4.2.3 Spectrograms, moving peaks and other animals

While a lock-in is an easy tool to have information on a single fixed (or almost fixed) resonance, and a power spectrum provides a catalog of all resonance peaks and the white noise level, there are cases in which both time and frequency information are required.

In Figure 57 the position of a peak in between the sensitive modes of the detector was manually traced hour by hour, using the standard hourly power spectrum produced by the AURIGA analysis toolset. The process of collecting data was slow, and though by scrolling successive hourly reports there was a rather clear evidence of a drift of the peak frequency, quantitative estimate of the actual behavior of the line in time was feasible only after Figure 57 was plotted.

The process of discovering other features like that in AURIGA data is speed up by producing a three-dimensional plot of the spectral density as a function of time, i.e. a *spectrogram*. It is a well known representation, which in the simplest version can be realized just producing spectral estimates on short timescales from consecutive time buffer, labeling each one with the mean time of the buffer, and then plotting the whole array as a surface-density plot. Then you get a *short time Fourier transform* (STFT) *spectrogram*.

Spectrograms are useful as diagnostic tools to have a comprehension of the behavior of the detector at a glance. In the following we give a few hints of the possible observations deriving from their use.

Figures at pages 90-95 represent the spectrograms relative to two different periods of the historical data set of AURIGA, one from August 1997 (just a couple of month after the start of the first acquisition run at ultracryogenic temperature and with cryogenic SQUID amplifier), the other from April 1999, a couple of month before the end of the last run and the disassembling of the cryostat for substantial upgrades. Three different bands are examined here, the low frequency noise at 0÷100Hz, the forest of peaks around 1400Hz and the region 860÷960Hz with the sensitive modes of the detector.

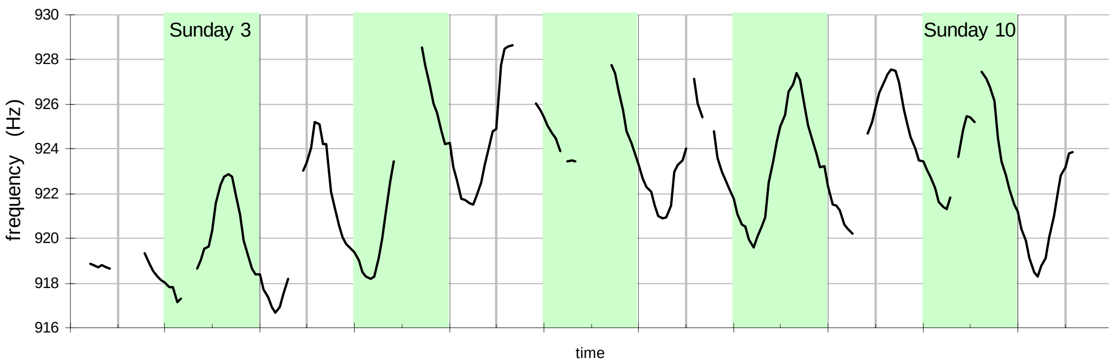
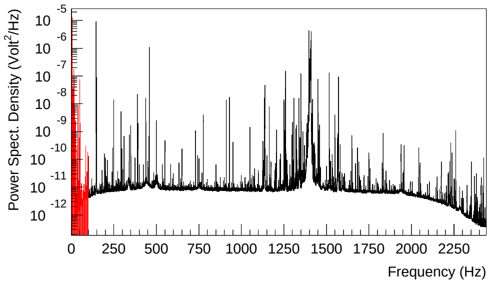


Figure 57 – A spectrogram precursor: position of a small peak moving around the two modes and tracked manually checking consecutive hourly PSD. You can recognise it rather clearly in Figure 60. Its fundamental harmonic was discovered at about 49Hz Figure 58

Figure 58 – Aug 1997 (3rd UTC 12h to 8th UTC 12h), low frequency band (0-100Hz). It is pretty far from the sensitive modes of the system, however it is worth a look at, as many of the peaks that can be seen at higher frequencies are just higher harmonics whose fundamental resonance frequency is below 100Hz. ①,②,③ are representative of an odd phenomenon: a widespread excitation that interest frequency bands that are otherwise silent. It has a very regular periodicity of about 21 minutes. ④ The different impact of a 1K-pot ^{4}He refill on the peak amplitudes helps us in classifying them: while the most part of the mechanical modes and the wide band noise get excited, the AC power line (“A”) at 50 Hz is (of course) not affected by it, and neither the “B” line (more about it in Figure 60).



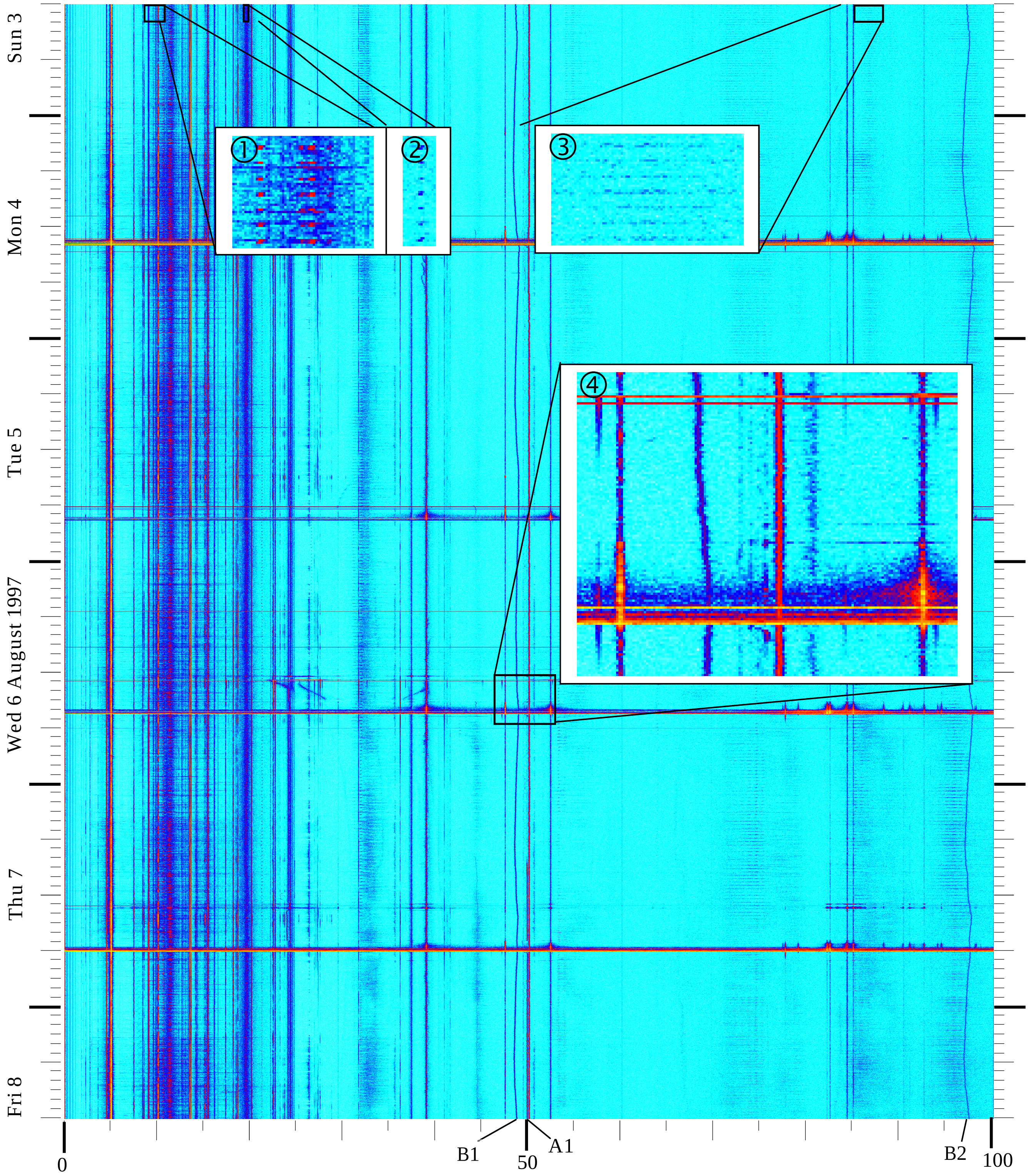
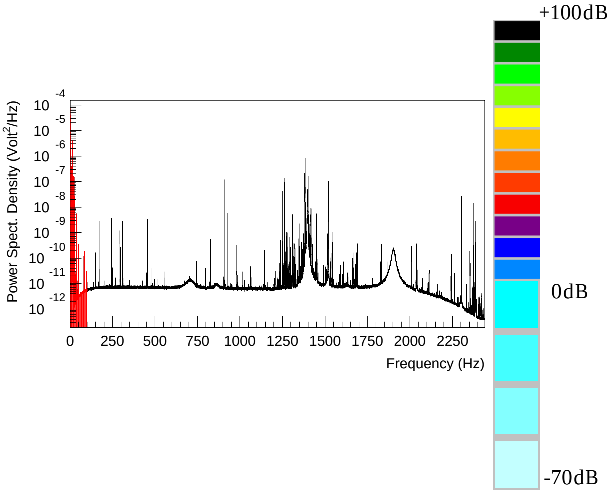


Figure 59 – Apr 1999 (20th UTC 12h to 25th UTC 12h), low frequency band (0÷100). After two years of operation, with constant maintenance, and a few upgrades (mainly aimed to the cryogenic refill system and to the room temperature electronic that controls the SQUID amplifier) the spectrum appears somewhat clearer (it is particularly noticeable in the thumbnail PSD on the right, compare it to the one in Figure 58). In the range 0÷10 Hz there is a noticeable day/night effect that disappears on weekend, a clear mark of an external environmental disturbance (it was present also in Figure 58). In correspondence to "^^^" signs there is an interruption in the analyzed data. The two apparent interruptions marked by ① and ② are due to electronics switch-off.



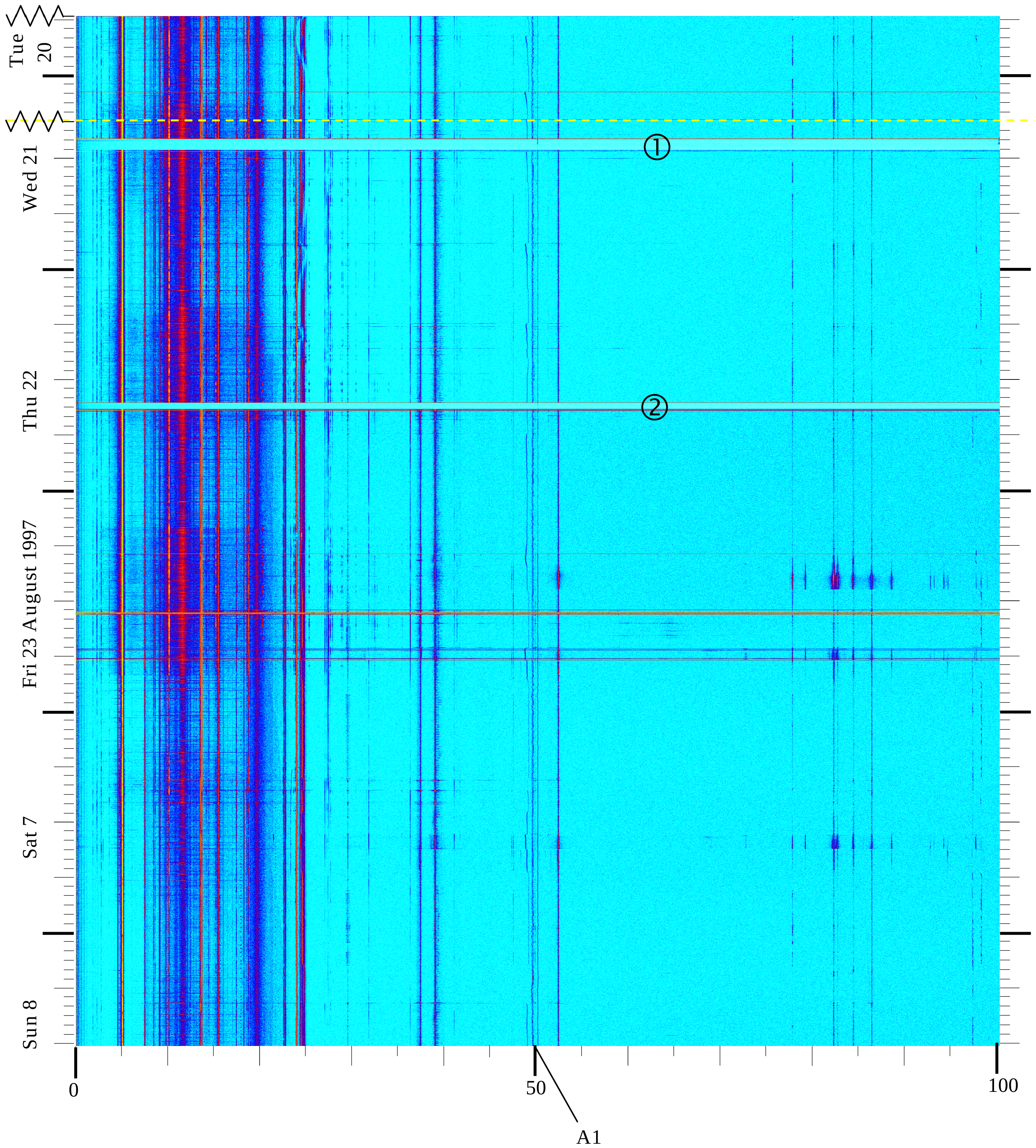
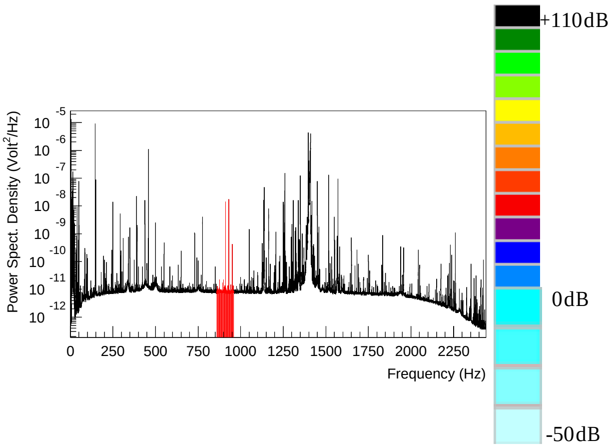


Figure 60 – Aug 1997 (3rd UTC 12h to 8th UTC 12h), (860-960Hz). The potentially sensitive region of AURIGA is quite clean, if compared with other parts of the spectrum. The 19th harmonic of the "B" line (see Figure 58) that is wandering among the modes is actually not a big trouble, as it is very faint. In the enhanced section the smoothed outputs of the digital lock-ins for the two sensitive modes ('-' and '+') are plotted as a black solid line (logarithmic scales, every tick is a factor 10). In the middle, the events above SNR=5 are represented as gray lines. Near the end of the stretch, the '-' mode gets excited, and correspondingly a lot of event is detected, while the '+' mode is calm.



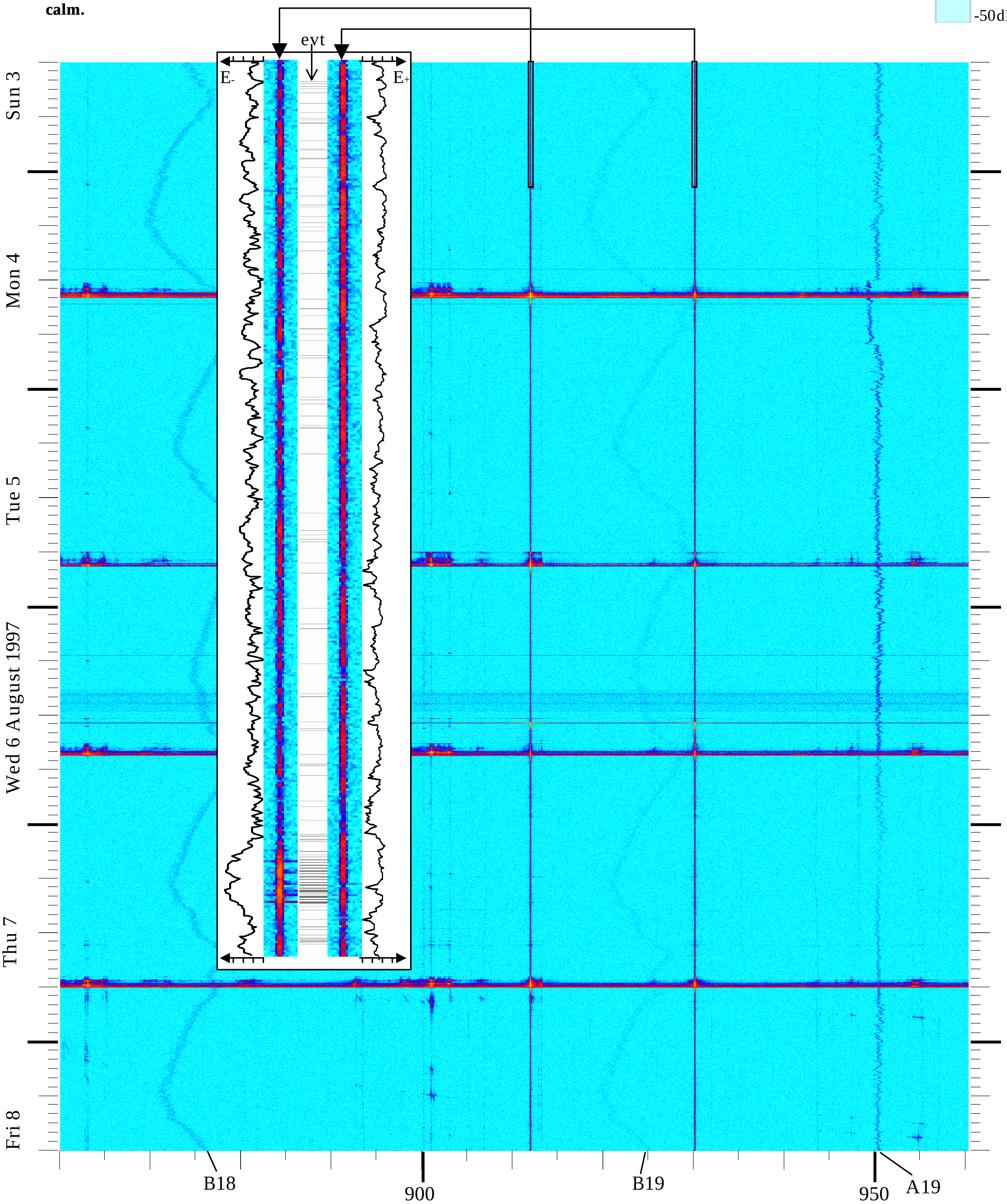
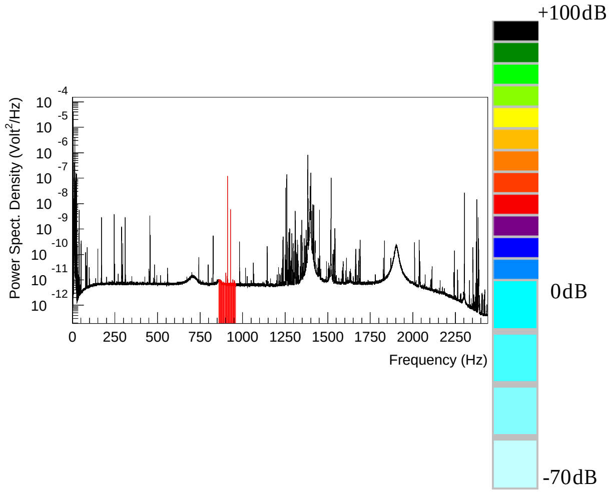


Figure 61 – Apr 1999 (20th UTC 12h to 25th UTC 12h), sensitivity band (860-960). Though the overall spectrum is nicer in Apr 1999 than in Aug 1997, the system near the '-' and '+' modes is not clean, and this is ultimately leads to a much shorter duty cycle. In ① the system is affected by *popcorn noise* (see p. 41)



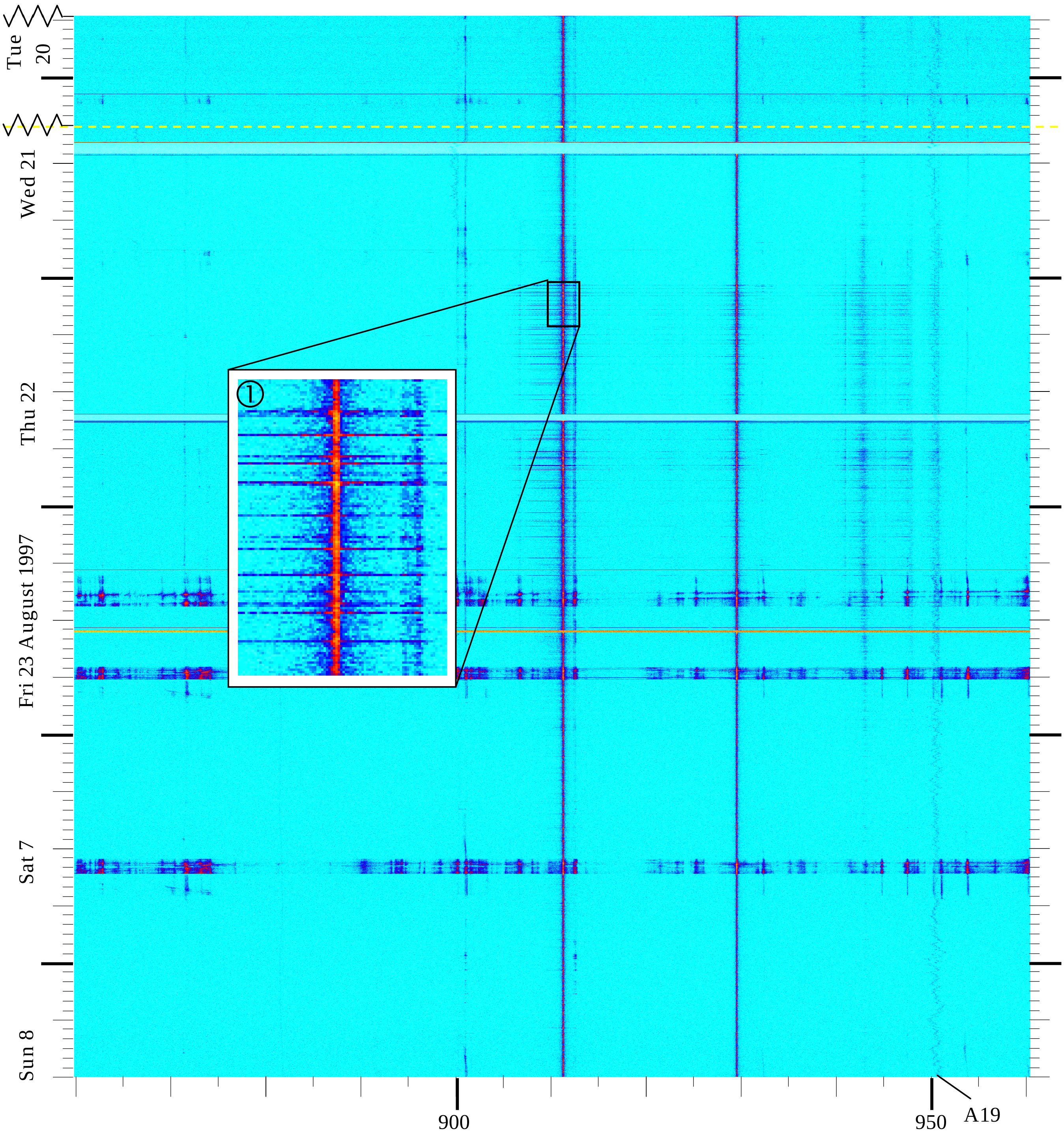
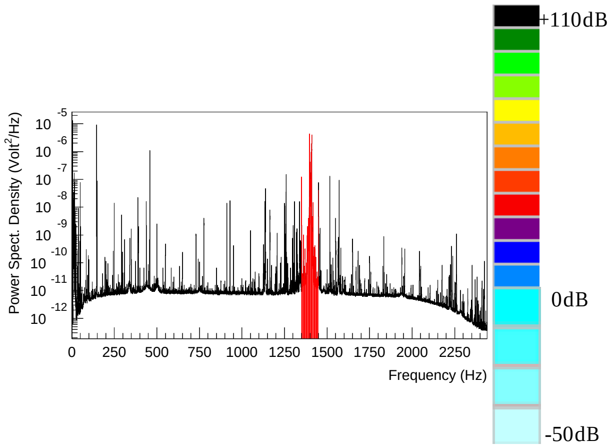


Figure 62 – Aug 1997 (3rd 12AM to 8th 12 AM), high frequency band (1350-1450Hz). In the enhanced box ① a very unusual behaviour of a few lines in the forest near 1400Hz is picked up. These peaks are alternating every ~5 min very strong excitation to almost no life sign at all (the time resolution is about 135s). Not all peaks share this behavior (for instance "E"), and this is an evidence for different input ports of these disturbances.



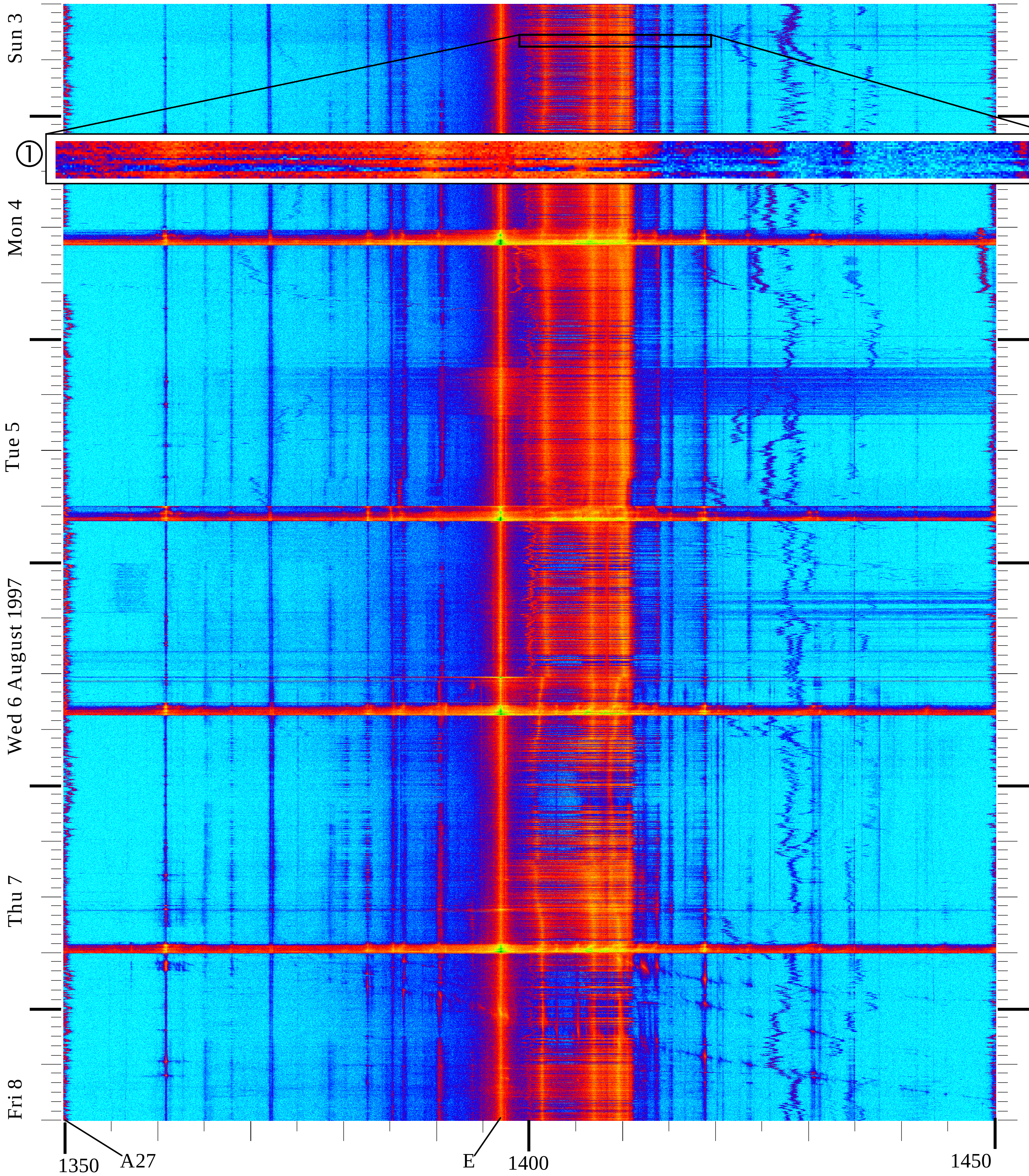
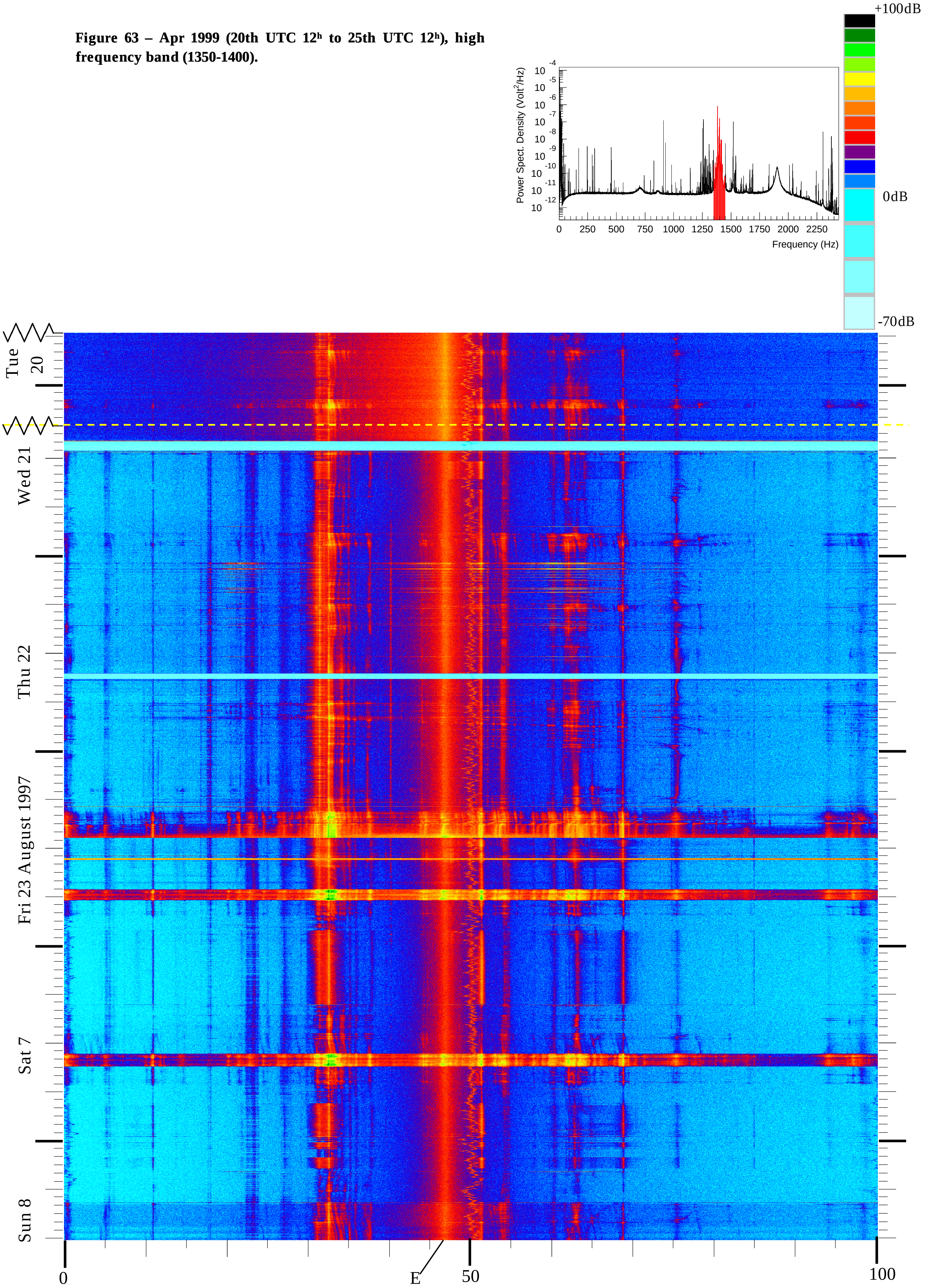
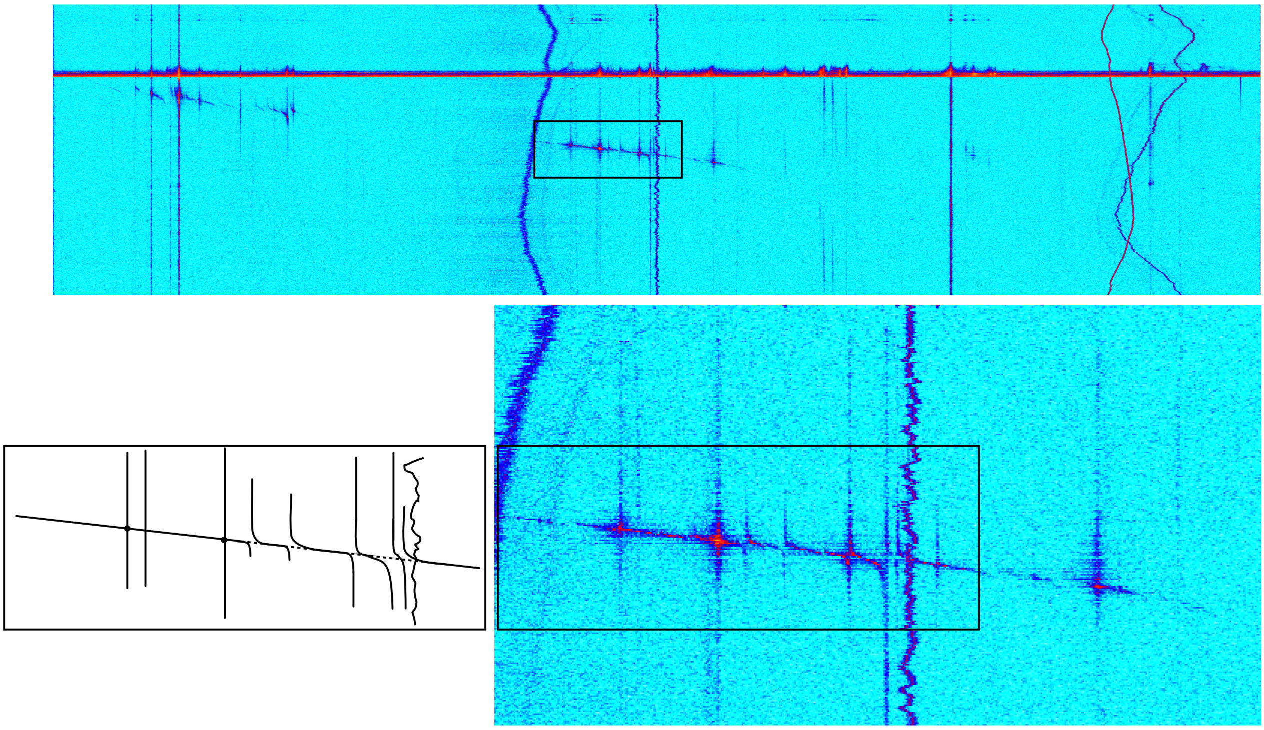


Figure 63 – Apr 1999 (20th UTC 12h to 25th UTC 12h), high frequency band (1350-1400).





a)

b)

Figure 64 - (*a*) UTC 0^h÷12^h 8 Aug 1997, spectrogram of the frequency interval 300÷400Hz. (*b*) Enhanced detail of the previous spectrogram (*right*), and its pictorial representation (*left*). As a 'chirp' moves across many fixed lines of the spectrum, it interacts differently with them, from a totally linear superposition, up to a strong structural coupling and interference of the modes. The latter can give hints about the nature and correlation of many modes (for instance, if the chirp originate from a mechanical resonance of the 1K-Pot, then it is likely that all the resonance modes which couple with it are mechanical modes of the dilution refrigerator).