Computing mass indices of meteor showers with BRAMS data

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Outline

1. Mass index determination from radio observations of meteors
2. The BRAMS network and data
3. Computing mass indices from BRAMS data
4. Conclusions & Perspectives

Mass index determination

Mass index

$$N_c \propto M^{-(s-1)}$$

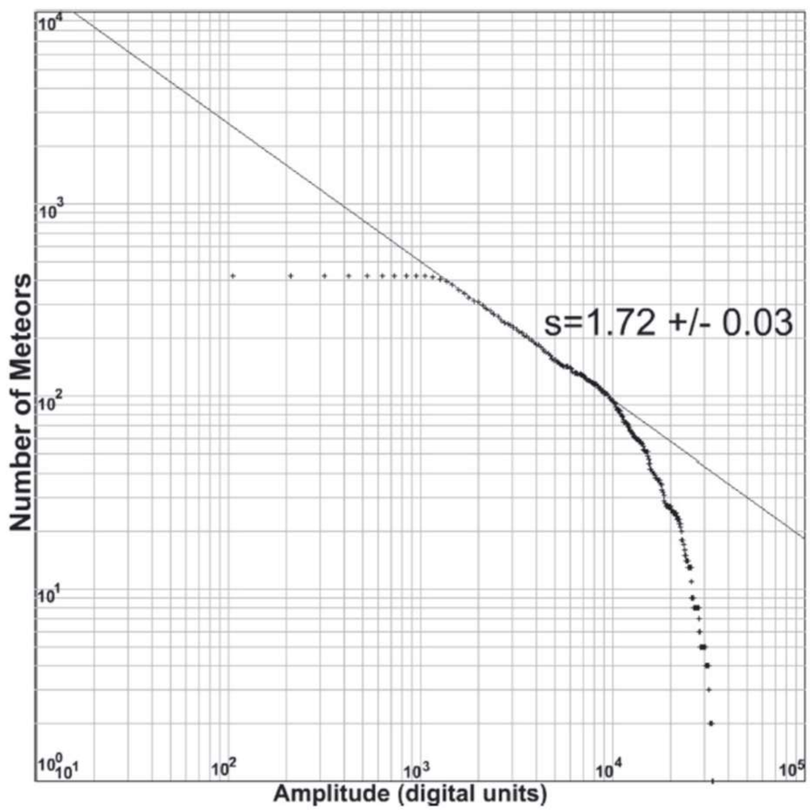
N_c : cumulative number of meteors with mass ≥ M
s : mass index

Log – log plot → There should be a straight line down with slope = 1-s for the lowest mass for which detection is complete

- s > 2 : more mass in small particles
- s < 2 : more mass in large particles

Mass index from radio observations

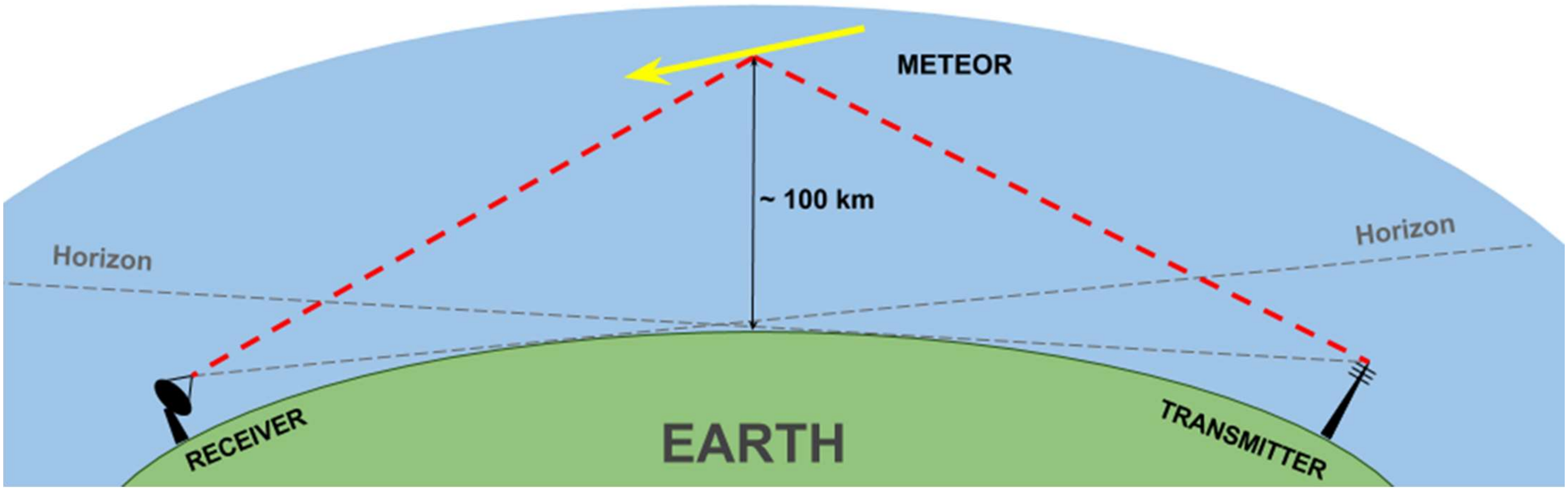
- Peak amplitude A of the meteor echo is used as a proxy for mass
- Underdense meteors : $A \sim \alpha$ (α = electron line density)
- Overdense meteors : $A \sim \alpha^{1/4}$



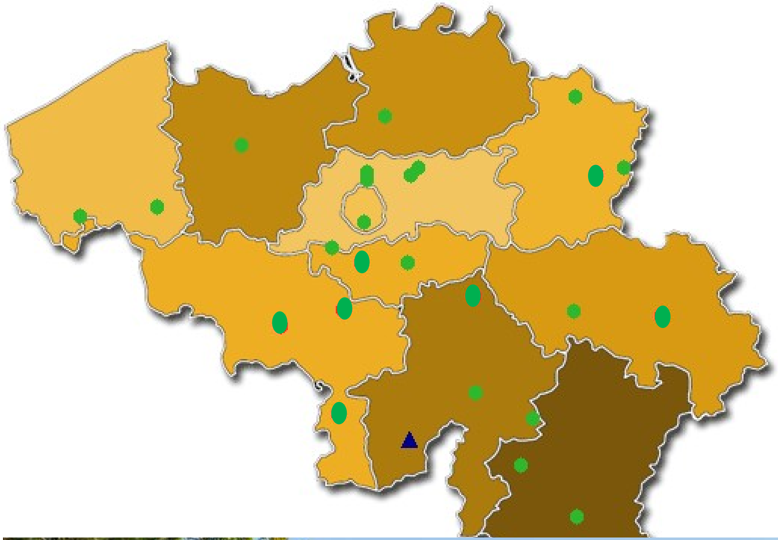
Blauuw et al (2011)
CMOR data
Geminids 2007

The BRAMS network and data

Radio forward scatter observations

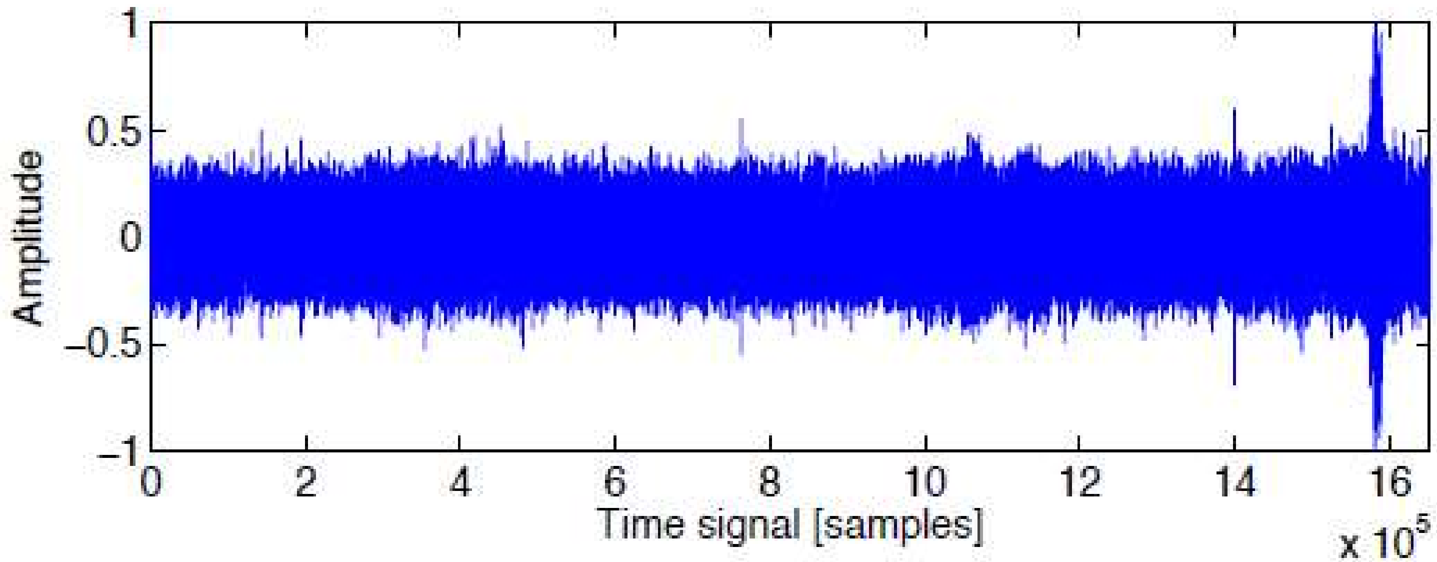


The BRAMS network



- ✓ 49.97 MHz
- ✓ 150 W
- ✓ pure sine wave

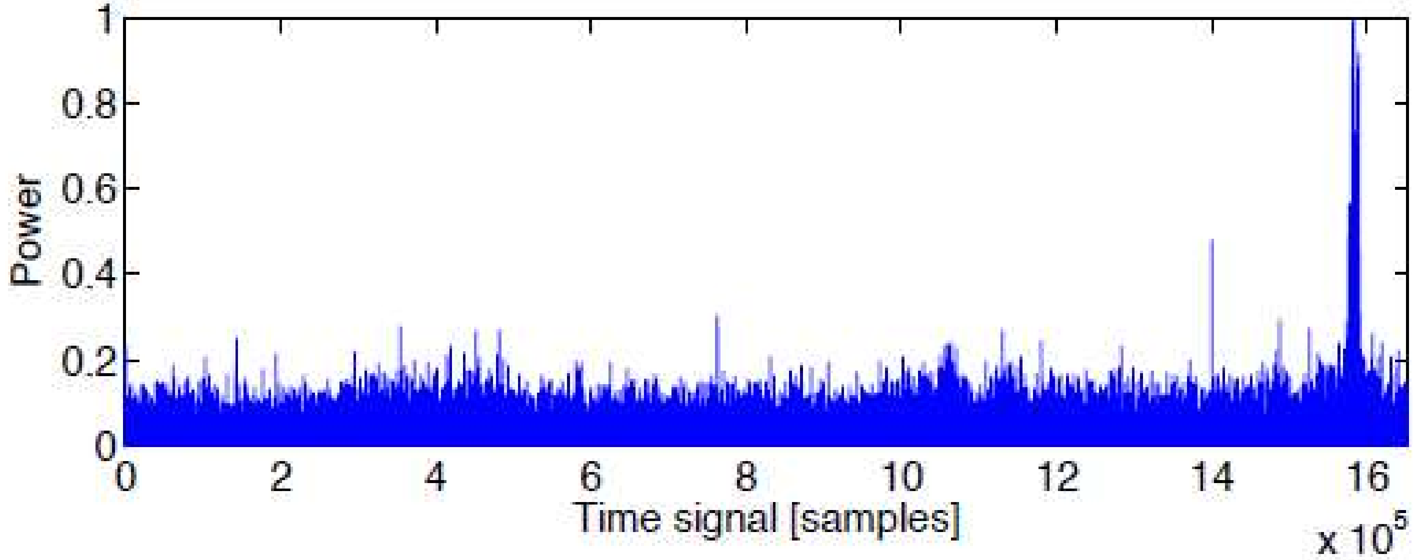
Example of BRAMS data



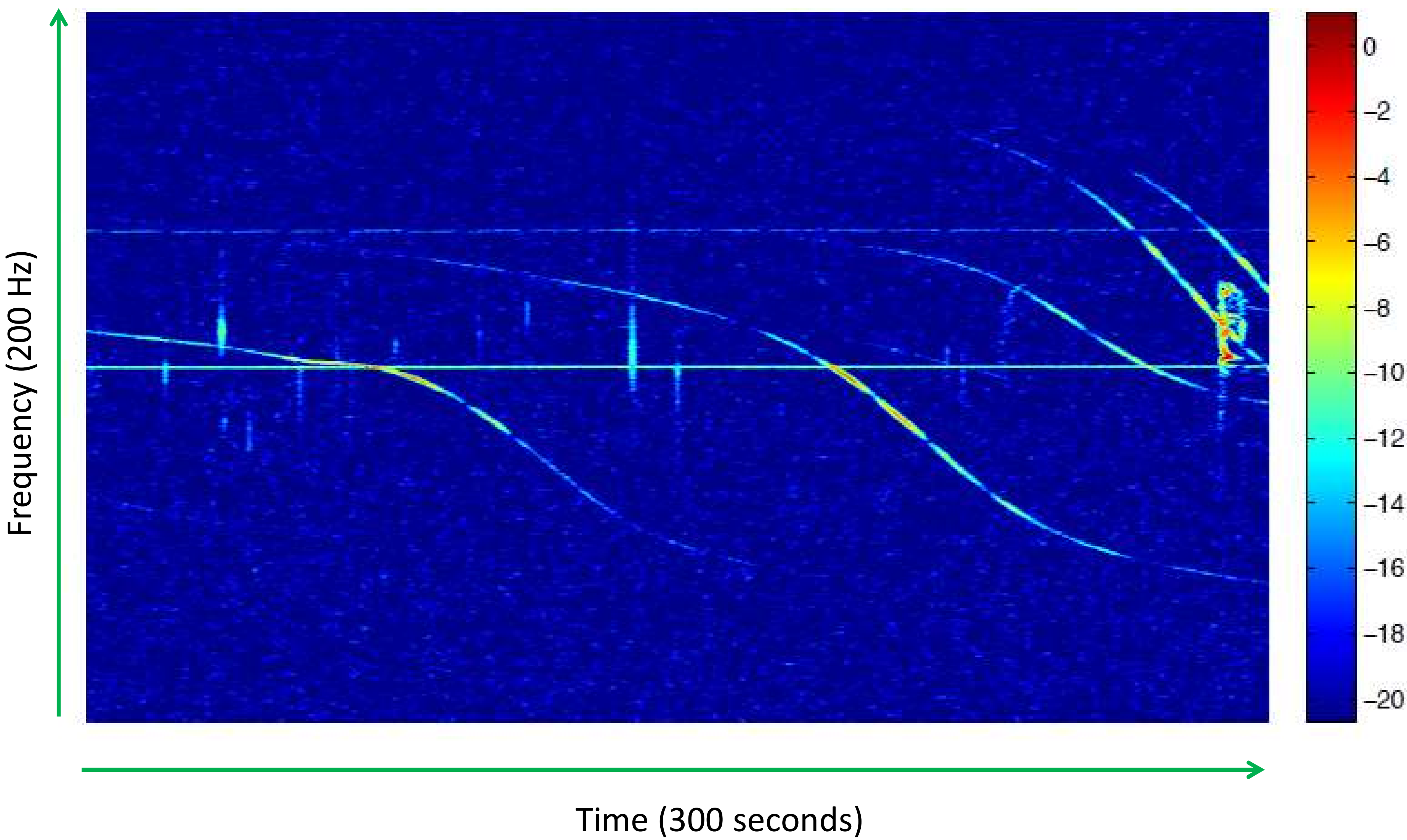
Time (300 seconds)

$300 \times 5512 = 1\ 653\ 600$ samples

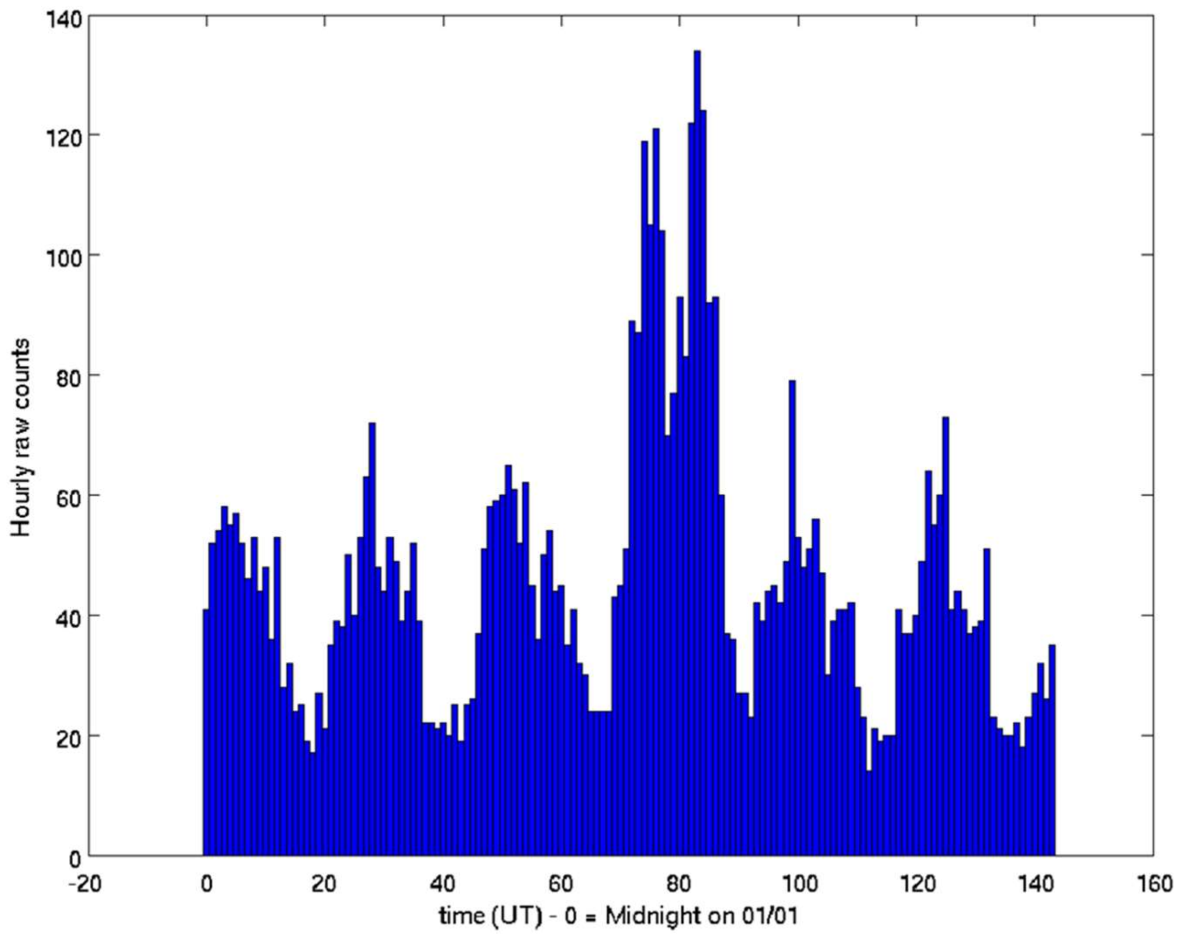
Example of BRAMS data



Example of BRAMS data



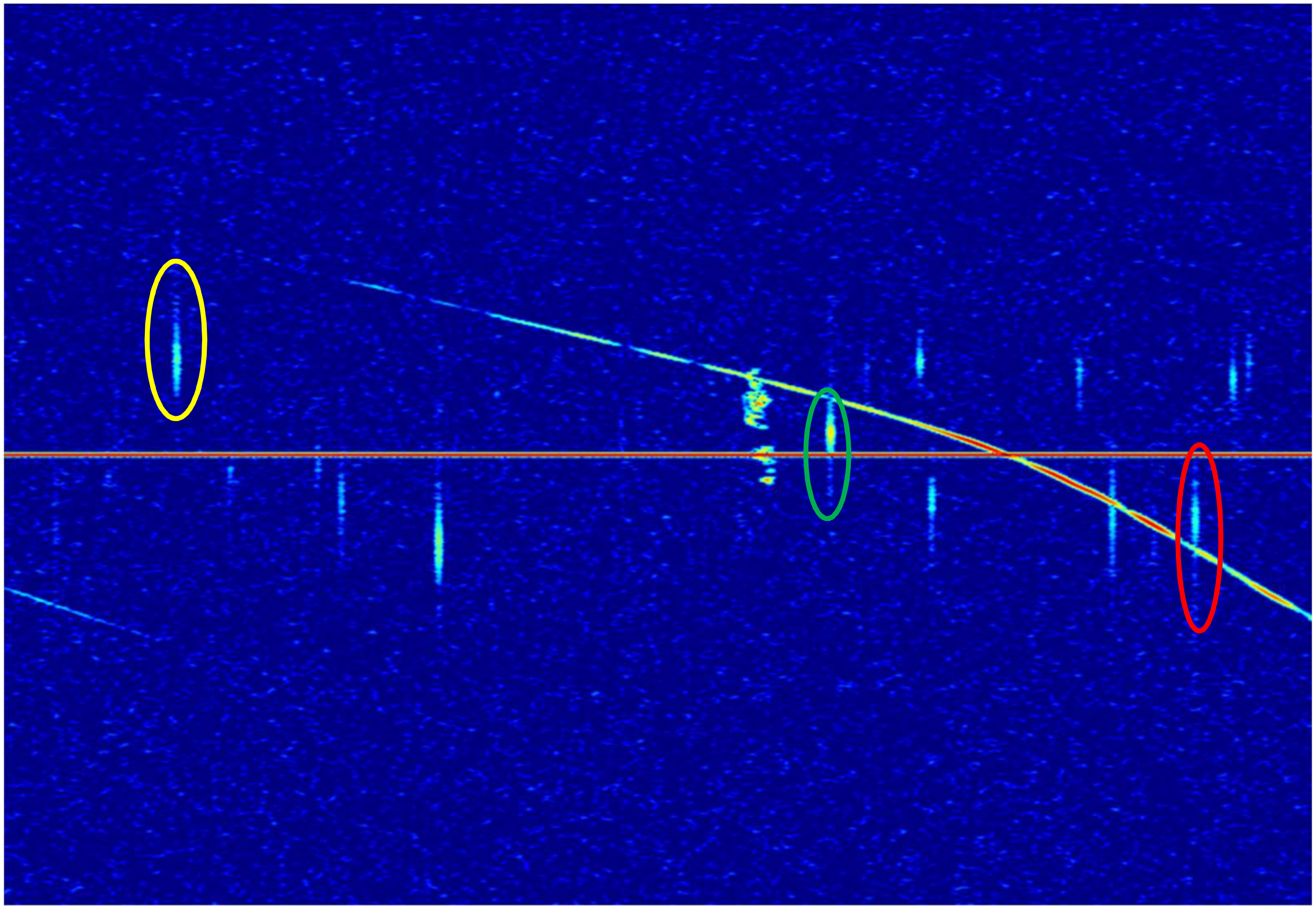
Quadrantids 2016



January 1-6, 2016

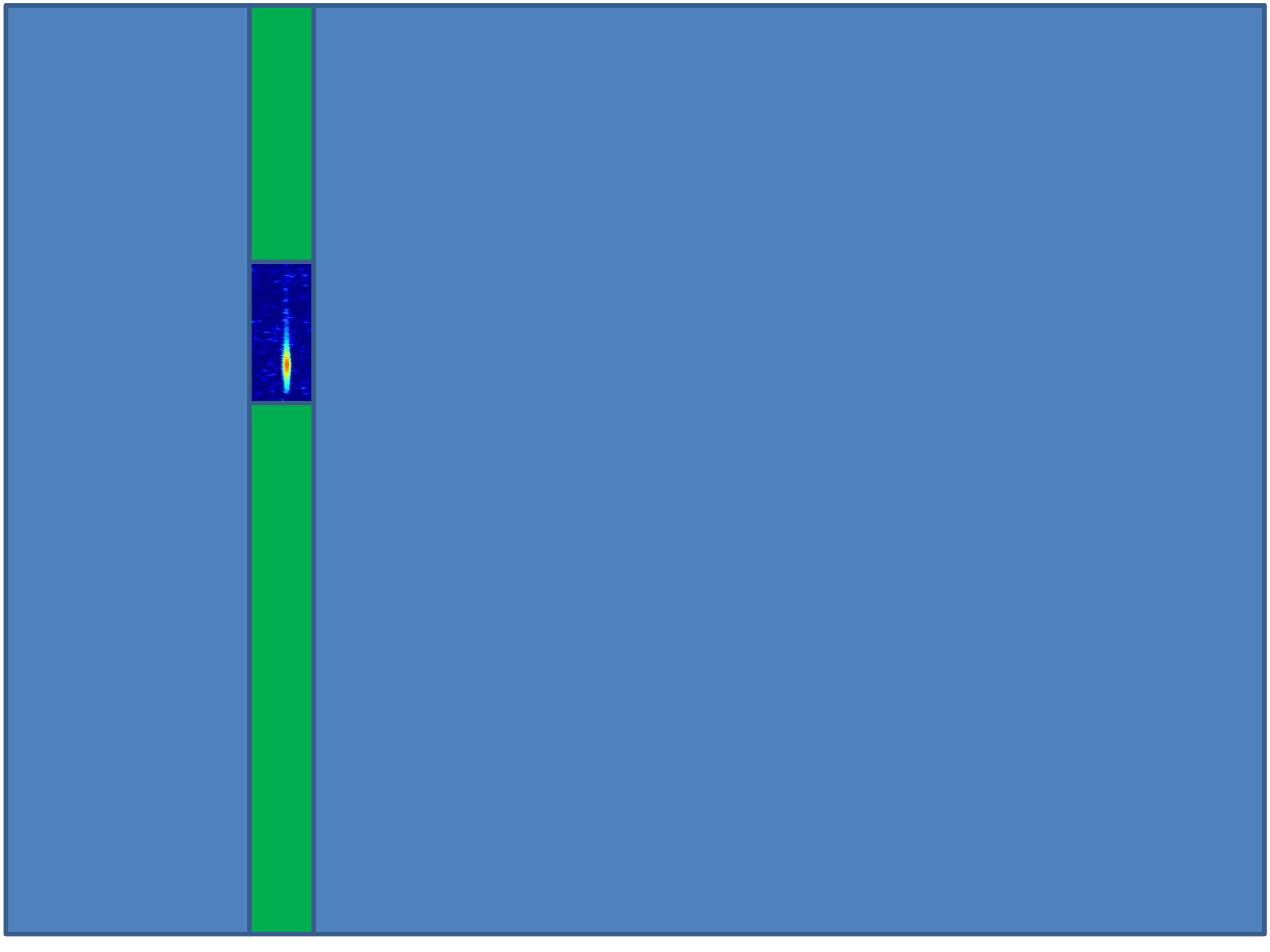
Computing mass indices from BRAMS data

Measurements of amplitude of meteor echoes

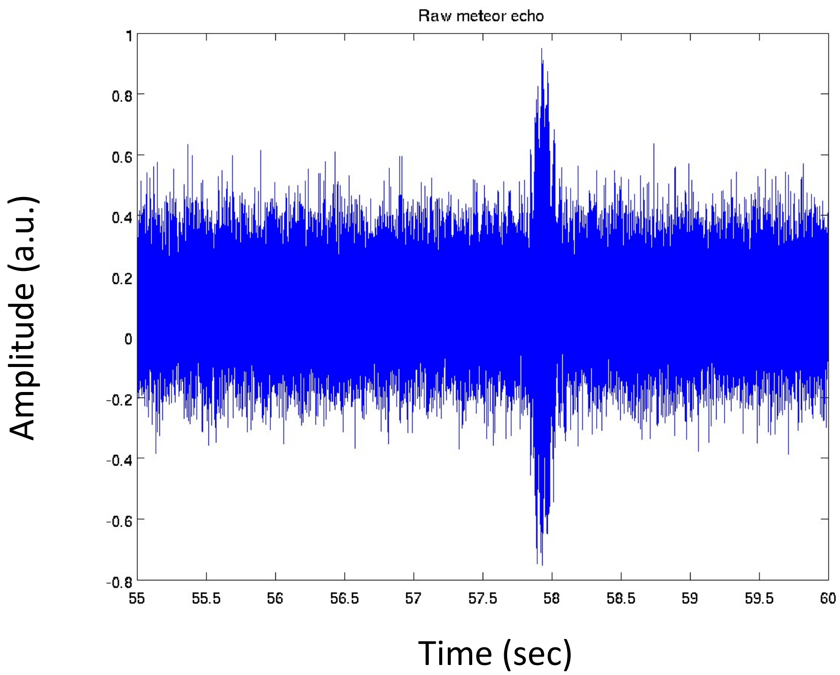


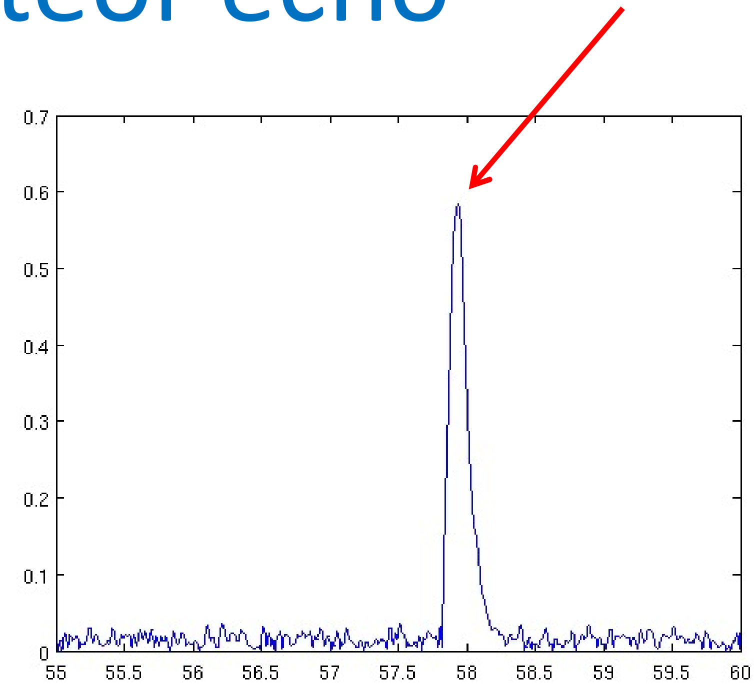
3 types of meteor echoes : 1) isolated, 2) superimposed with direct signal from beacon, 3) superimposed with reflections on airplanes

1) Isolated meteor echo

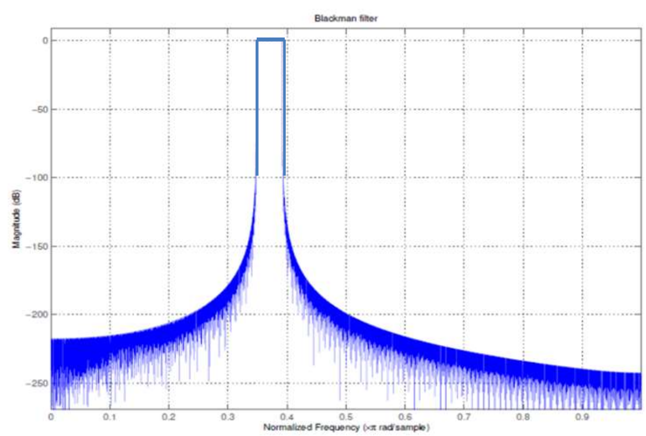


1) Isolated meteor echo





Blackman filter



2) Meteor echo + direct signal from the beacon

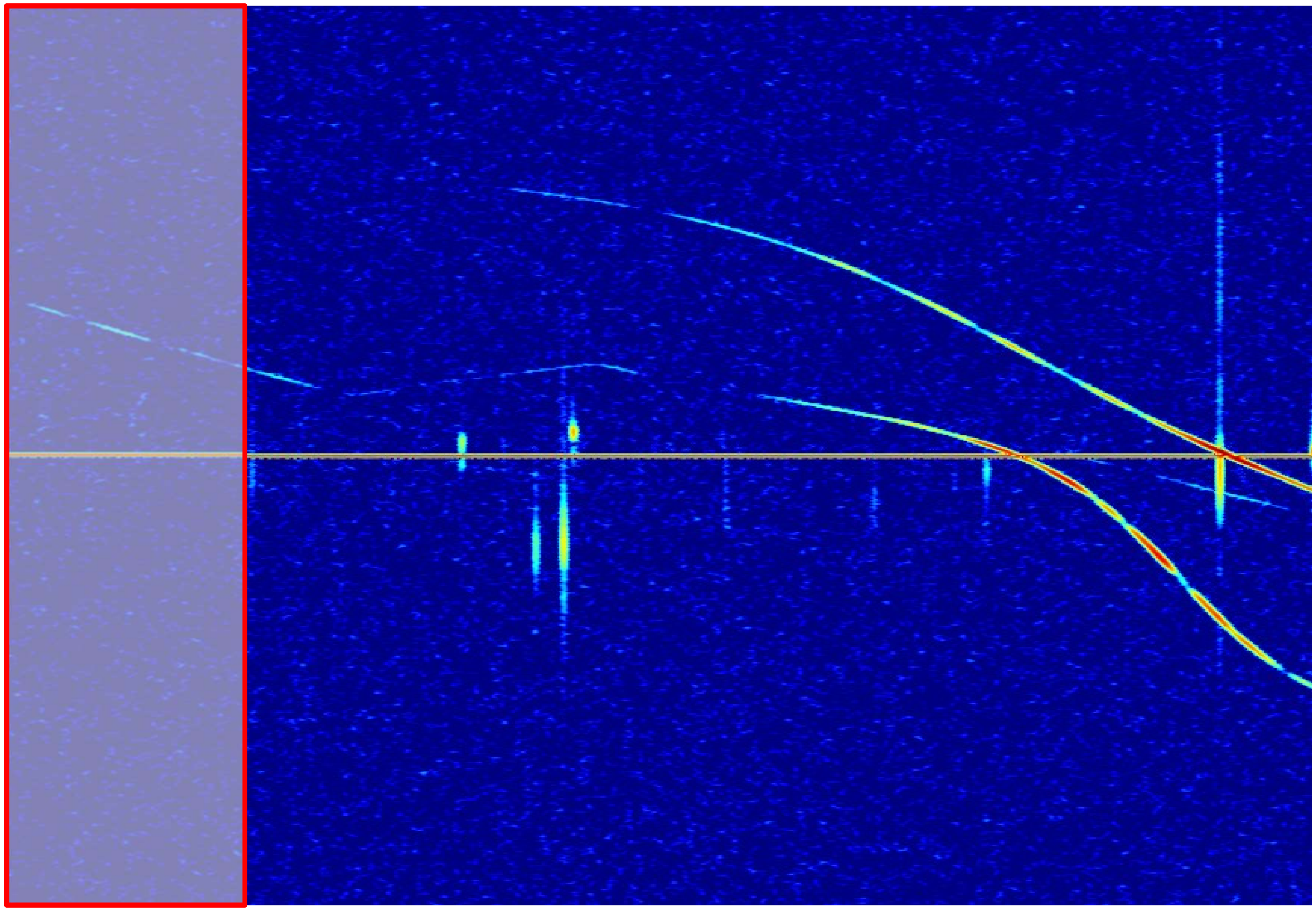
- Method :
  - Reconstruction of the beacon signal via FFT of the raw signal and identification of the strongest peak :

$$A \sin(\omega t + \phi)$$

  - Subtraction of this reconstructed signal from the raw data
  - Desired : highest SNR and frequency resolution as possible for the FFT so longest time interval (maximum 5 minutes)

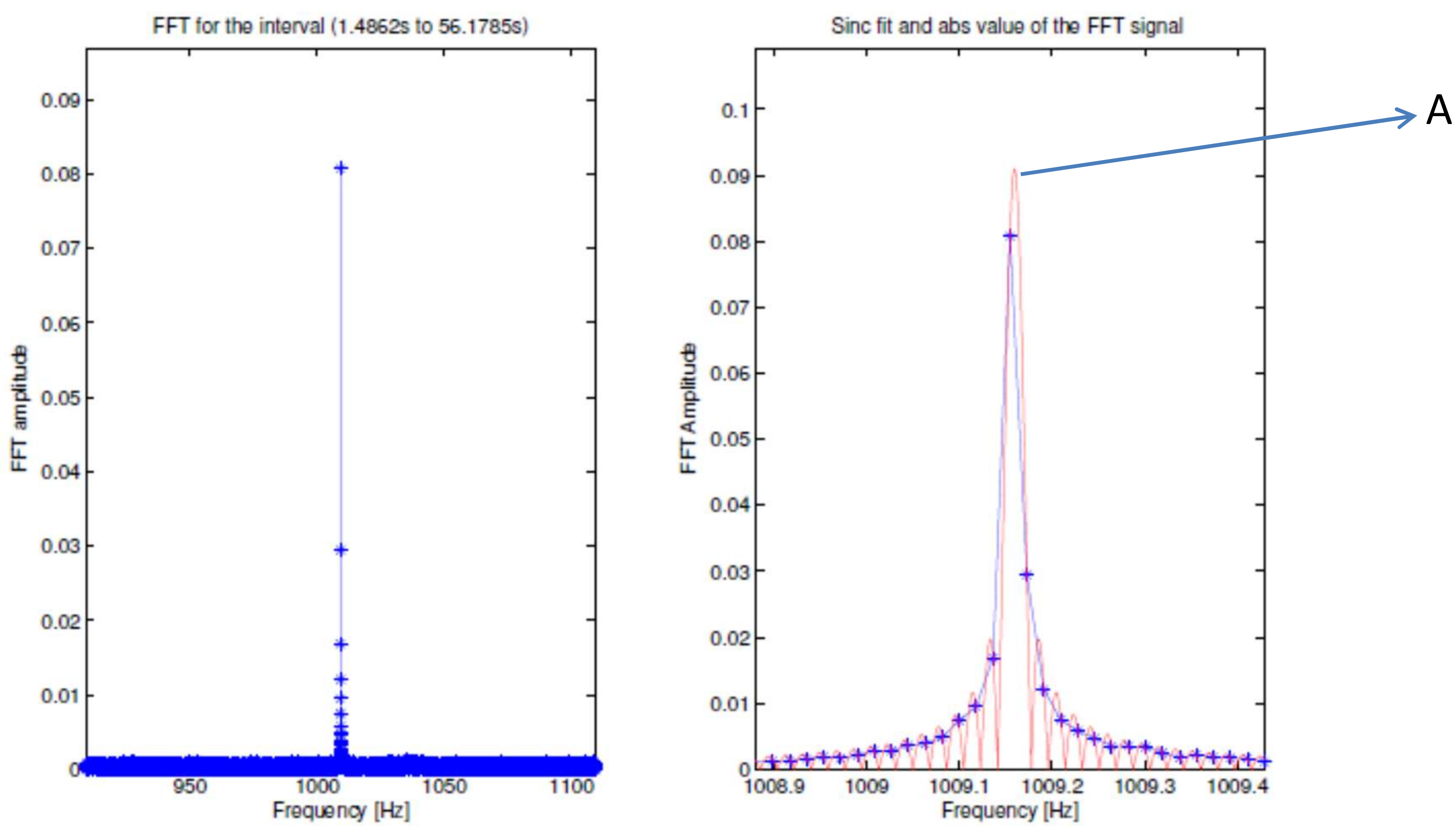
- Difficulties :
  - Direct signal can be « contaminated » by other signals (meteor echoes / plane reflections/interference)
  - Amplitude A and phase ϕ of the direct signal can change quickly due to propagation conditions
  - Frequency ω can slightly change due to slight variations of the LO of the receivers

Reconstruction of amplitude and frequency



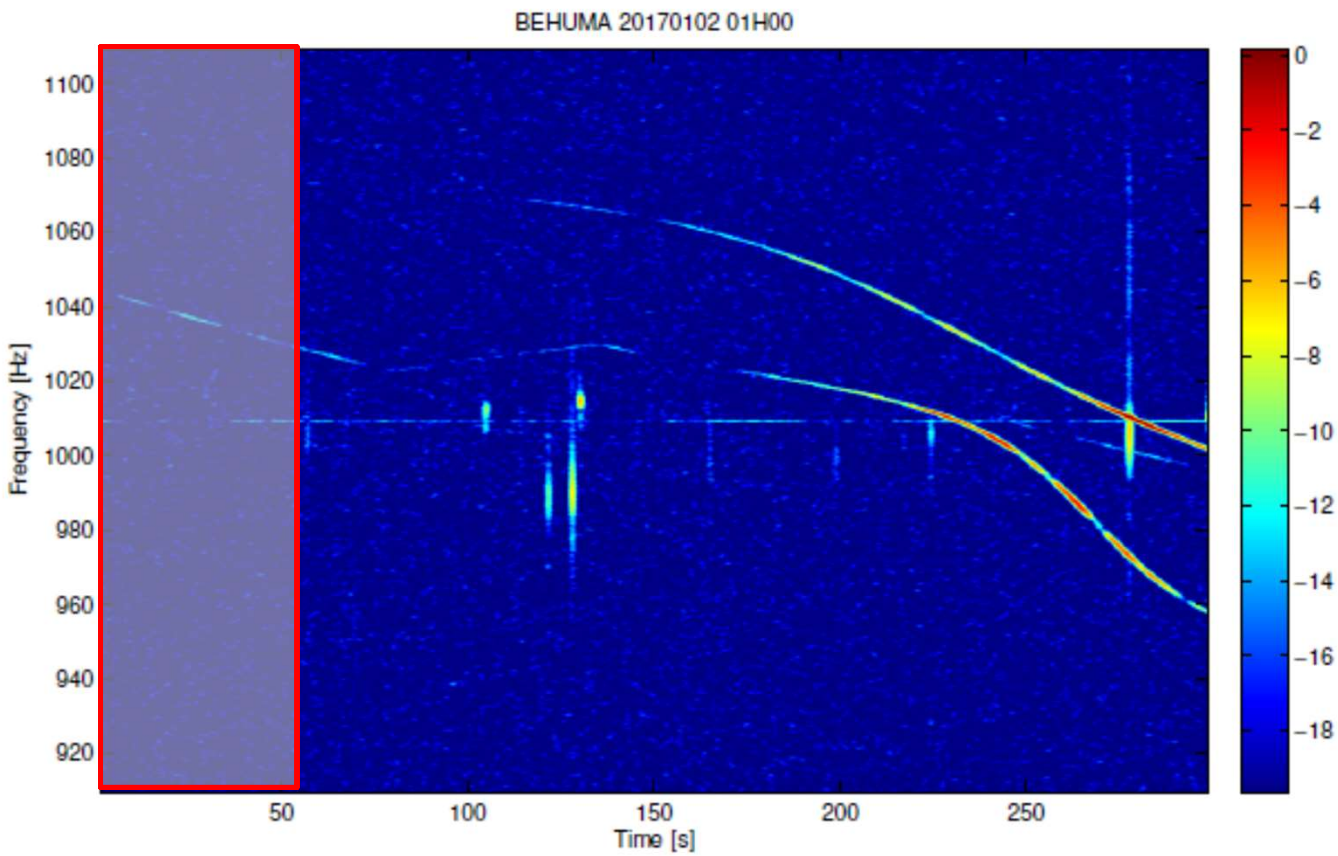
<u>First step</u> : select the largest time interval where the direct signal from the beacon is not « contaminated » by meteor echoes or reflections on airplanes

Computation of amplitude and frequency of the direct signal from the beacon



The discrete FFT spectrum does in general not include the exact frequency of the signal and therefore the maximum of the FFT does not correspond either to the right amplitude. To determine correct frequency and amplitude, we fit a sinc to the FFT spectrum around the maximum of the FFT as we use a rectangle to select the samples to compute the FFT

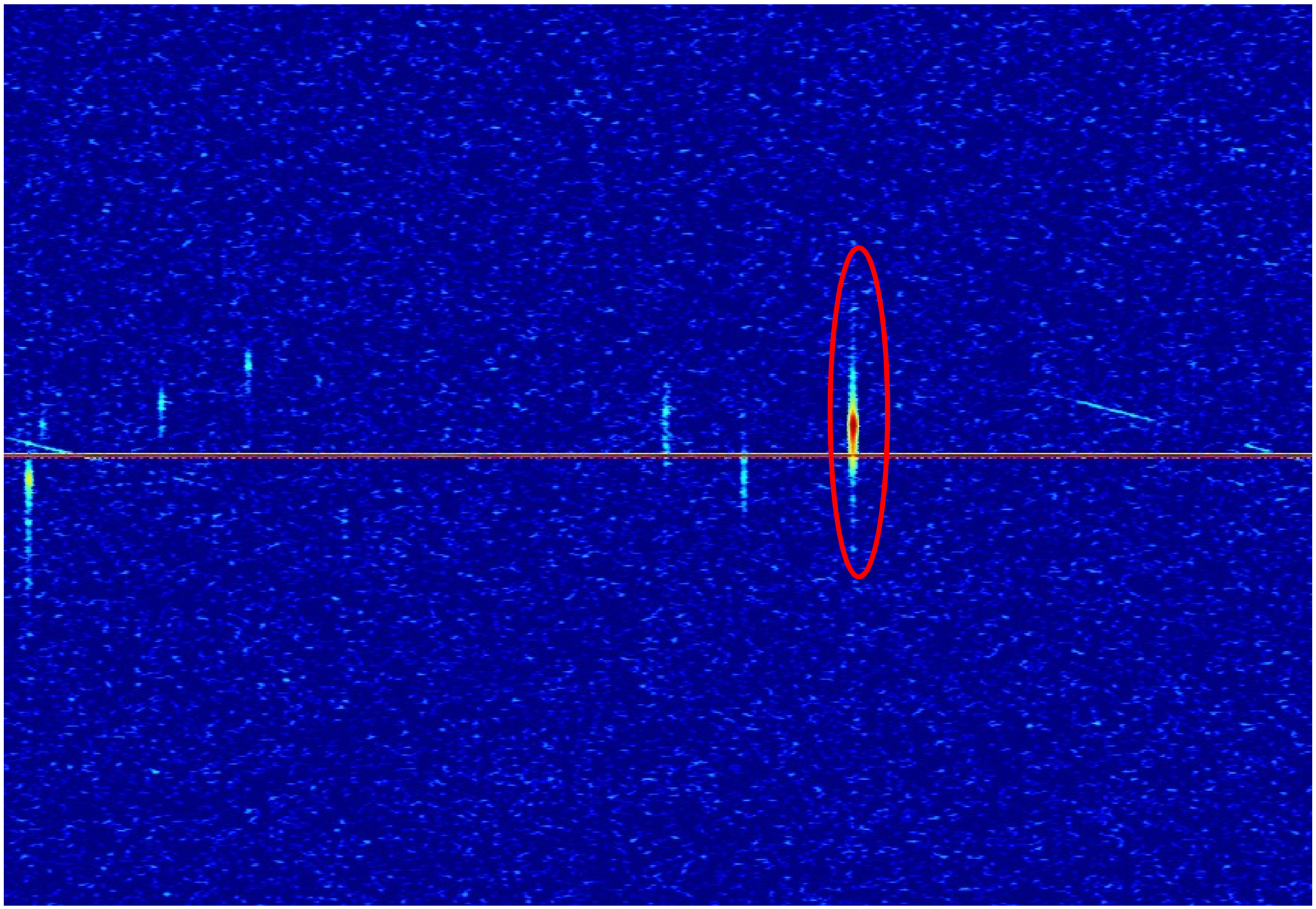
Meteor echo + direct signal from the beacon



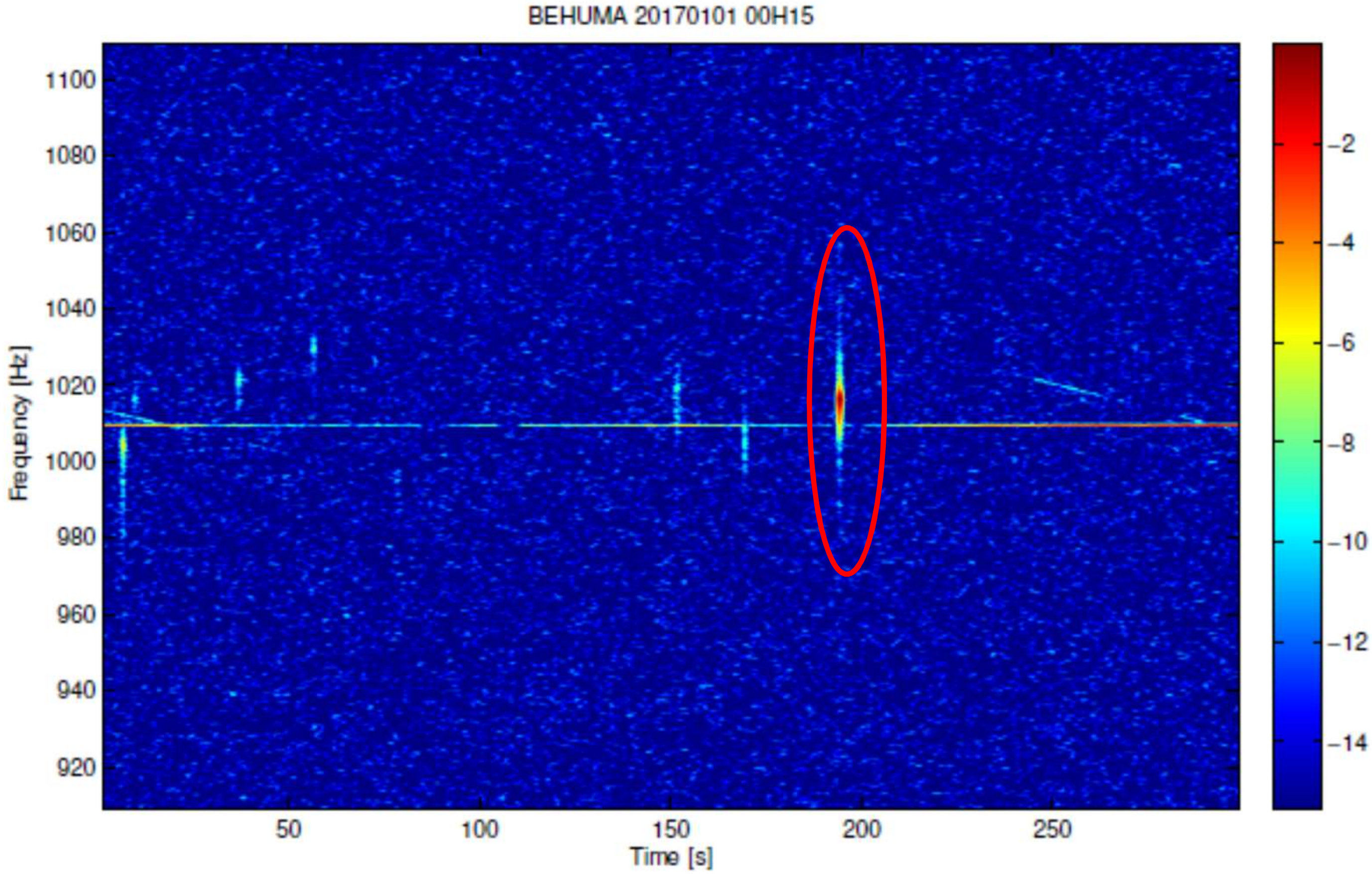
« Local » attenuation ~ -13 dB → ~ 5% of the initial signal remain

Example : initial spectrogram

1009 Hz

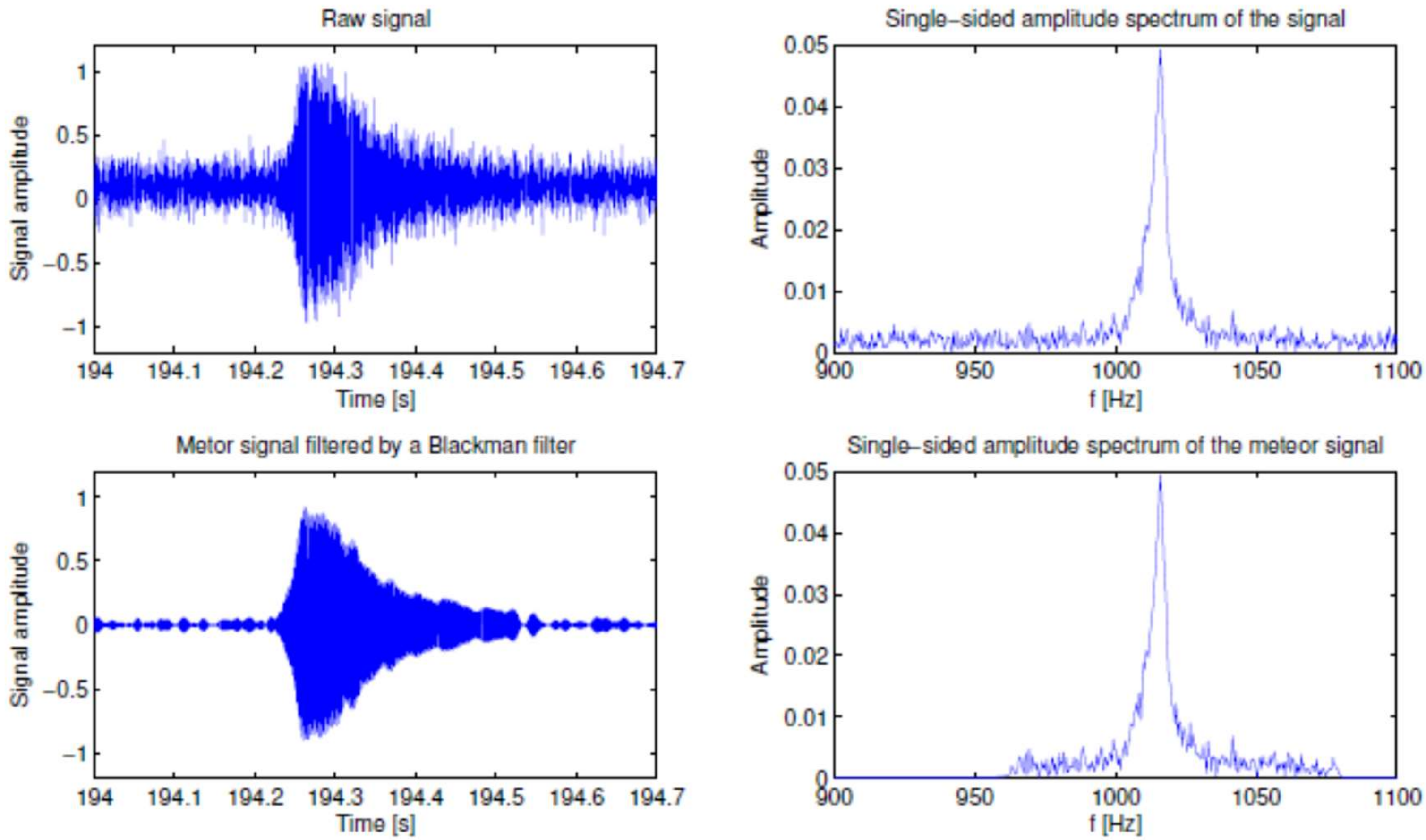


Example : initial spectrogram – direct signal

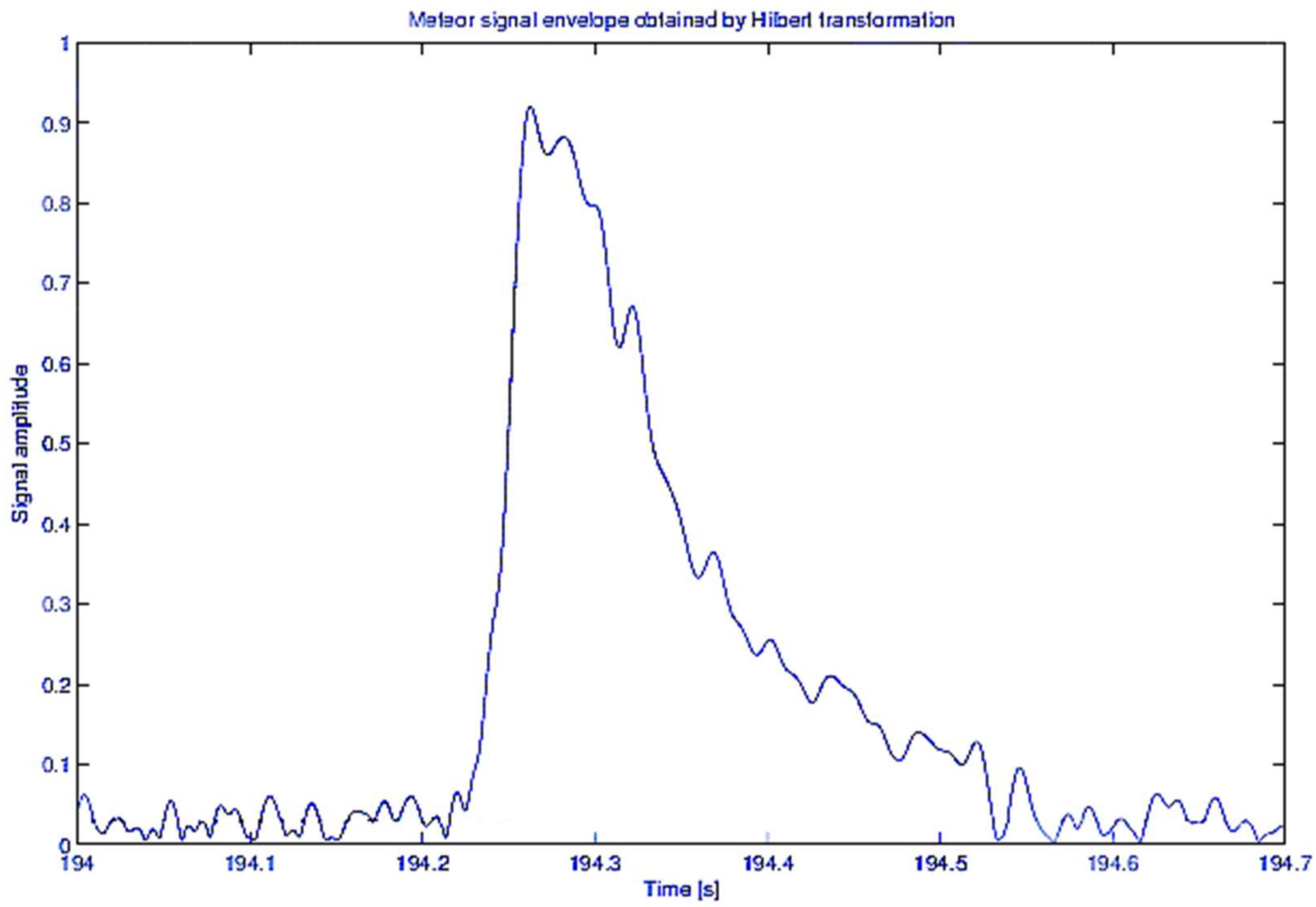


Direct signal from the beacon locally subtracted

Example : raw and filtered meteor echo

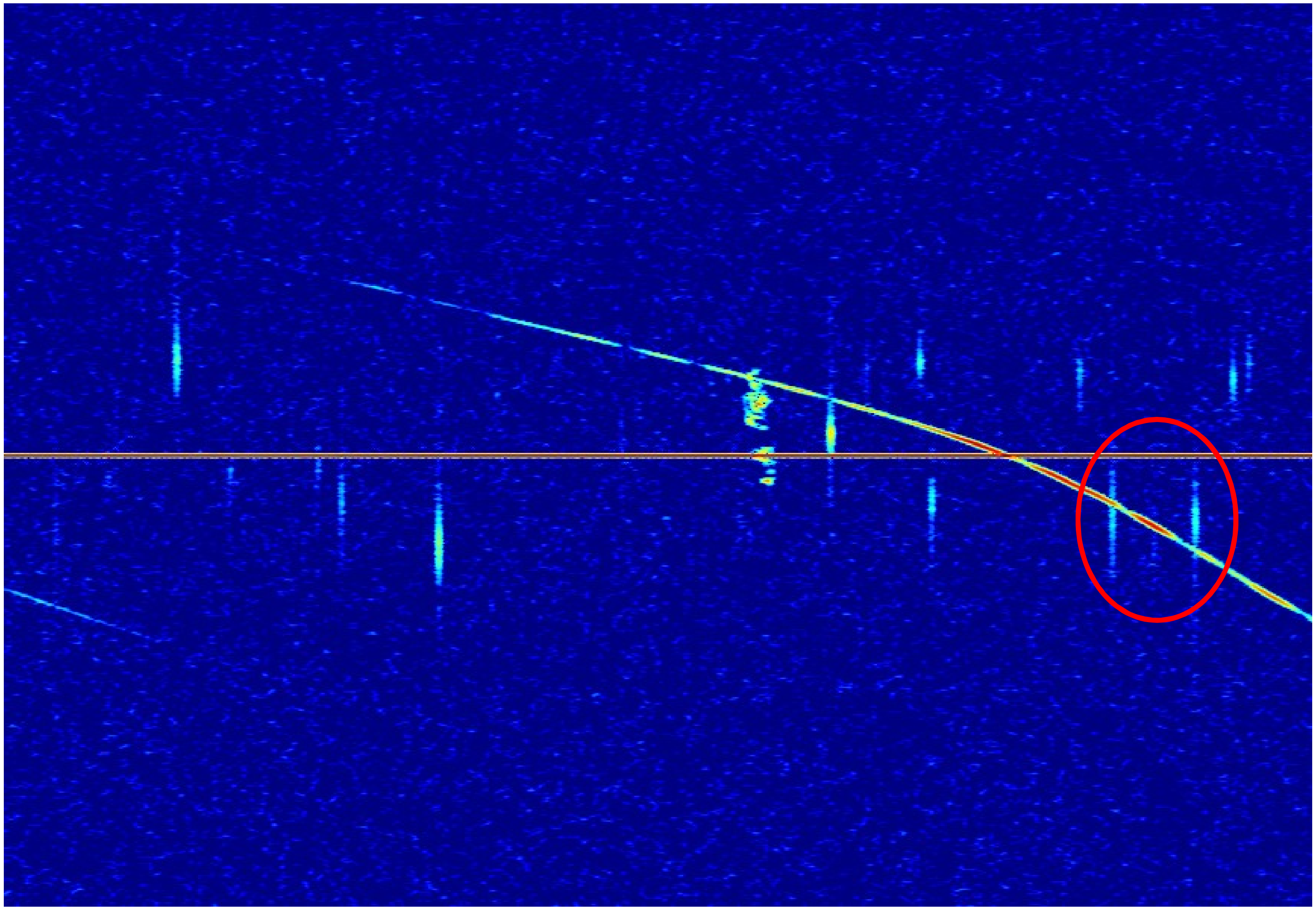


Example : envelope of meteor echo



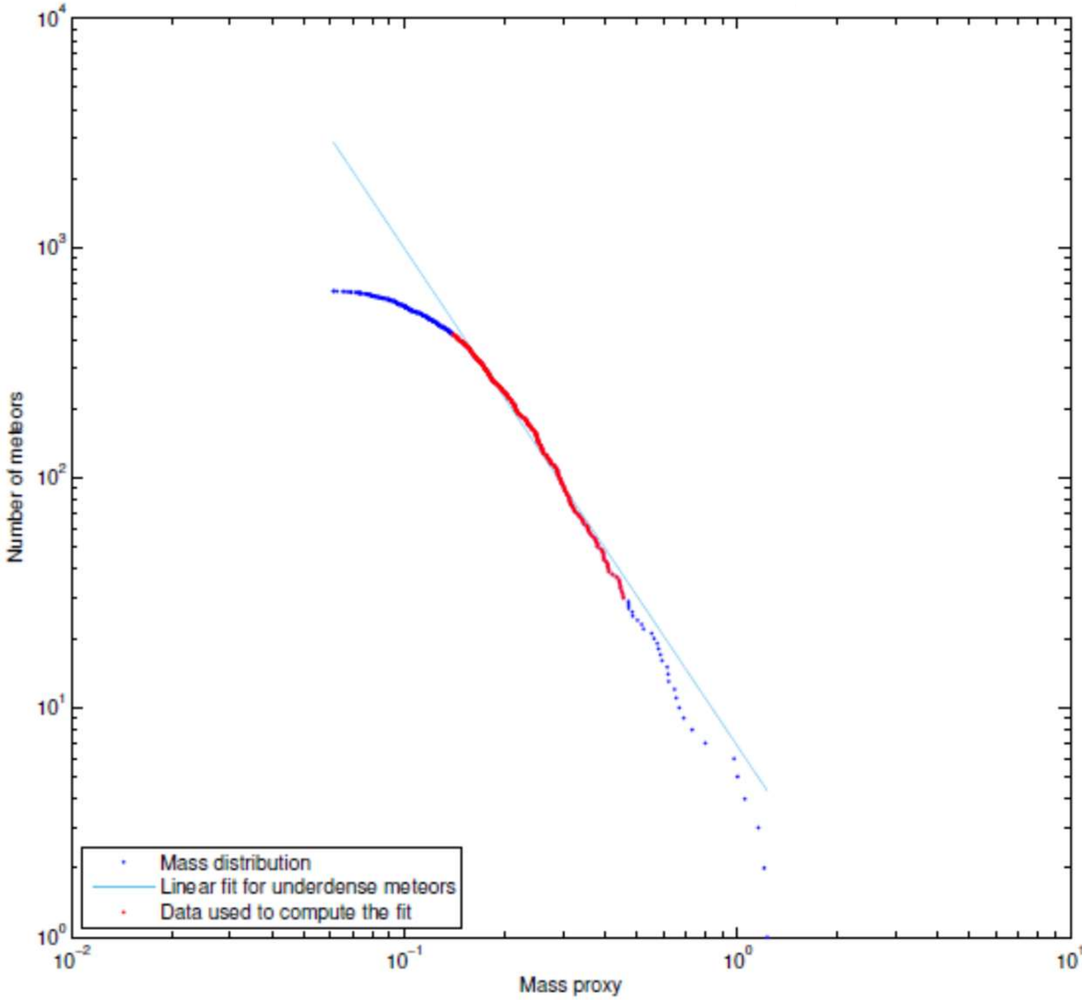
Envelope obtained via Hilbert transform

Meteor echoes superimposed with reflections on planes



Cumulative amplitude distribution

Log N



Log A

1 day of data : 01/01/2017

Sporadic meteors

Isolated meteors only

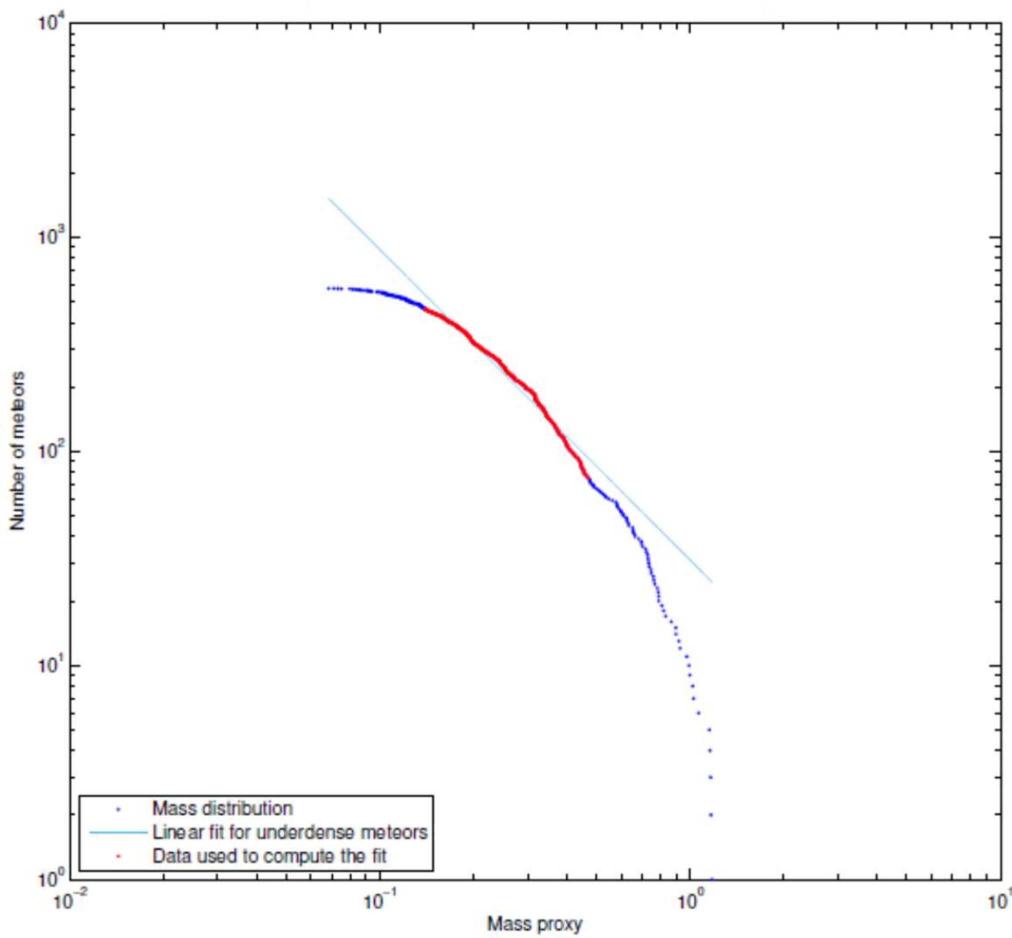
Underdense meteor echoes (red part)

$A \sim \alpha$

s= 3.17

Cumulative amplitude distribution

Log N



Log A

1 day of data : 01/01/2017

Sporadic meteors

Meteors superimposed with beacon only

Underdense meteor echoes (red part)

$A \sim \alpha$

s=2.45

Probable issue

- Range is currently not known : a faint meteor echo can be intrinsically faint or just distant

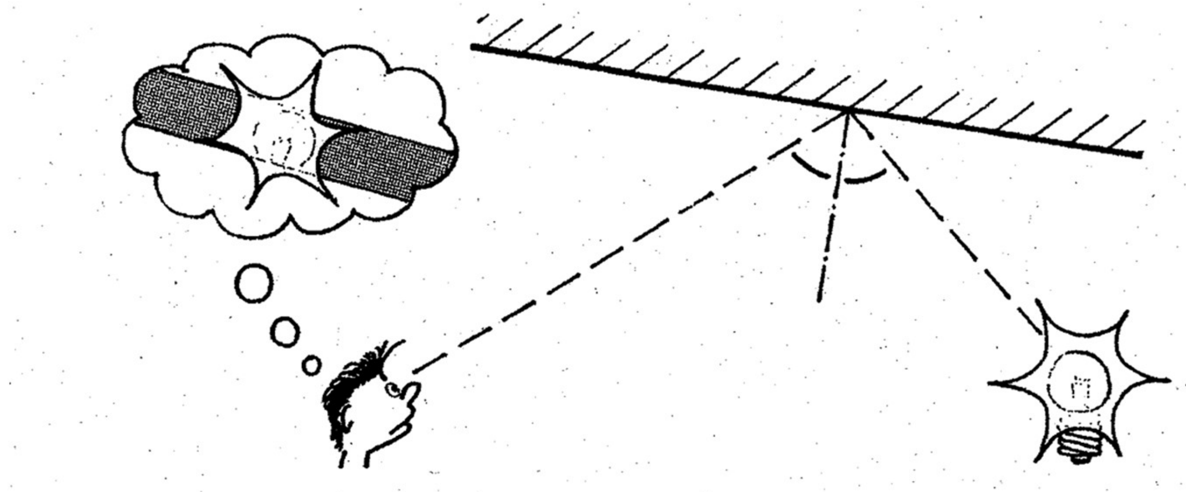
  - Solution : trajectories from multi-stations observations
  - Quick check : look at the shapes of meteor echoes. If they look like underdense meteor echoes or faint overdense meteor echoes.
  - Simulations : take an amplitude distribution with an expected s for the sporadic background (e.g. s=2.1 from Blaauw, 2011)

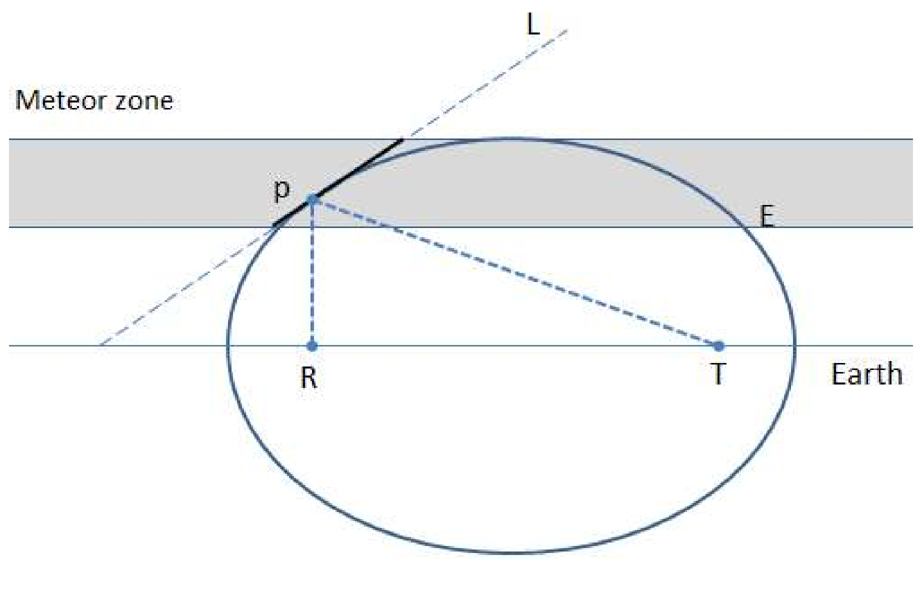
Conclusions

- BRAMS network is fully operational with 25 receiving stations
- A lot of data are available to study meteor showers
- Here we presented preliminary results with data from the Quadrantids 2016 to test the filtering of meteor echoes and try to compute the mass index.
- The computation of the mass index will be more accurate when individual trajectories will be available from BRAMS data.


Thank you

SPECULAR REFLECTION





Mass index

$$dN_c = cM^{-s}dM \Rightarrow N_c \sim M^{-\alpha}$$

Cumulative mass distribution

α = s-1 = cumulative mass index exponent

- $\alpha > 2$: more mass in smaller particles
- $\alpha < 2$: more mass in larger particles

For radio observations : amplitude of the radio meteor echo is used as a proxy for mass

Mass index

Line electron density q

< 10^{13} e-/m

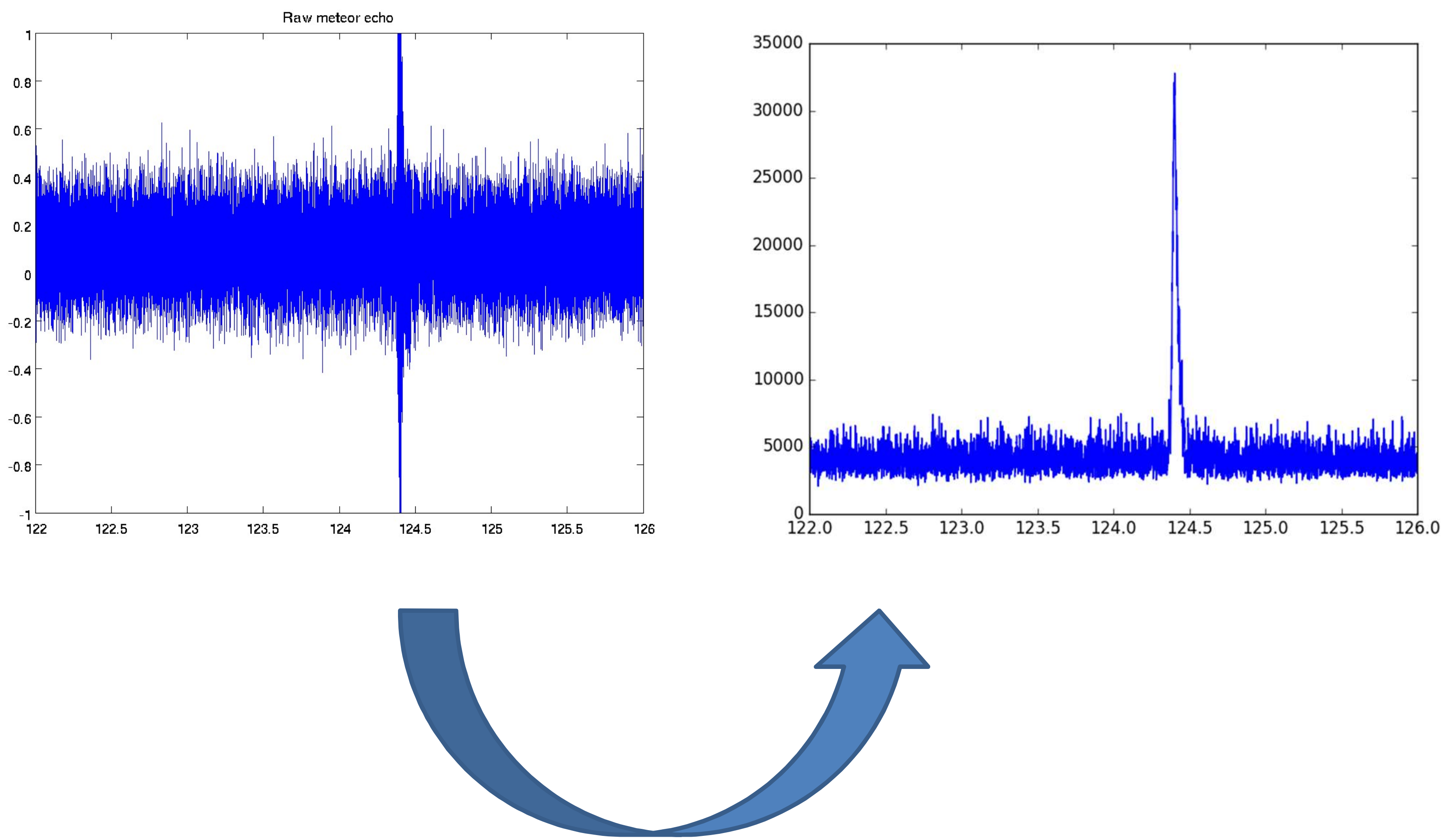
> 10^{15} e-/m

Underdense meteor trail

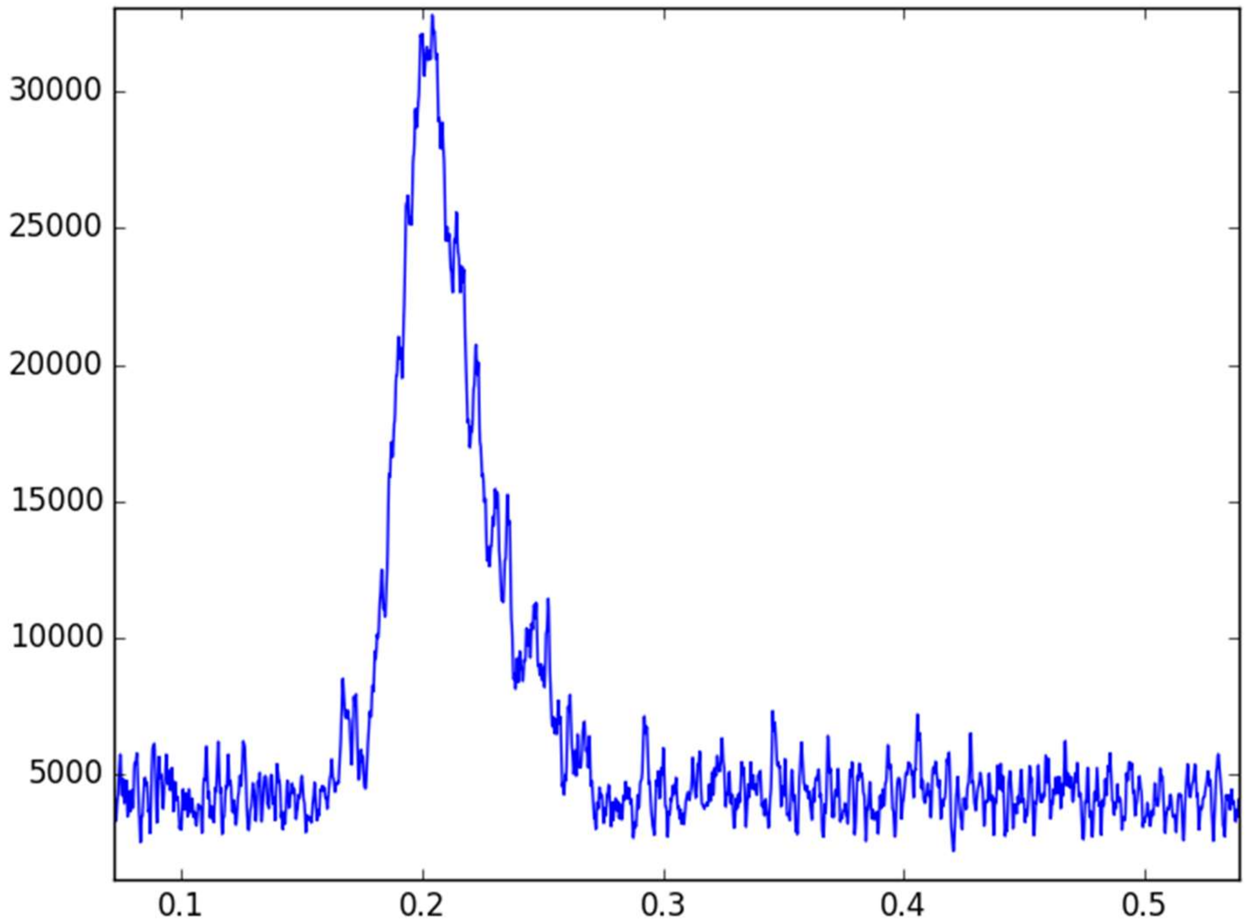
Overdense meteor trail

$$P_R = \frac{P_T G_T G_R \lambda^3 \sigma_e}{64\pi^3} \frac{q^2 \sin^2 \gamma}{(R_1 R_2)(R_1 + R_2)(1 - \sin^2 \phi \cos^2 \beta)}$$

Meteor echo + direct signal from the beacon



Zoom on the meteor echo



BRAMS data

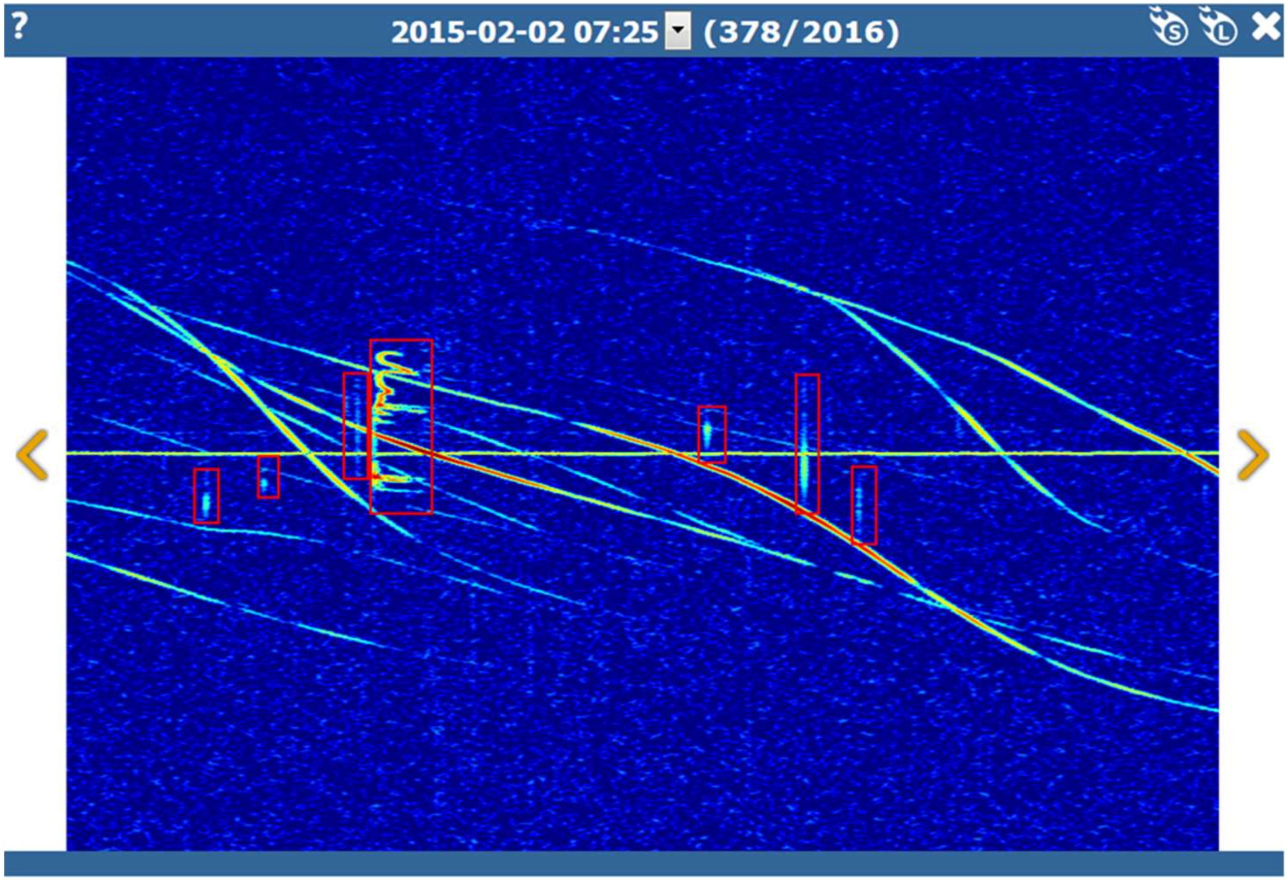
- 25 stations
- 288 files per day per station
- 1500-2000 meteor echoes per station

Algorithm for automatic detection

+

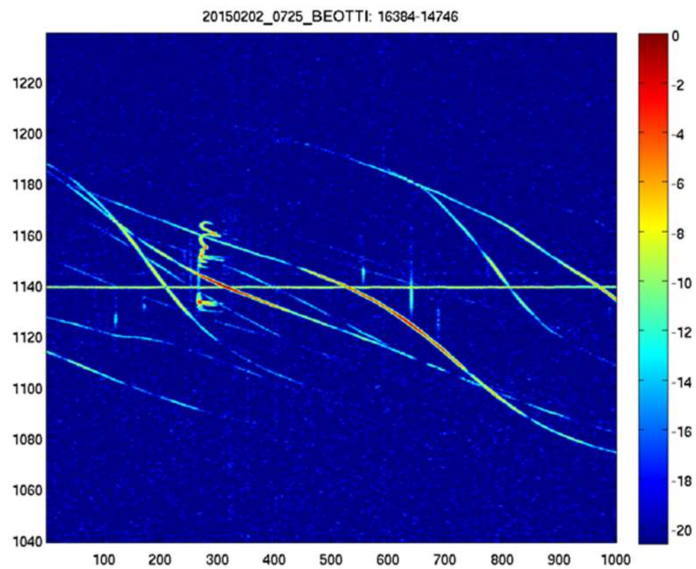
Database of manual counts for validation

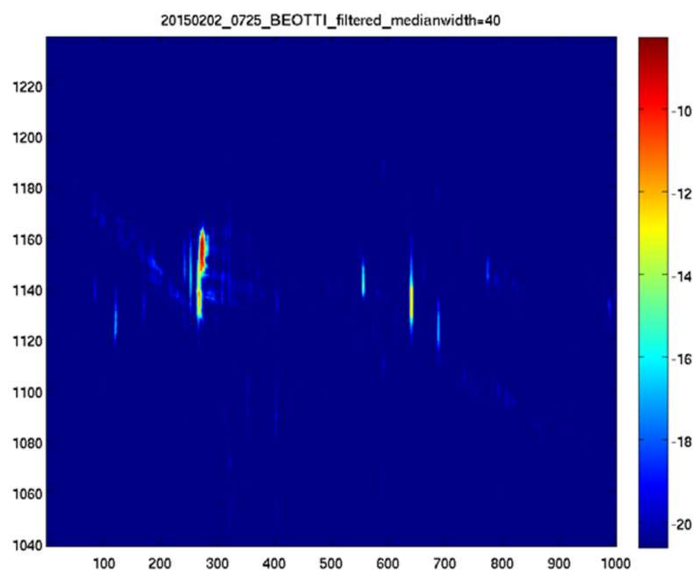
Manual counts

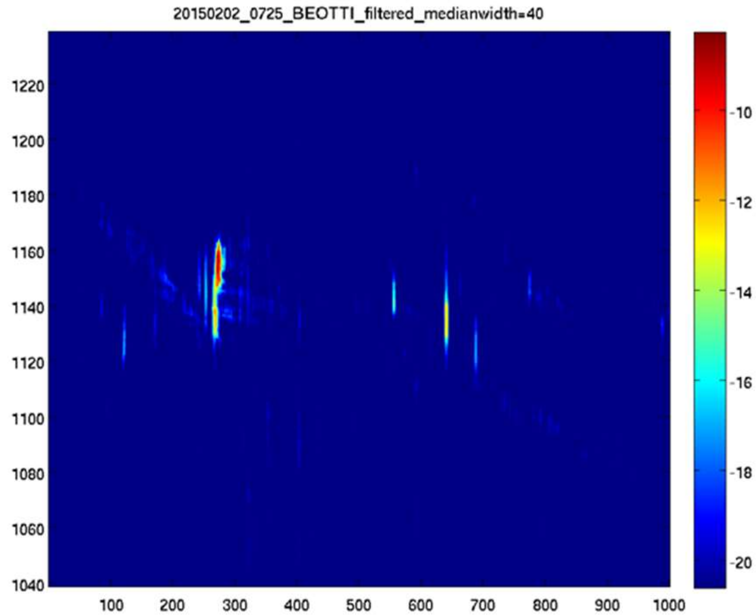


Manual counts : 7

Moving median method






20150202_0725_BEOTTI_filtered_medianwidth=40
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1180
1160
1140
1120
1100
1080
1060
1040
100
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900
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-10
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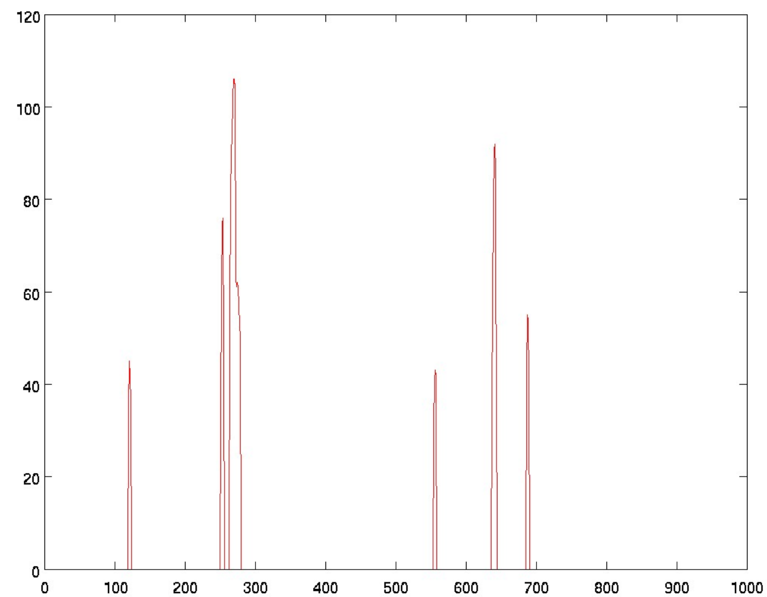
-16
-18
-20


120
100
80
60
40
20
0
0
100
200
300
400
500
600
700
800
900
1000

Comparison manual-automatic

01/01/2016

- TP ~ 72 %
- FP ~ 10 %

02/01/2016

- TP ~ 73 %
- FP ~ 14 %

03-06/02/2016 : TBD

Still some problems to solve …