Automatic determination of nose frequency and time of initiating sferic of whistlers

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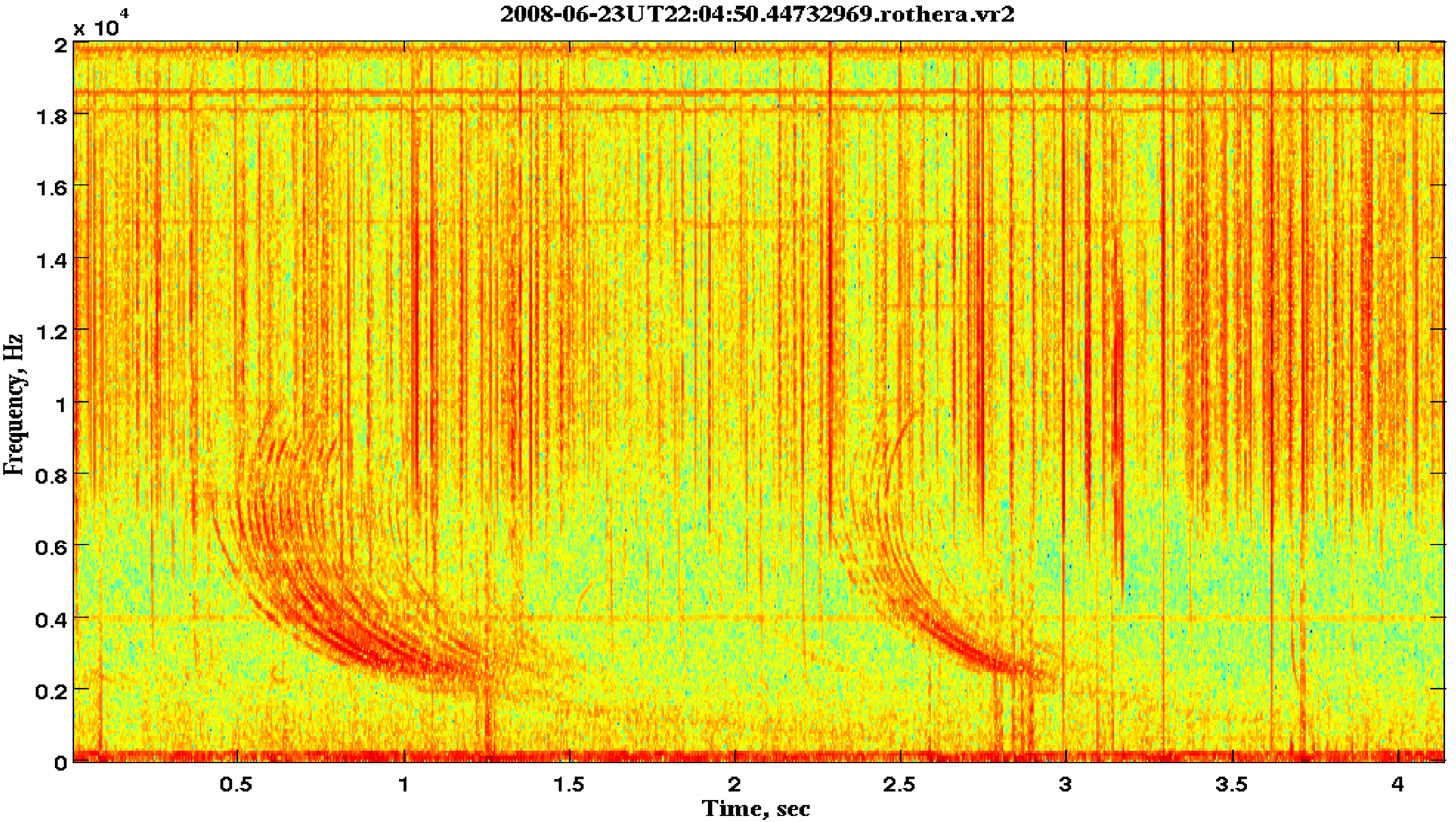
Why it is important?

Because we need to *invert whistlers* to obtain plasma and propagation parameters

For inversion we need to use

1. wave propagation model,
2. magnetic field model,
3. plasma density distribution model (along propagation path).


2008-06-23UT22:04:50.44732969.rothera.vr2
x 10^4
Frequency, Hz
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0.5
1
1.5
2
2.5
3
3.5
4
Time, sec

“Standard” model (Park, 1972)

1. Appleton-Hartree dispersion formula neglecting collisions,ions and assuming longitudinal propagation
2. Dipole field model
3. Diffusive Equilibrium models (DE-1,2)

+ nose extension methods for non-nose whistlers (Bernard, 1973; Tarcsai, 1975)

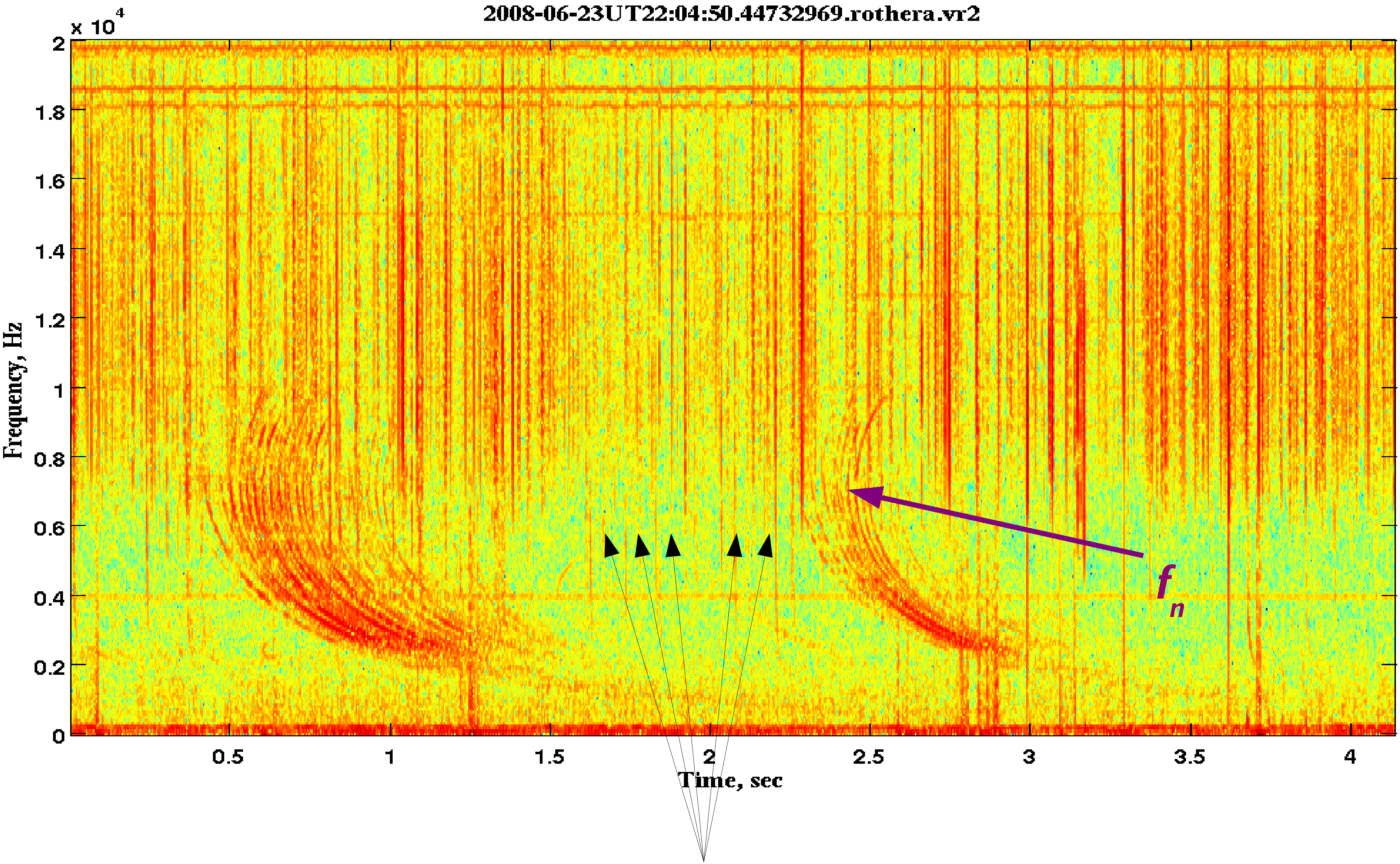
“Standard” model (Park, 1972)

$$f_{Heq} = K f'_n$$

$$L = \left(\frac{f_{Hoeq}}{f_{Heq}}\right)^{1/3} = \left(\frac{8.736\times10^5}{f_{Heq}}\right)^{1/3}$$

$$n_{eq} = K_{eq} \frac{f'_n t'^2_n}{L^5}$$

=> f_n and t_n are the basic parameters



But where to measure t_n from? That is, which ***sferic*** generated the whistlers?

“Standard” model (Park, 1972)

Nose extension methods for non-nose whistlers (Bernard, 1973; Tarcsai, 1975) estimates f_n, D_0 and t_n — but estimation of t_n is far less accurate than the estimation of the other two parameters.

Automatic Whistler Detector and Analyzer (AWDA) system [Lichtenberger et al., *JGR*, 2008]:

Whistlers are searched in the broad-band VLF signal without human interaction

Automatic whistler analysis yields plasma and propagation parameters → electron density distribution → *Space Weather*

AWDANet

Extending network of AWDA systems covering low-, mid- and high (magnetic) latitudes since 2002 including conjugate locations

~50 000-10 000 000 traces/year/station

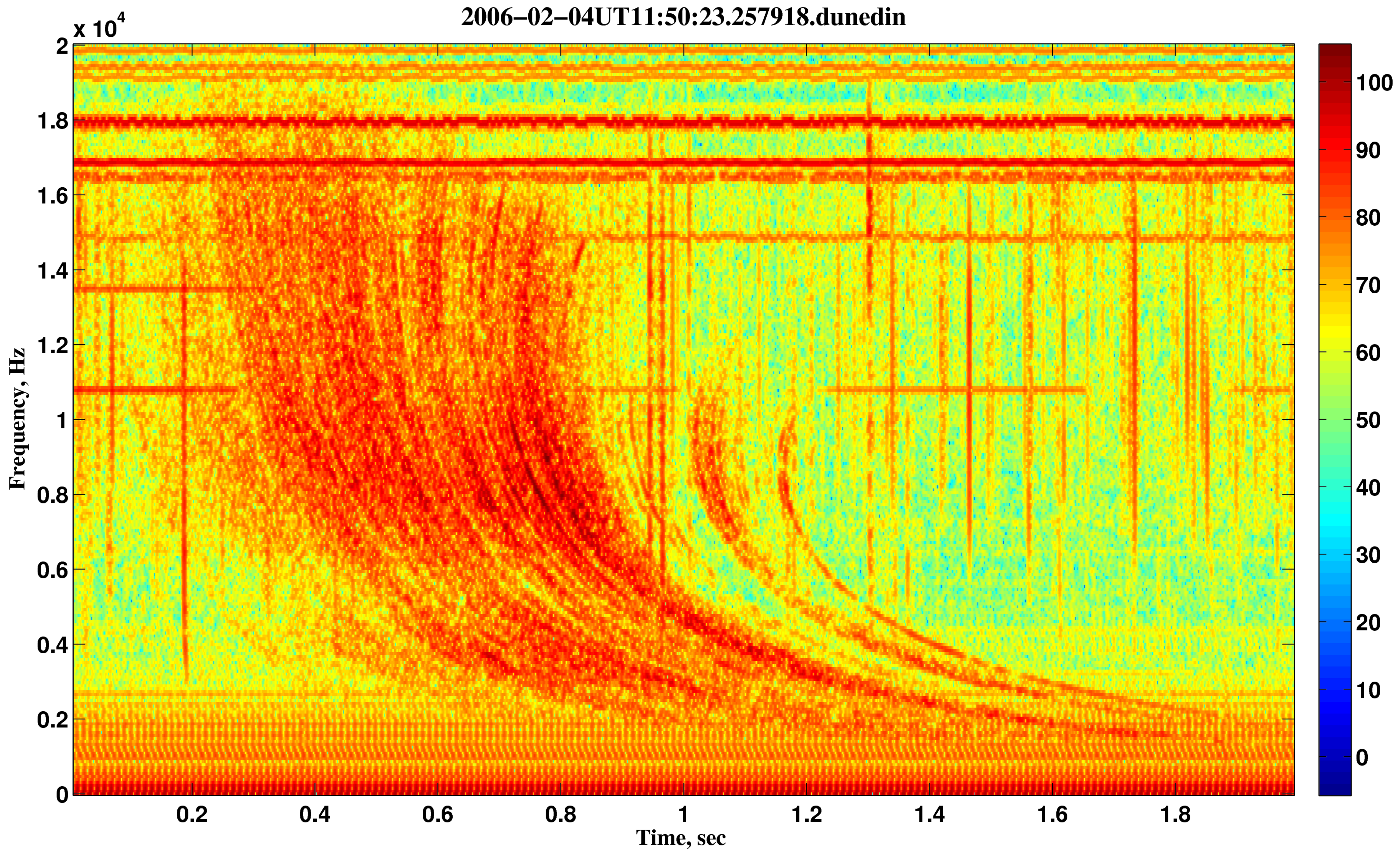
Real time operation is in *experimental* phase

Multiple path whistler group model:

- A new, simplified equatorial electron density profile is introduced in a meridional section of the plasmasphere:

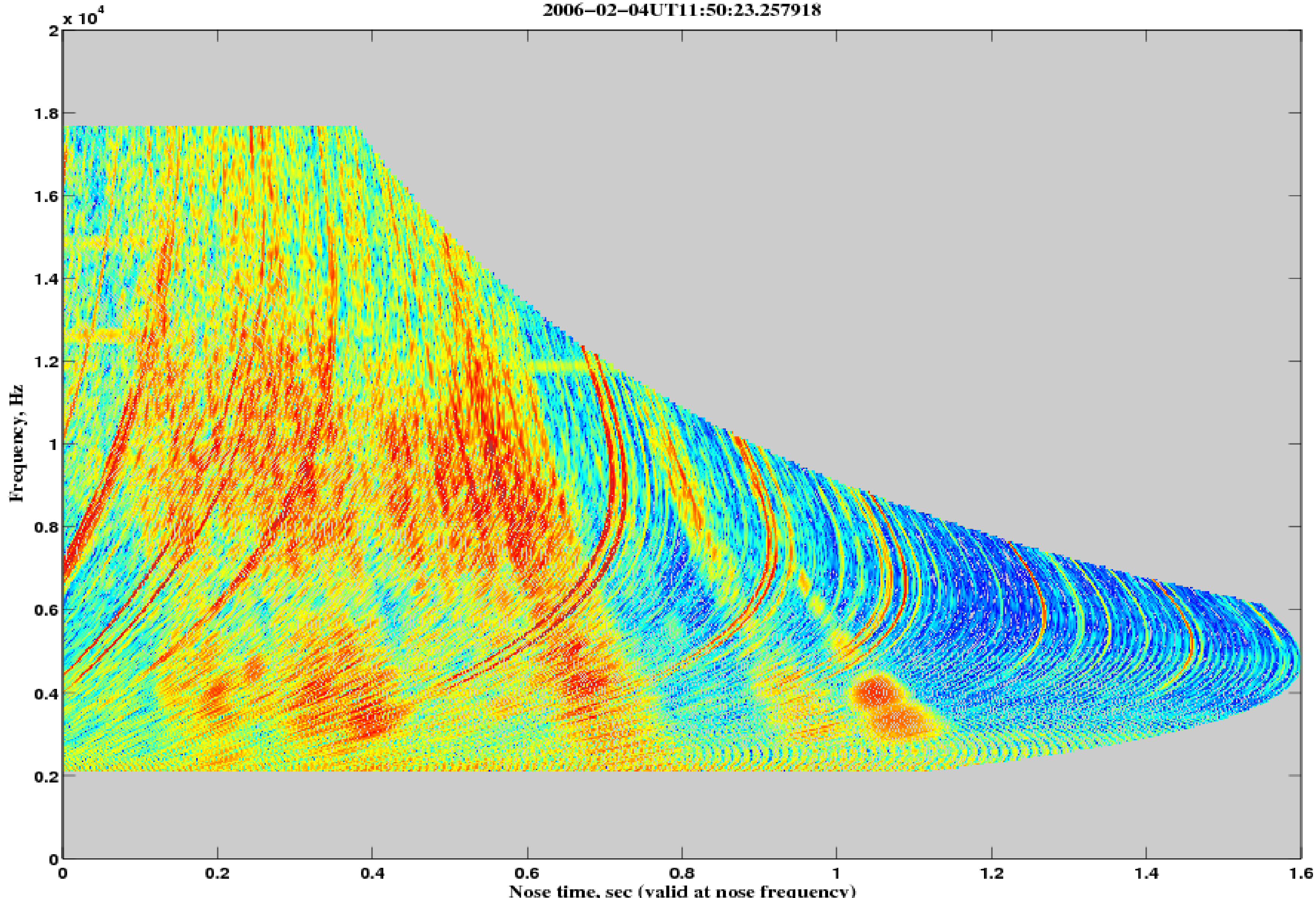
$$\log_{10} n_{eq} = A + B \cdot L$$

- *A* and *B* are constants for a MP group, but may vary to time and place.
- This approximation is valid between ~ 2 < L < min (8, L_{pp}), where L_{pp} is the location of plasmapause.
- Taking a pair of *(A,B)*, the electron density in magnetic equator decreases monotonically. In principle, a whistler can propagate along each field line described by an *L* in this range with corresponding n_{eq} forming a ***virtual whistler continuum***. Of course, in reality only a few whistlers of that continuum may be real.

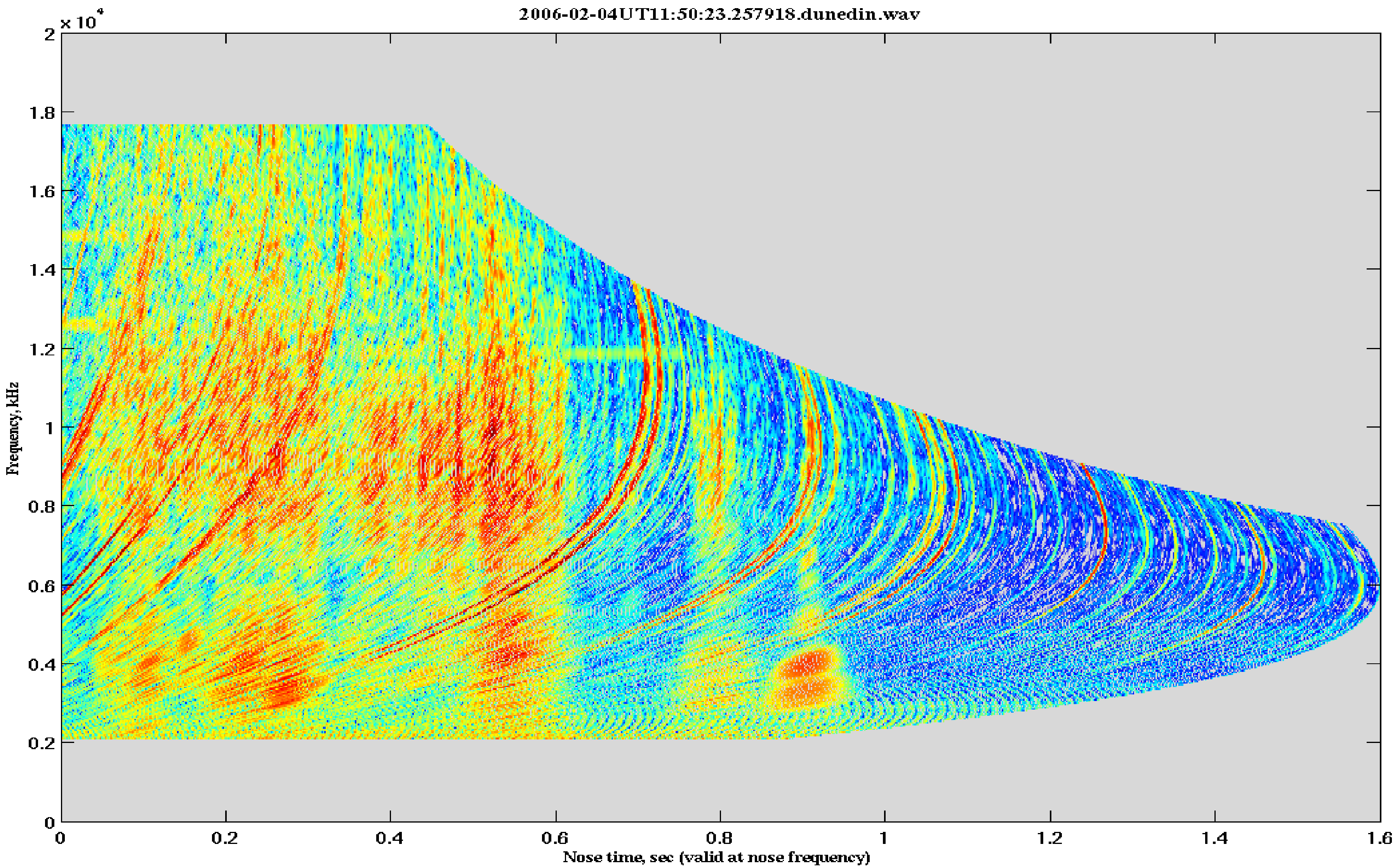


2006−02−04UT11:50:23.257918.dunedin
x 10^4
Frequency, Hz
Time, sec
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
100
90
80
70
60
50
40
30
20
10
0

VTT – unmatched parameters



VTT – matched parameters



Both “Standard” and “New” models need t_n (and f_n) for successful inversion

how can we get it?

The traditional way is (was) to estimate/guess the time of causative sferic – e.g using repeated MP groups overlayed.

BUT!

Journal of Atmospheric and Terrestrial Physics, 1971, Vol. 33, pp. 1125–1129. Pergamon Press. Printed in Northern Ireland

SHORT PAPER

Determination of nose frequency of non-nose whistlers

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(*Received* 26 *October* 1970)

Abstract—A method is described for determining nose frequency (f_n) and minimum group delay (t_n) from measurements of group delay at many frequencies along the observed whistler trace. It is primarily intended for the analysis of whistlers which do not reach the nose frequency, but the multipoint sampling may give improved accuracy for nose whistlers also, particularly if the traces are ill-defined. It is well suited to digital computation since only algebraic manipulations

2. Empirical Relations from Observed Whistlers

Consider the quantity (the reciprocal of the 'dispersion')

$$Q(f) = (t\sqrt{f})^{-1}$$

where t is the group propagation time per hop at frequency f. Figure 1 shows Q as a function of frequency for a well-defined nose whistler. The $Q(f)$ points fit closely a straight line which intercepts the $Q = 0$ axis at $f_0 = 41$ kHz, or 3·06 times the observed nose frequency (13·4 kHz). This linearity of Q–v–f has been found in about 100 non-nose whistlers measured. Measurements of 19 well-defined nose whistlers gave a mean ratio* of zero-Q frequency (f_0) to observed nose frequency of $3{\cdot}09 \pm 0{\cdot}04$ (standard deviation).

Consequently one can use this property to determine the nose frequency (f_n) of whistlers, which do not exhibit the nose by extrapolation of the $Q(f)$ regression line obtained from $t(f)$ measurements within the available frequency range. The value

This implicitly assumes that t_n is known!

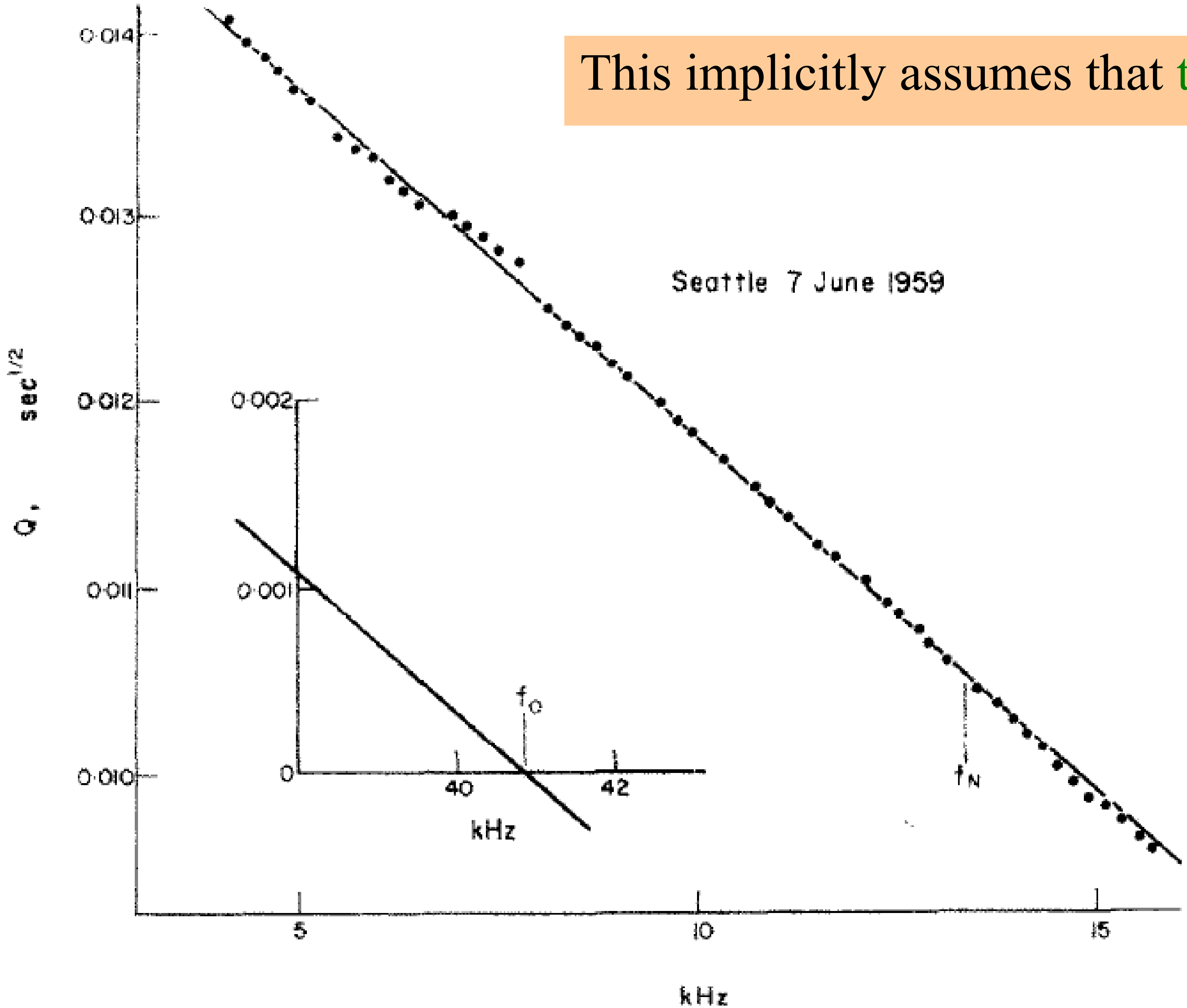
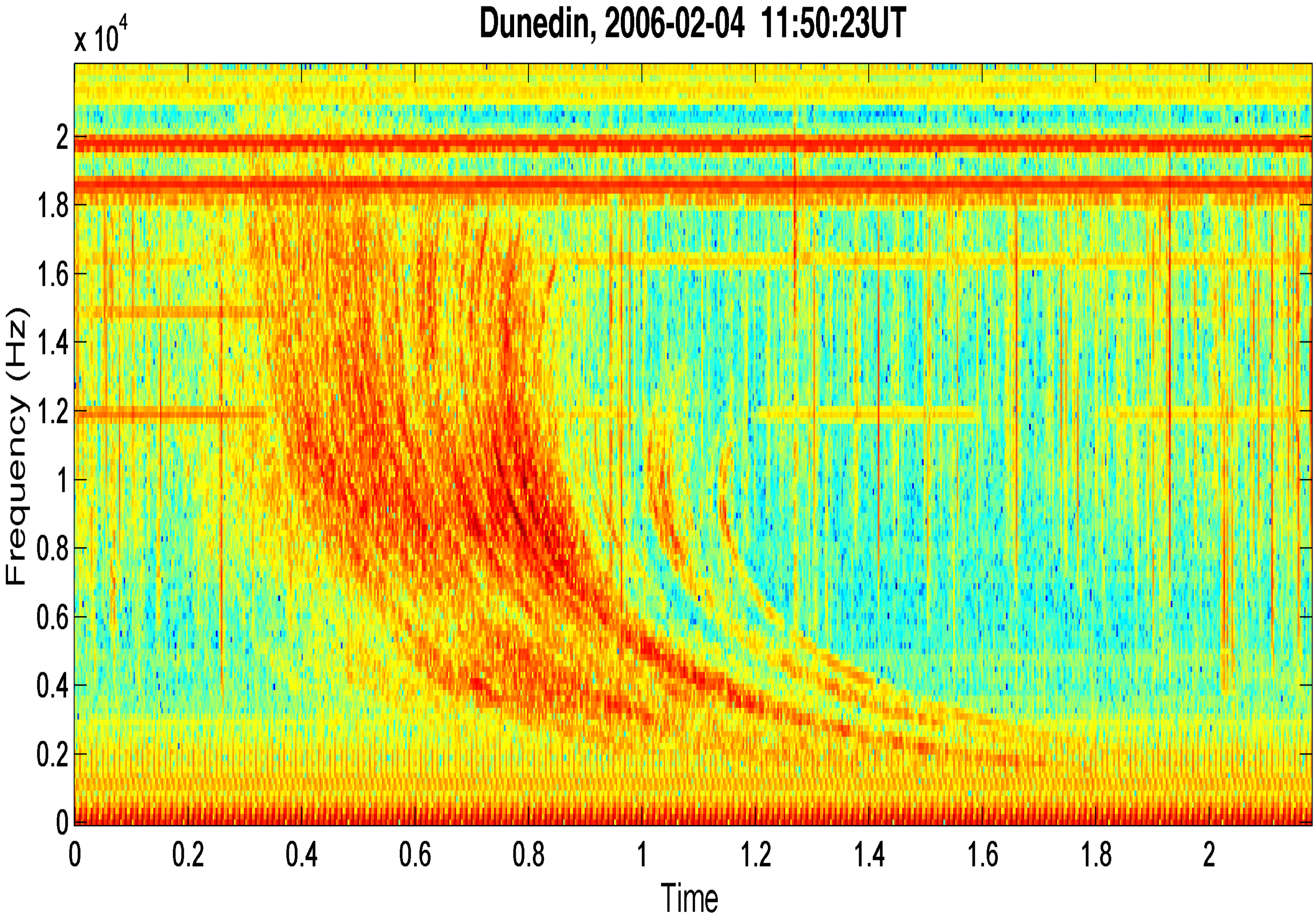
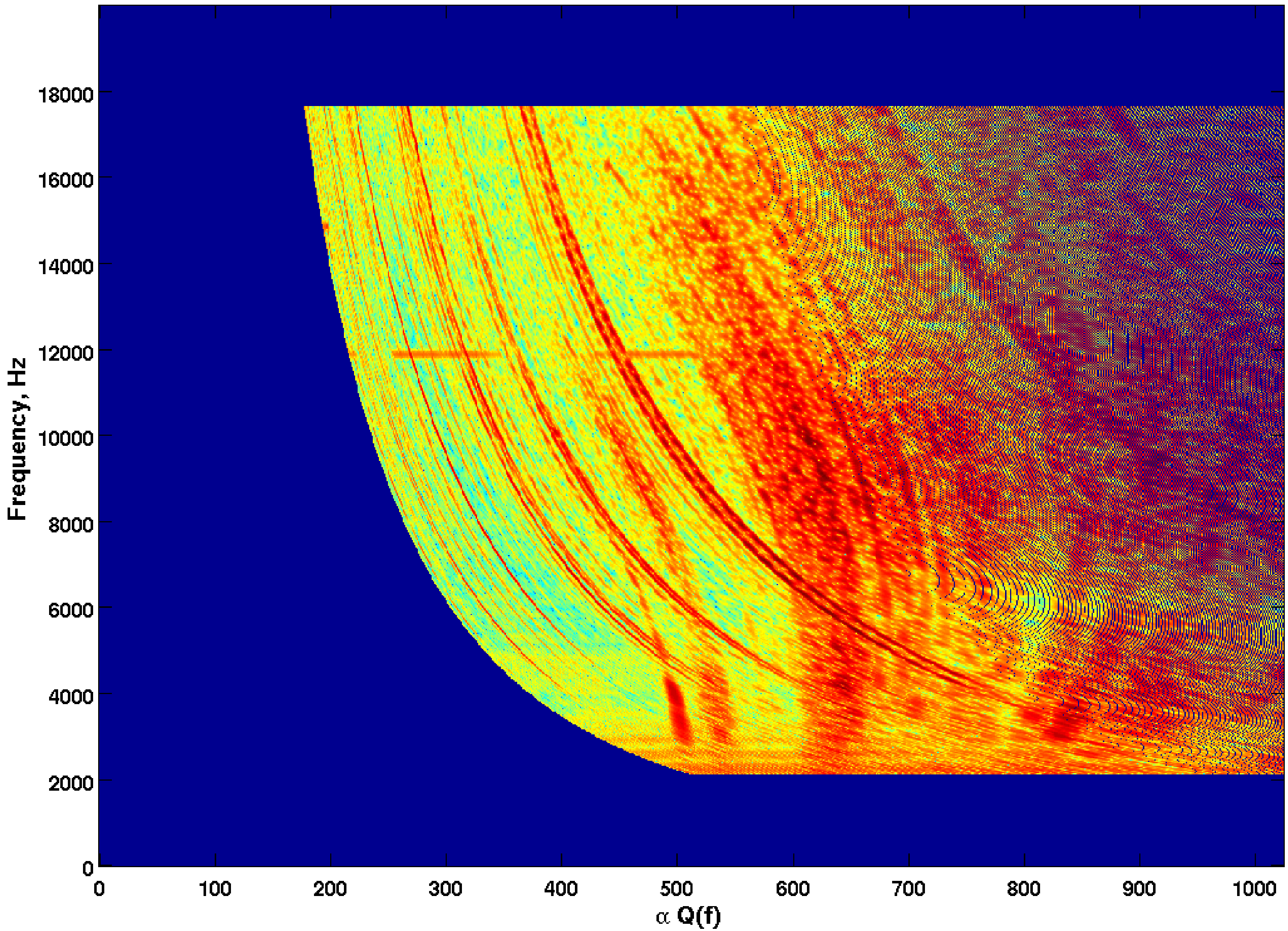


Fig. 1. $Q(f)$ plot of a well-defined nose whistler. (This whistler is shown in Fig. 4-17b of HELLIWELL (1965) and the $f(t)$ data was taken from his Fig. 4-18.) The Q and f scales used here have been offset and expanded to show up any non linearity. Extrapolation of the regression line (see inset) shown gives $f_0 = 41$ kHz, or 3·06 times the observed (arrow) nose frequency, at $Q = 0$.

Let's apply the Q transformation on a spectrogram matrix!



Let's apply the Q transformation on a spectrogram matrix!



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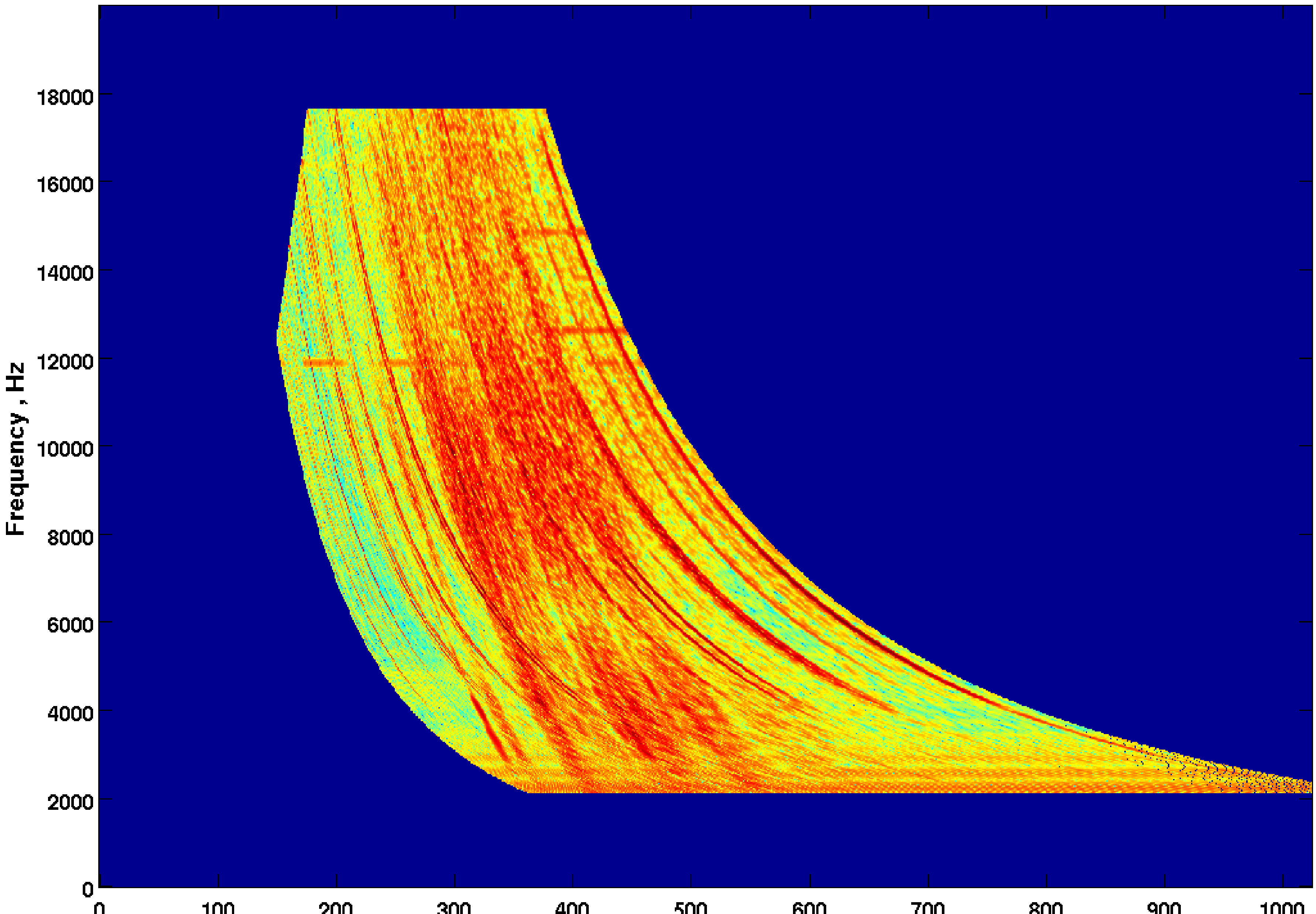

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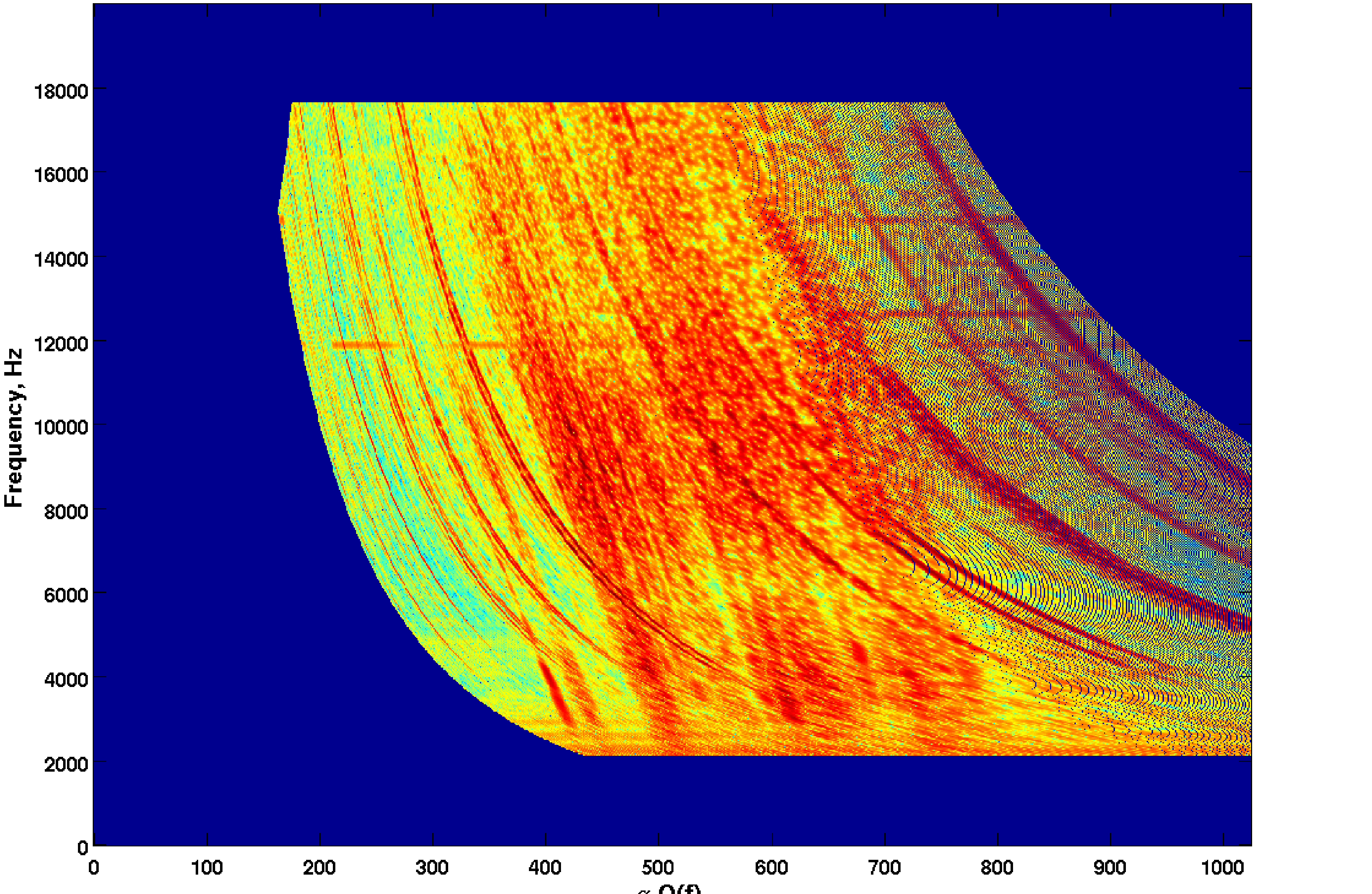
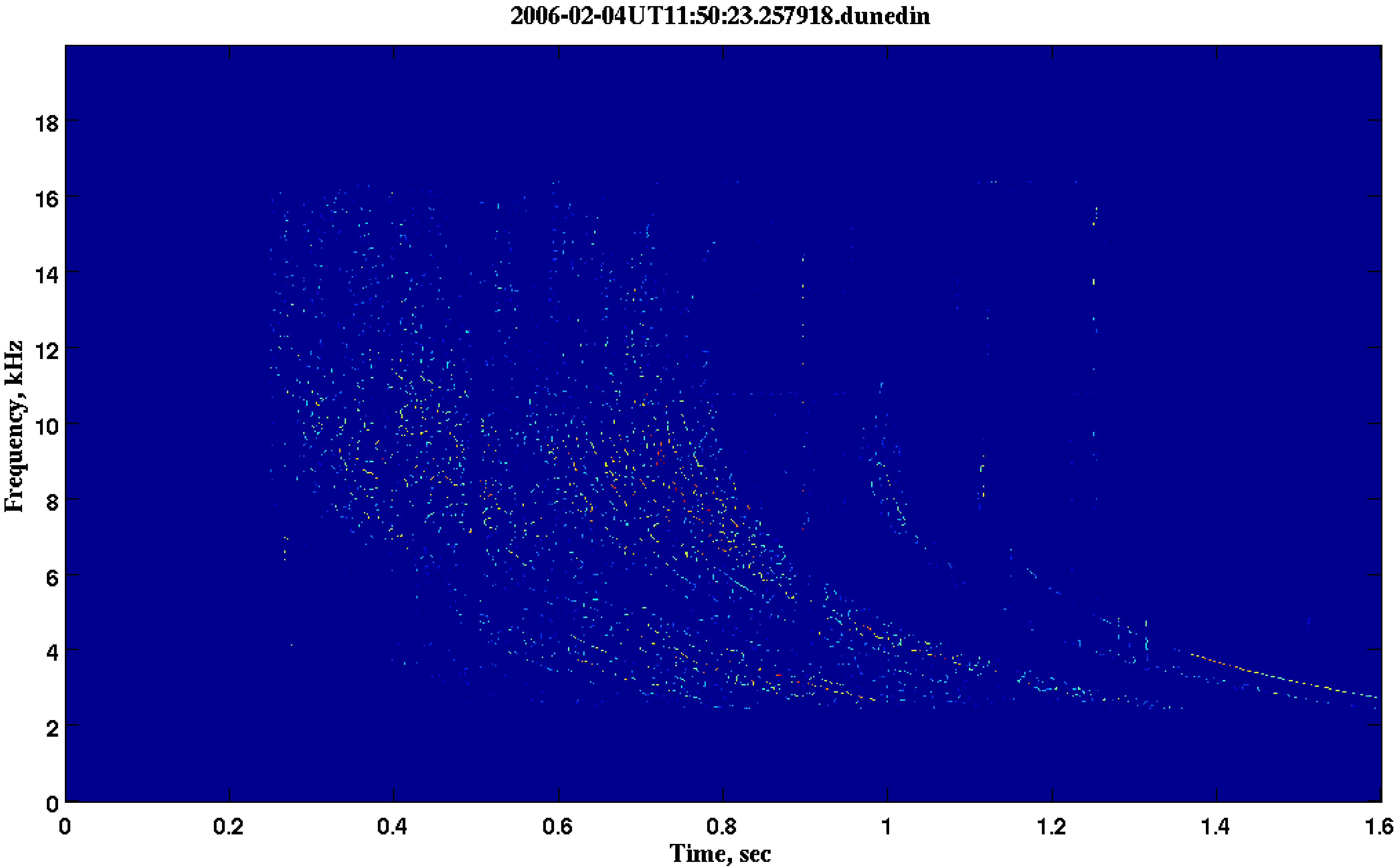


Let's apply the Q transformation on a *reassigned* spectrogram matrix!



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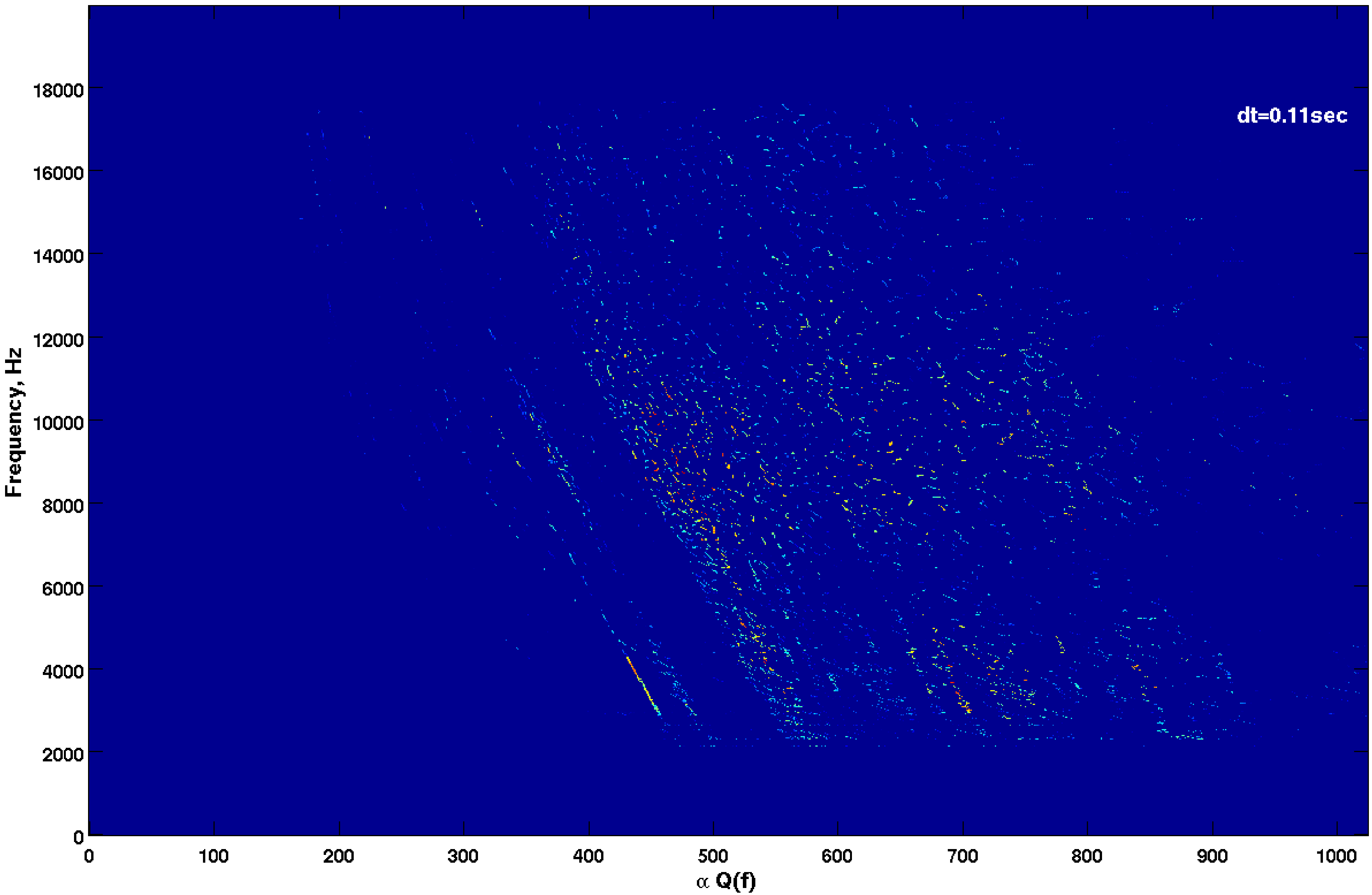

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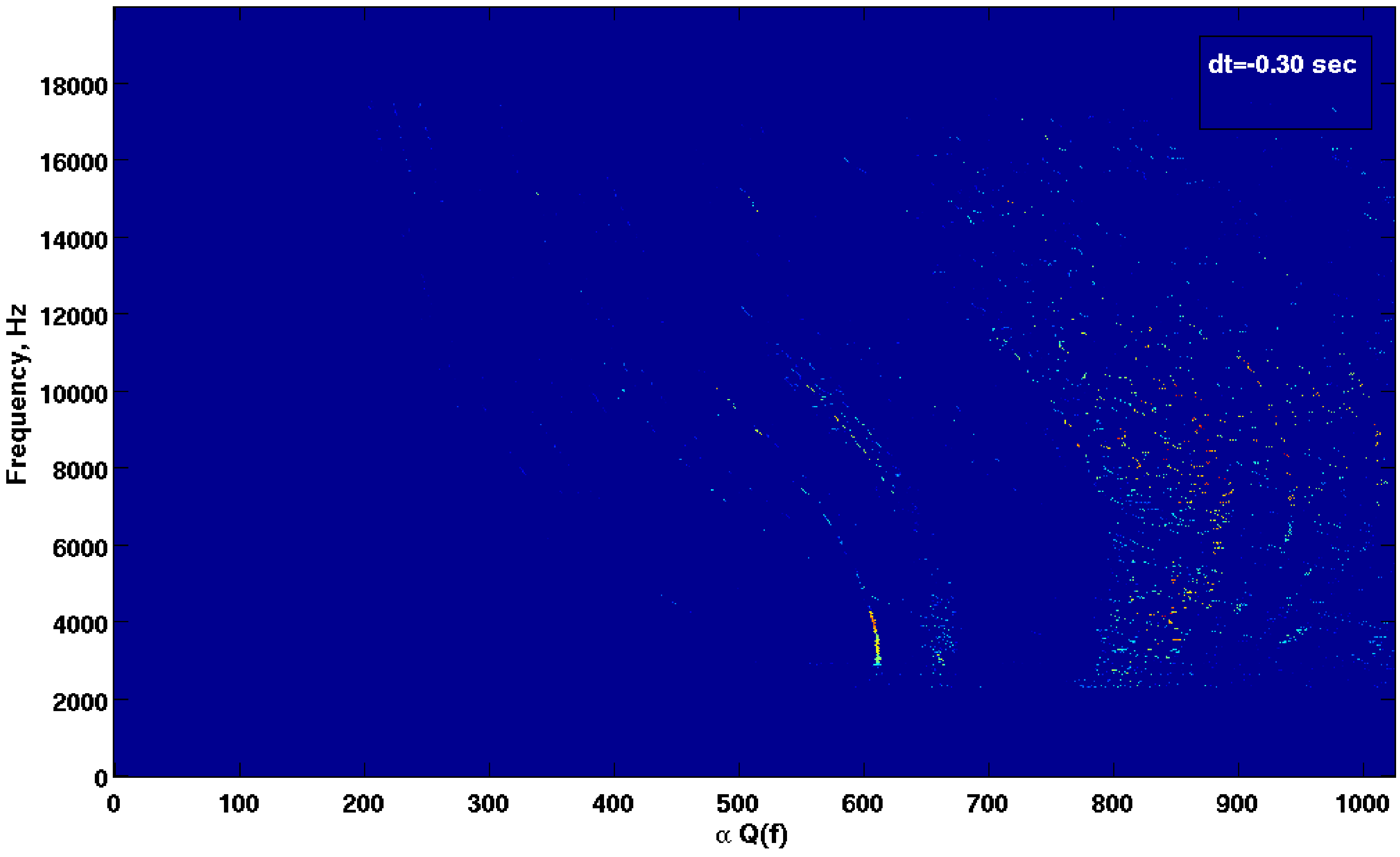

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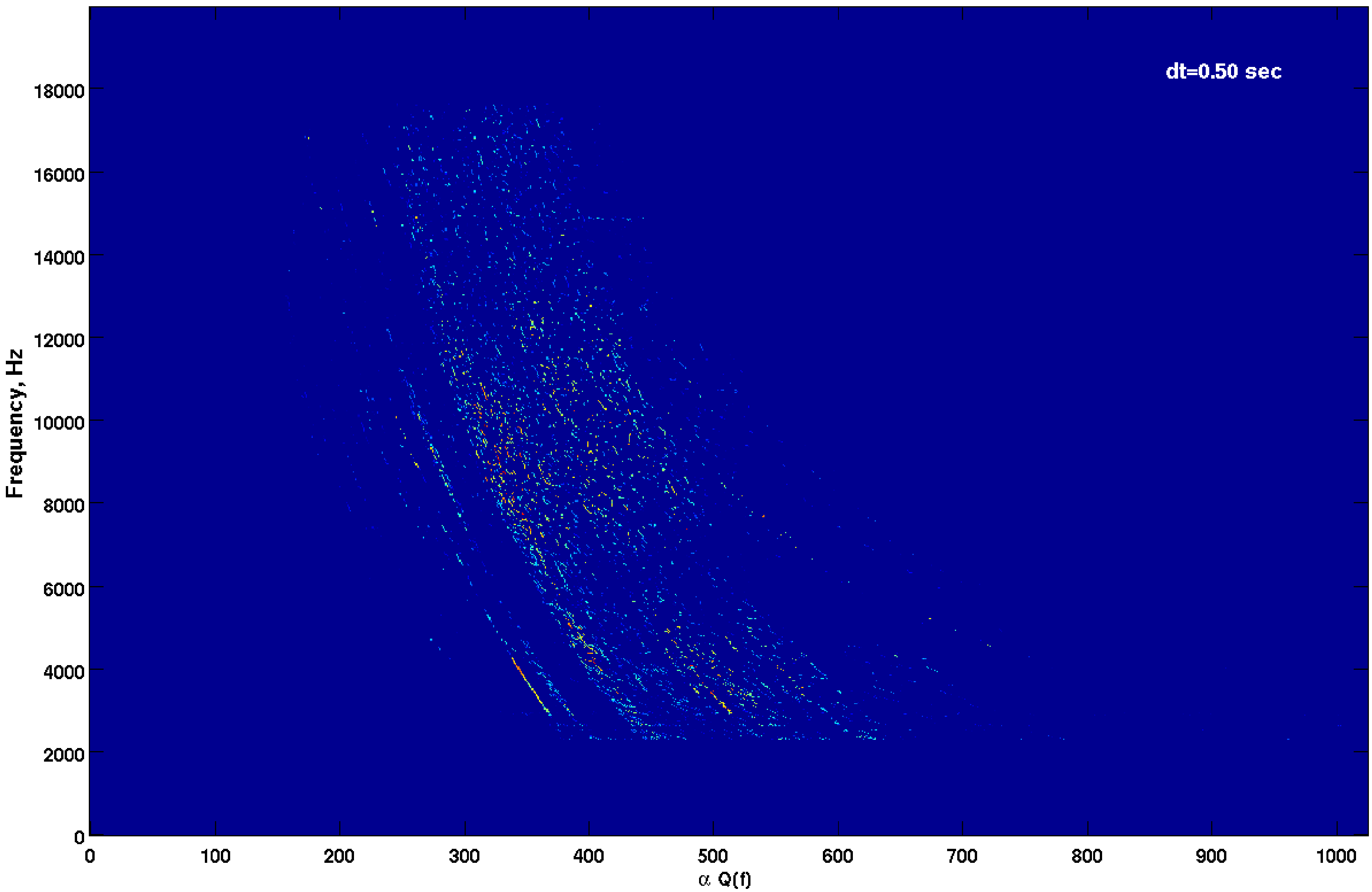

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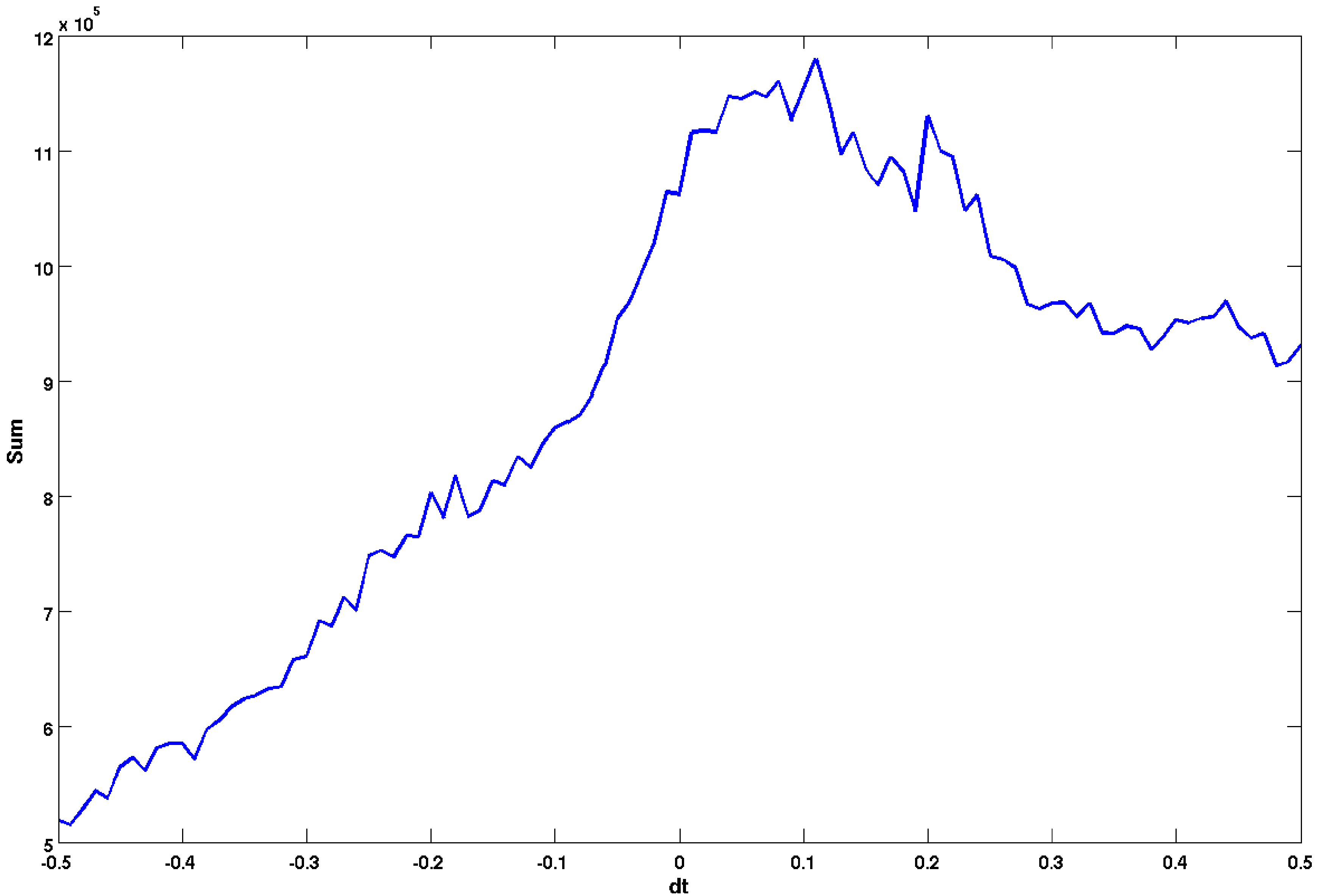
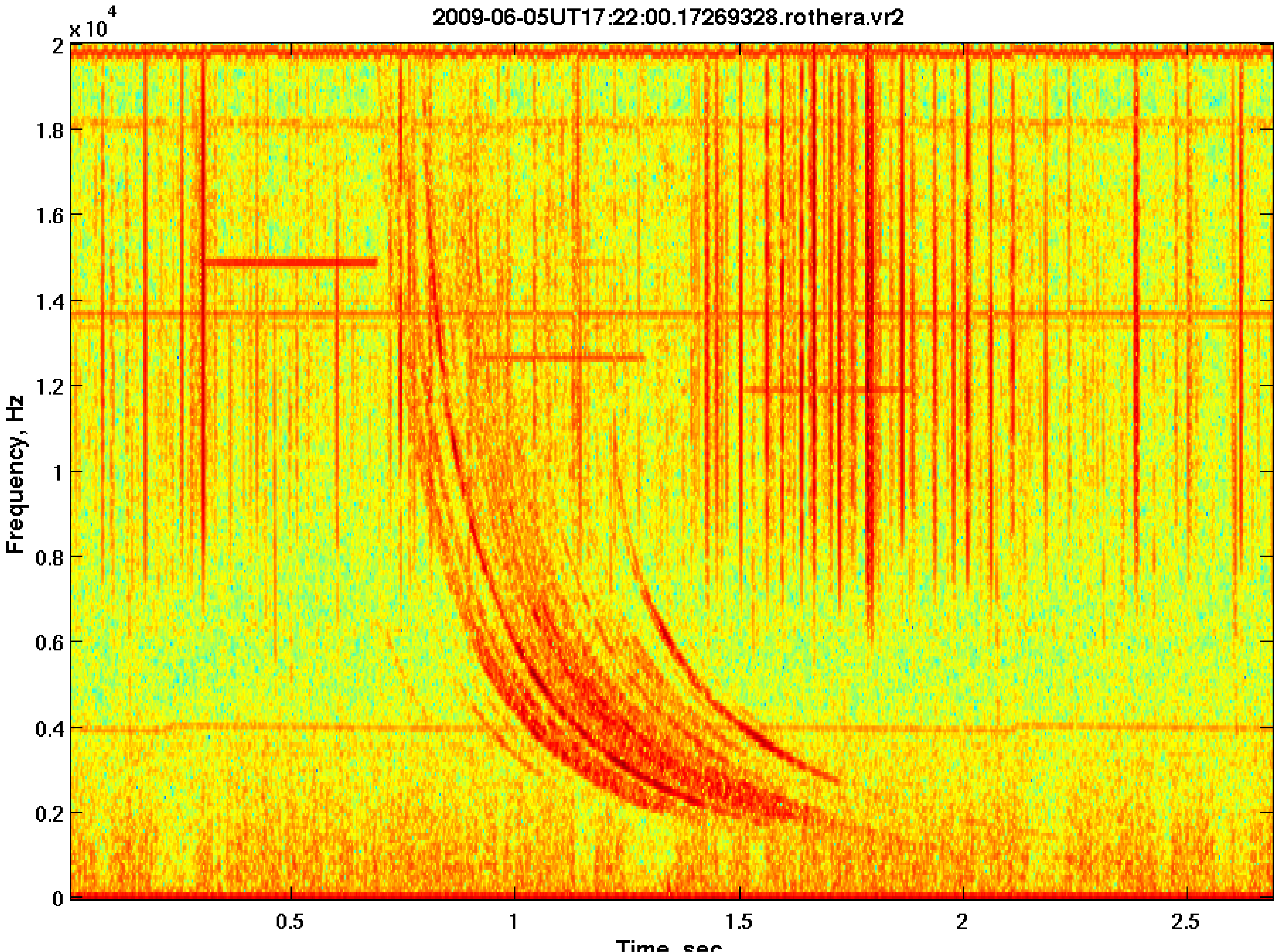
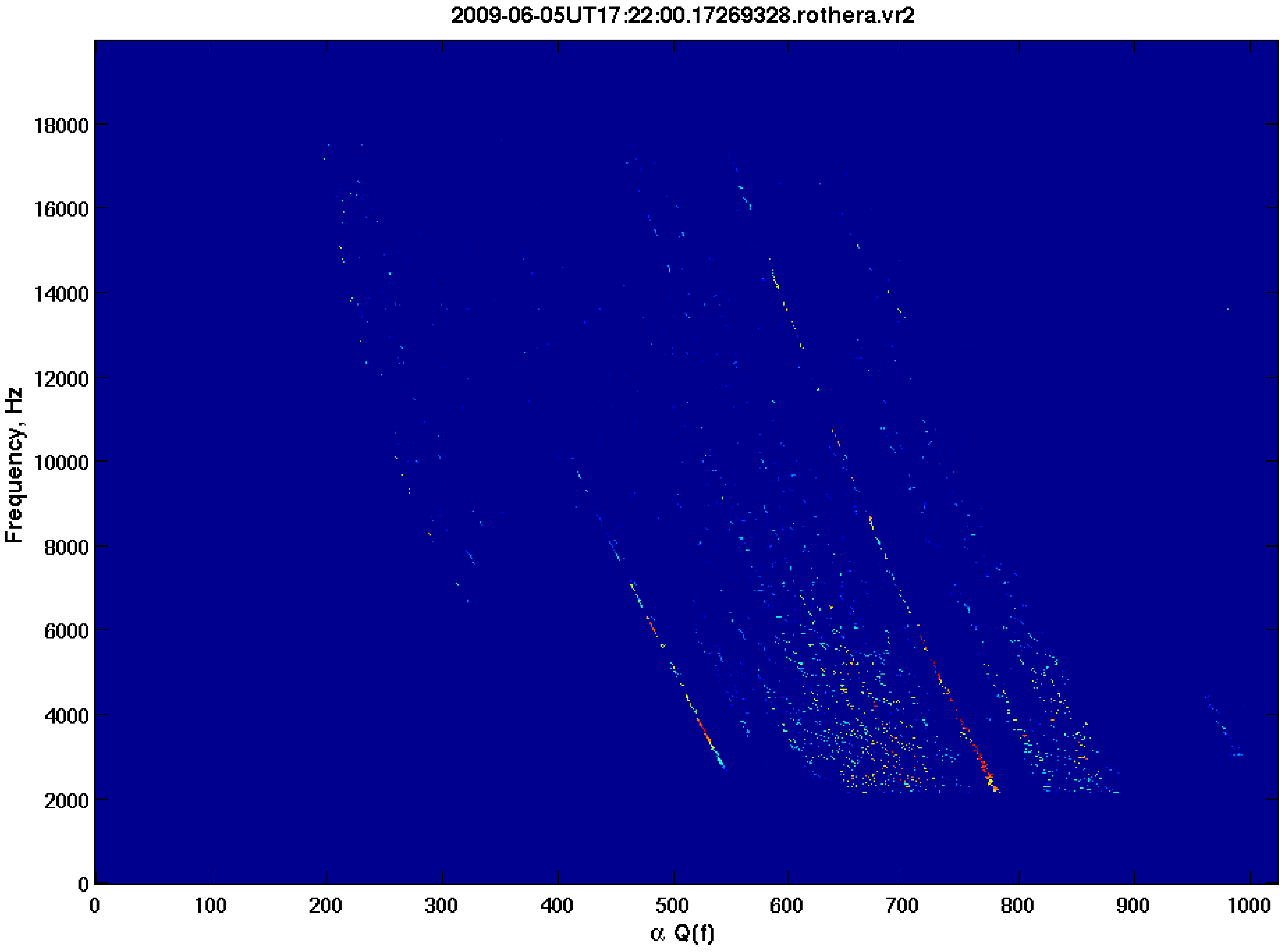


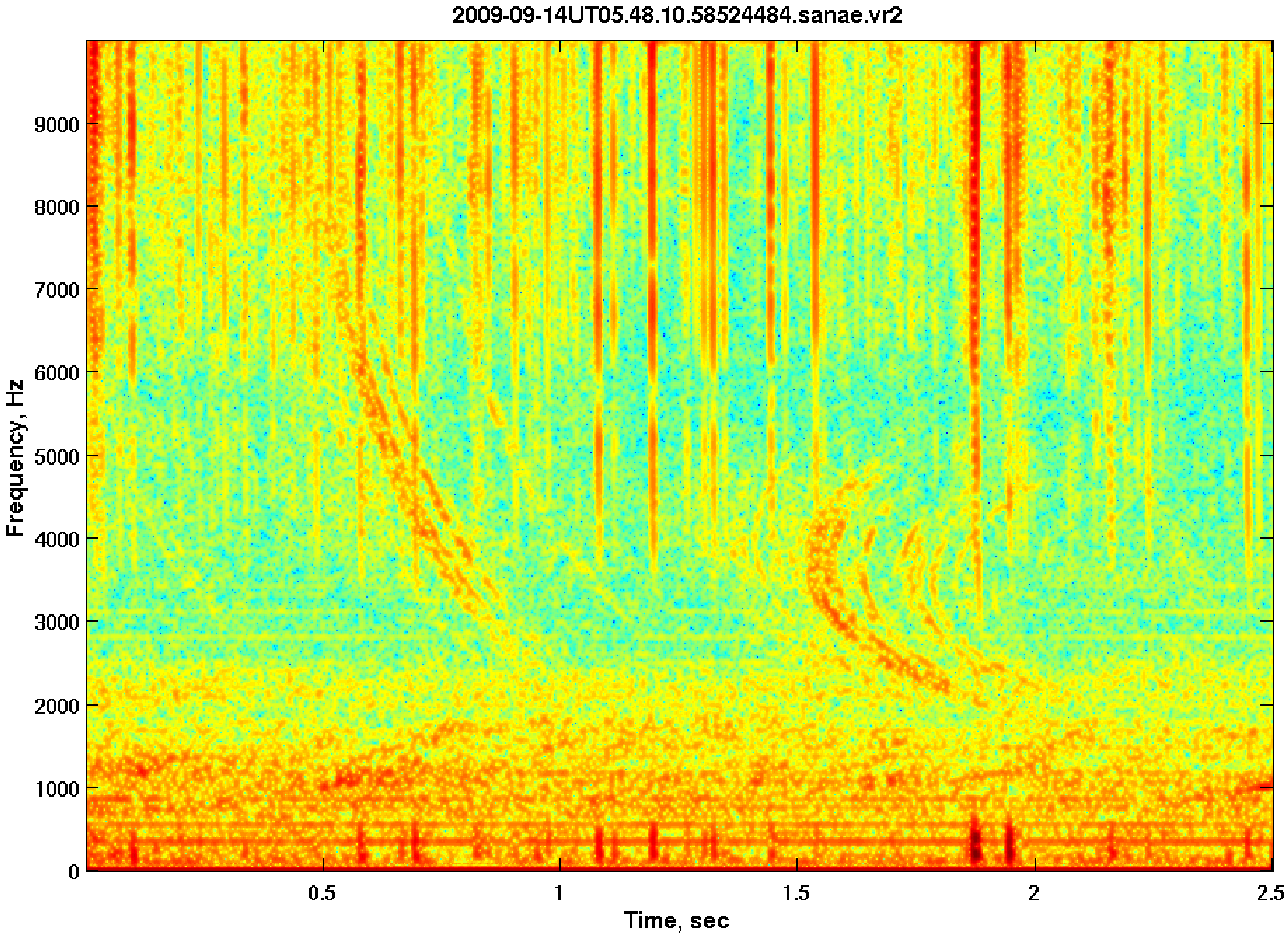
O transformation on Antarctic whistlers: *Rothera*



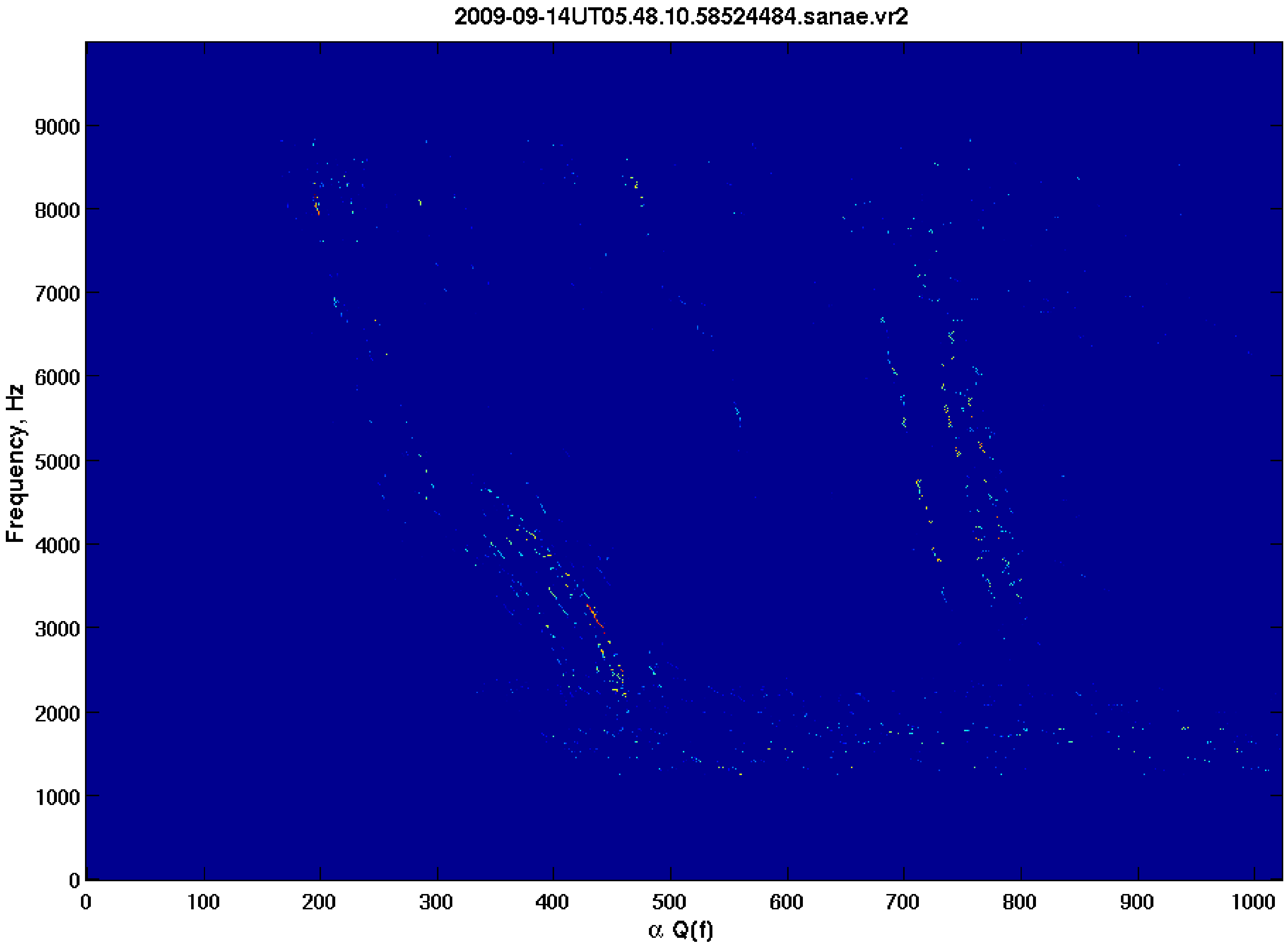
Q transformation on Antarctic whistlers: *Rothera*



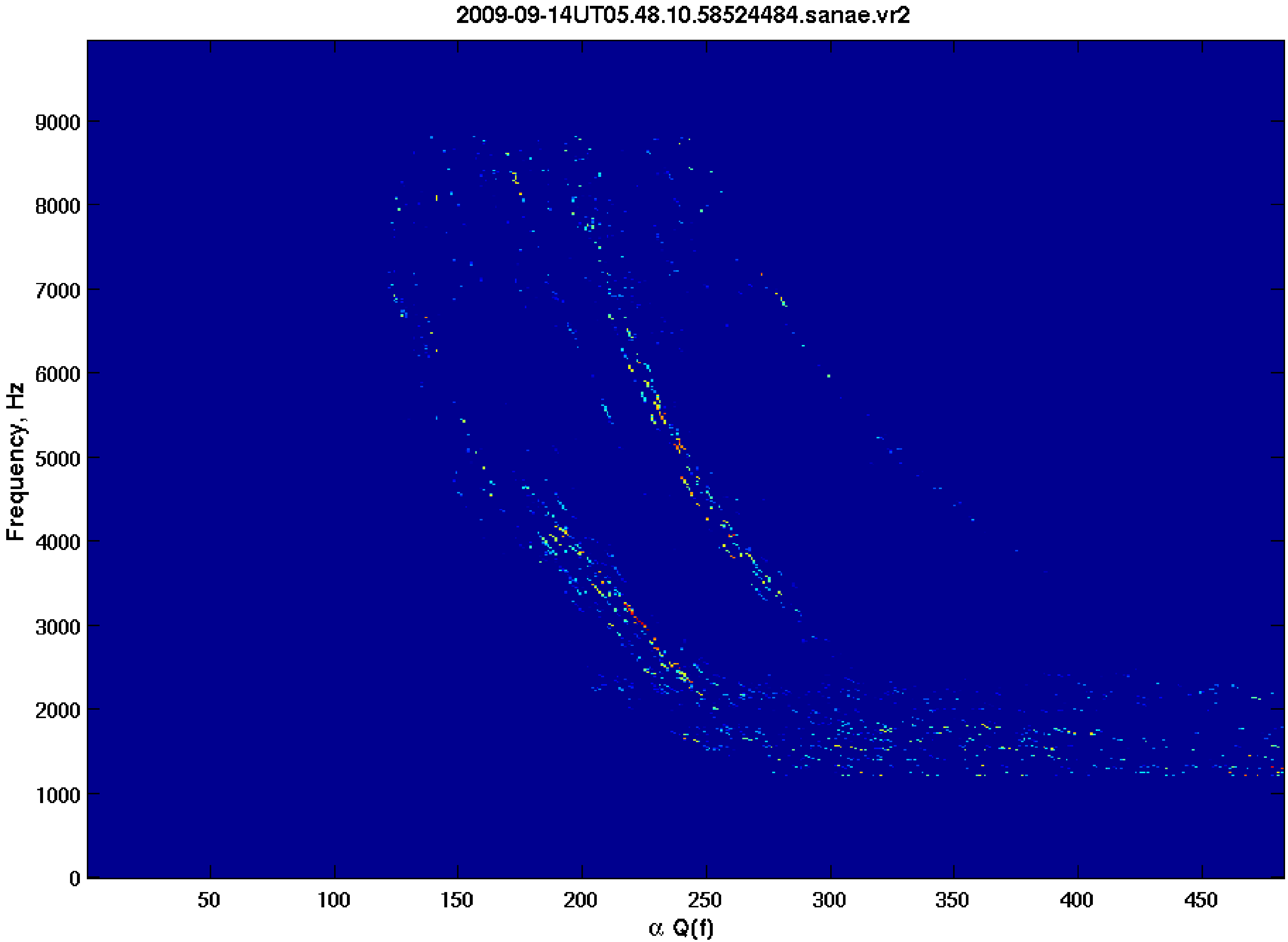
Q transformation on Antarctic whistlers: *SANAE*



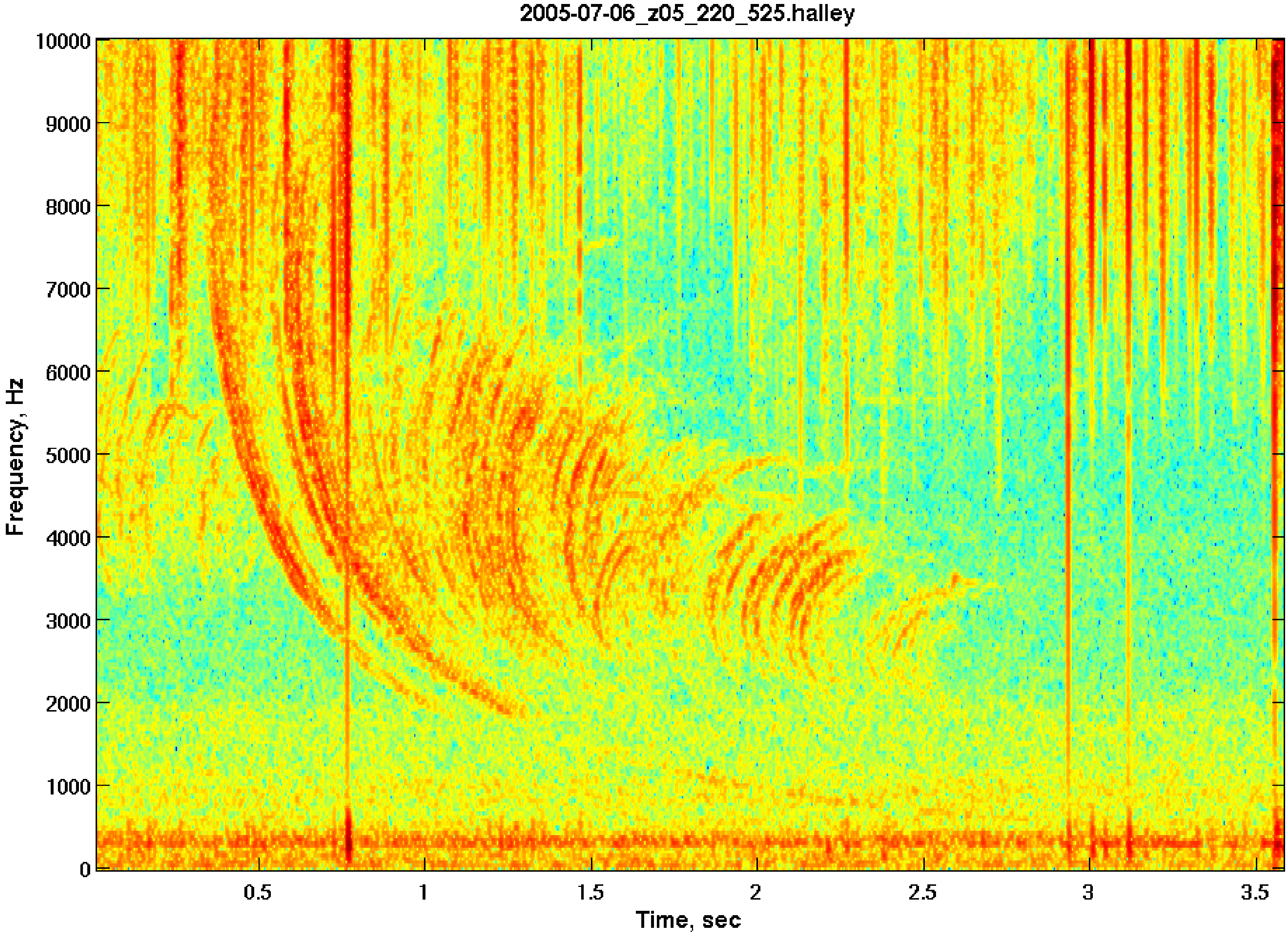
Q transformation on Antarctic whistlers: *SANAE – 2 groups!*



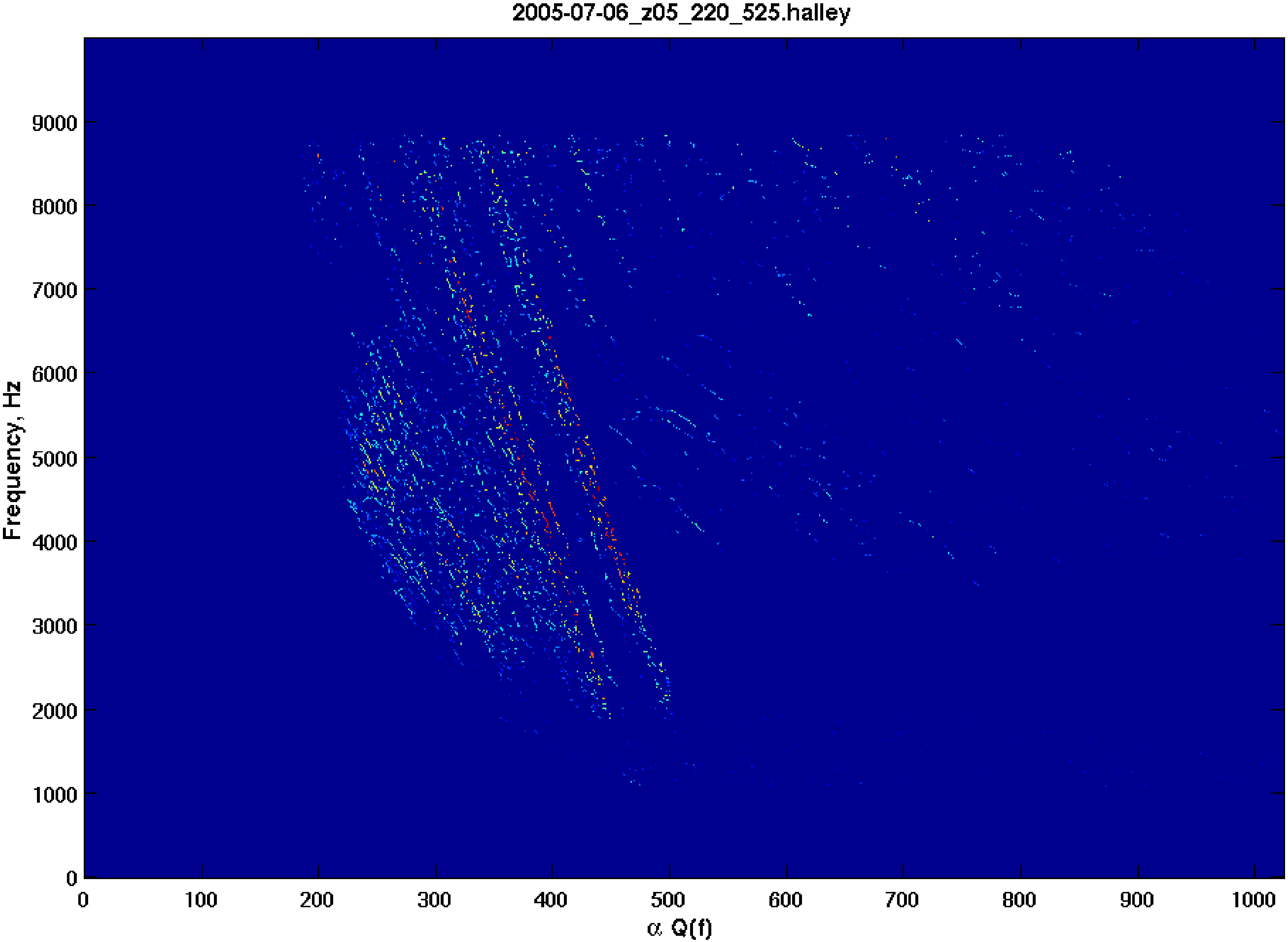
Q transformation on Antarctic whistlers: *SANAE – 2 groups!*



Q transformation on Antarctic whistlers: *Halley*



Q transformation on Antarctic whistlers: *Halley*



Conclusions

1. The automatic determination method of nose frequency and time of initiating sferic has established

2. Both the traditional and automatic whistler inversion method can use it

3. It particularly useful in AWA implementation

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Thank you

Gorely volcano, Kamchatka, 18 August 2012