Unexplained Resonances in the Gravitation Field of the Earth

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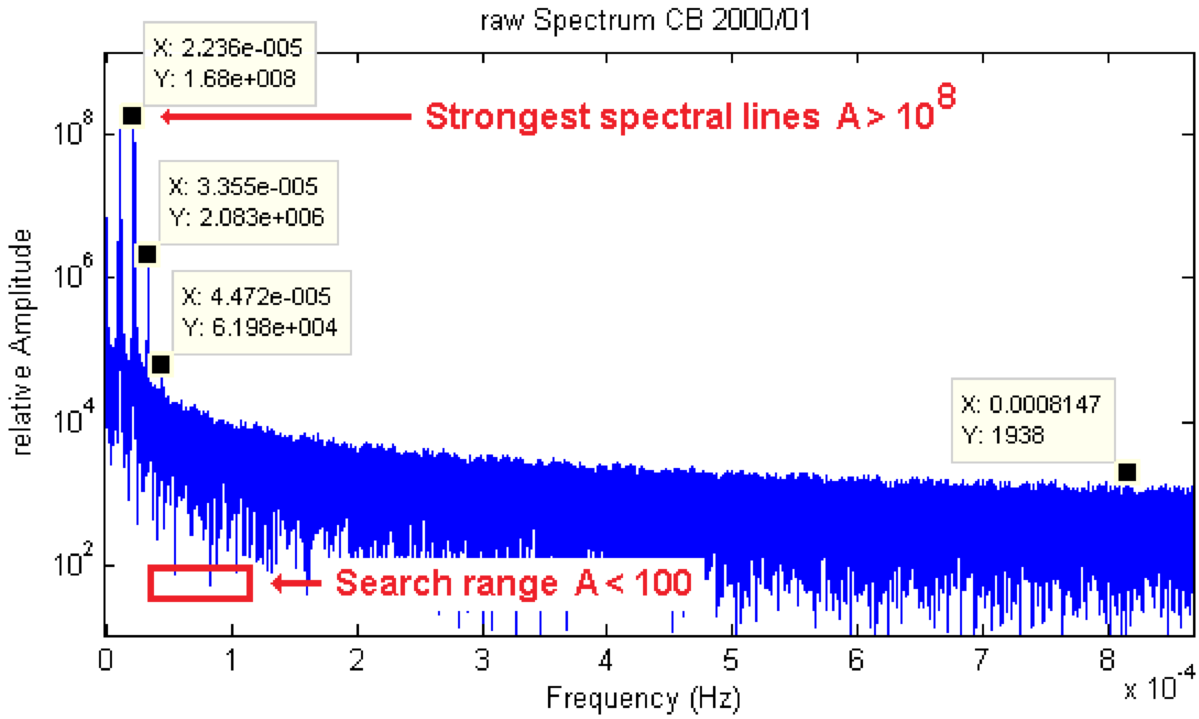
Abstract: High resolution spectra of 74 SG stations were calculated with quadruple precision in order to reduce the numerical noise. The product spectrum shows 13 previously unknown spectral lines between 42 µHz and 70 µHz. Some of them may belong to the long-sought Slichter triplet.

Introduction

In the Global Geodynamic Project, changes in the earth gravitation are measured by a net of about 30 SG stations distributed over all continents. The results are gathered and stored at the *Information System and Data Center for geoscientific data* (ISDC) in Potsdam and may be retrieved there. The aim of this study was to identify weak resonant frequencies of the Earth between 35 µHz and 110 µHz, which are not listed in the known catalogs HW95S.DAT and KSM03.DAT.

Each step of the data processing has been carefully analyzed to generate no additional numerical noise, because a raised noise level obscures weak signals. The picture shows a typical raw spectrum, computed with a standard FFT-program (using *double precision*) on a standard laptop.



Between 45 and 814 µHz all spectral lines disappear in the noise. The amplitude of the spectral line at 814.7 µHz exceeds the average noise around only by a factor of two and is by a factor of 90,000 (99 dB) weaker than the amplitude of the strongest spectral lines near 22.3 µHz.

The search range is120 dB below the peak level and 40 dB below noise level around 80 µHz. No chance for standard methods.

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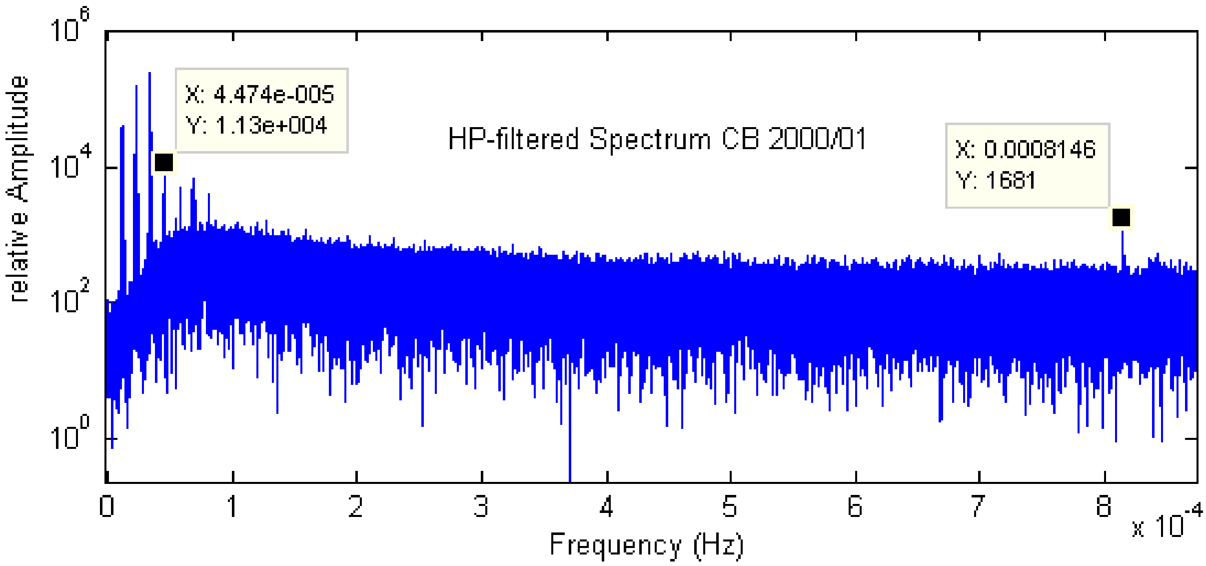
Sources of Noise

The noise level of SG data is increased by different causes:

- Spikes, created by earth quakes and poor electronic circuits, are normally eliminated by lowpass-filtering. Low-pass filters cause interpolation of the data and increase slightly the number of significant digits.
- Insufficient numerical accuracy of the ISDC data: Five or six digits in fixed point format limit the dynamic range to about 100 dB.
- Unadjusted precision in calculations with data having unusually large dynamic range. The coefficients inside filter programs have values between 100 and 0.01 and may reduce the dynamic range by about 40 dB.
- Intermodulation, occurring if two or more high power spectral lines are present.

A selective reduction of the amplitudes of the most intense spectral lines near 0.8 µHz, 11 µHz and 22 µHz by a factor of 2000 or so will have the greatest success. The subsequent FFT analysis provides a very different picture:



Suddenly, several spectral lines near 68 µHz appear. These were not amplified, rather the numerical noise has been reduced. The much lower dynamic range of 80 dB allows standard FFT-calculations with (only) double precision. The search for hidden spectral lines in the 74 records is no longer hopeless.

The required accuracy

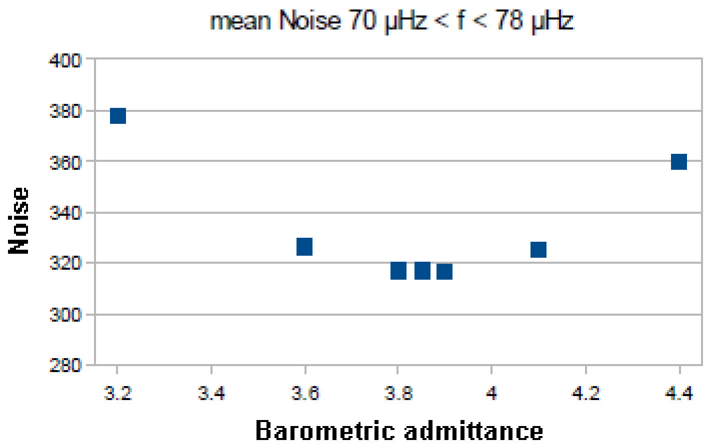
Crucial is a sufficiently accurate representation of numbers and suitable numerical methods. The enormous amount of data requires a computer with math co-processor, which usually meets the requirements of the IEEE 754 standard, called *double precision*. Each number is processed and stored with the accuracy of 52 bits, which corresponds to about 15 significant decimal digits. That is not always enough to handle the extremely large dynamic range of the SG data without non-linearity. The largest errors occur when the computer subtracts approximately equal large numbers. Because of its limited numerical accuracy, the result may have too a few digits, which creates additional noise.

A simple example shows the problem: The readings have only three digits, a = 8.98e5 and b = 8.96e5. They will be stored and processed with this precision. Floating point format is used like in every math co-processor. The calculated difference is c = 2.00e3. Changing the last digit of reading a by one unit (± 0.11%) makes c jump between 1.00e3 and 3.00e3. The tiny inaccuracy of a measured value appears enhanced in the result, increasing the noise. FFT and digital filter use several million subtractions...

There is only one means to reduce the loss of accuracy with the inevitable subtractions: All numbers must be processed with as many significant digits as possible. Programs that can handle an arbitrarily large number of digits are usually much too slow. Faster is *quadruple precision*. This doubling to 104 bits takes full advantage of the math co-processors in standard computers, but increases the computation time at least by a factor of 50.

Method

The CORMIN-data from ISDC have been grouped into more than a hundred two-year-packets (each about 1,051,200 rows of data). The mean noise in the *region of interest* is minimal when the air mass above the meter is considered by a barometric admittance of 3.85 nm / s^2 / hPa.

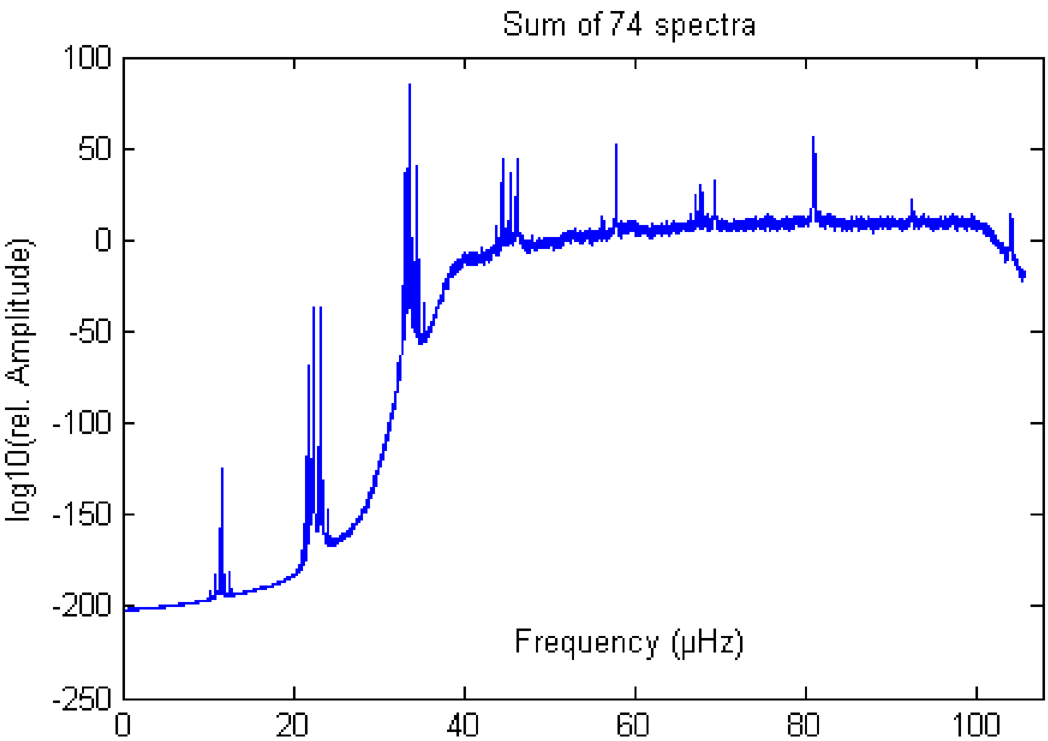


MATLAB does not have a fast program for Fourier analysis with quadruple precision (30 decimals). Therefore, the dynamic range *must* be reduced before FFT. The spectrum of each two-year package was calculated using the following steps:

1) Narrow-band notch filters reduce the amplitude of the strongest spectral lines at 0.8 µHz, 11 µHz and 22 µHz. (Calculated with quadruple precision)
2) The sampling rate Ts = 60 s is changed to 3600s.
3) A band filter limits the bandwith between 40 µHz and 100 µHz. (Calculated with quadruple precision)
4) The spectrum is calculated with the resolution Δf = 240 pm.

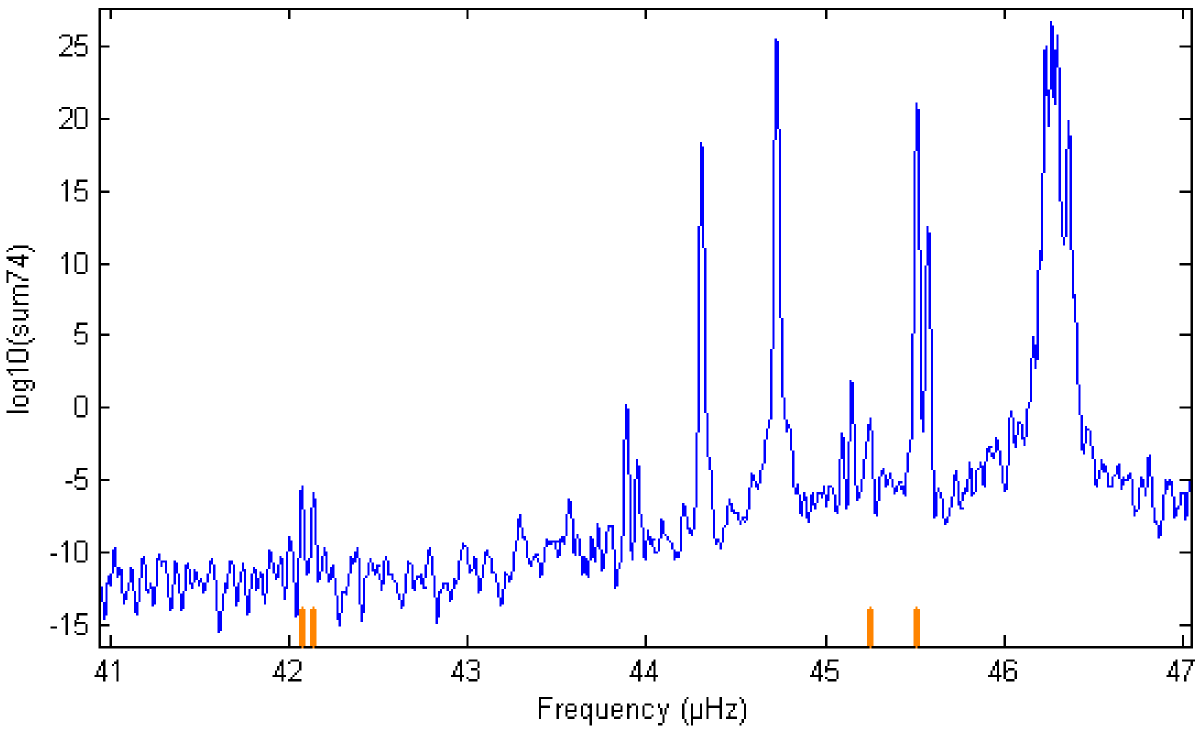
Some spectra had to be ignored, either because the background noise significantly outperformed the average or because the data contained too many glitches or gaps. The remaining 74 spectra with low noise floor were normalized so that between 40 µHz and 78 µHz each spectrum has the same mean noise level. Maybe it brings additional profit when spectra with very low noise in the search area are weighted more heavily.

In a final step, the logarithms of all spectra were added, which corresponds to a multiplication of the amplitudes (product spectrum). The figure shows the result: Many spectral lines are well known, but some do not fit into the known frequency grid n*11.55 µHz and are not listed in the catalog HW95S.DAT. Some of them are much stronger than expected.



Resonances near 45 µHz

After enlargement of the region between 43 µHz and 47 µHz, four unexpected lines are discovered in the image, marked in red.

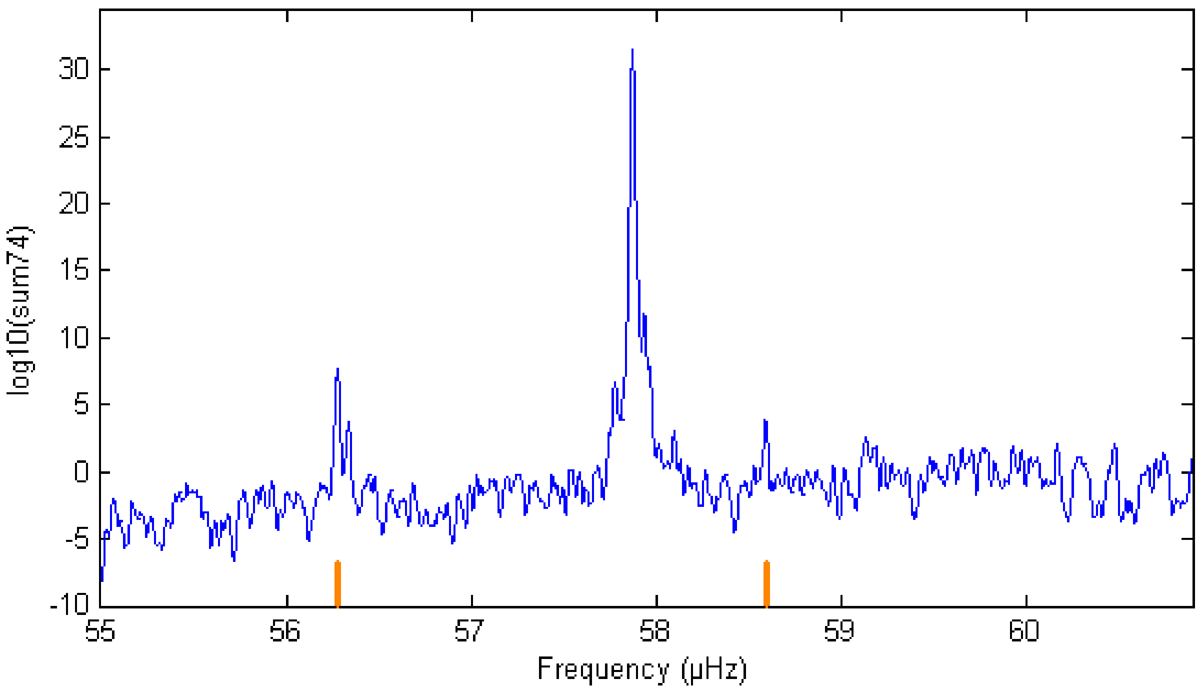


The accumulation of lines around 46.2 µHz are resonances of the Earth's atmosphere with T ≈ 6 hours, called S4. The two spectral lines at 42.0711 µHz and 42.1362 µHz are not listed in HW95.

On average across the 74 spectra, the peak at 45.2487 µHz is about 200 times stronger than the nearest spectral line in the catalog. The maximum at 45.5136 µHz is even 480 times stronger than expected. These two lines are easily measurable in some of the 74 SG stations. In the records of some other stations, they disappear in the noise.

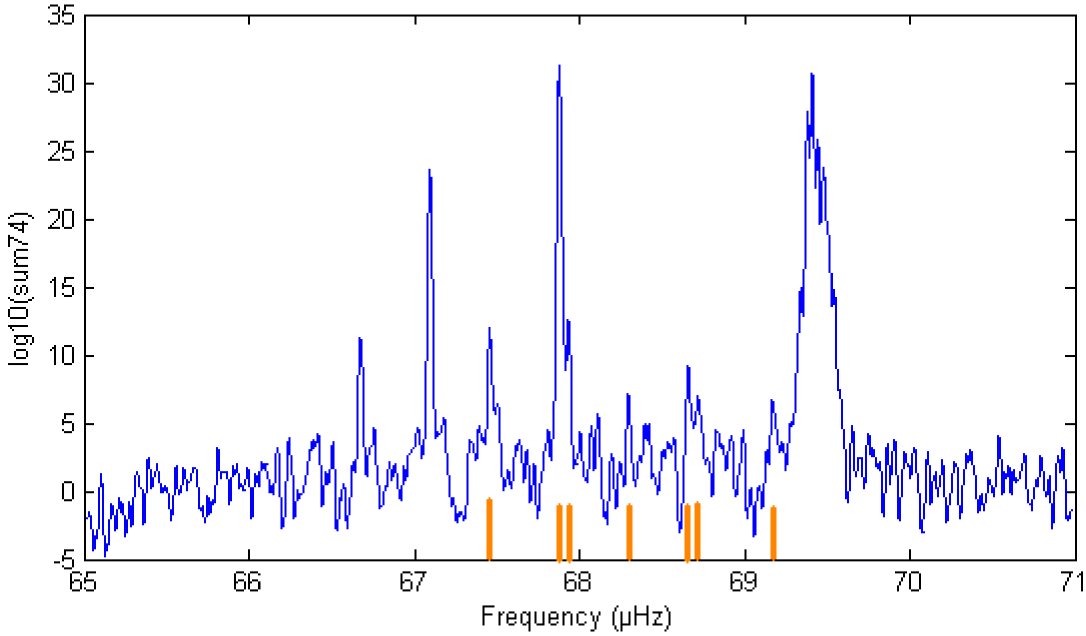
In all years, the spectral line 45.5136 µHz was remarkably strong in the records of the stations S1, S2, CB, MC. At the station ST, however, this line disappeared in the years 2001-02 but is easily measurable in the other years. The temporal behavior of both spectral lines varies over time with no apparent regularity. Perhaps the observation period of only ten years is too short.

Resonances near 57 µHz

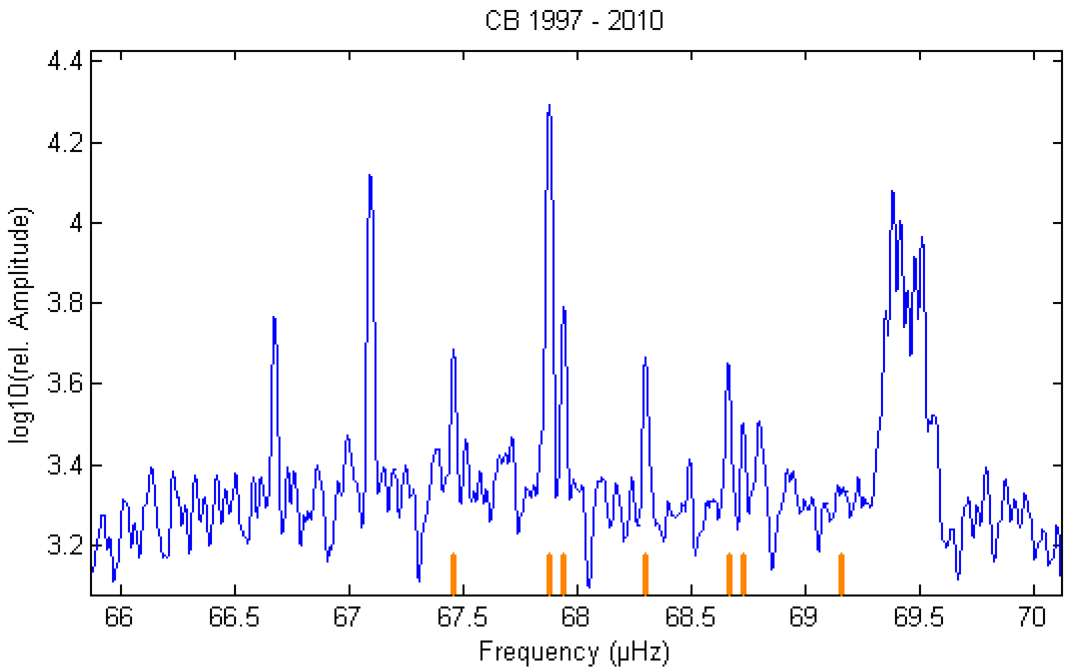


According HW95, the line at 55.91 µHz should be about ten times stronger than that at 56.33 µHz. In fact, both are clearly outweighed by the comparatively very strong response from 56.2721 µHz (marked in red), which should disappear in the noise according to the catalog. In fact, this amplitude exceeds the noise by a factor of 10. The peak at 58.5930 µHz is weak and lacking in HW95. The strong triplet at 57.87 µHz (T ≈ 4.8 hours) arises again by resonances of the Earth's atmosphere, called S5.

Resonances near 68 µHz

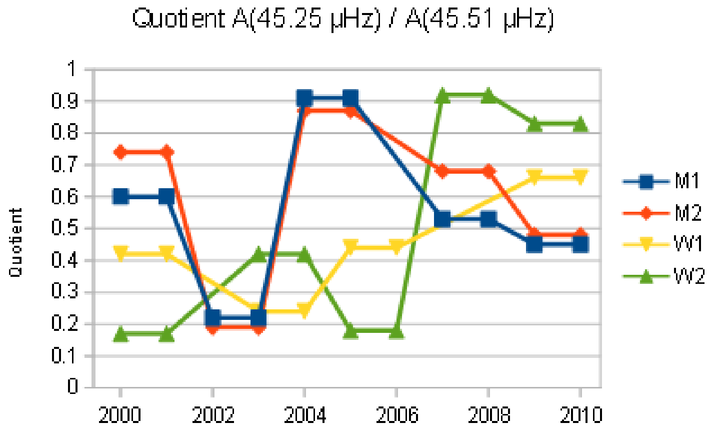


The broad peak near 69.4 µHz is S6. None of the spectral lines marked in red can be found in HW95. Since these lines are clearly visible in every record of the station CB, all records were connected to a single file 1997-2010. The enormous number of total 6,726,080 measured values has two advantages: The frequency resolution can be reduced to Δf = 66 pm, whereby adjacent lines can be separated better and the summation (stacking) of more sequential individual spectra reduces the noise level, weak lines are easier to see. The following figure shows the result, the red marks indicate the same frequencies as in the picture above.



Conflicting measurements

Some SG stations measure the gravity with two measuring balls and, of course, they should provide no contradictory results. Tracing the amplitudes of the spectral lines (45.2495 ± 0.0002) µHz and (45.5136 ± 0.0002) µHz, the two balls of the station Moxa measure about the same ratio. The ratio varies over the years, but the curves for upper and lower ball do not deviate significantly from each other.



The opposite is true at the station Wettzell: The results of the two balls contradict each other and show no similarity with the data from Moxa, though the stations are only 200 kilometers away from each other. This discrepancy can only be caused by the instrument itself.

Summary

All unidentified spectral lines are summarized in the following table:

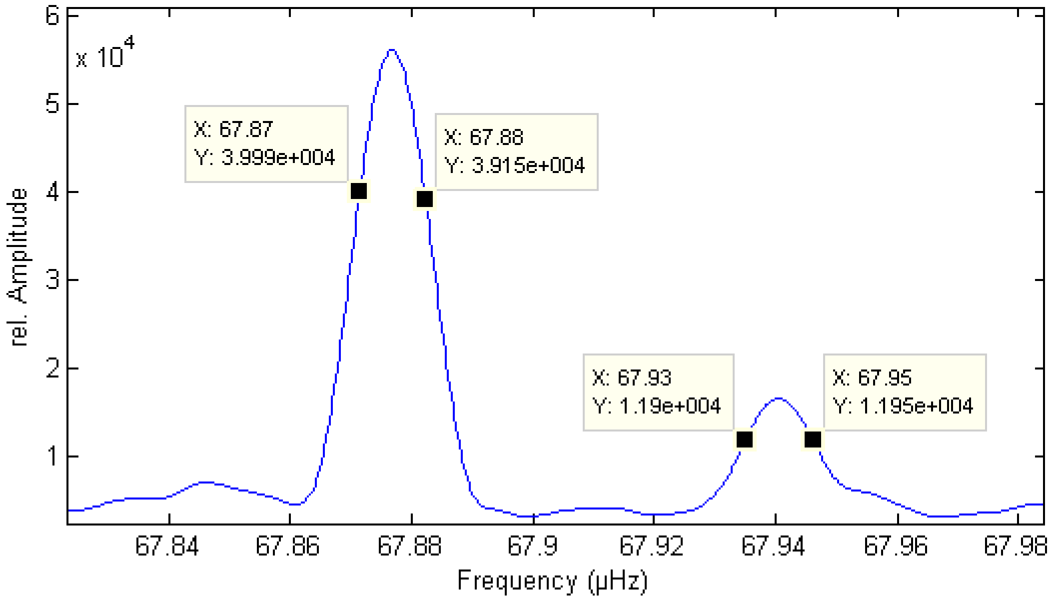
Frequency (µHz)	Period time (h)	Quality factor	Rel. amplitude	Predicted?
42.0711	6.6026	?	weak	Crossley (1992)
42.1362	6.5924	?	weak	Dahlen and Sailor (1979)
45,2495	6.1388	?	weak	----
45,5136	6.1032	4190	Very strong	----
56,2721	4.9363	?	strong	Smith (1976) Crossley et al. (1992)
58,5930	4.7408	?	weak	Crossley (1992) Dahlen and Sailor (1979) Rogister (2003)
67,4560	4.1179	6063	strong	Smylie et al. (2009) Dahlen and Sailor (1979) Crossley (1992) Rogister (2003)
67,8778	4.0923	6250	Very strong	----
67,9350	4.0889	6104	strong	----
68,2955	4.0673	5859	weak	----
68,6598	4.0457	6028	strong	Smith (1976) Smylie et al. (1993; 2009)
68,7189	4.0422	?	weak	----
69,1705	4.0158	?	weak	Smylie et al. (2009)

Since 1961, there is an intensive search for signs of translational vibration of the solid Earth's core, showing up in the so-called Slichter triplet[1]. Some peaks in the list above coincide with predicted intrinsically periods. Yet another guess is marked yellow.

It is noteworthy that the strongest lines at 45.51 µHz and 67.88 µHz are clearly visible in the records of the stations S1, S2 and CB, lying far south of the equator. In the records of most European stations, these two lines are weak and tend to disappear in the noise. If these spectral lines are caused by movement of the Earth's core, this may be an indication of the direction of vibration.

The Quality Factor

A resonator's Q-factor may be computed from the bandwidth (measured at the -3 dB- or 70.7%-level below peak) and the center frequency of the spectral line.



Since the FFT of the very long file CB1997-2010 has the resolution Δf = 66 pm, the bandwith of strong spectral lines may be determined very accurate, yielding in

$$Q_{67.88}=\frac{f_0}{\Delta f}=\frac{67.8778\,\mu Hz}{0.01086\,\mu Hz}=6250 \quad \text{and}$$

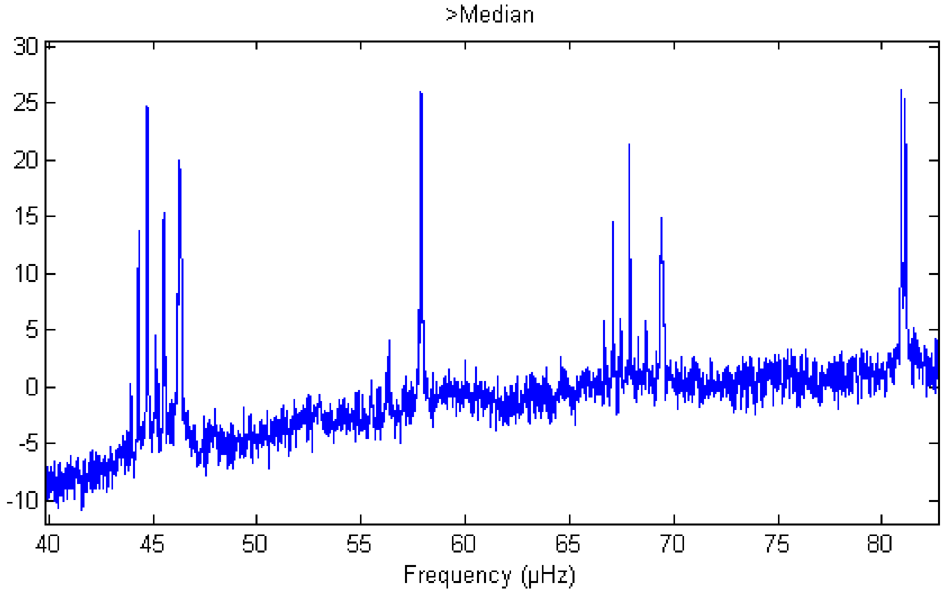
$$Q_{67.93}=\frac{f_0}{\Delta f}=\frac{67.9350\,\mu Hz}{0.01113\,\mu Hz}=6104$$

Theoretical considerations require the minimum value $Q > 2000$ for the Slichter triplet[1].

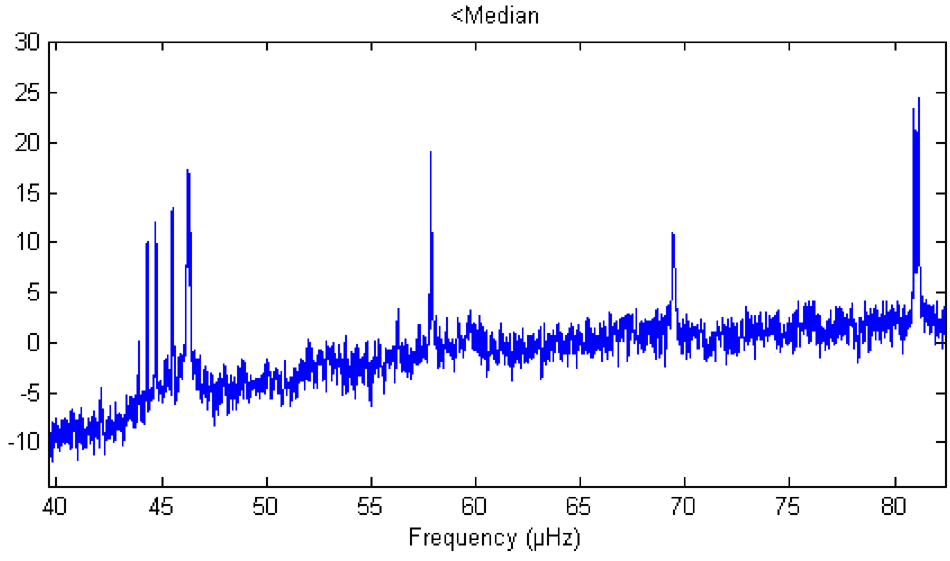
Strange Connections

No two of the 74 spectra agree well, you can arrange them according to different criteria. All spectra were normalized to the same noise level in the range 40 µHz to 78 µHz. Measuring the signal-to-noise ratio (SNR) of the spectral line 67.8778 µHz in each of the 74 spectra leads to a surprising result. In the spectra CB9799 and CB0001 the amplitude of this line is eleven times higher than the average noise. Bottom is ST0102 with the relative amplitude of well below noise level.

When the 74 spectra are classified with the amplitude of the spectral line 67.8778 µHz as order parameter, a notable difference emerges:



Adding up the spectra of all SG stations with SNR >1, the entire group around 68 µHz is easily recognizable, shown in the picture above. The sorting criteria of the files is decreasing amplitude: CB0001, CB9799, CB0405, CB0203, CB0607, TC0708, CB0810, BA0103, MB0203, MB0001, MB0708, KA0405, MA0405, MA9799, H20506, MA0203, MB0405, MA0001, KA0810, MB9697, MB9899, KA0607, MB0910, H10507, MA0607, S10001, H30910, S20506, W10506, ST9900, M20405, M20708, S20102, ST0708, W10910, ST9798, MC0607.



Adding up the spectra of all SG stations with SNR <1, not a single spectral line of this area can be seen. All or nothing. The sorting criteria is again decreasing amplitude: W20910, M20001, MC0203, MC0809, H30708, 10304, M10405, WE9698, MC0001, M10910, W20304, M10001, S10405, W20001, W19899, M10203, MC9899, W10001, MC0405, ST0304, H20304, W10002, H20102, H10102, B10910, BO9798, W20506, M10708, M20910, BO9900, W10304, M20203, ST0506, W20708, S20304, S10203, ST0102.

[1] S. Rosat, A Review of the Slichter Mode: An Observational Challenge, The Earth's Core: Structure, Properties and Dynamics, pp. 63-77, 2011 Nova Science Publishers