Scintillation spectral index measurements with PL610 LOFAR station.

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LOFAR description

LOFAR is international radio interferometer located in Europe.

Consist 52 station, each can operate in limited parameter as independent radio telescope.

Operate in 2 frequency bands:

- 10-90 MHz (LBA)
- 110-270 MHz(HBA)

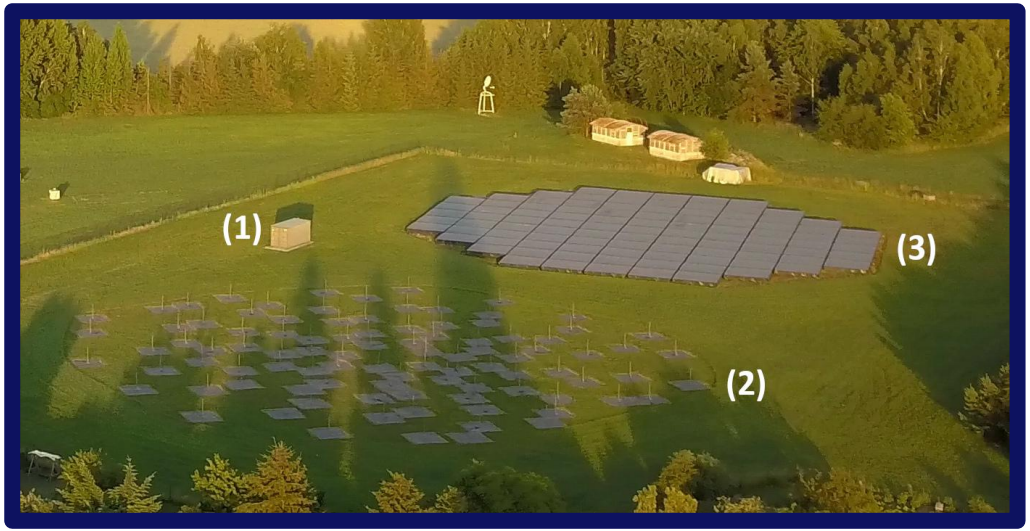


Fig. : LOFAR PL610 Station in Borówiec, Poland (52°16'32.7"N, 17° 04'25.5"E), owned by SRC PAS; (1) the container with electronic equipment, (2) LBA antennas, (3) HBA antennas.

Lofar Scintillation measurements

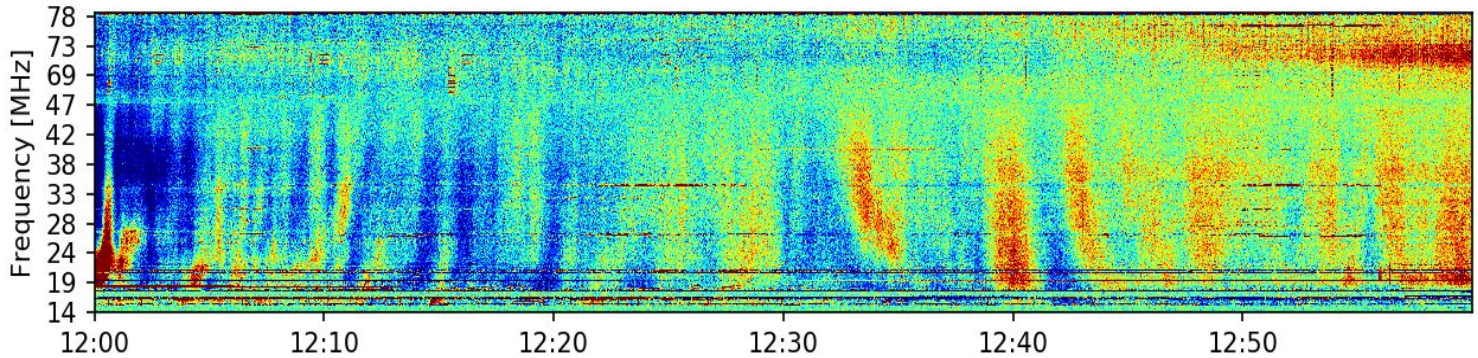
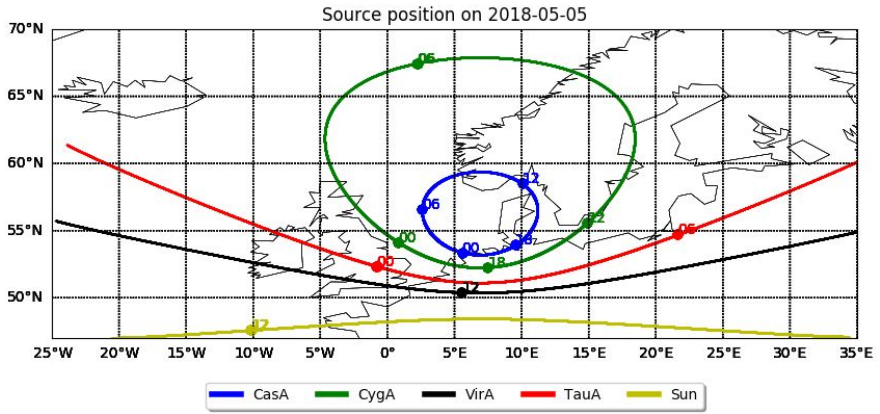


Fig. One hour example of normalized amplitude of CasA recorded on PL610

Scintillation measurements on PL610

Methodology:

- Simultaneous observation up to 4 directions,
- Four strongest radio sources (LOFAR A-Team sources) for scintillation observation purposes,
- 244 frequency channel for each direction,
- 100 samples per second.



Measurements

Effects:

- More than 8000 observations of scintillation from 2017.

Problem:

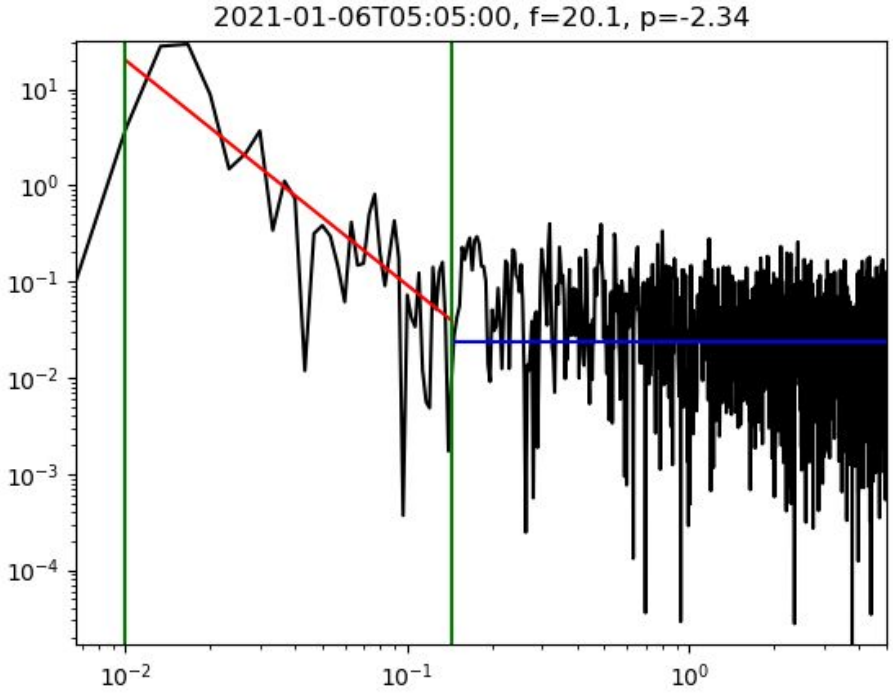
- More than 8000 observations of scintillation from 2017.

Solution:

- automatic processing
  - Automatic data filtration and S_4 index computation for all subbands and different time spans,
  - Computation of pierce point location, geomagnetic coordinates, local time, geomagnetic indices,
  - Storing in database for simplified statistical analyses.

Spectral index

- Estimating spectral slope directly related to ionospheric irregularities,
- Additional parameters can be fitted (noise level, fresnel frequency, scintillation spectral range, as well as parameters allowing estimation of the quality of the fit).



Data quality

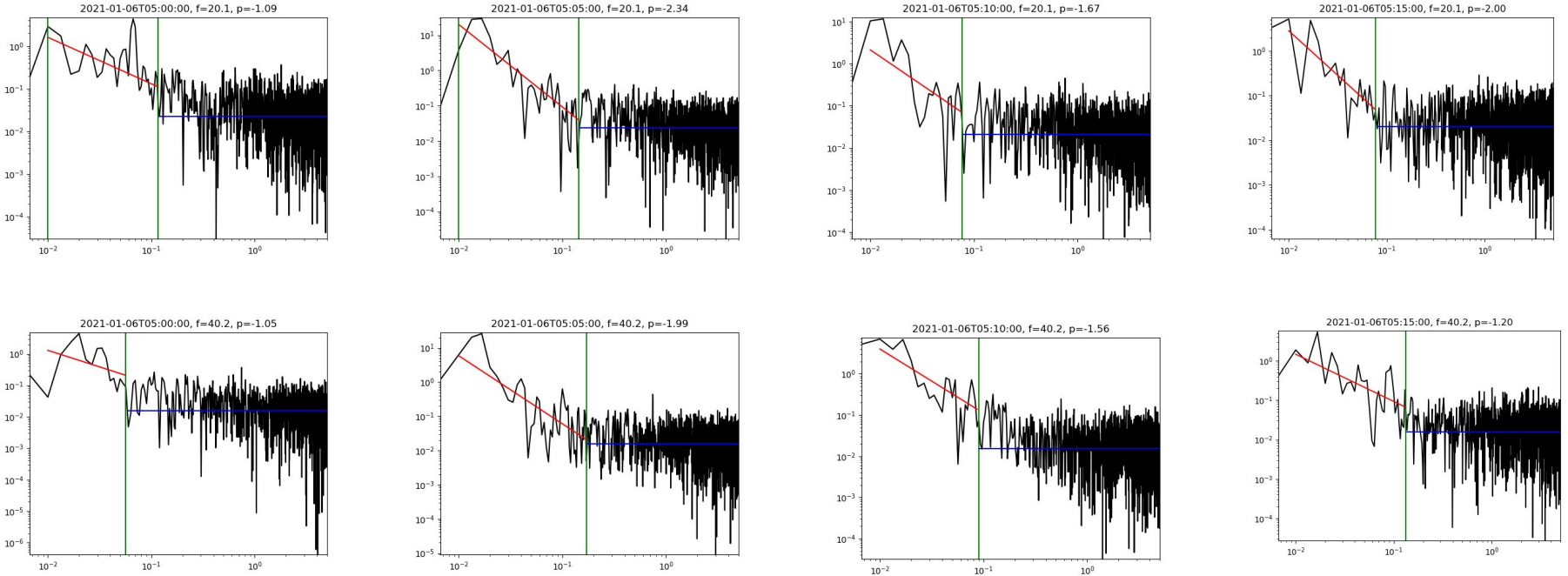
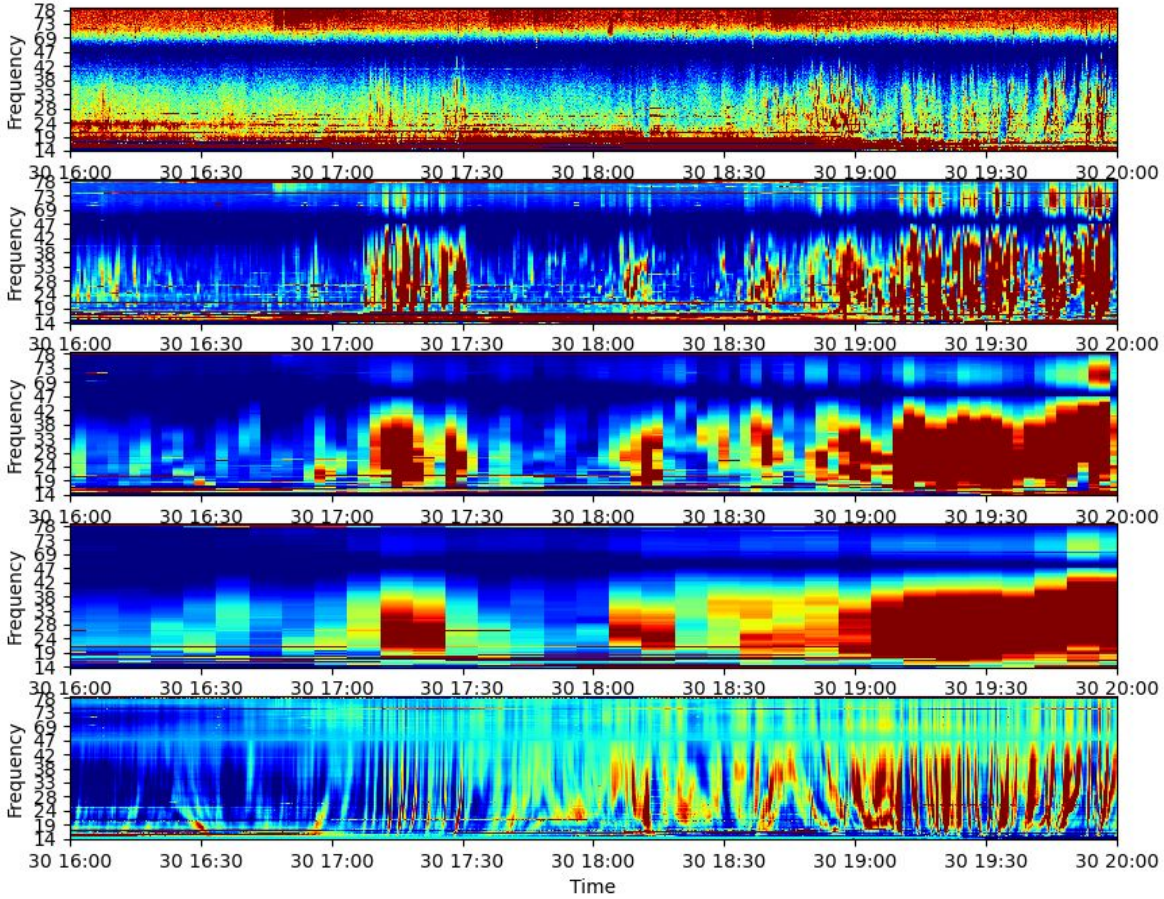


Fig Example of automatic spectrum fitting

S4 dynamic index

S4 is the ratio of the standard deviation of signal intensity to the average signal intensity

Dynamic S4 index computed for different time data length 10,60,300,900 second and normalized signal amplitude



Example S_4 index measurements

Strong rise in S_4 index at approximately 4:00 pm UTC is related to the drop of value of Dst index during the main phase of the magnetic storm, followed by high scintillation activity at the start of recovery phase.

There seems to be no dependence on frequencies in the initial peak of the storm, then there is a decrease in the signal observed for low frequencies in the recovery phase.

The plot showing S_4 for different integration times, presents dependence on phase of the storm. At the beginning the dependence is minimal, then it drops down for the shortest integration times during recovery phase of the storm.

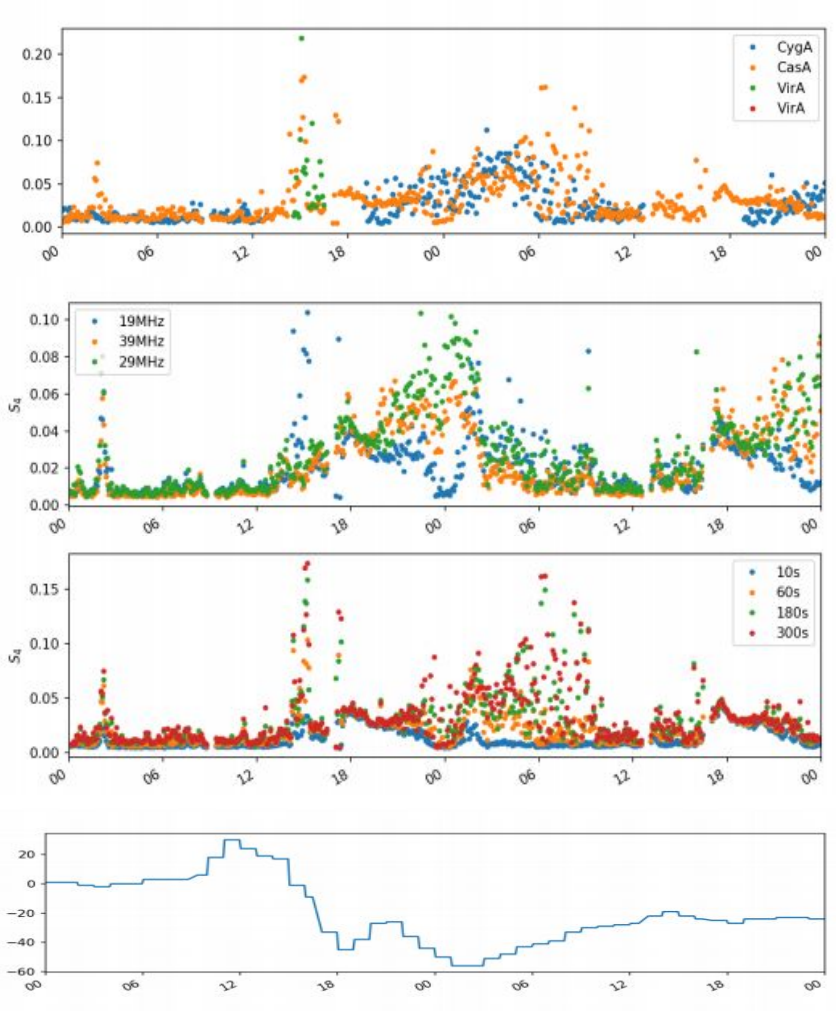


Fig. From top to the bottom: (1) The S_4 index for 20 MHz for available A-Team sources, (2) The dependence of S_4 index on observed frequencies for CasA, (3) The dependence of S_4 index on different integration times for CasA. (4) The Dst during the magnetic storm. Recorded at 5 May 2018.

Conclusions

- LOFAR is an excellent tool to observe weak ionospheric scintillation in the middle latitude region
- Even in a low activity pattern signal is clearly visible
- Is point measurement - good for case studies to track changes in time but for statistical analyses geometry must be taken into account.
- ionospheric scintillation observed by LOFAR is only to use as a part of analysis with other measurement