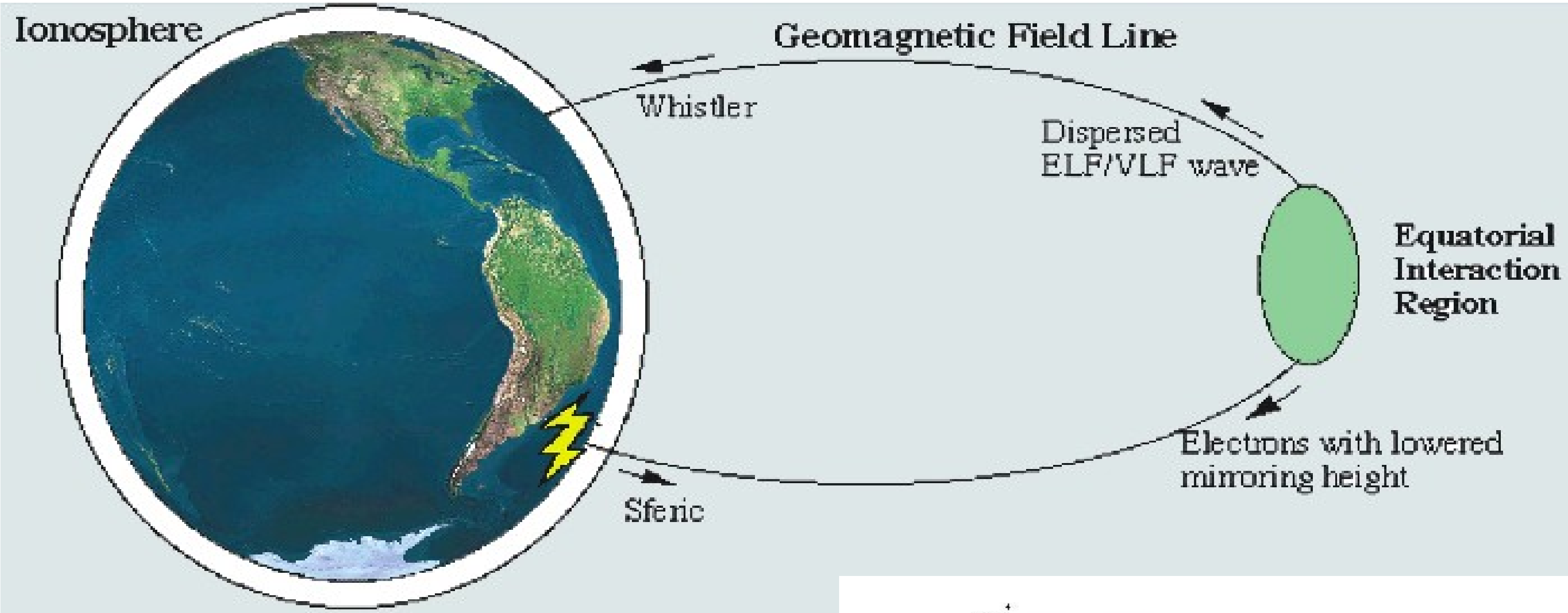
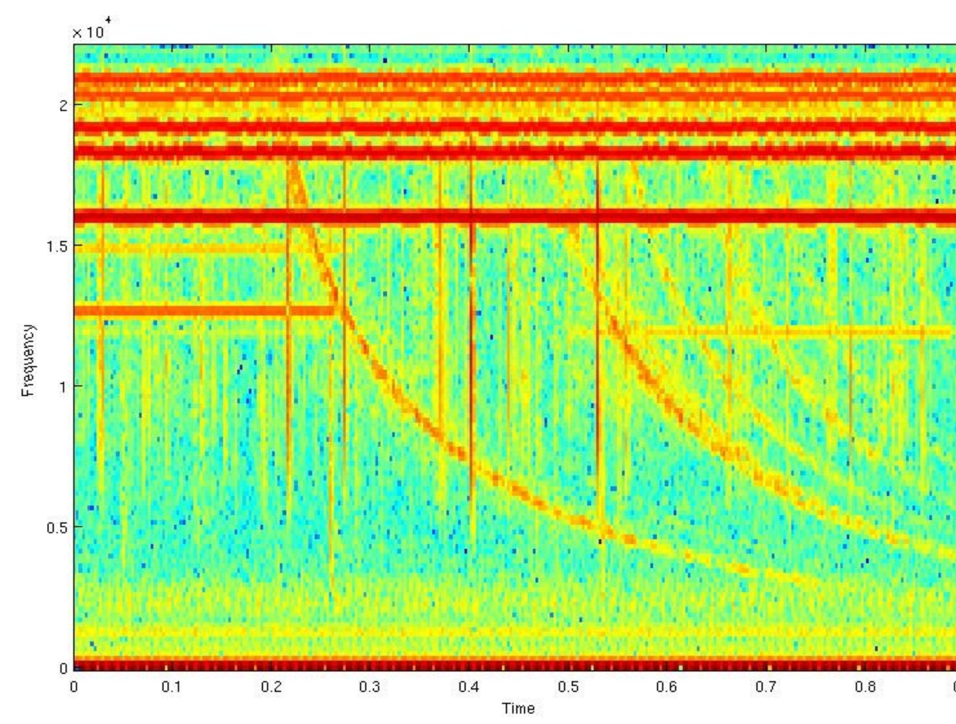
Monitoring the Plasmasphere by VLF whistlers

János LICHTENBERGER,

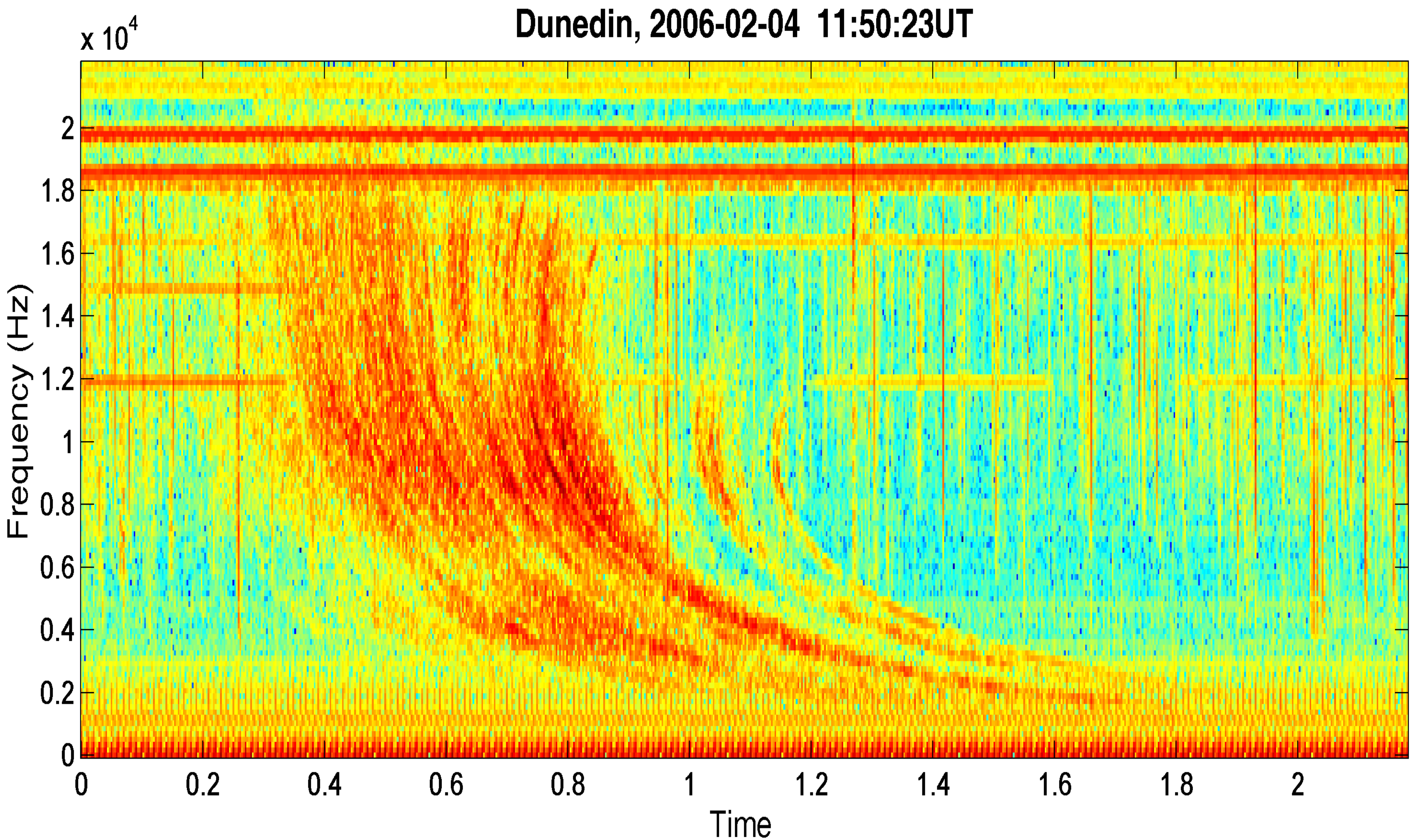
Space Research Group, Department of Geophysics and Space Sciences, Eötvös University, Hungary

Origin of *whistlers*





Music of the spheres
How does it look like?



What are the *whistlers* good for?

1. ***Nose*** frequency

2. ***Dispersion***

From ***1.*** + ***2.*** => where & what

Where did it travel in *plasmasphere*

What was the *plasma density* there

OK., but ***why*** is it important?

Plasmasphere: why is it important?

Space Weather

- Radiation Belts dynamics: wave-particle interactions

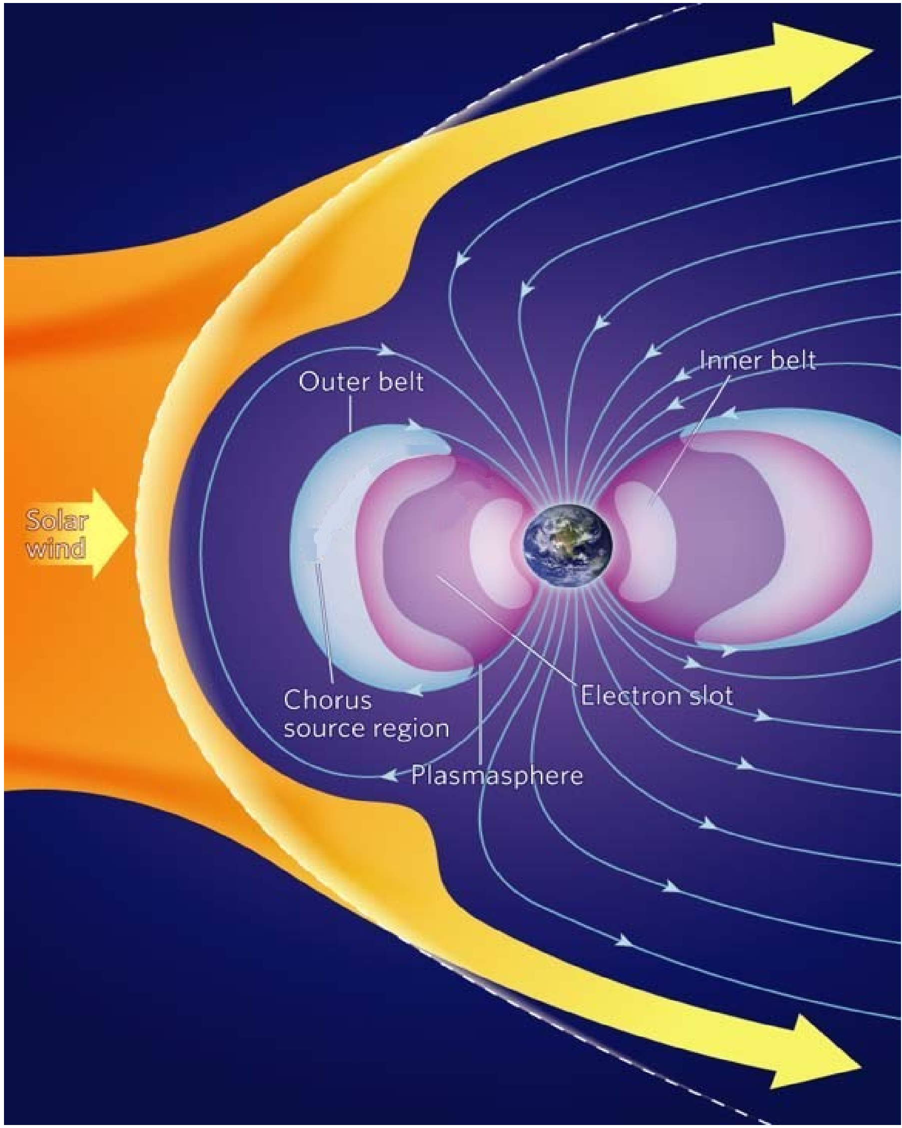
  - chorus

  - hiss

take place in/at ***plasmasphere/plasmapause***

→ we need a model

of the plasmasphere /plasmapause location



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*

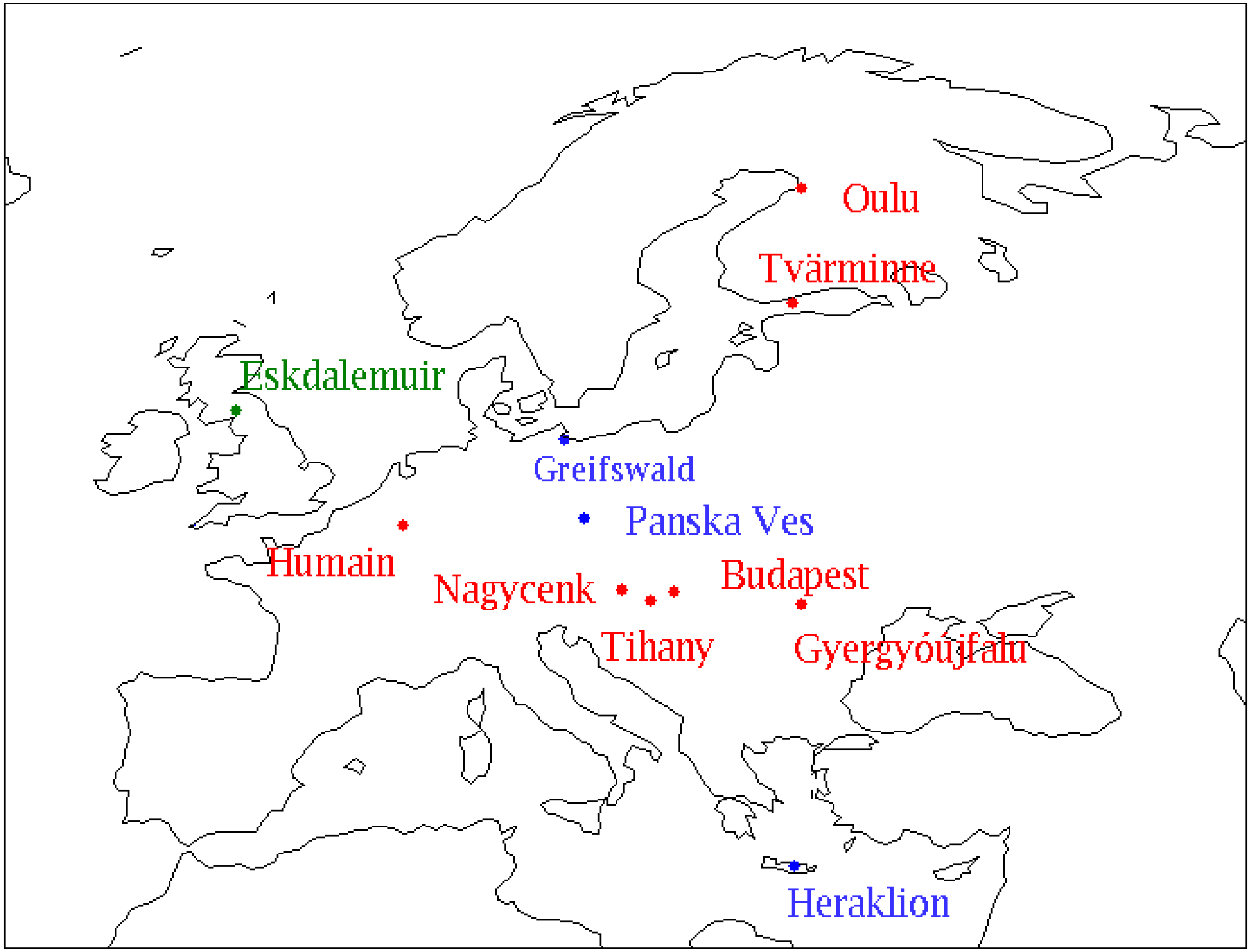
AWDANet

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

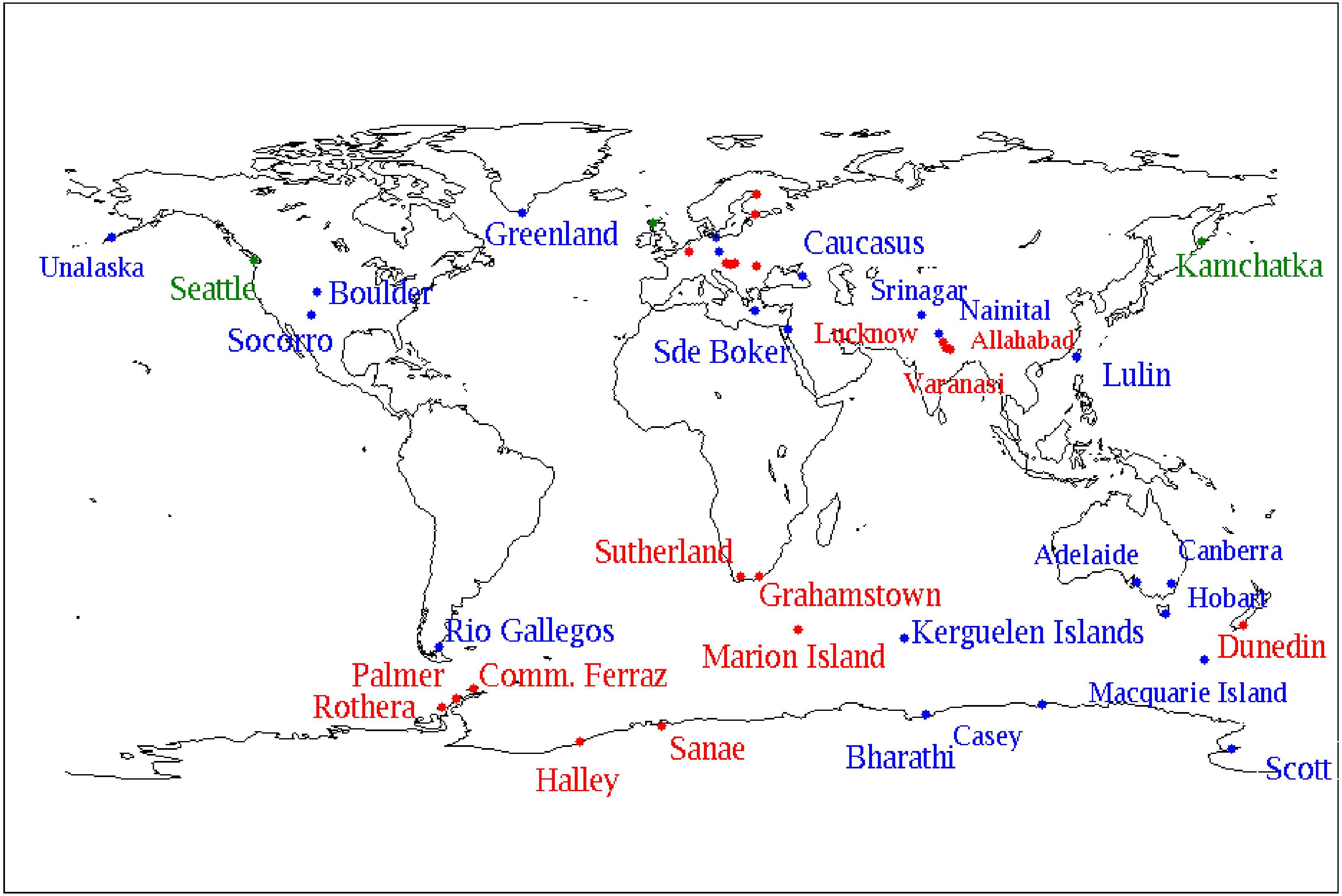
~50 000-10 000 000 traces/year/station

Real time operation is in *experimental* phase

AWDANet -Europe



AWDANet - World

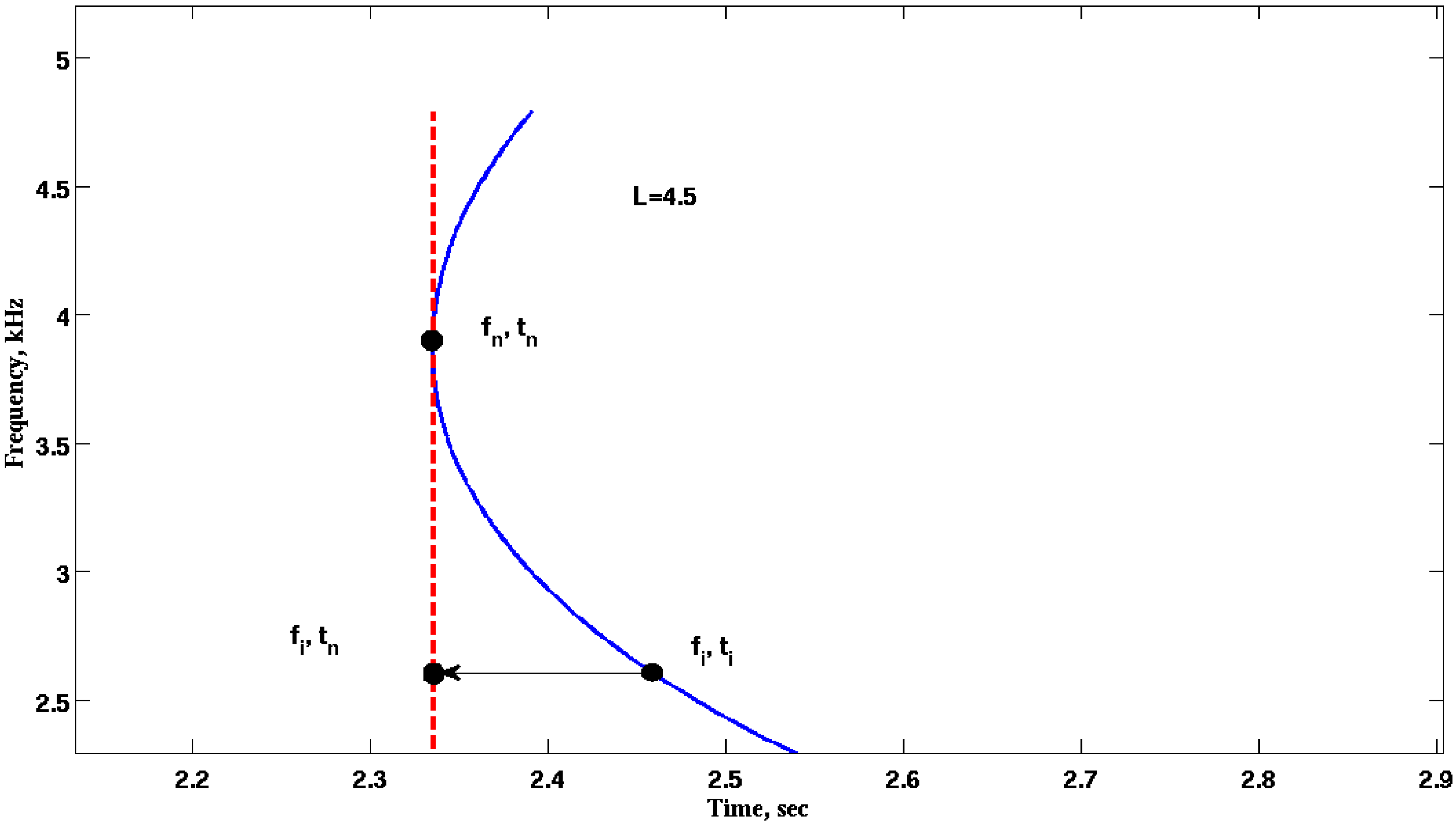


A new *whistler inversion* method

+

Virtual (whistler) Trace Transformation

[Lichtenberger, *JGR*, 2009]

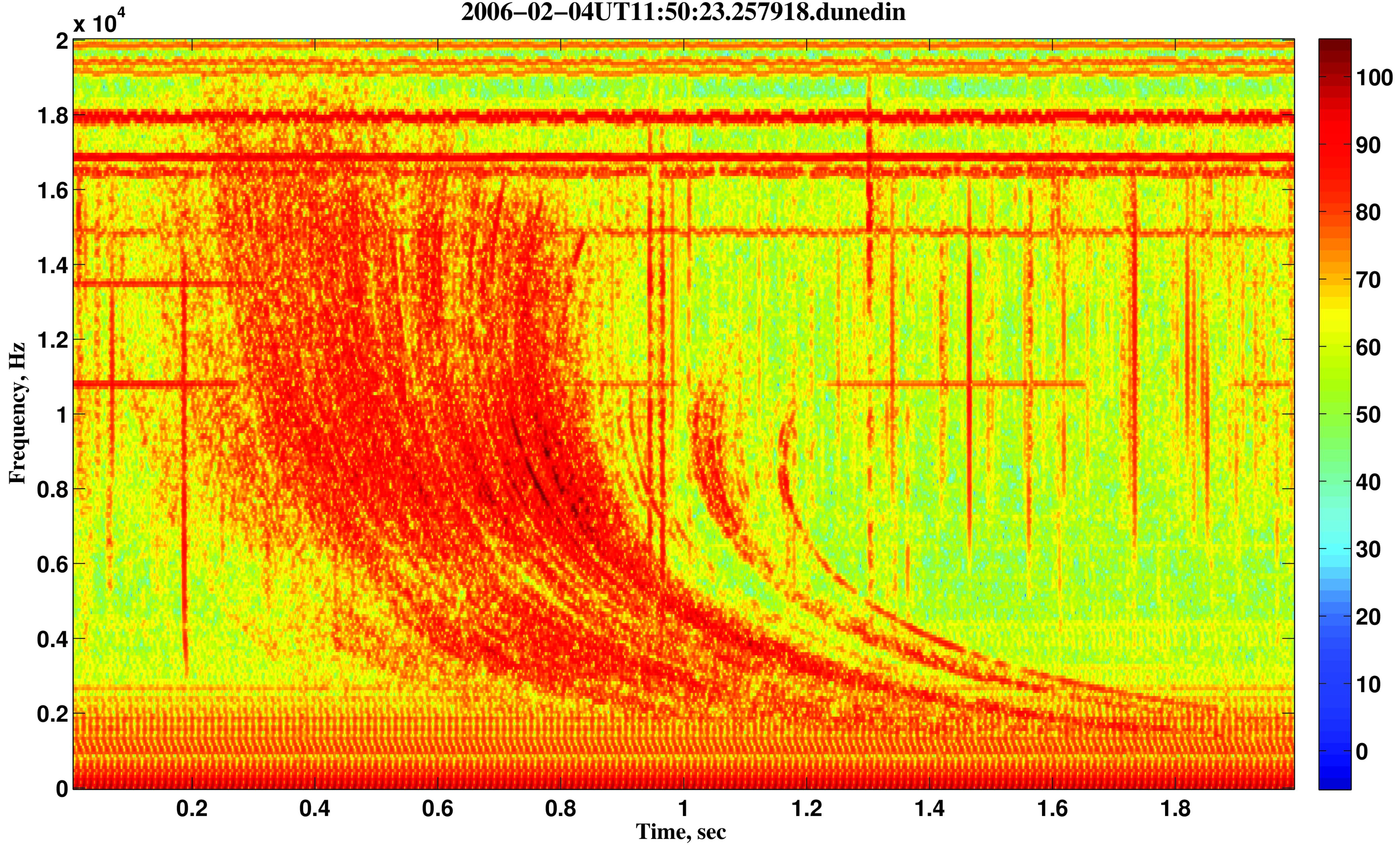


Multiple path whistler group model:

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

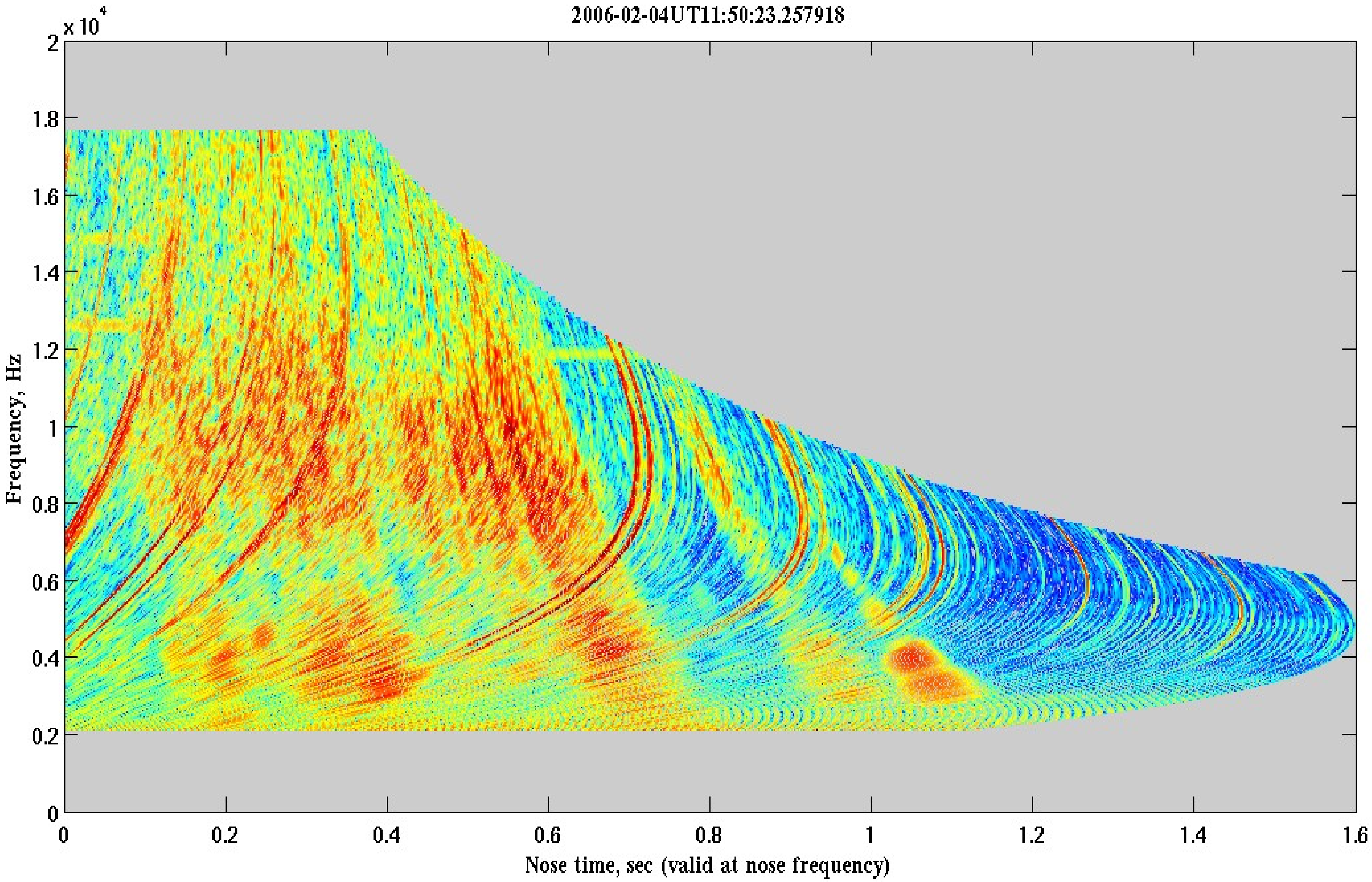
$$\log_{10} n_{eq} = A + B \cdot L$$

- *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.

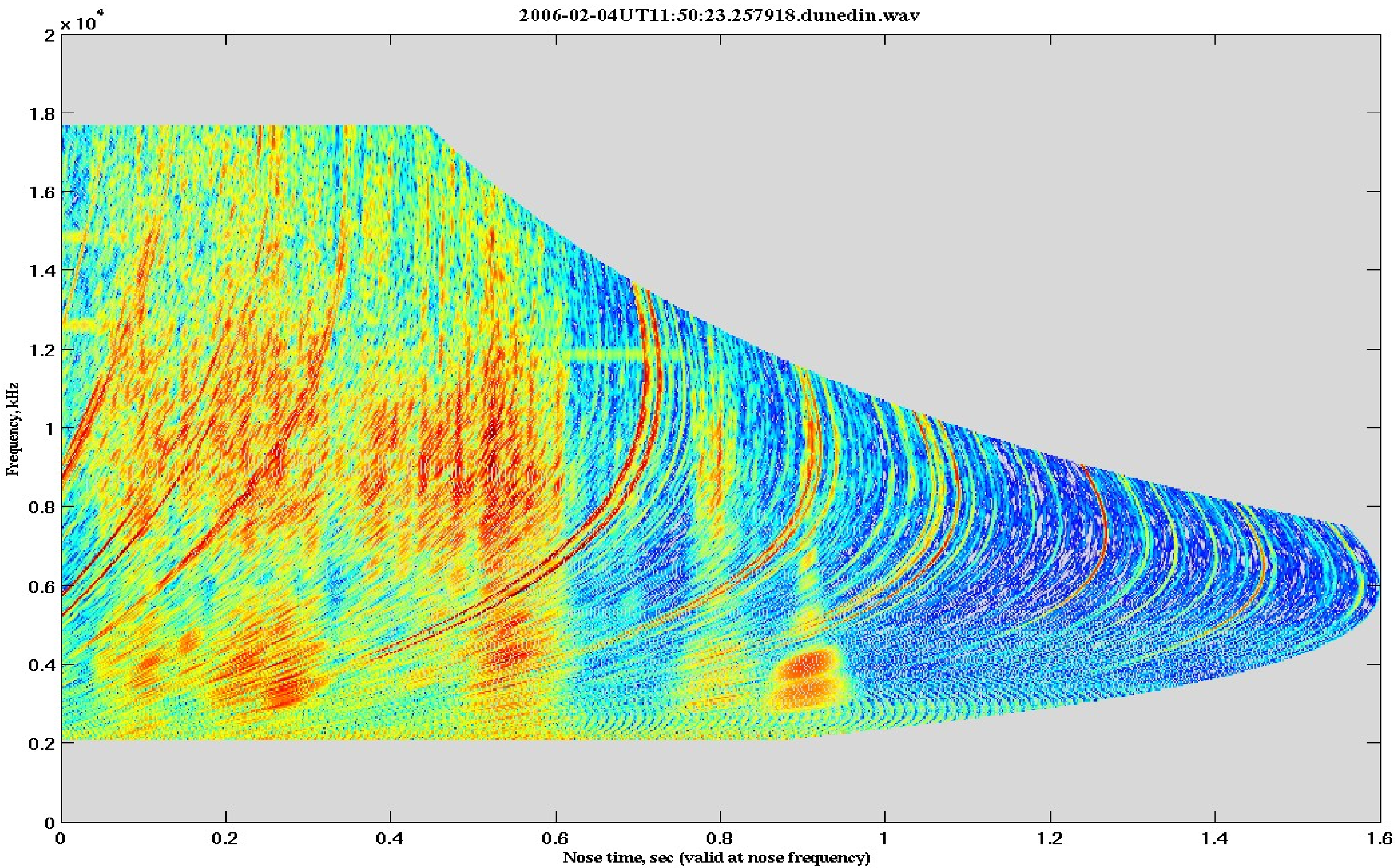


2006−02−04UT11:50:23.257918.dunedin
x 10^4
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
Frequency, Hz
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
Time, sec
100
90
80
70
60
50
40
30
20
10
0

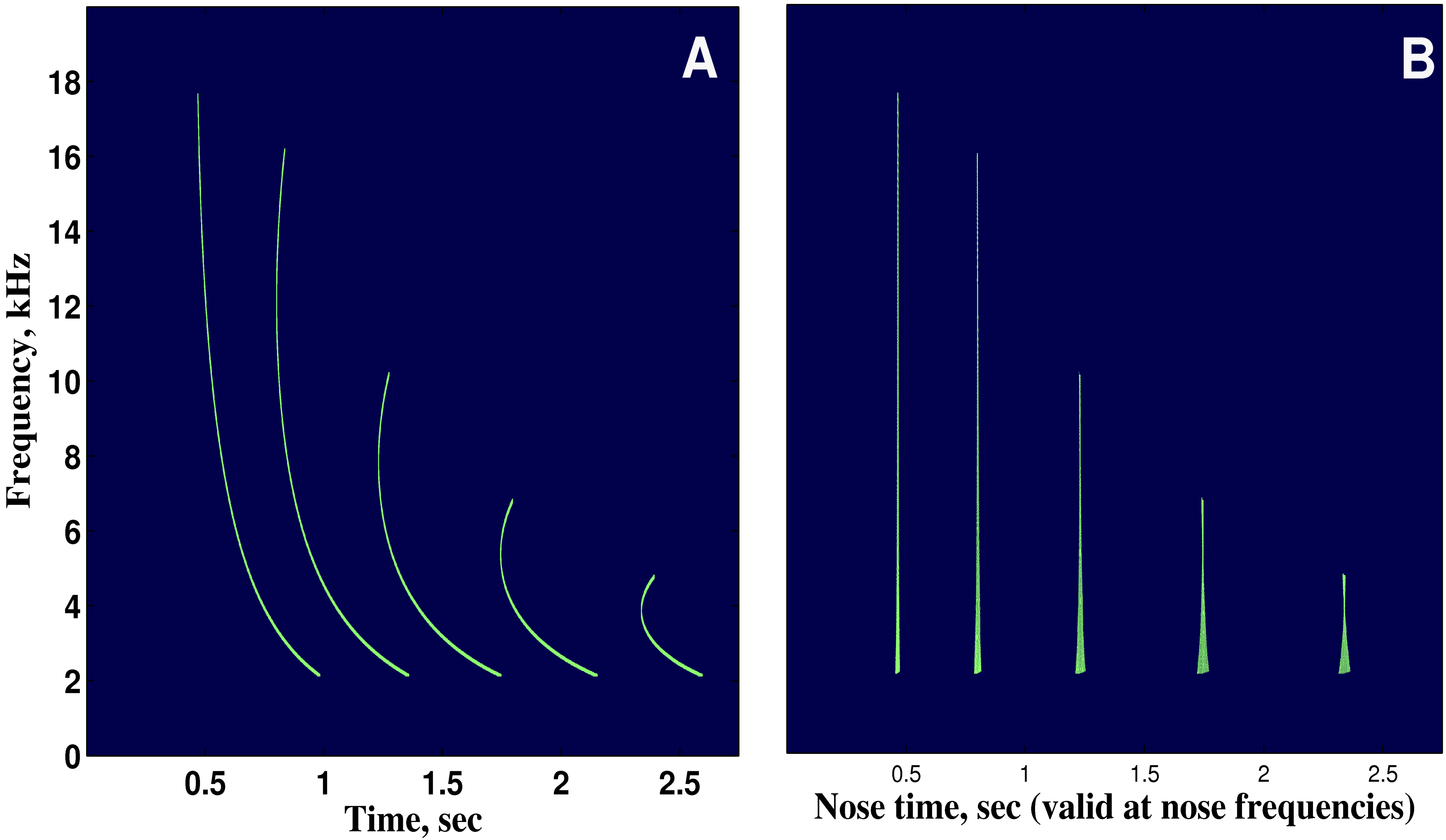
VTT – unmatched parameters



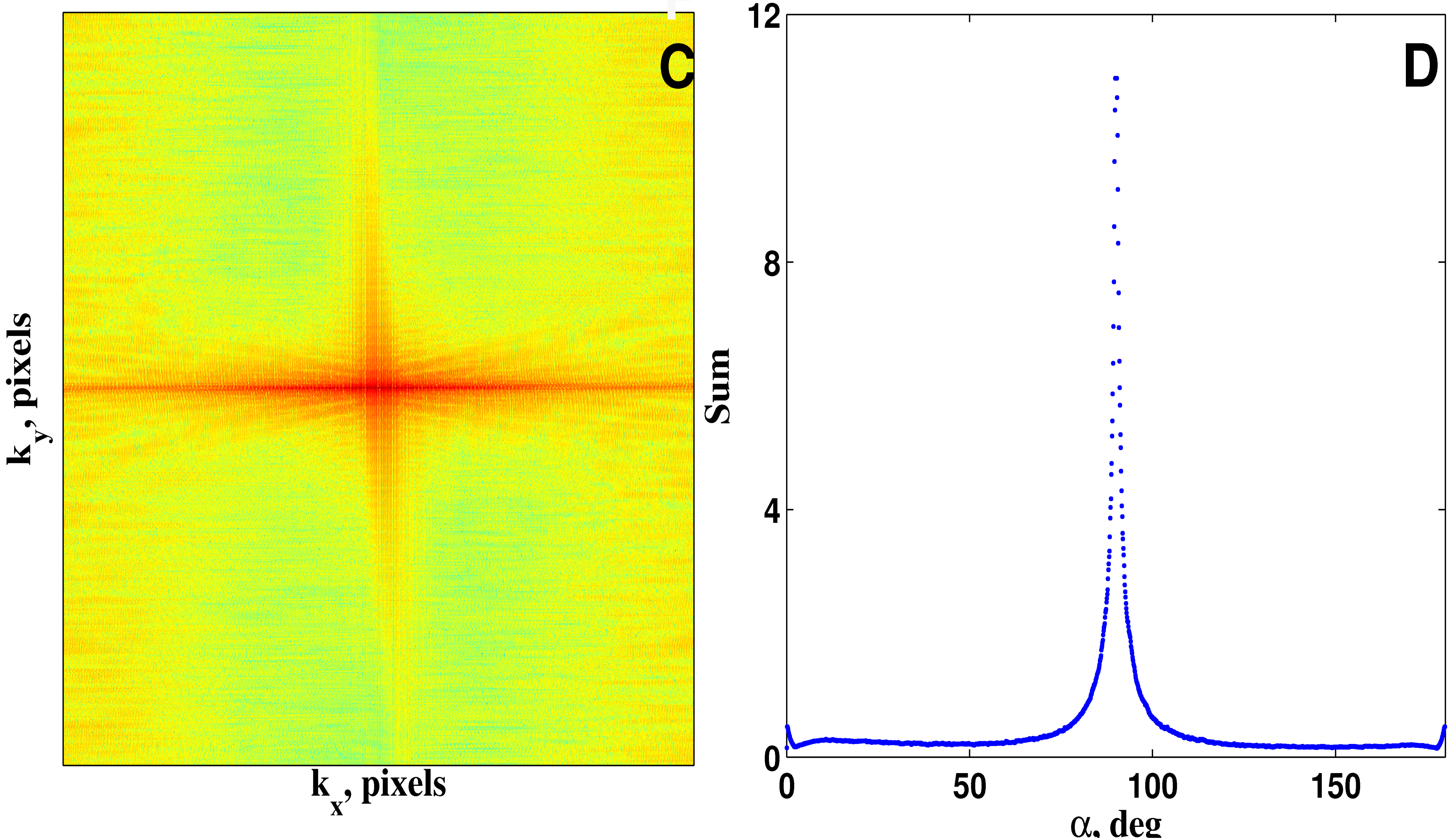
VTT – matched parameters



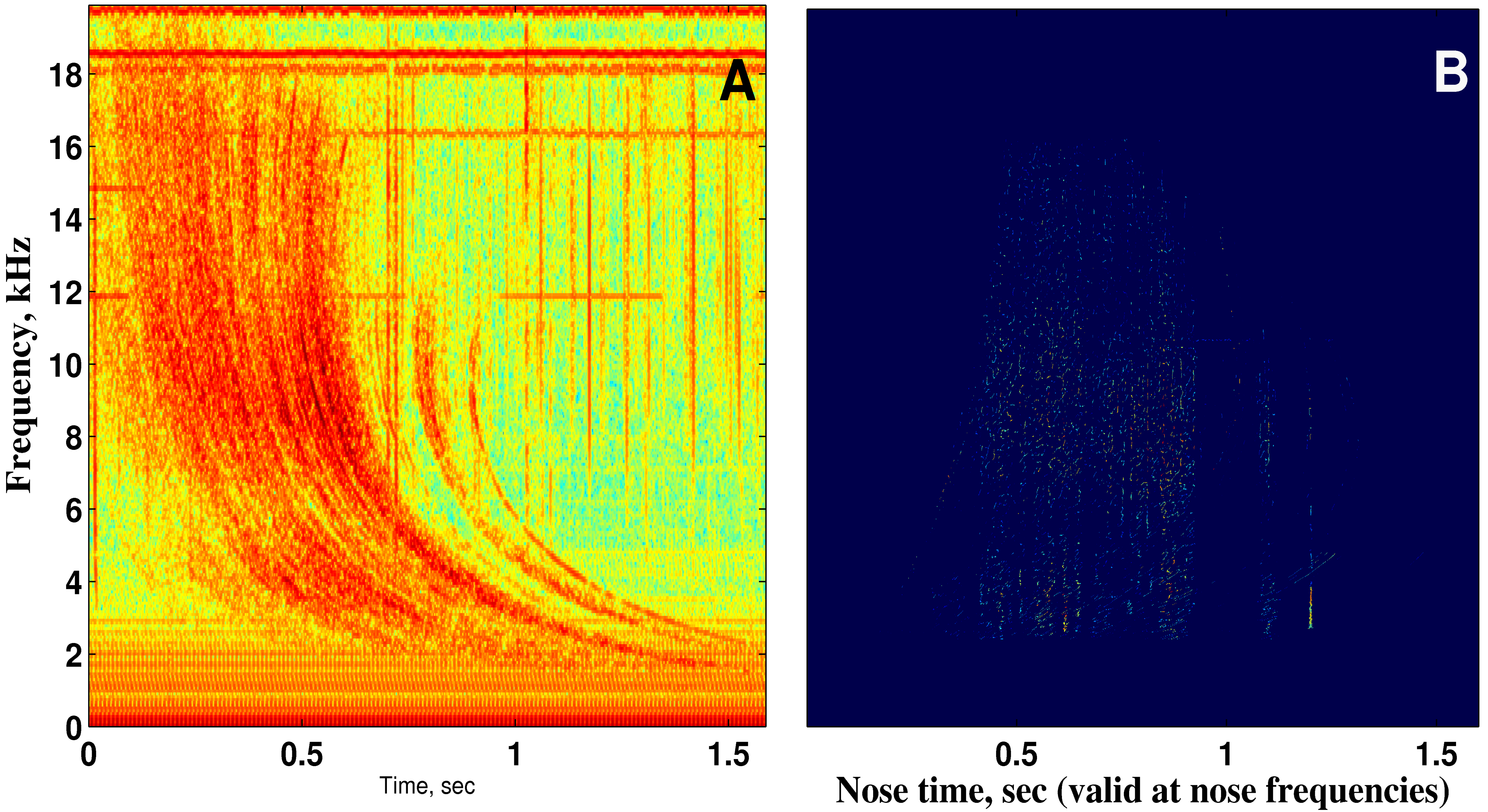
VTT – applied to model MP group



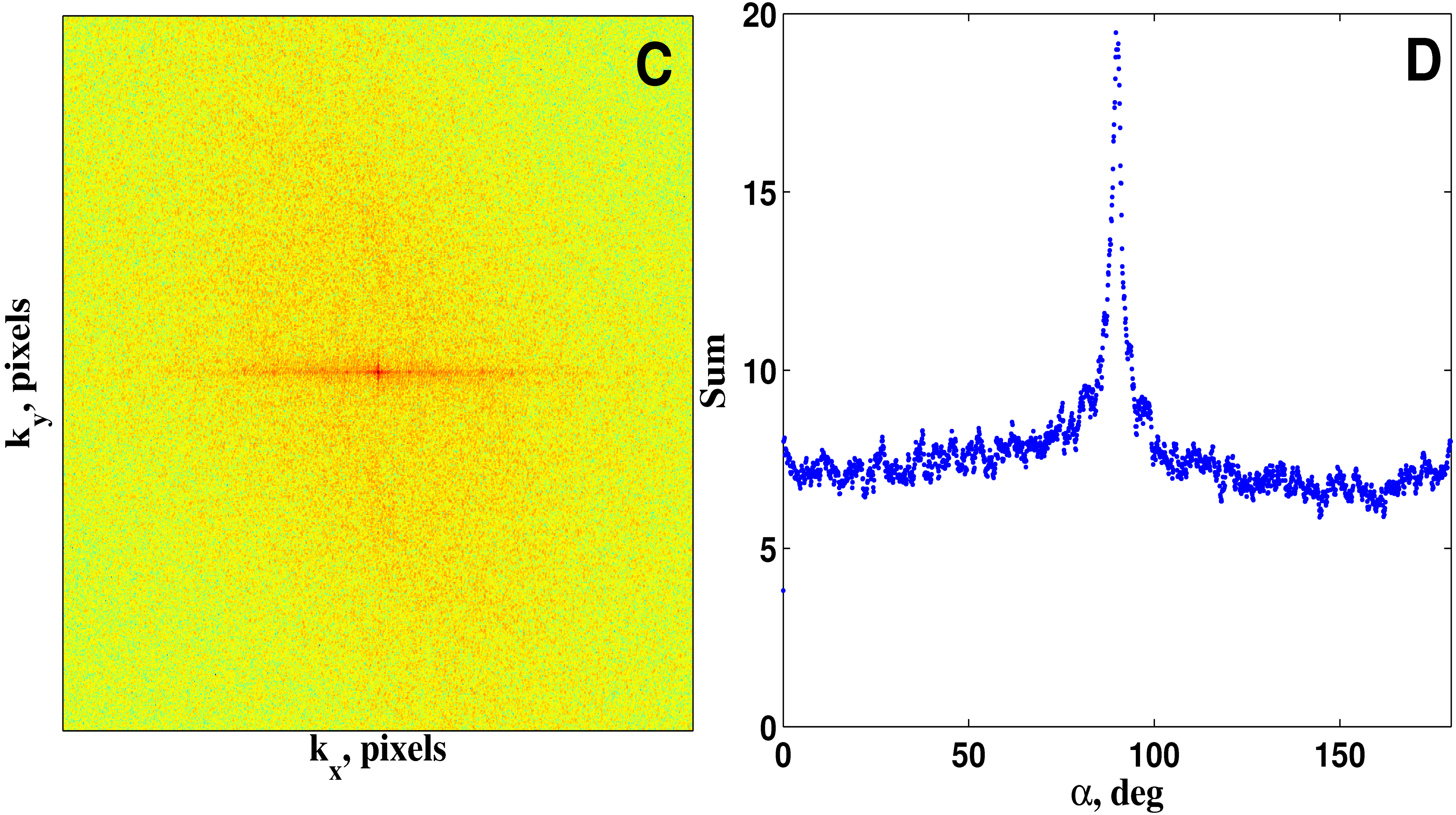
2D FFT of VTT and the “sharpness” plot– applied to model MP group



VTT – applied to real MP group



2D FFT of VTT and the "sharpness" plot– applied to real MP group

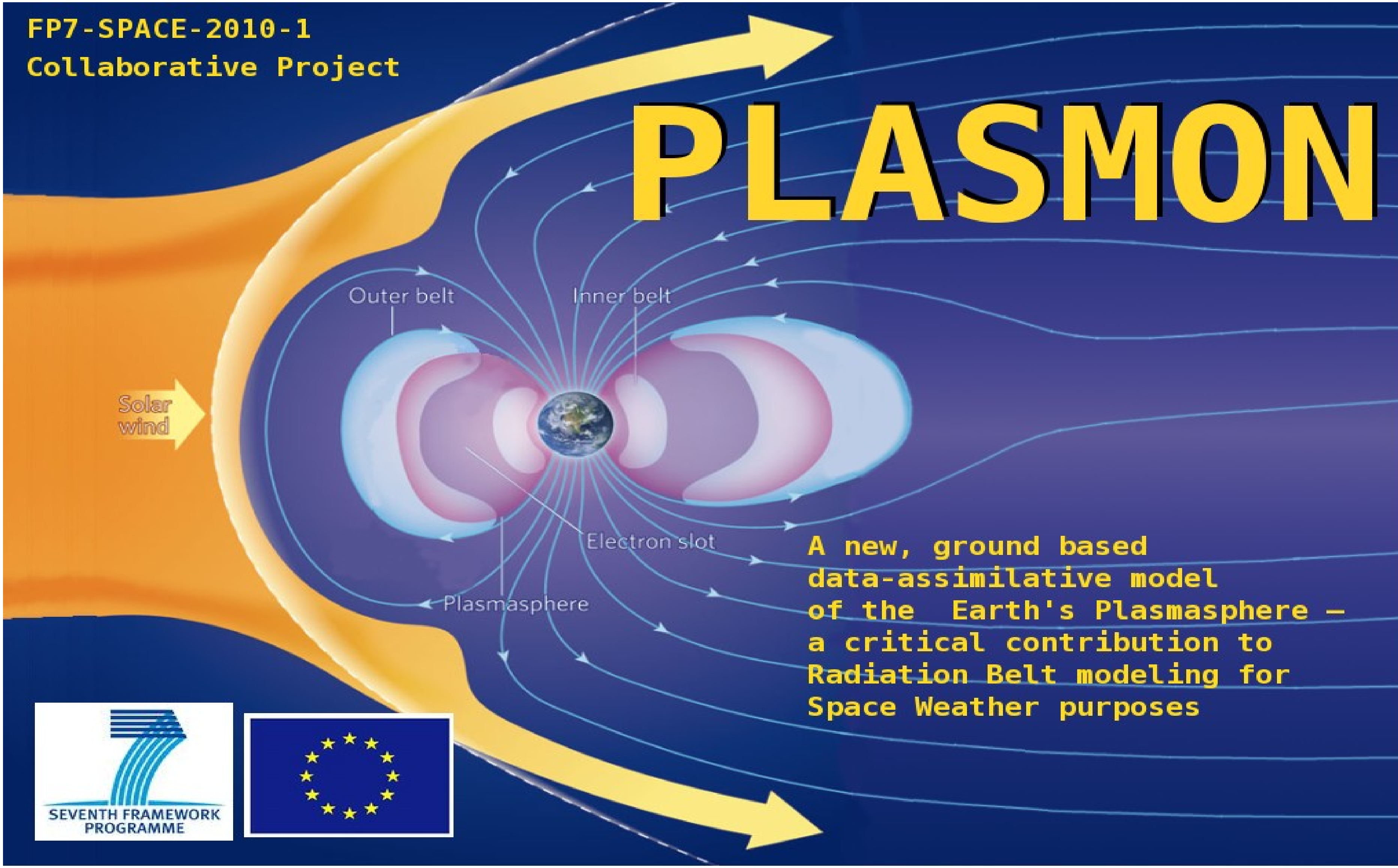


Implementation of AWA algorithm
[Lichtenberger et al., *JGR*, 2009]

1. Application of VTT to the spectrogram matrix with an initial set of *(dt,A,B)* parameter triplet.
2. Computation of 2D FFT of VTT image.
3. Calculation of sharpness plot for the 2D FFT image and p_{max}, $|\alpha - 90|$ and w from it. The sharpness plot is used as an objective function in the optimiziation procedure
4. Iterate steps 1-3 while tuning the *(dt,A,B)* triplet to simultaneously maximize p_{max} while minimize $|\alpha - 90|$ and w.

- An AWA run on an MP group takes *4.5-5 hours* on a single CPU →

  PC cluster (100 threads) : 5-15 min
- 10-15 density data per hour as an input for a plasmasphere model
- GPU computing → ~1000 times speed up



http://plasmon.elte.hu

Objectives

- **Regular longitudinally-resolved measurements plasmaspheric electron and mass densities and hence monitor the changing composition of the plasmasphere, one of the properties which determines wave growth in wave-particle interactions in the Radiation Belts**

- **To develop a data assimilative model of the plasmasphere using. Even dense measurements only sample the plasmasphere at limited resolution in both space and time. Yet determining the effect of wave-particle interactions on the Radiation Belts require a continuous map of the plasma density in both time and space. In order to provide such a complete map it becomes necessary to interpolate between measurements, again in both time and space with data assimilation schemes to combine plasmaspheric measurements with a numerical physics-based plasmasphere model. The two data assimilation schemes which we are pursuing are Ensemble Kalman filtering and particle filtering.**

- **To monitor the occurrence and properties of Relativistic Electron Precipitation, tying the time-resolved loss of relativistic electrons to the dynamic plasmasphere observations. Our approach will primarily use ground-based networks of observing stations, operating in the ULF and VLF ranges, deployed on a worldwide level**

Workpackages and methology

***WP1*: Automatic retrieval of equatorial electron densities and density profiles by Automatic Whistler detector and Analyzer Network (AWDANet)**

***WP2*: Retrieval of equatorial plasma mass densities by European quasi-Meridional Magnetometer Array (EMMA) magnetometer arrays and cross-calibration of whistler and Field Line Resonance method**

***WP3*: Data assimilative modeling of the Earth's plasmasphere**

***WP4*: Modeling REP losses from the radiation belts using the Antarctic-Arctic Radiation- belt (Dynamic) Deposition – VLF Atmospheric Research Konsortia (AARDDVARK) network**

PLASMON structure