Low-frequency environmental noise evaluation at Sos Enattos, the Sardinian site proposed for Einstein Telescope

Davide Rozza, Andrea Contu, Domenico D'Urso, Matteo Di Giovanni,
Luca Naticchioni, Rosario De Rosa, Tommaso Zini and many others

PRELIMINARY ANALYSIS

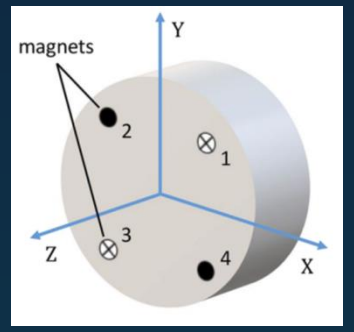
Why we need magnetic studies?

Every device which carries an electric current generates a magnetic field

which can couple

with magnetized components like:

- actuation magnets on mirrors and suspensions chain
- Faraday isolators on susp. Benches



Thanks to B.Garaventa

Virgo is overwhelmed by “self-inflicted” noise (~10-50 times above local Earth noise)

Virgo is a clear example of the importance of magnetic noise mitigation strategies for GW interferometers

It is important to plan magnetic noise measurements at potentially existing infrastructures at the candidate sites

Magnetic noise sources for ET-LF

Human

Anthropic infrastructures (power lines)

Train and railway lines can produce E.M. noise

Natural

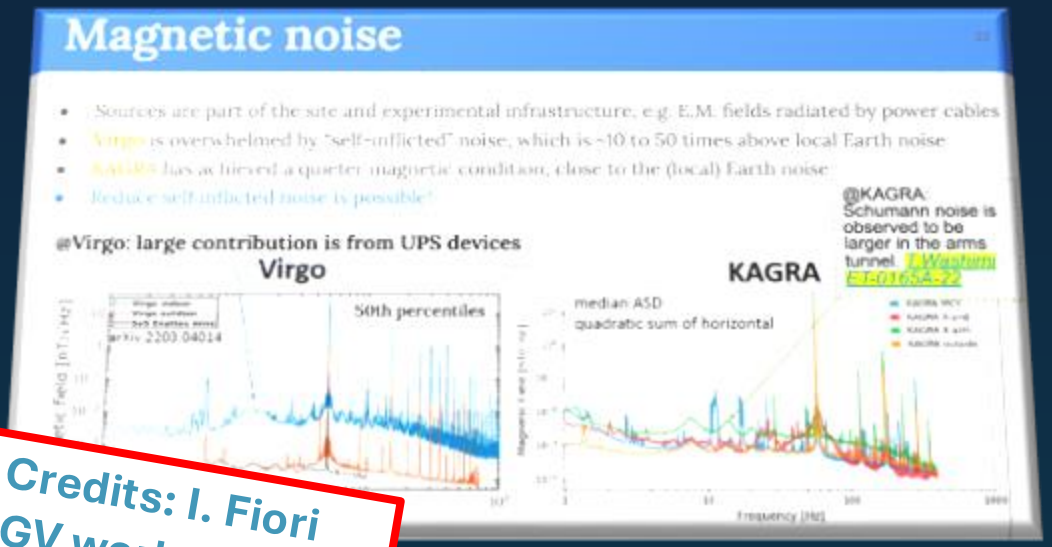
Schumann resonances (combined effect of global lightning)

Solar activities (Geomagnetic pulsations)

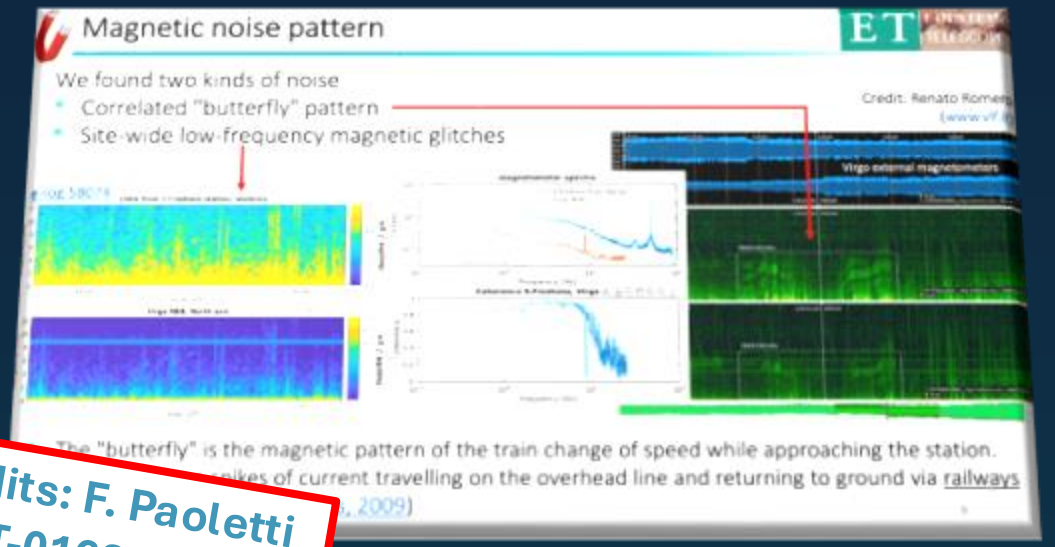
self-inflicted

ET infrastructures
ET detector

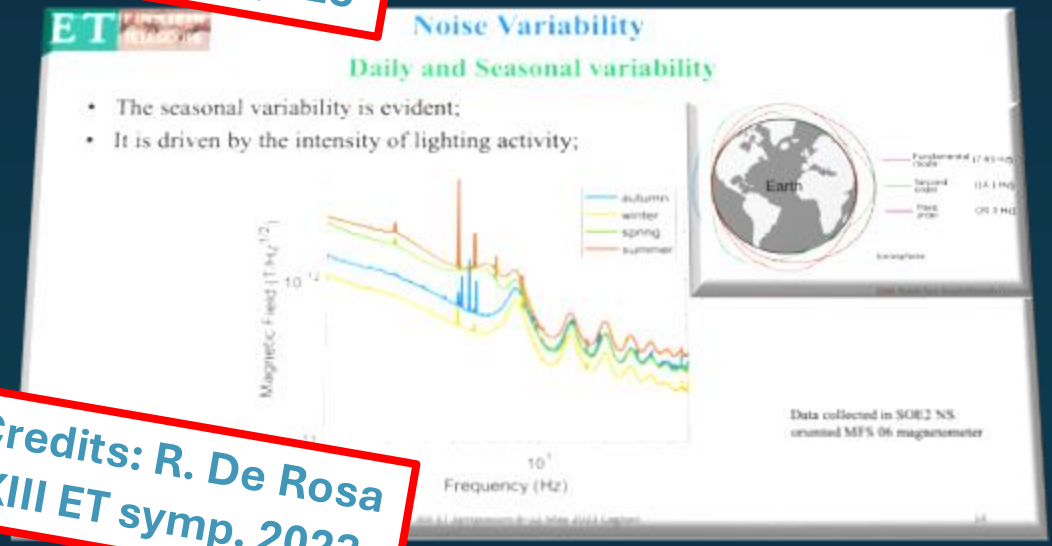
Magnetic sources



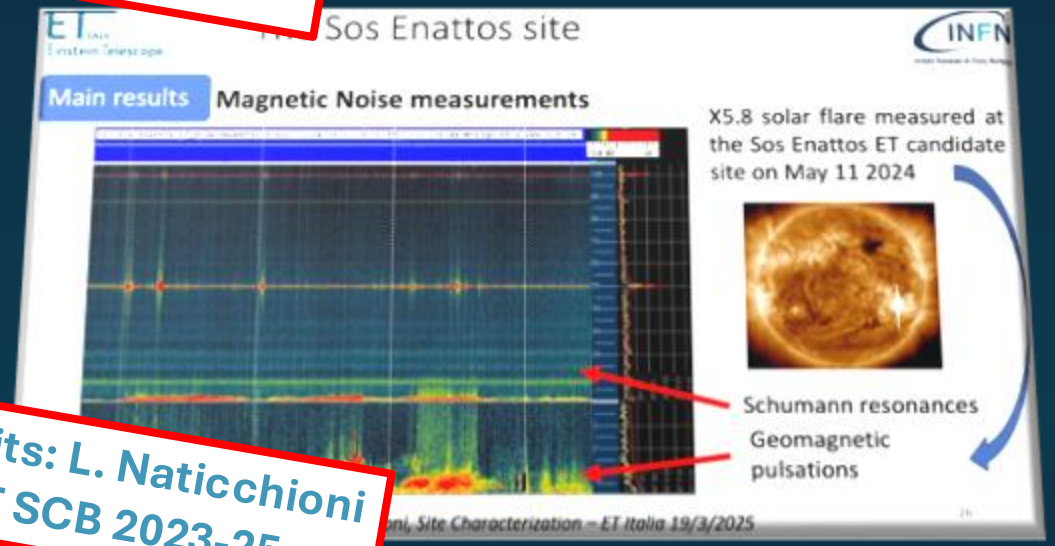
Credits: I. Fiori
INGV workshop '25



Credits: F. Paoletti
ET-0163A-23



Credits: R. De Rosa
XIII ET symp. 2023



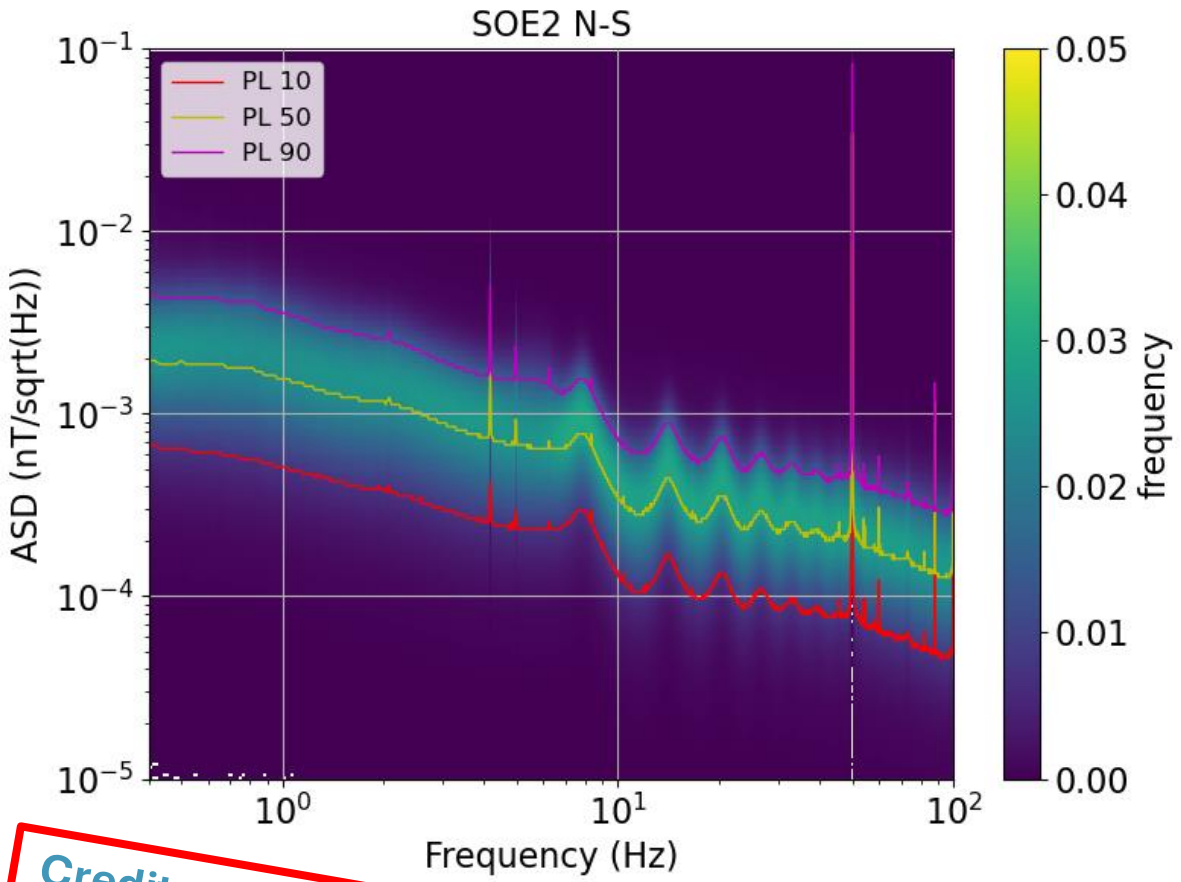
Credits: L. Naticchioni
ET SCB 2023-25

Sensors: Magnetometers Metronix MFS-06e (10’000 s → 10’000 Hz)

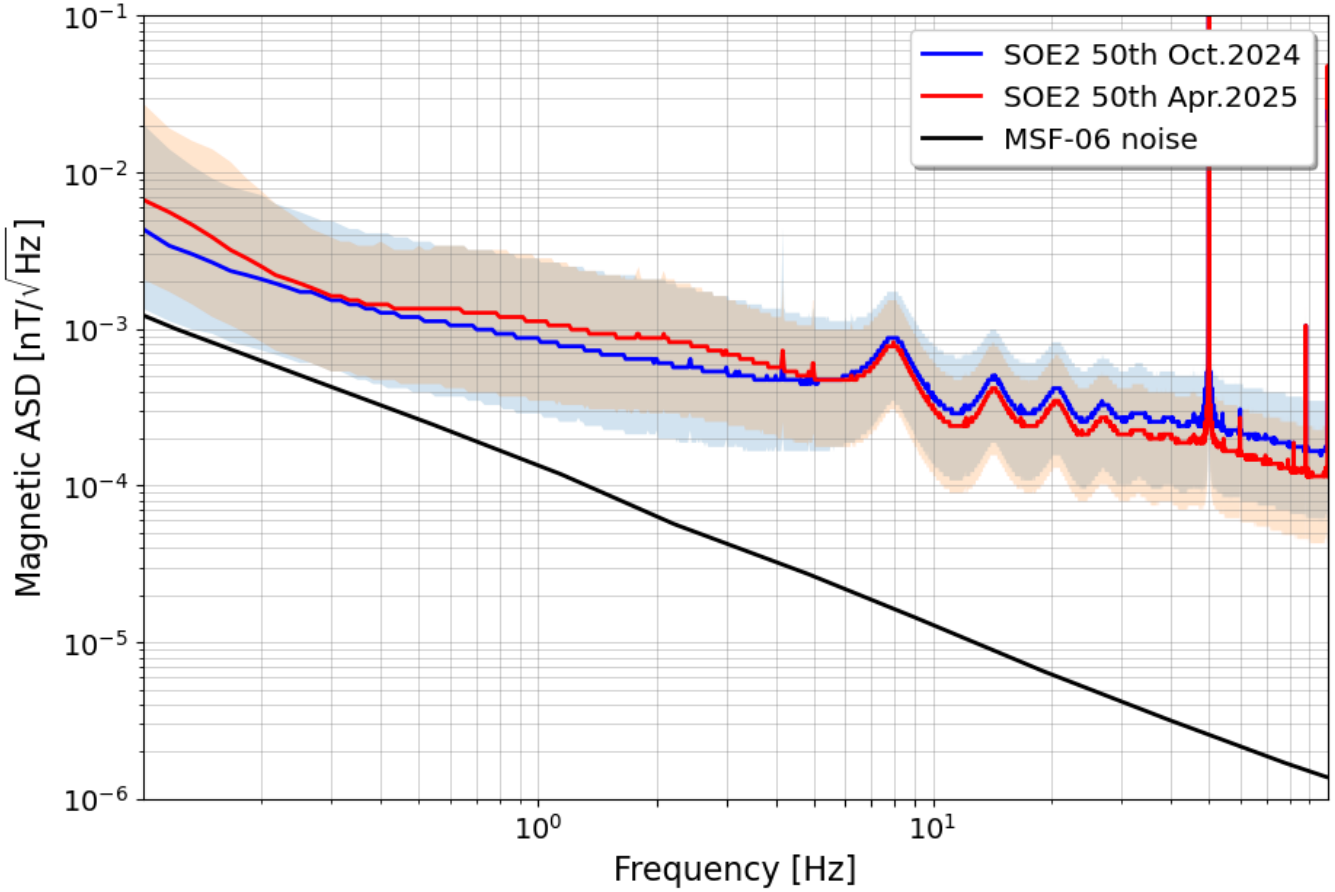
Sos Enattos [A23]
Surface: 397 m a.s.l.

Sos Enattos [SOE2]
Underground
155 m of rock above

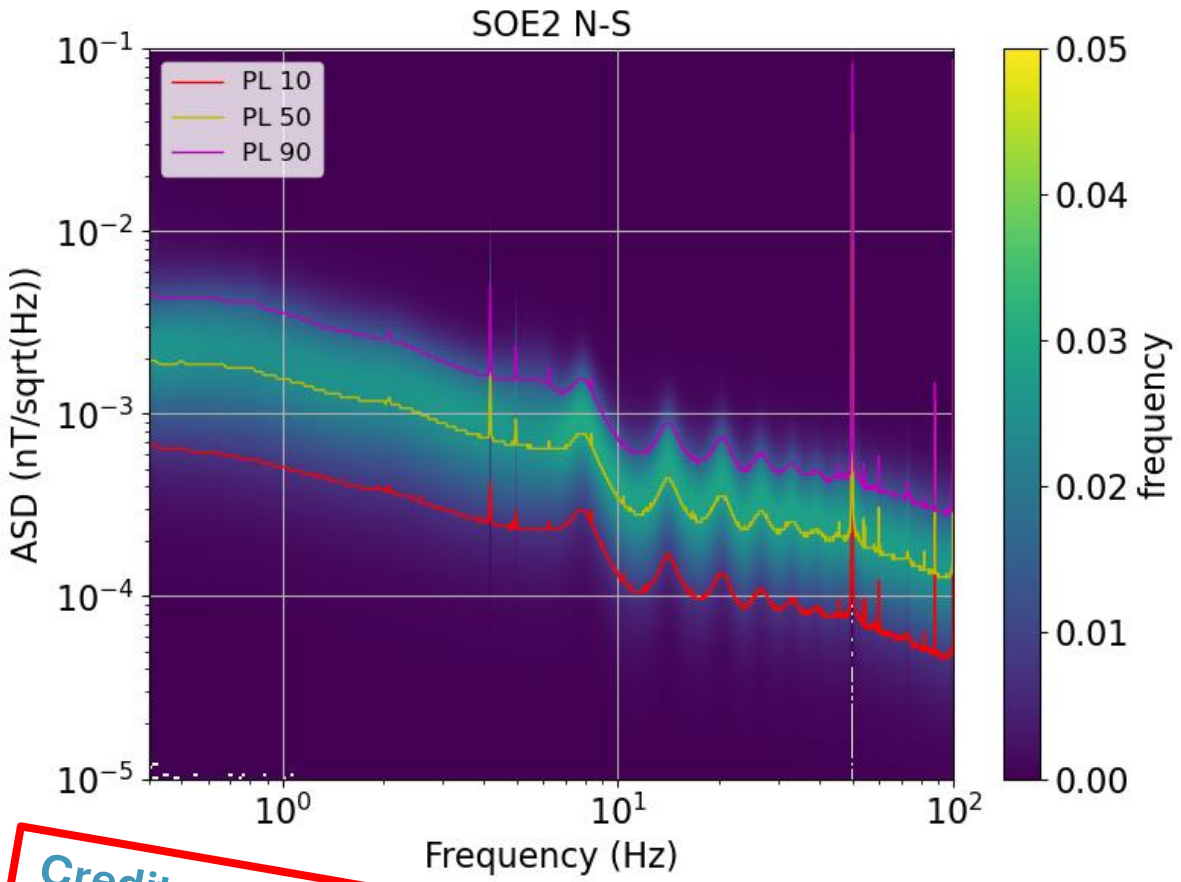
Spectrum analysis over years and months



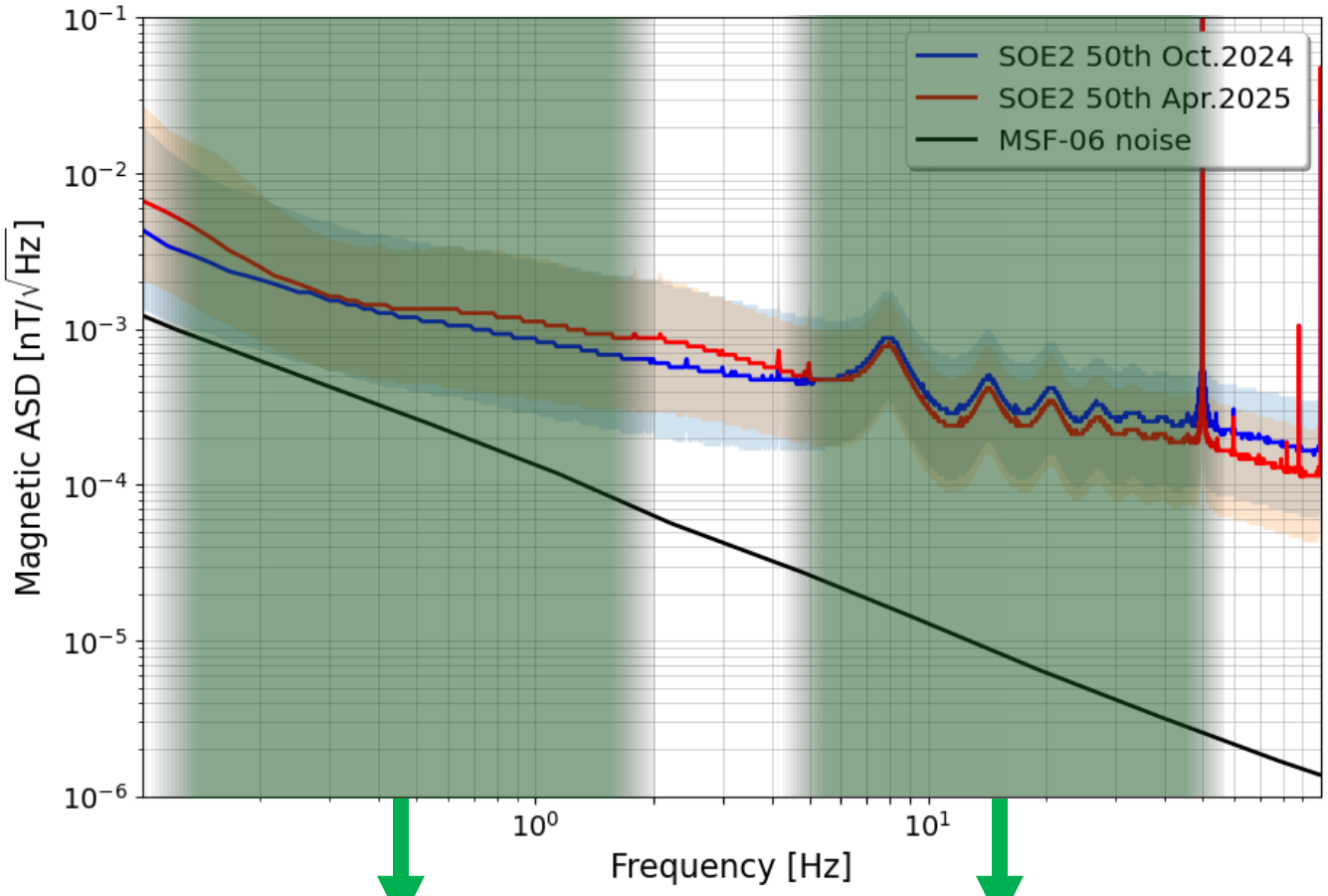
Credits: R. De Rosa



Spectrum analysis over years and months



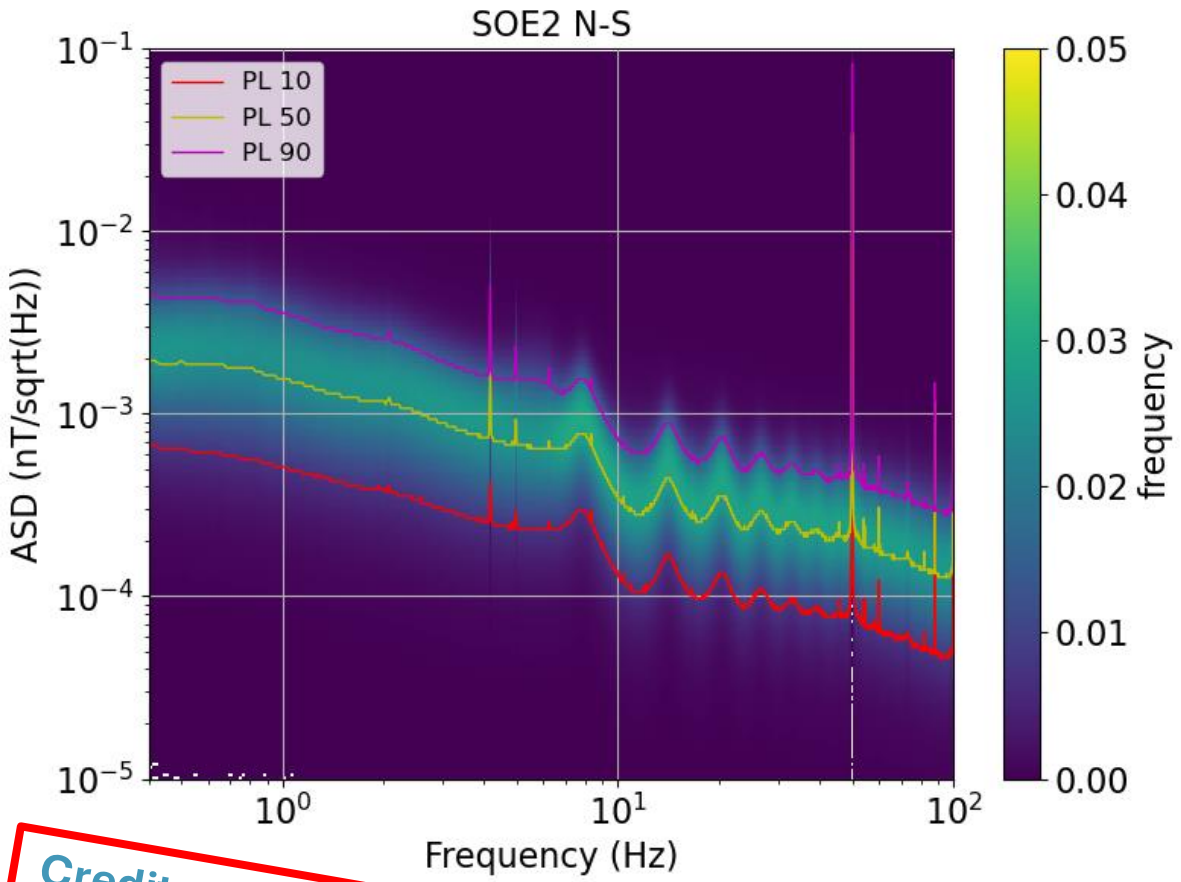
Credits: R. De Rosa



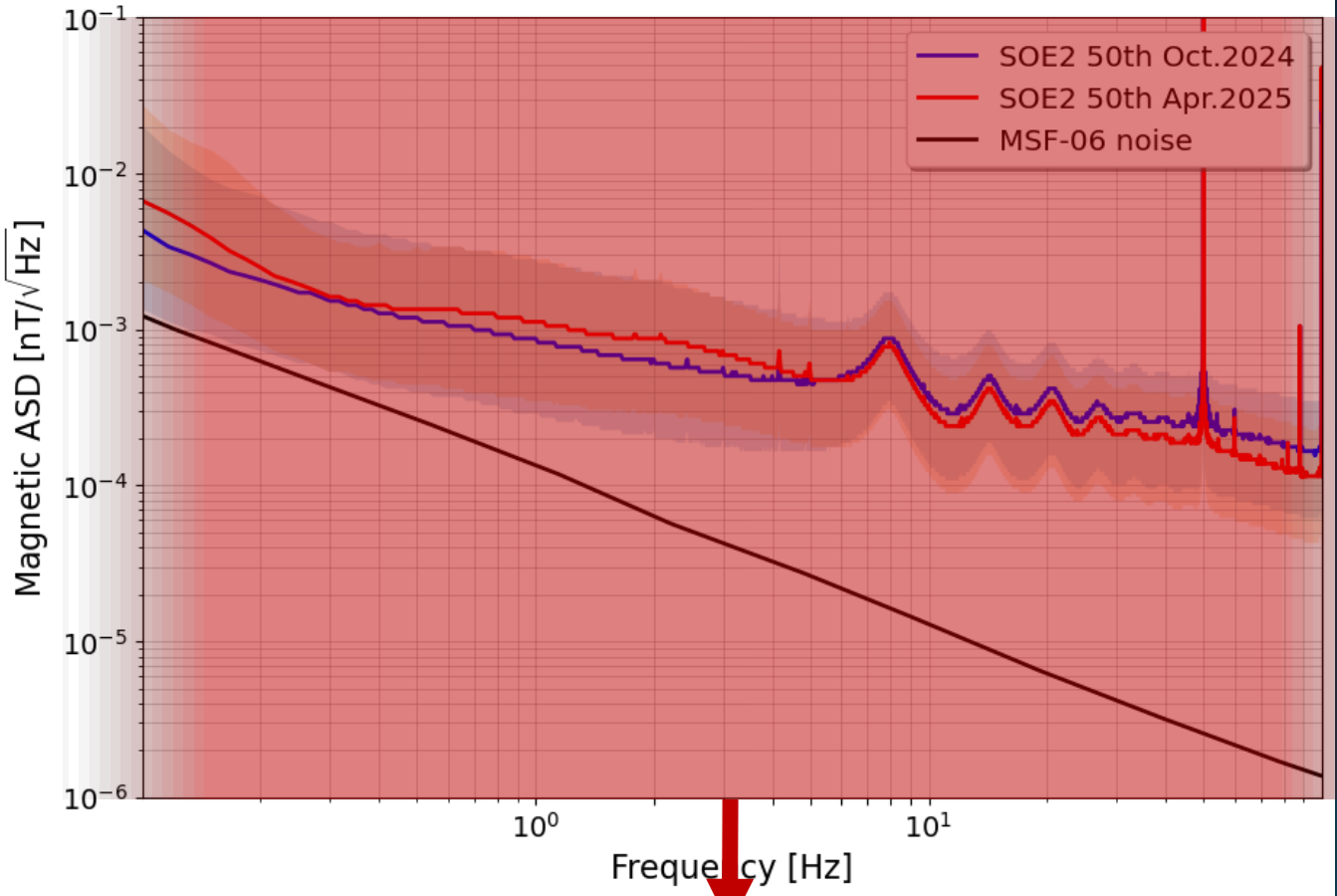
Solar activities

Schumann resonances

Spectrum analysis over years and months



Credits: R. De Rosa

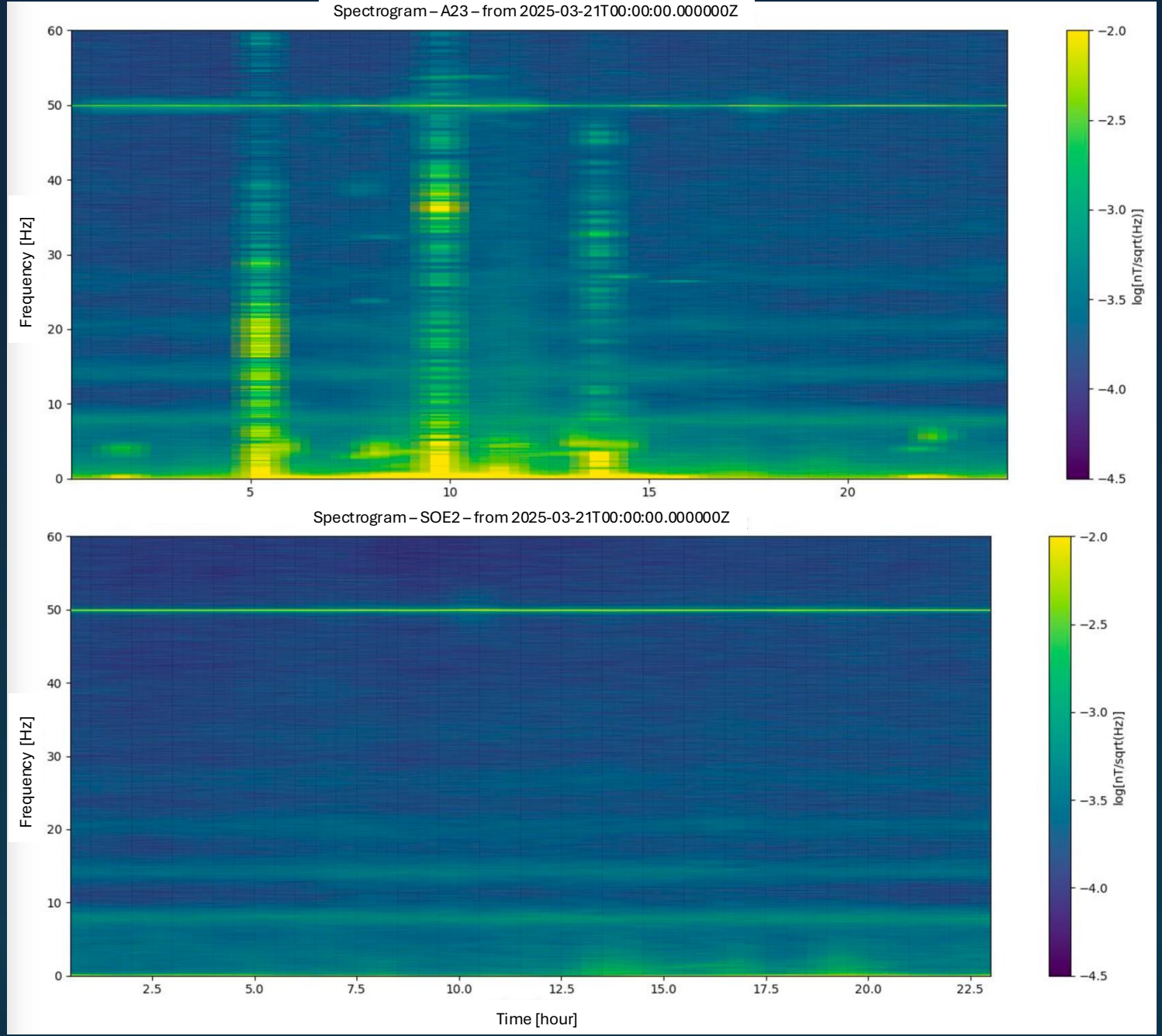


Human activities

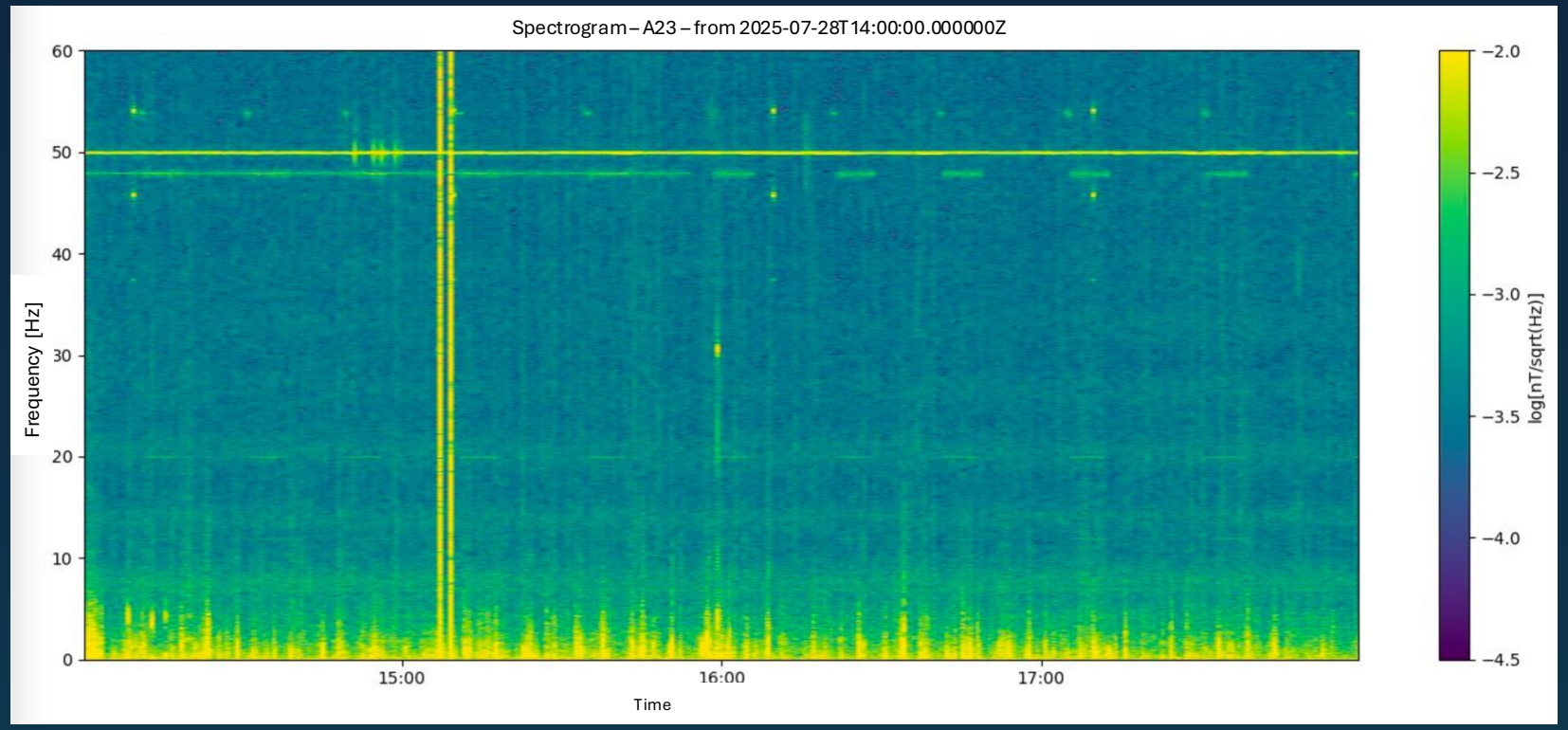
Spectrograms

A23

SOE2

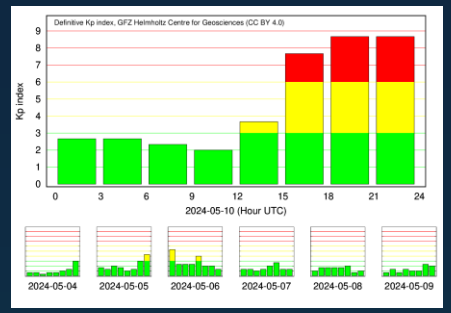


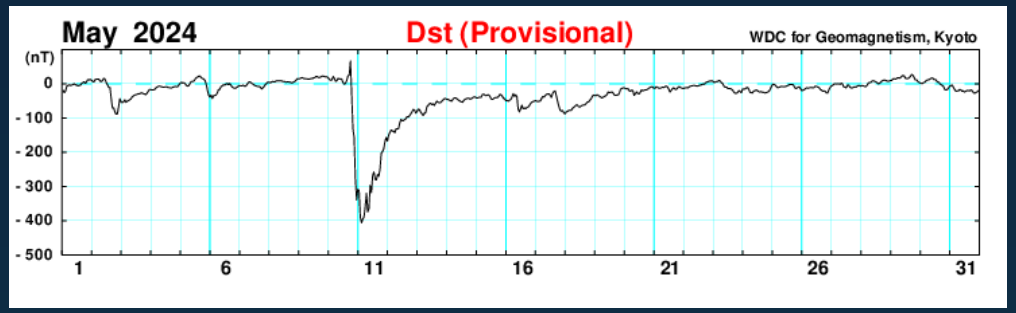
Narrow disturbances associated to car transit



- The disturbances are visible in all frequency bins
- Can be recognised combining seismometer data
- What about the very low frequency range for solar activities?

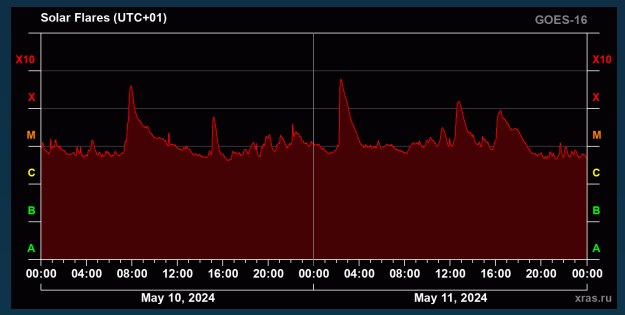
Solar and magnetic indices and data

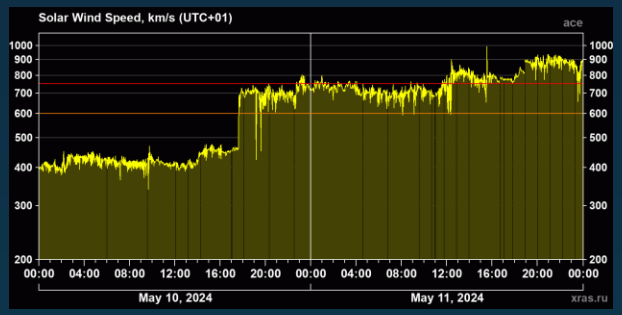


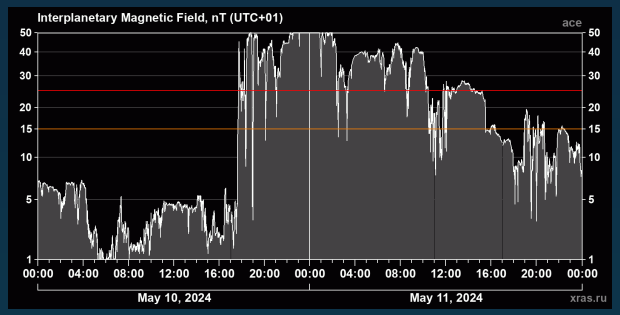


Kp → https://kp.gfz.de/en

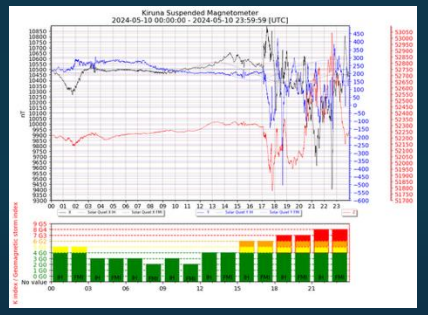
Dst → https://wdc.kugi.kyoto-u.ac.jp/wdc/Sec3.html





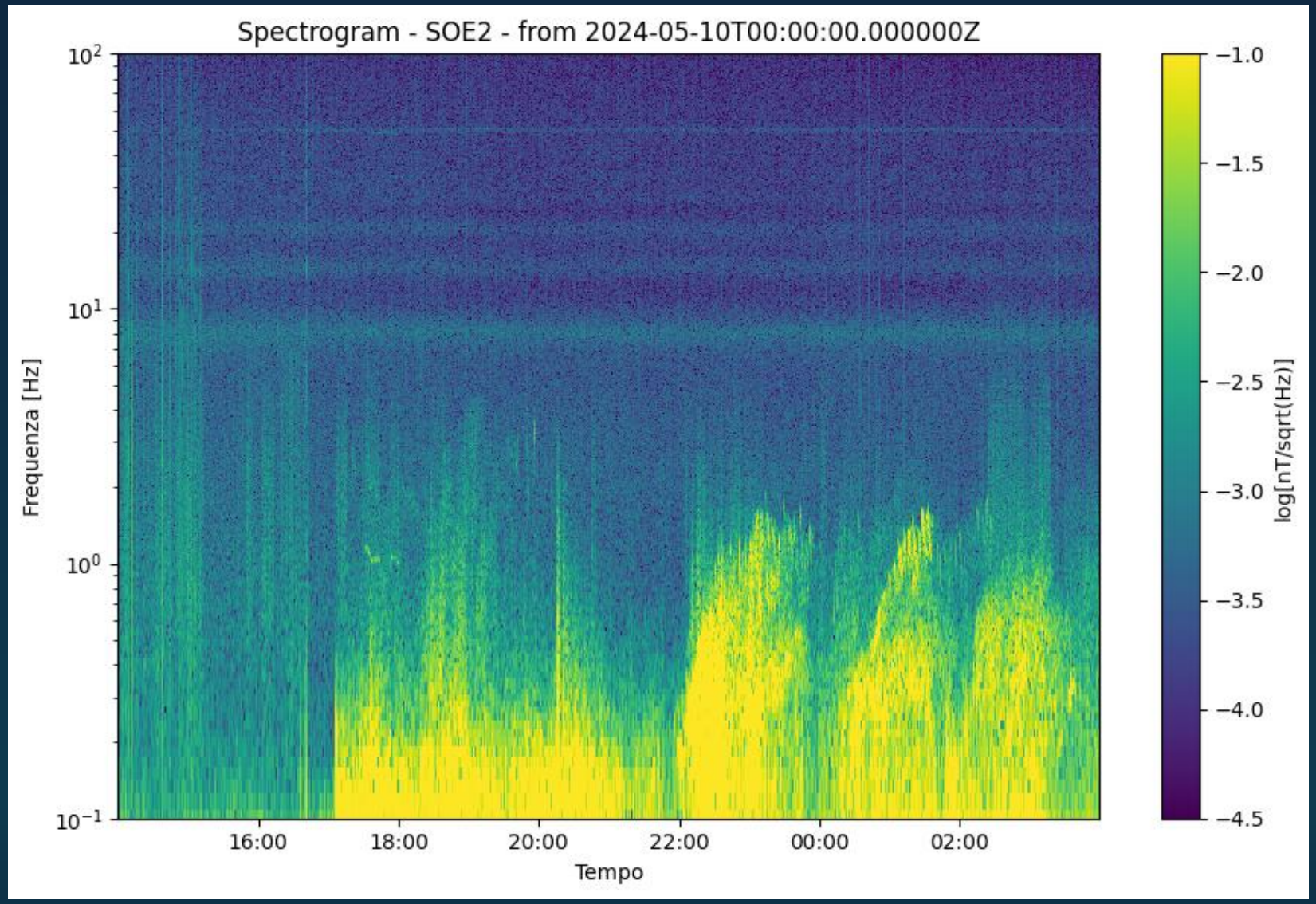


Solar Flares → https://xras.ru/en/sun_flares.html

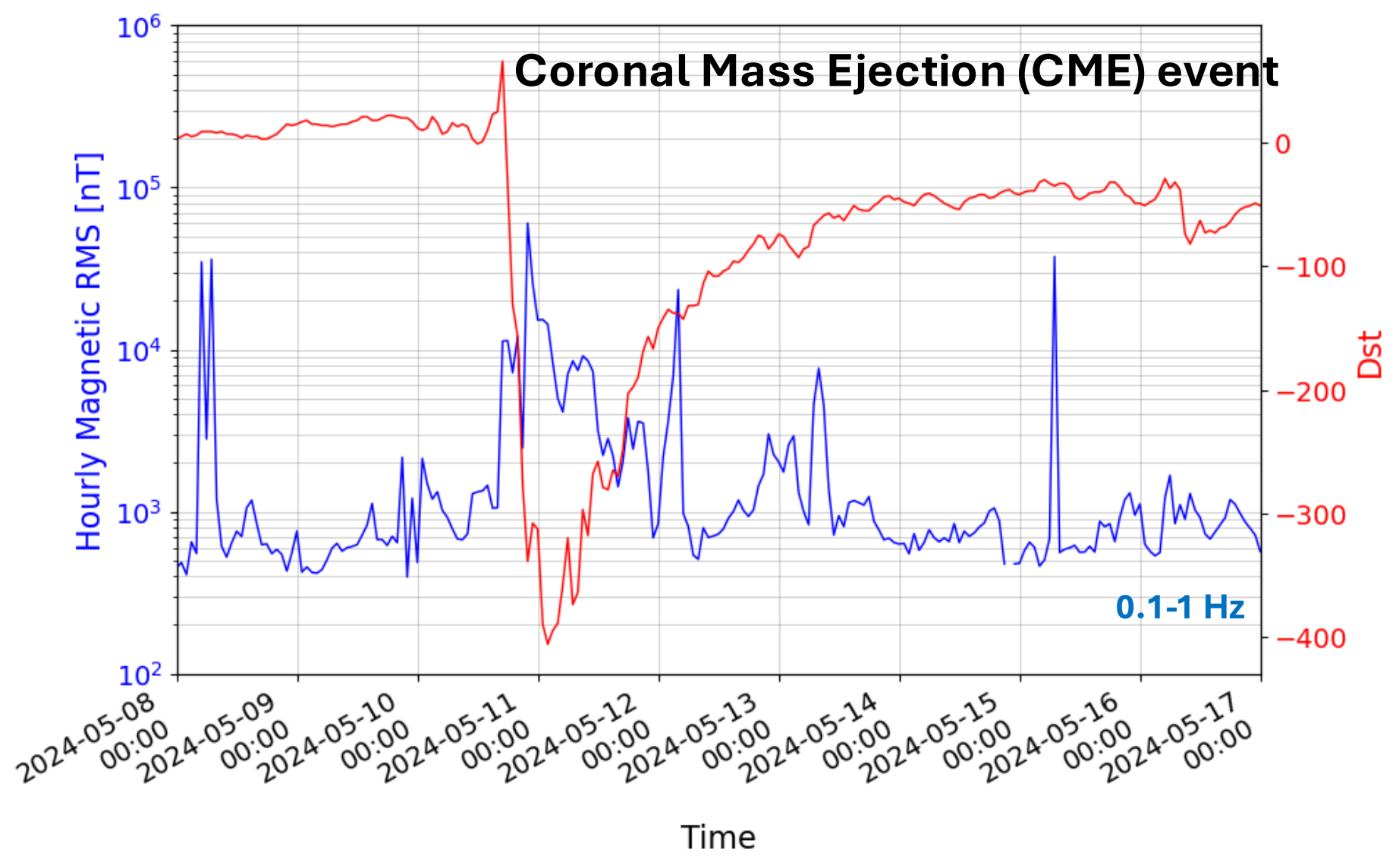


Magnetic Field → e.g. https://supermag.jhuapl.edu/mag/

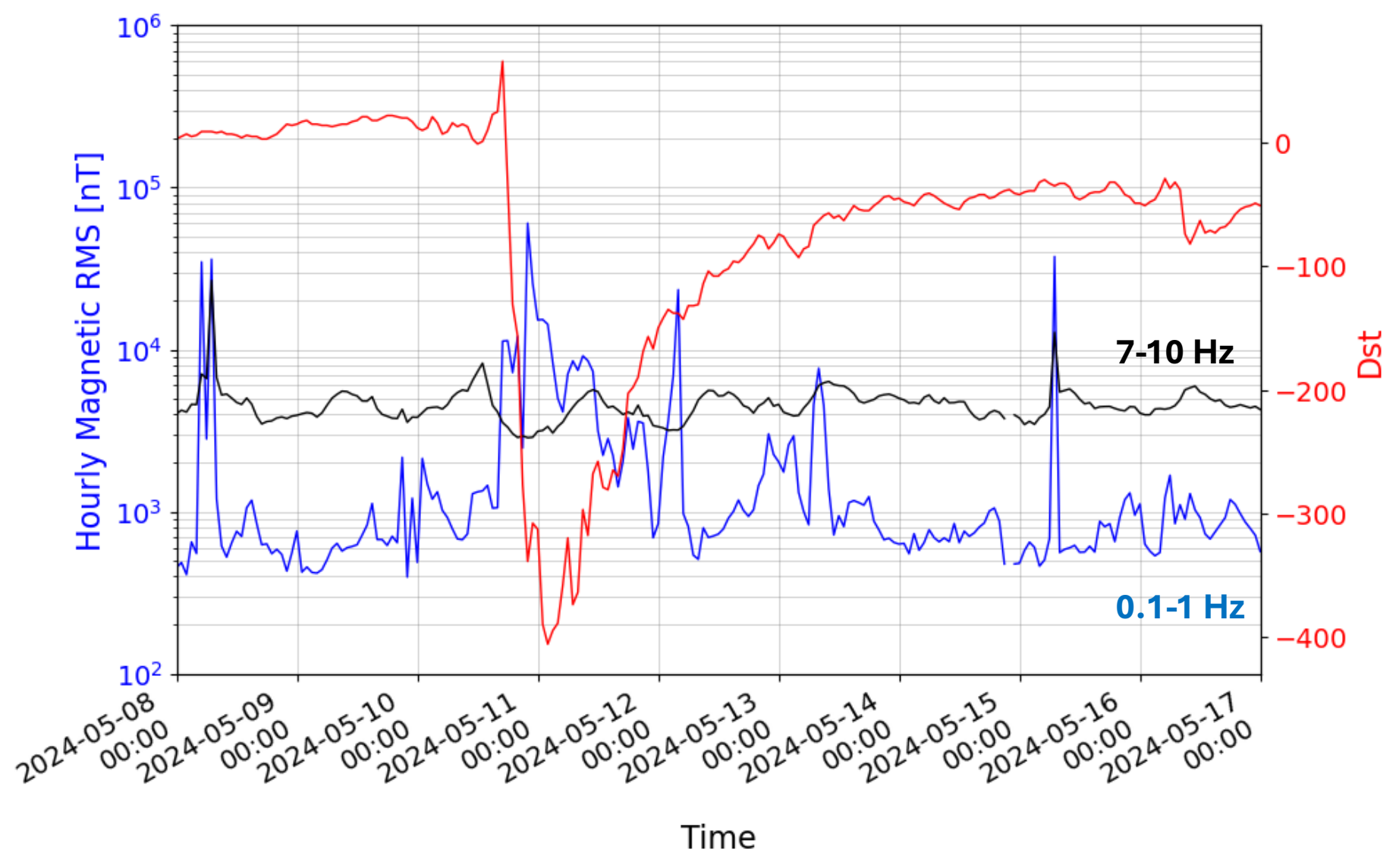
Spectrogram of underground mag. during solar disturbancy



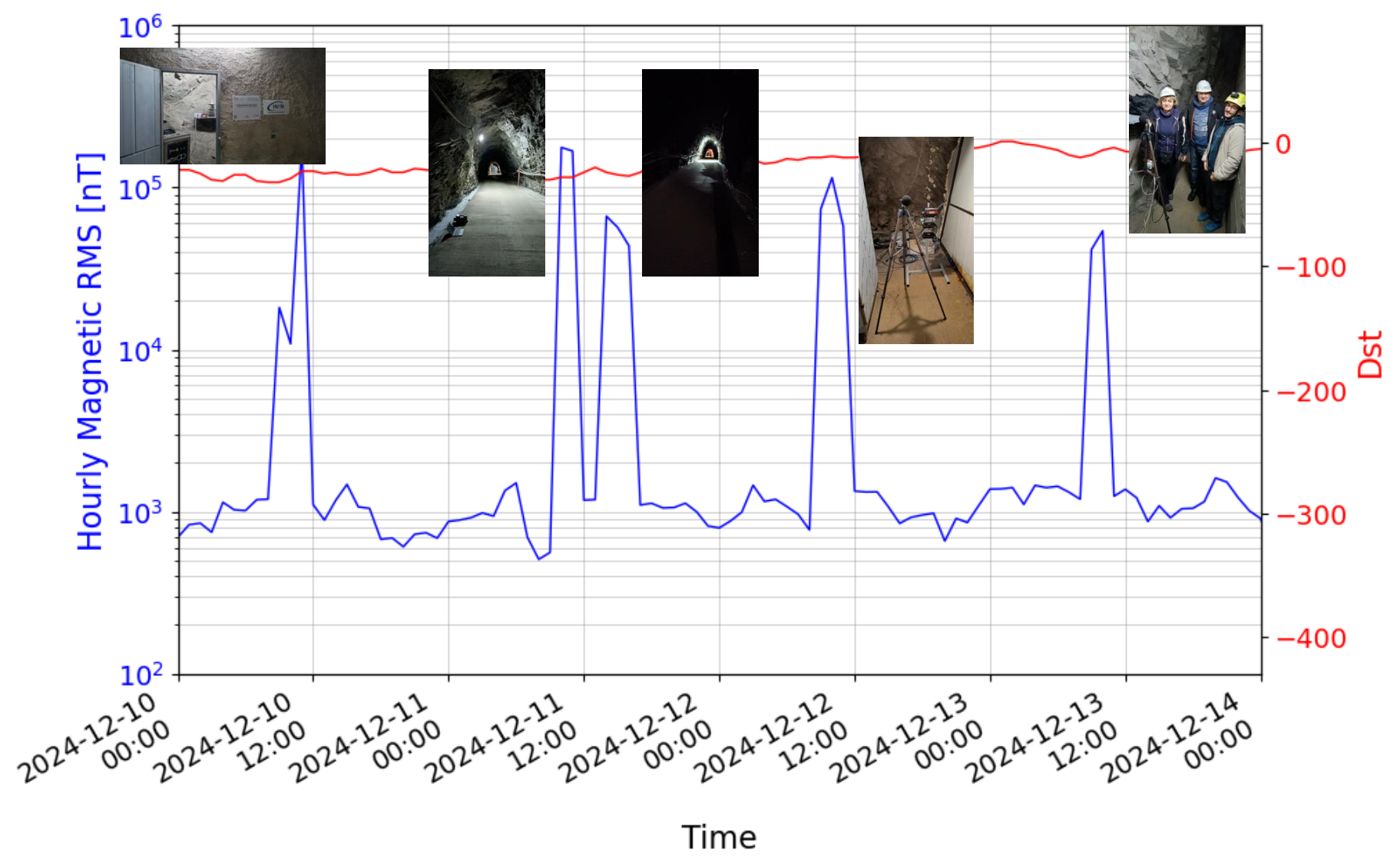
Magnetic RMS (0.1-1 Hz) compared with Dst



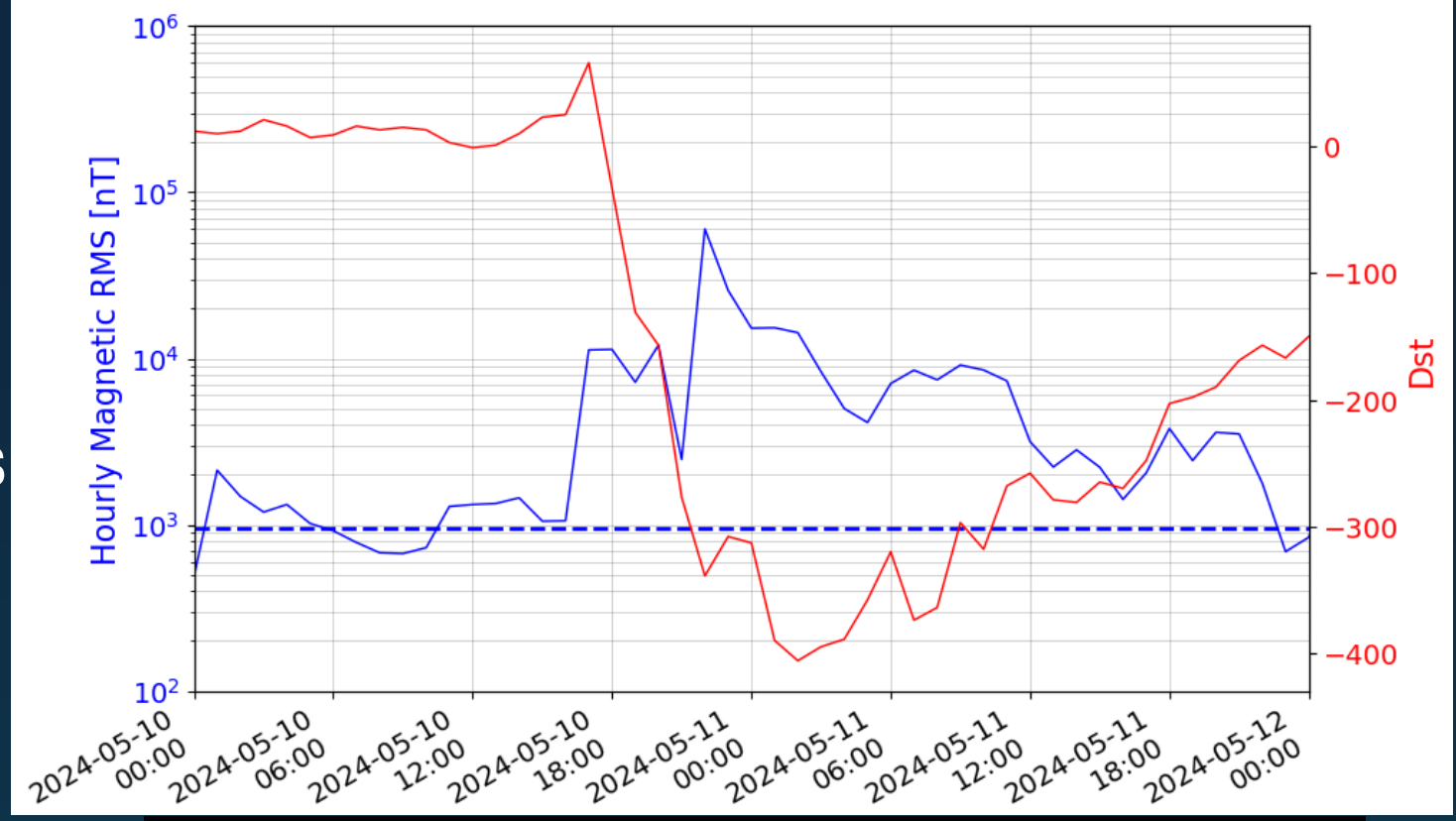
Magnetic RMS (0.1-1 Hz and 7-10 Hz) compared with Dst



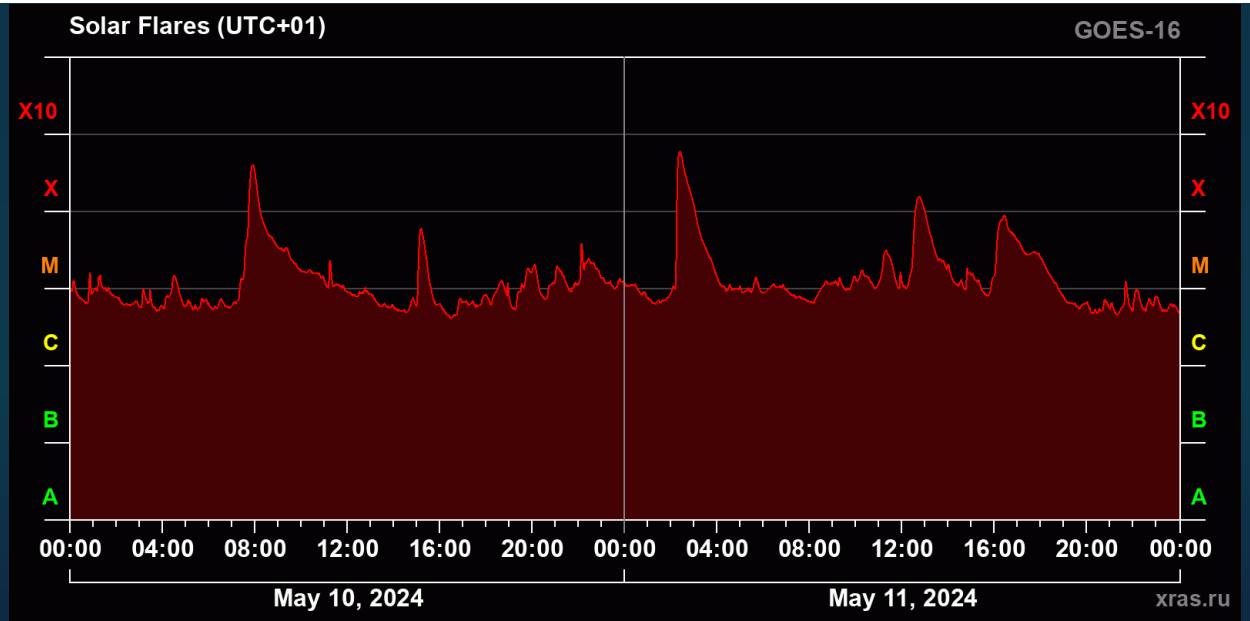
Car transit into 0.1-1 Hz signal



Underground measurements

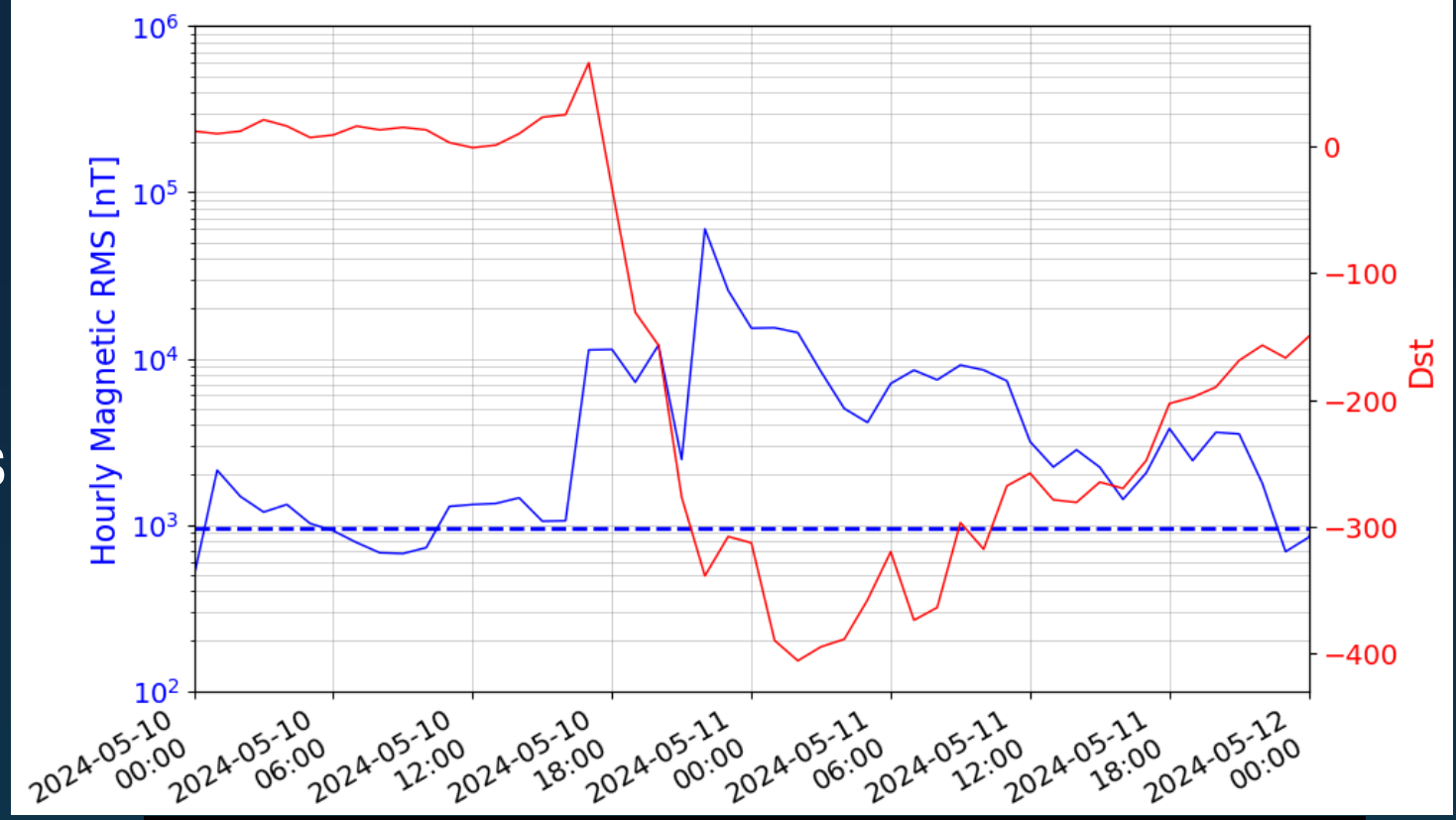


Time resolution: 1 h

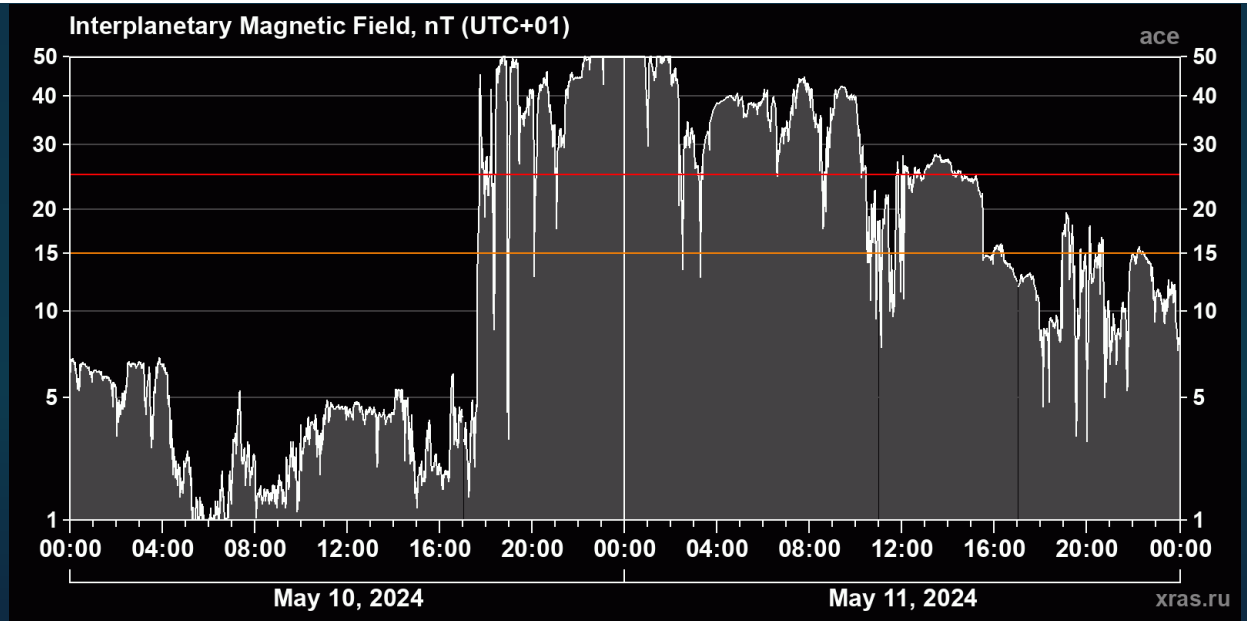


Time resolution: 1 min

Underground measurements



Time resolution: 1 h



Time resolution: 1 min

Are CMEs primarily responsible for this effect?

How many events? Few per years?

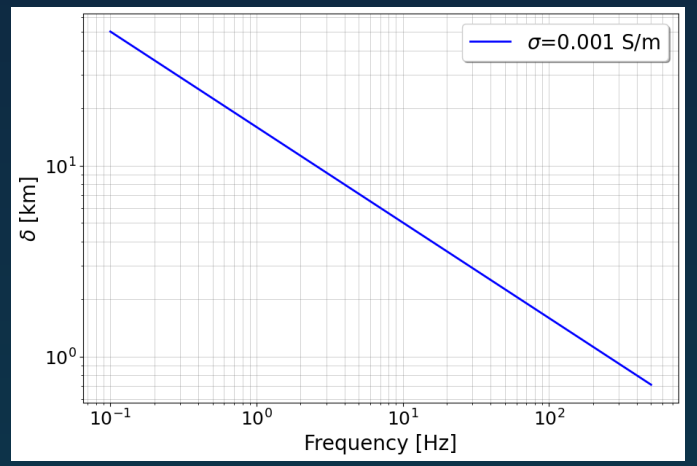
Solar cycle? 11 years

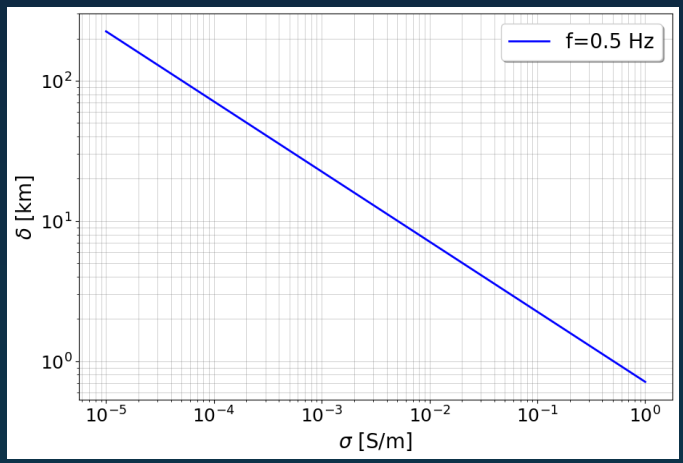
Can we have alerts of these events? Hours?

Skin Depth

The skin depth, δ, is defined as the depth at which the amplitude of the plane-wave electric or magnetic field in a homogeneous half-space falls to 1/e (nearly 37%) of its surface value (Stratton, 1941)

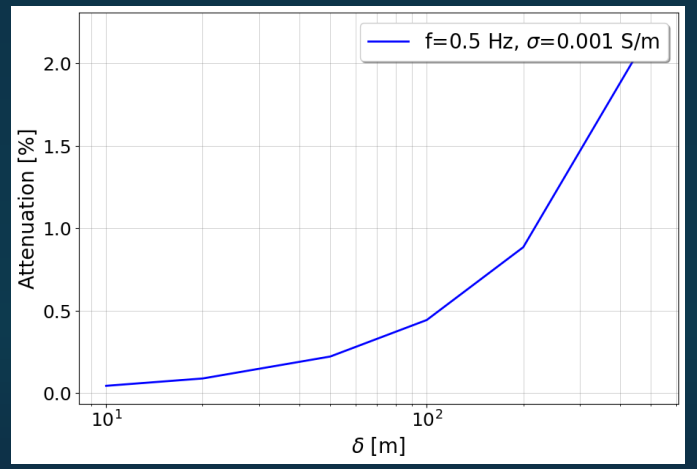
$$\delta = \sqrt{\frac{2}{\omega\mu\sigma}}$$





$$\text{Att.} = 1 - e^{-\frac{x}{\delta}}$$

Having a source at 0.5 Hz passing through granite rocks we have a 1% attenuation 200 m underground



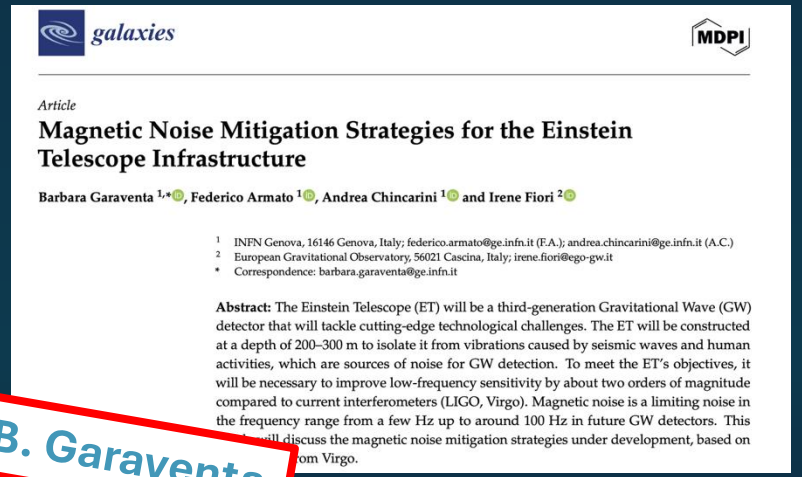
f (Hz)	δ (km)	Att. (%) @ 200 m
0.5	22	0.9
2	11	1.8
10	5	4

Conclusions

It is important to evaluate the contribution to background magnetic noise by planning measurements campaigns at existing infrastructures compatible with the ET requirements

To evaluate the contribution of magnetic sources in ET components we need:

- magnetic analysis with other sensors e.g. seismometers (disentangle human/natural magnetic sources)
- Evaluate how many solar events can be observed and at which geomagnetic latitude we'll build ET
- Evaluate the impact through the rocks from surface to underground
  skin-depth of the order of km, attenuation depending on the rocks and small
- Evaluate magnetic mitigation strategies to keep into account these noises



galaxies

MDPI

Article

Magnetic Noise Mitigation Strategies for the Einstein Telescope Infrastructure

Barbara Garaventa [1,*], Federico Armato [1], Andrea Chincarini [1] and Irene Fiori [2]

[1] INFN Genova, 16146 Genova, Italy; federico.armato@ge.infn.it (F.A.); andrea.chincarini@ge.infn.it (A.C.)
[2] European Gravitational Observatory, 56021 Cascina, Italy; irene.fiori@ego-gw.it
* Correspondence: barbara.garaventa@ge.infn.it

Abstract: The Einstein Telescope (ET) will be a third-generation Gravitational Wave (GW) detector that will tackle cutting-edge technological challenges. The ET will be constructed at a depth of 200–300 m to isolate it from vibrations caused by seismic waves and human activities, which are sources of noise for GW detection. To meet the ET's objectives, it will be necessary to improve low-frequency sensitivity by about two orders of magnitude compared to current interferometers (LIGO, Virgo). Magnetic noise is a limiting noise in the frequency range from a few Hz up to around 100 Hz in future GW detectors. This [illegible] will discuss the magnetic noise mitigation strategies under development, based on [illegible]om Virgo.

Credits: B. Garaventa