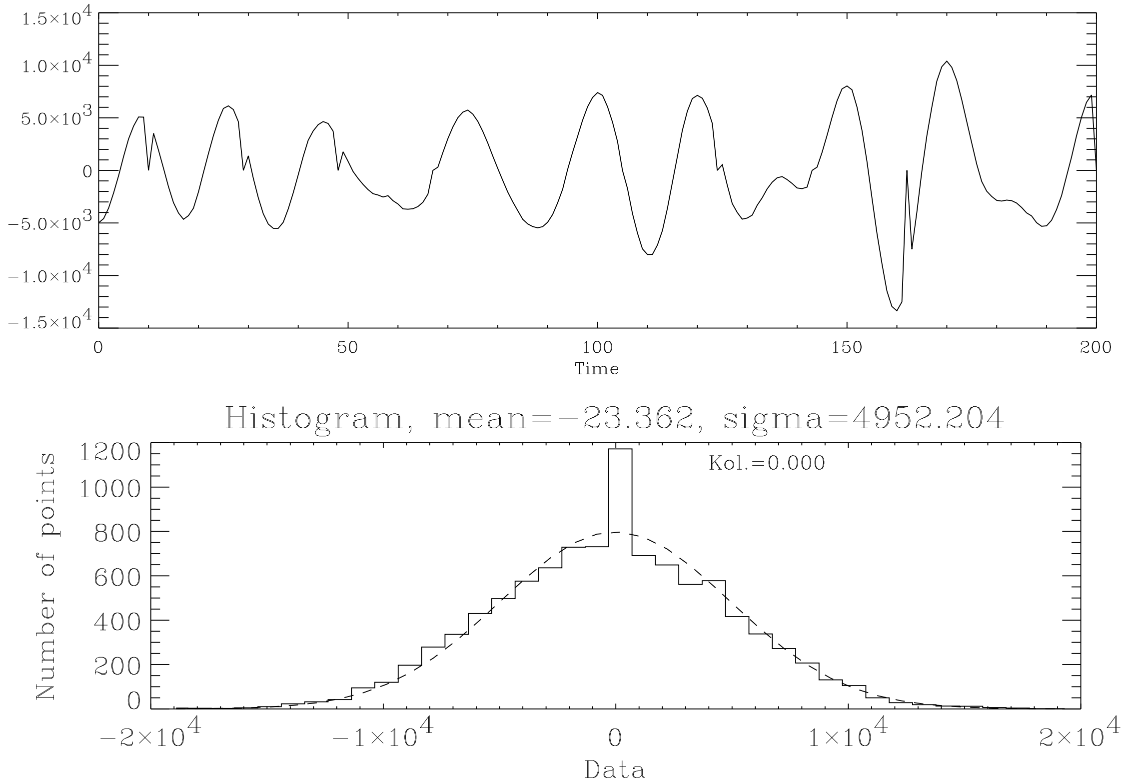

Figure 3: Timeseries showing the 20-min gaps and the histogram.

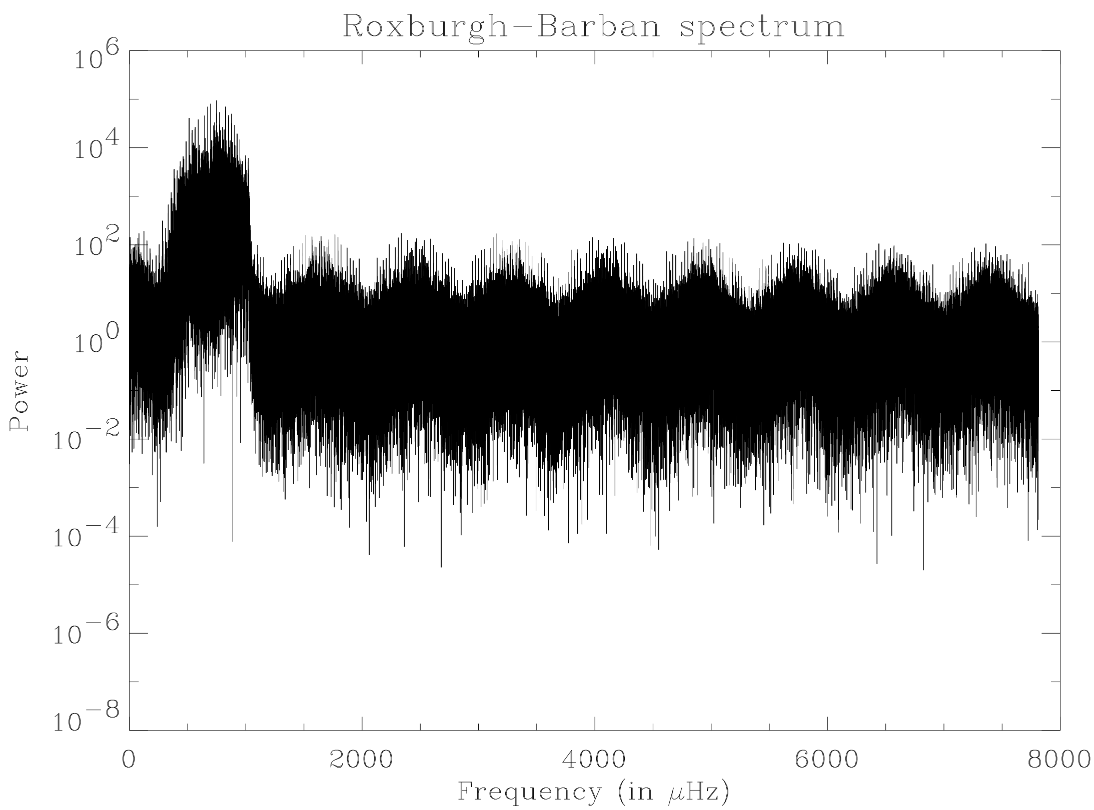

Figure 4: Power spectra of the raw data. The 833-μHz modulation due to the gap is easily visible, so are the modes.

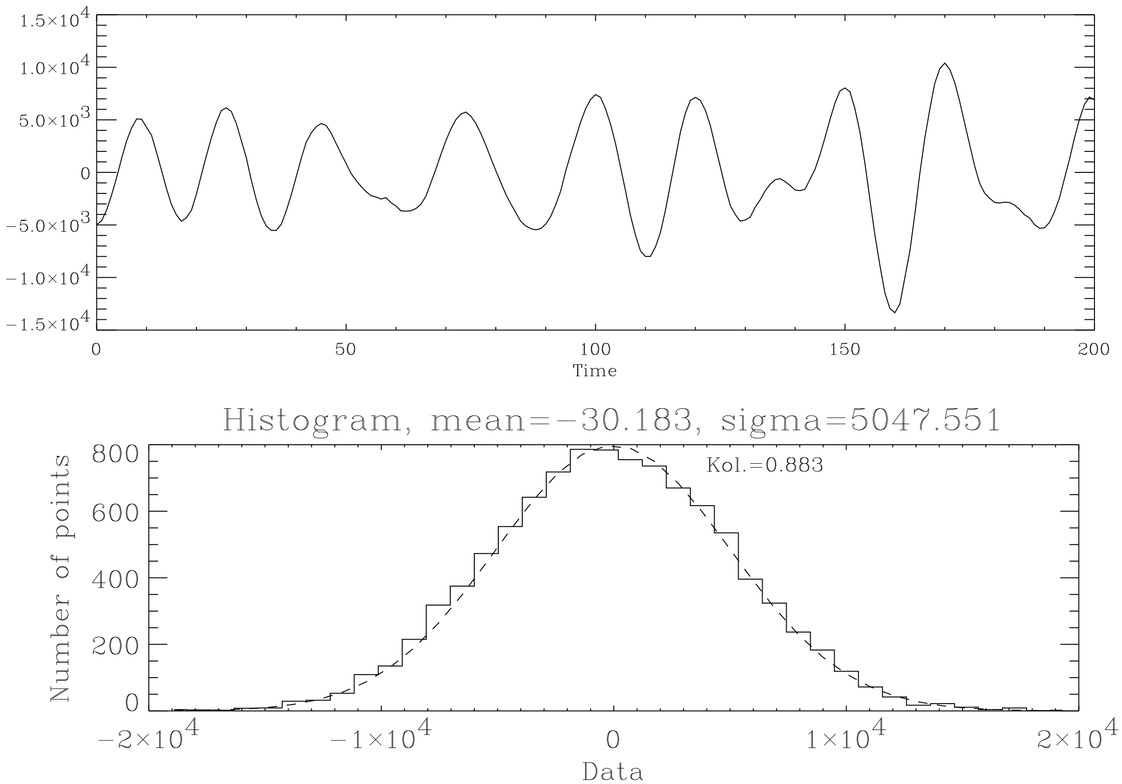

Figure 5: Timeseries showing the 20-min gaps and the histogram after filling the gaps.

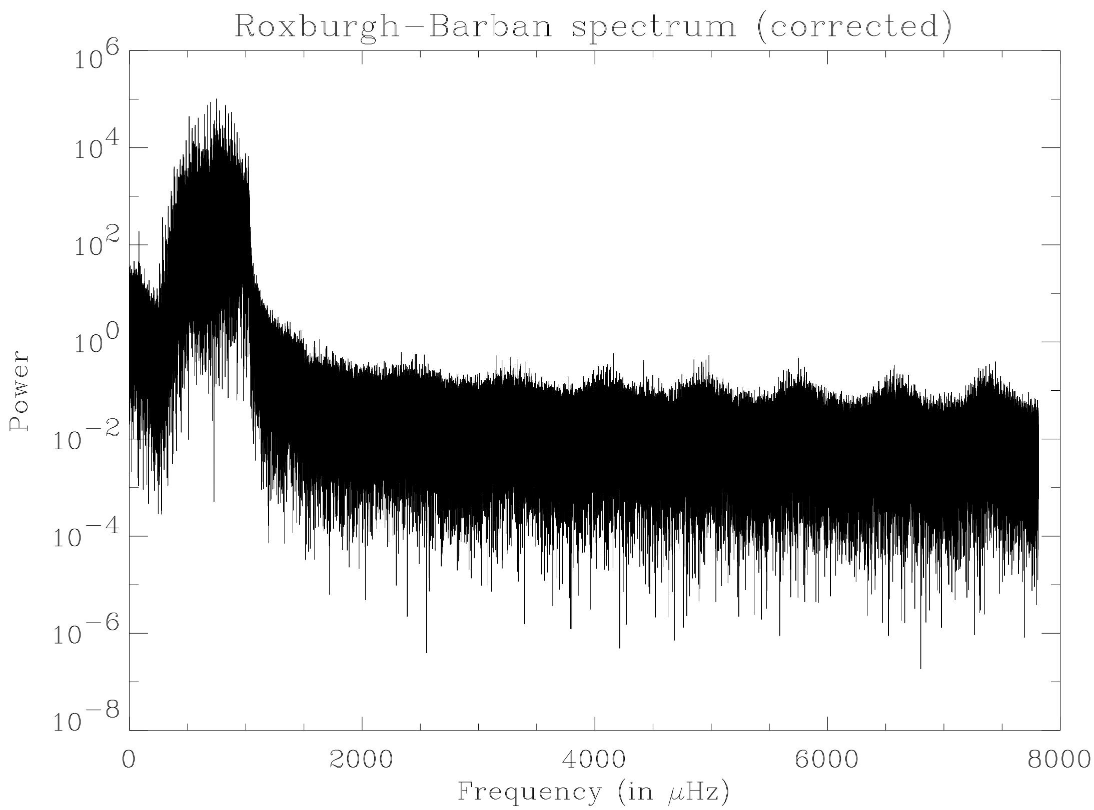

Figure 6: Power spectra of the corrected data. The 833-μHz modulation due to the gap reduced by a factor 100.

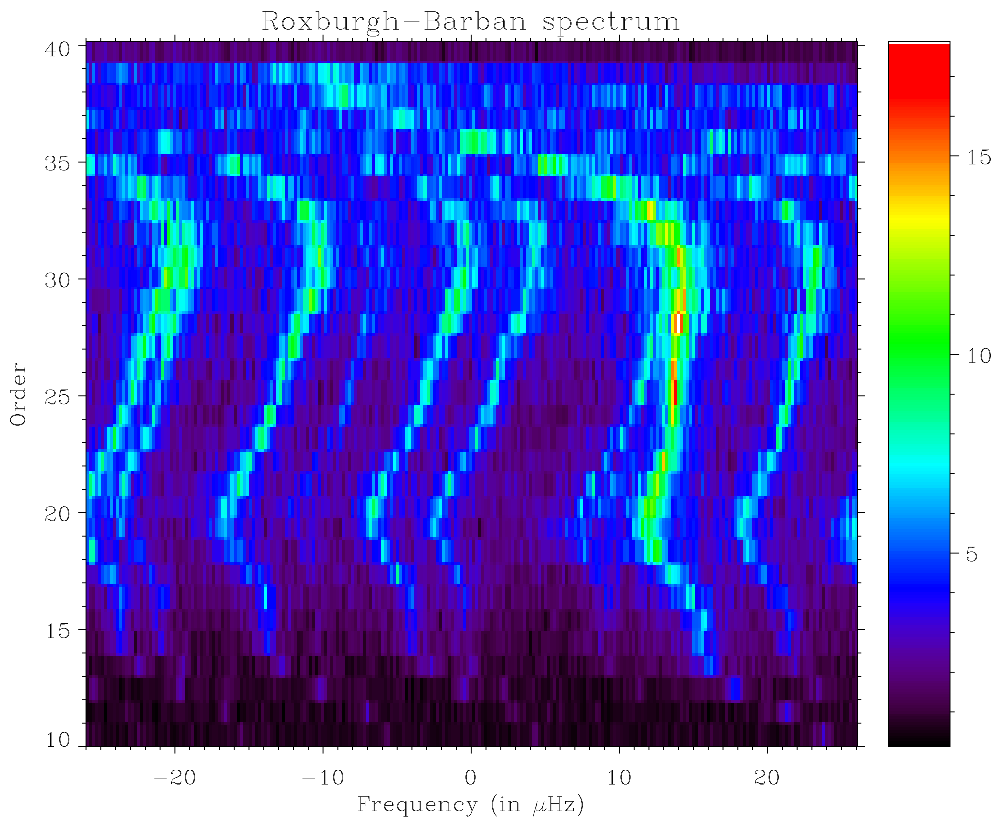

Figure 7: Echelle diagramme with a spacing of 52 μHz. Given the structure of the ridges, we assumed that the strongest ridge is the $l = 0$ modes. We assumed that the splitting was 10 μHz. The tiny ridge crossing the $l = 0$ mode was believed to be due to the $l = 2, m = 0$ modes; the ridge corresponding to $l = 2, m = 1$ is at the rightest while the $l = 2, m = 2$ wraps around and appear at the left hand side; the $l = 2, m = -1$ is close to the zero frequency while the $l = 2, m = -2$ appears to be the faintest of all; the $l = 1, m = 0$ ridge is roughly at -15 μHz while the $l = 1, |m| = 1$ ridges are on either side.