

# Review of measured environmental noise effects @ Virgo

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*European Gravitational Observatory*

ET-0496A-23

— Einstein Telescope Site Preparation Board Workshop 3 - Amsterdam, 6-7 Dec 2023 —

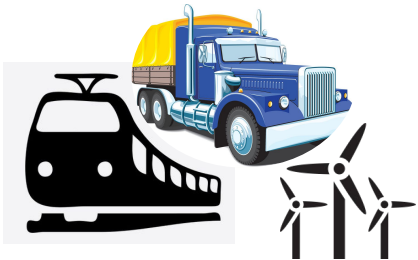
# This talk

Focus on **anthropogenic** noise sources

A few **examples** of relevant sources

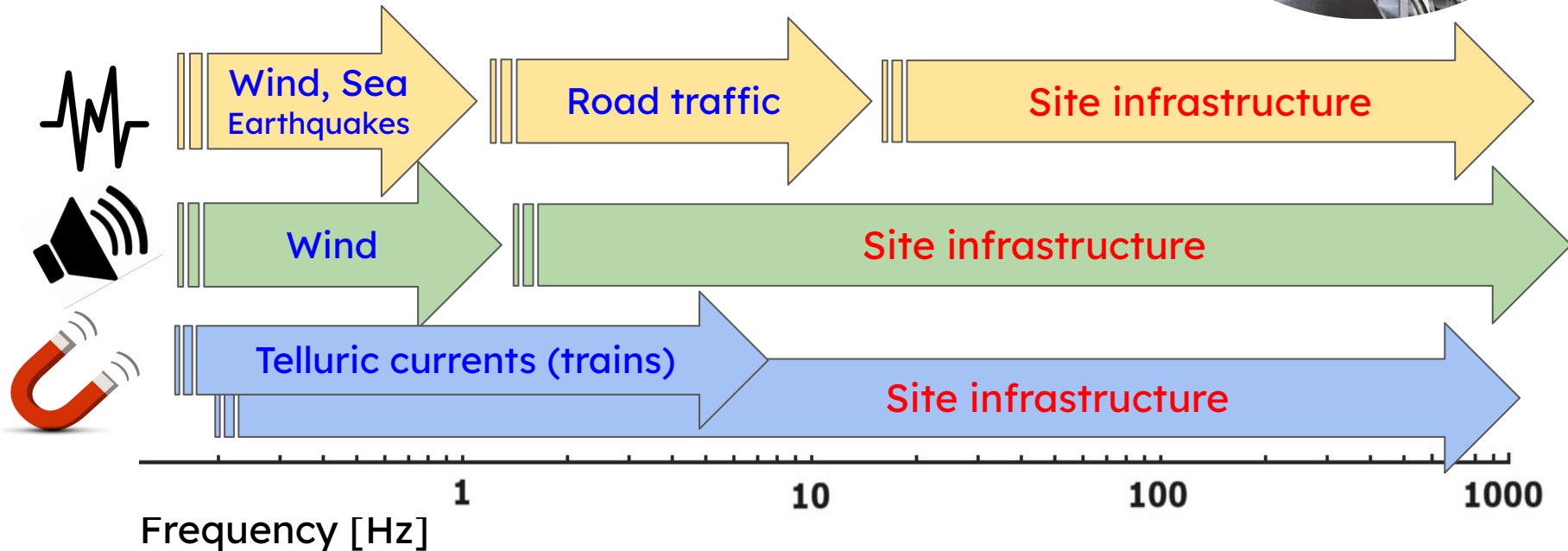
The issue of **preserving the noise climate** at the site

# Environmental noise sources @Virgo



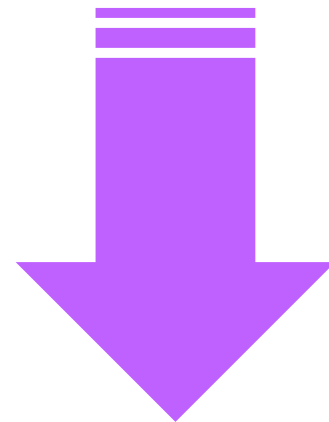
Natural and Anthropogenic versus Site infrastructure  
(see also [ET-0016A-23](#))

Site infrastructure  
(see also [ET-0164A-22](#))



# Anthropic sources

Number increased during Virgo lifetime:  
1997 - today



**Need to  
Preserve  
the  
“Noise Climate”  
of the site**

# Which impact on Virgo?

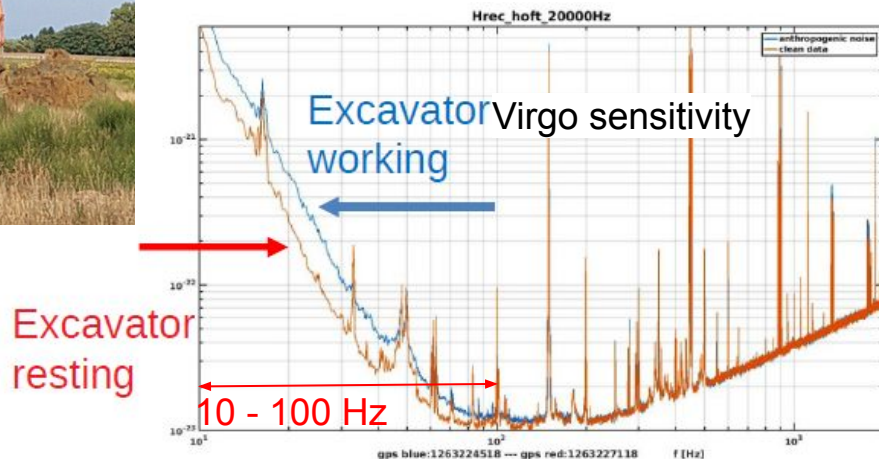
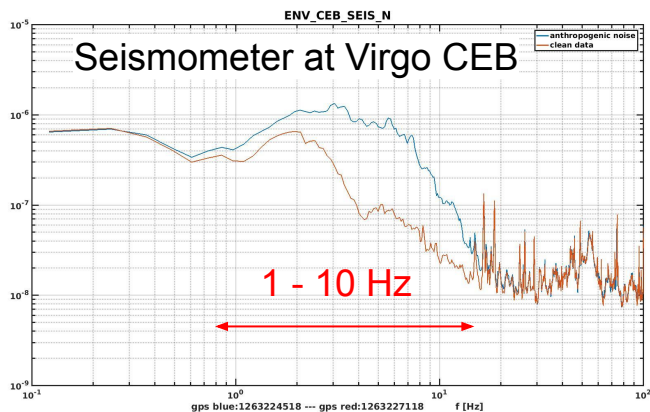
See also another example -  
Tractor noise [VIR-0560A-11](#)

Some anthropic sources impacted on Virgo sensitivity. All of them increase the risk factor for the future upgrades.

The case of excavator noise (O3 run). Trigger scattered light processes

Excavator at few 100 m  
from Central Building producing  
seismic bursts at 1-10 Hz

[logbook 48311](#)



# The wind farm

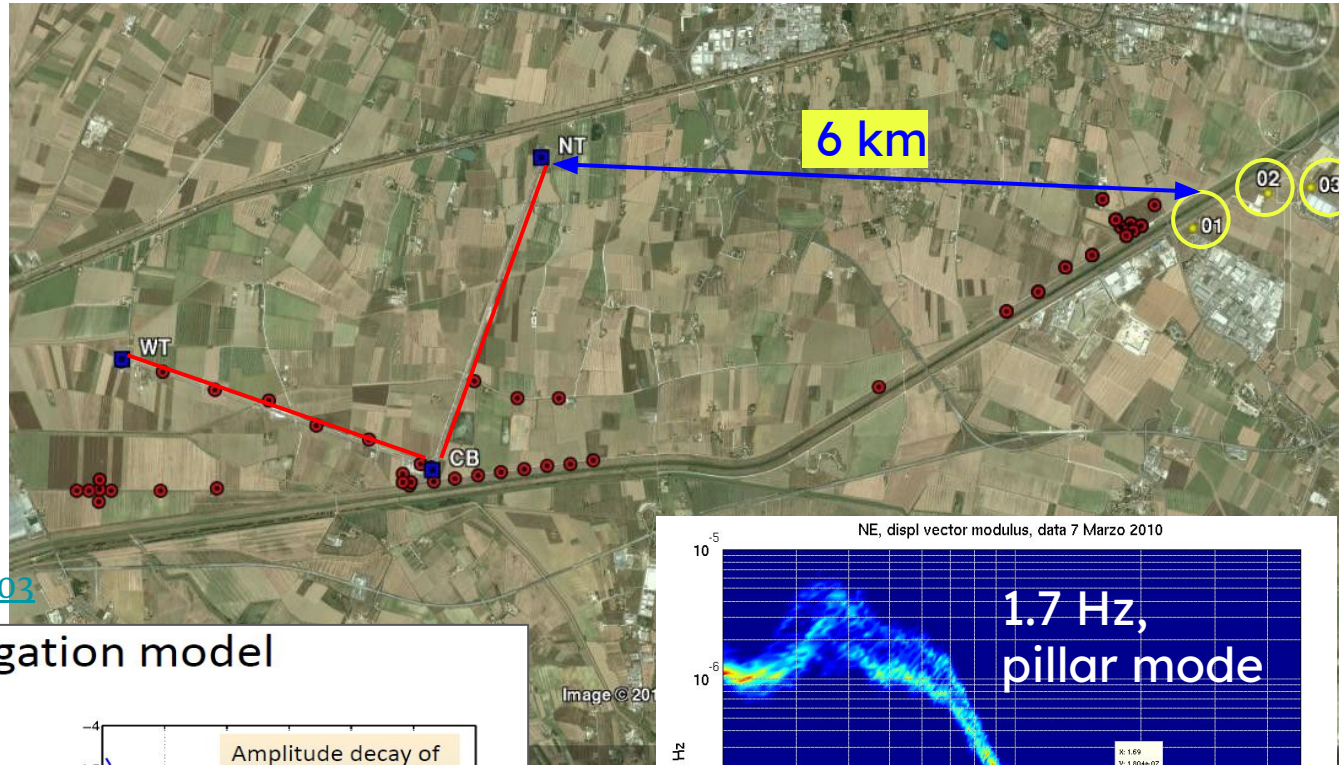
4 windmills at 6-10 km from Virgo

Issue if frequency matches suspensions modes.

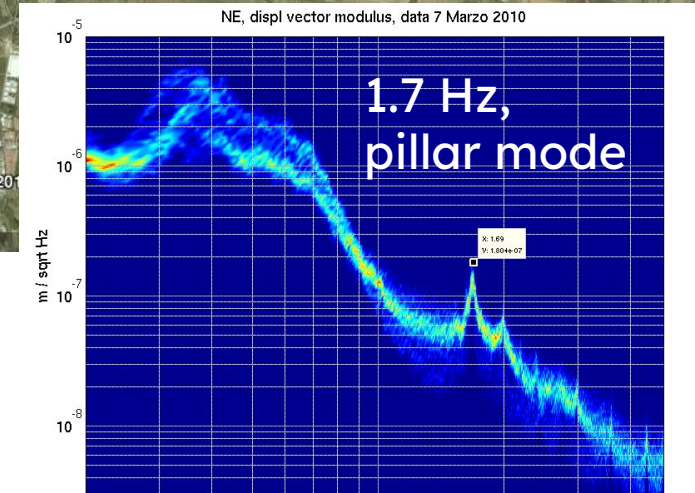
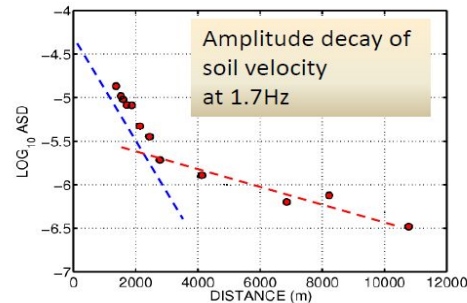
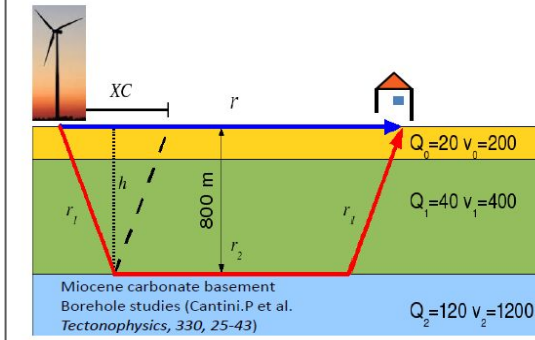
Propagation model includes reflections by deep soil layers.

G.Saccorotti et al. -

<https://doi.org/10.1785/0120100203>



## Seism propagation model



# Viaducts noise



- Seismic bursts at all Virgo vertices, peaking at  $\sim 2$  Hz. Reduced rate on weekends
- Correlated with seismic waves from eigen-mode oscillations of elevated roads (bridges) excited by heavy vehicles.

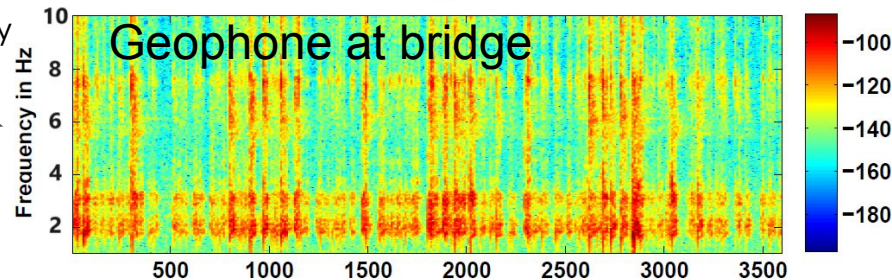
I. Fiori et al. <https://doi.org/10.1088/0264-9381/21/5/008> - preliminary

S. Koley et al. [10.1190/segam2017-17681951.1](https://doi.org/10.1190/segam2017-17681951.1), deep study

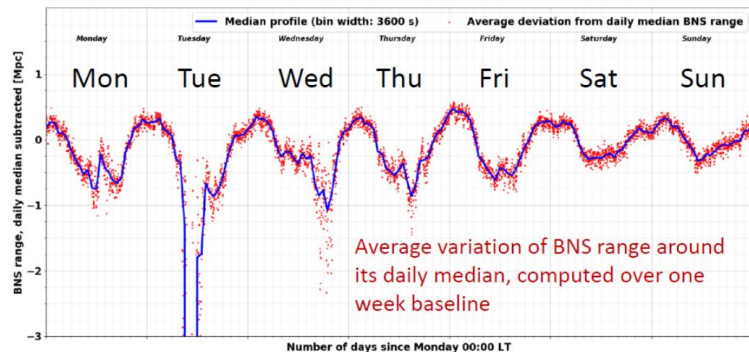
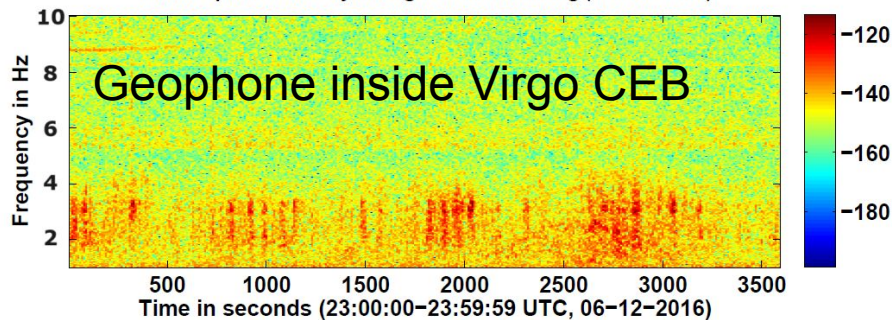
- Possible impact in O3

<https://doi.org/10.48550/arXiv.2203.04014>

Power Spectral Density in units of  $10\log_{10}((m/s)^2/Hz)$  at Bridge A1 (sensor # 61)



Power Spectral Density at Virgo Central Building (sensor # 108)



# Trains noise



See also F. Paoletti - ET XIII symposium Cagliari - [ET-0163A-23](#)

Sitewide magnetic transients, rate is approximately one per minute, less between 1:00 and 3:00 LT, and no difference on weekends.

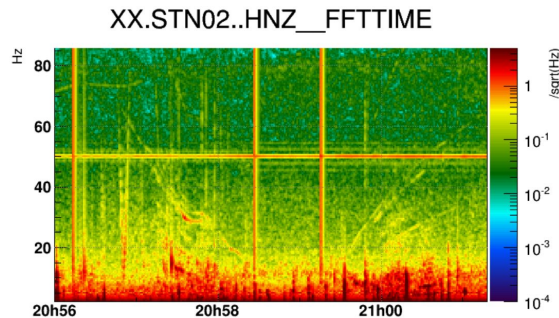
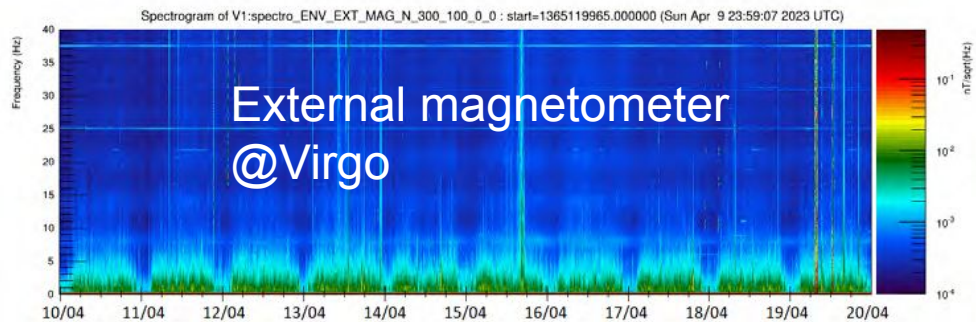
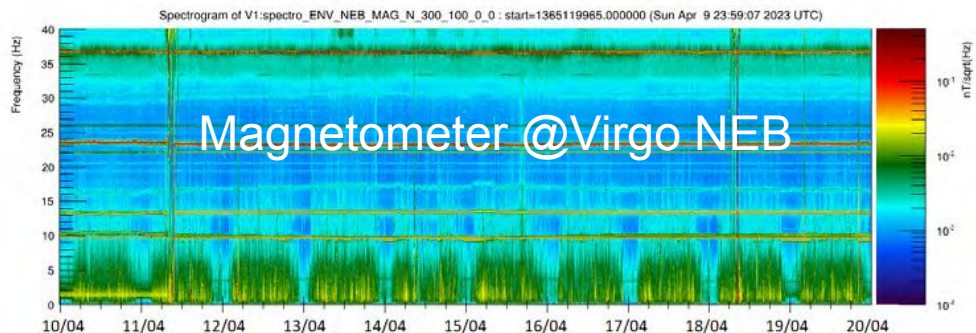
Intensity @Virgo is 10-100 pT, slightly more intense in the North Building. Range is DC to 20Hz.

Amplification close to arm tubes, consistent with a noisy current flowing in the tubes.

Two kind of glitches:

Fast transients (~1s)

Butterfly shaped



Magnetometer at Cascina station. “Rock “ train stopping and starting at Pontedera.



# Trains noise



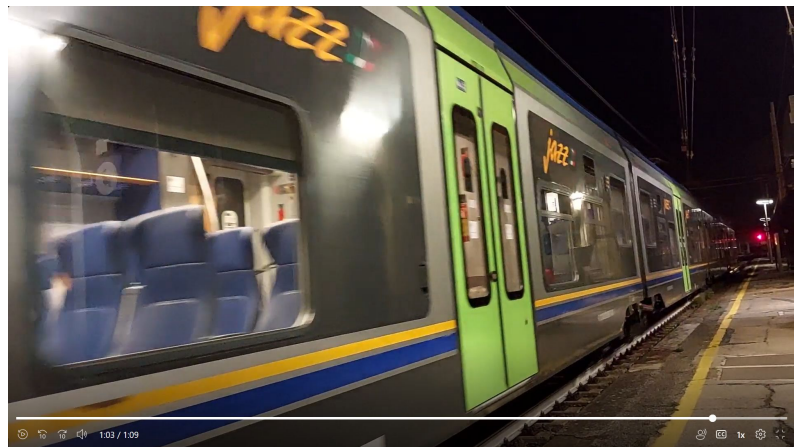
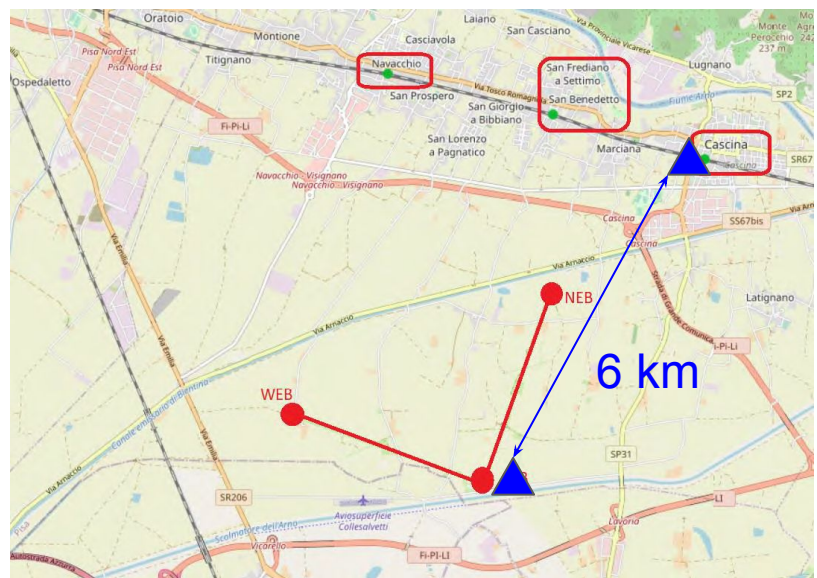
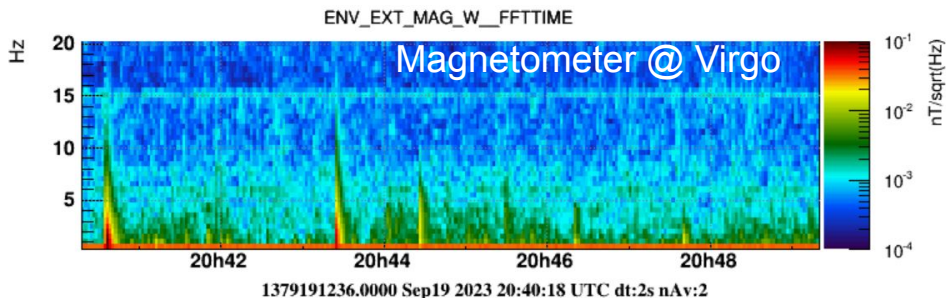
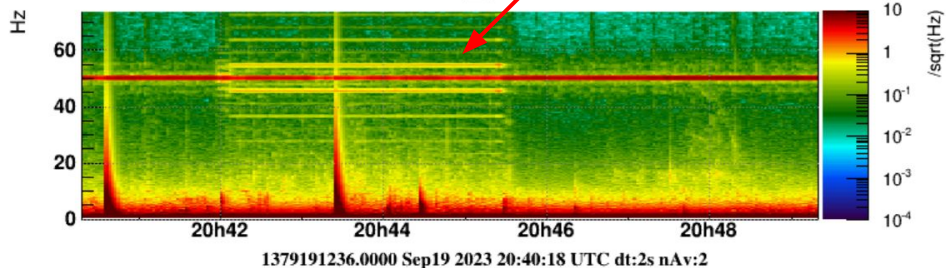
## Measurements at Cascina station.

Credits: Olivier Nauwelaers, Max Lalleman (Antwerpen U.)  
Plan further measurements on board the train.

Magnetometer @  
Cascina station

XX.STN02..HNX\_FFTTIME

BAcc signals, codified  
currents for automatic block



# Trains - how the noise is produced?

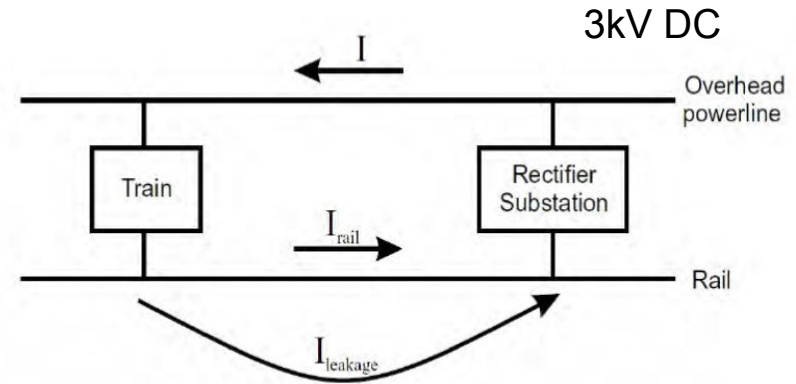
Noise from electrified railways is very well known disturbance for magnetotelluric measurements (Padua et al. <https://doi.org/10.1186/BF03353047>)

## Possible mechanisms:

- Large current ( $\sim 1\text{kA}$ ) flow in the loop between the overhead power line and the rail
- Current leakage propagates through soil  $\gg$  magnetic field
- Also, induction from the current loop.
- How deep in the ground?

**Fast glitches** - when trains are crossing powering substations (every  $\sim 20$  km) or when pantographs have bad contact with the overhead powerline (sparks)

**Butterfly shaped patterns** - due to variable power surging by the engine when the train accelerates or decelerates.



# Airplanes



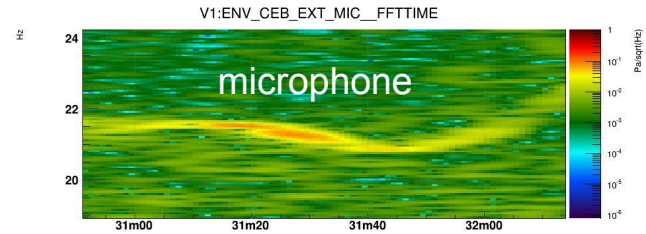
Large soil vibrations from pressure waves, typical range 10-100Hz, triggers scattered light processes in the interferometer.

## How we acted:

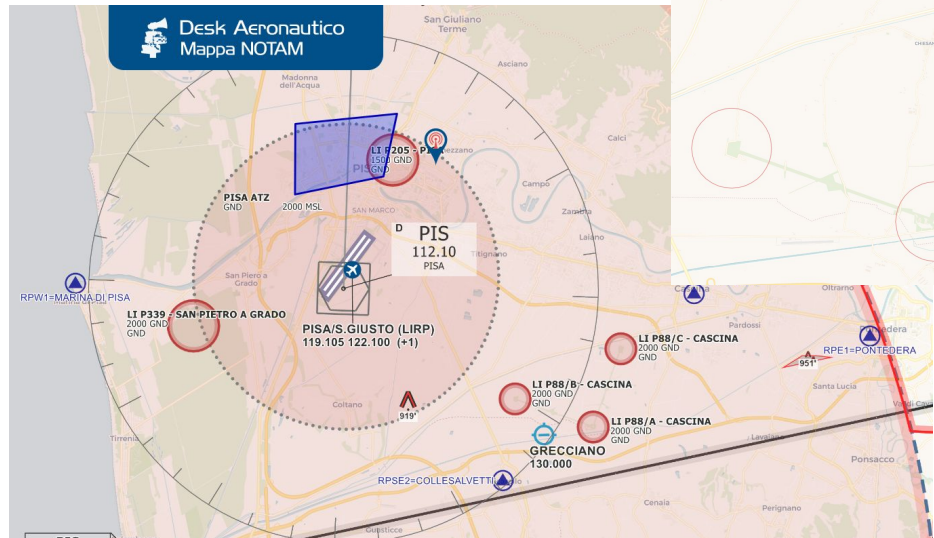
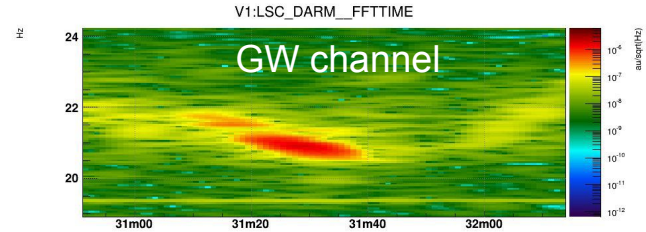
(credits Valerio Boschi)

Aeronautica Militare is the counterpart for this matters.

We performed fly-over tests (65th Air Brigade) and set NOTAM (no-fly zones) over Virgo Buildings. **Enforced since 2019.**



1230888669.0000 : Jan 7 2019 09:30:51 UTC dt:20.00s



# Preserving the site noise

Something we did not think about from the very beginning. The issue was triggered by the wind farm noise study and additional proposed wind farm projects.

In 2006 EGO set an agreement with the local authorities (Provincia di Pisa, *Ufficio Ambiente*).

We proposed an “[Annex to the Piano Territoriale di Coordinamento](#)” (its content is described in the next slide). This was accepted and has been part of PTC since 2006.

In 2011 we proposed an amendment which was received but never integrated (the process stopped because it was no further pursued also by EGO side).

*Credits Francesco Fidecaro.*

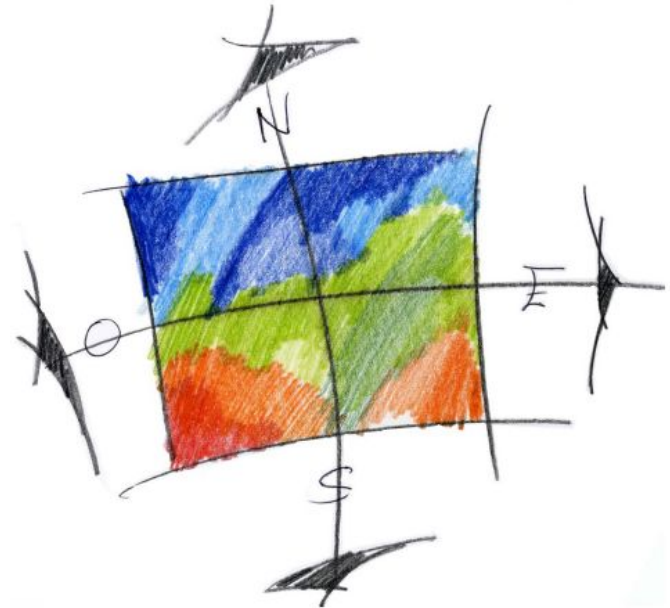


Provincia di Pisa

## Piano Territoriale di Coordinamento

Approvato con Deliberazione di Consiglio Provinciale n. 100 del 27/07/2006

**Limiti di compatibilità con il funzionamento dell'antenna interferometrica Virgo. L'inquinamento dell'ambiente da vibrazioni, rumore acustico e campi elettromagnetici**



# PCT annex - “Limits of compatibility with the operation of the Virgo interferometric antenna”

Define the **type of noises** of relevance for Virgo:

- Random noise, periodic sources (pure tones), impulsive sources

Provide **reference spectra** for Seismic, Sounds, Electro-Magnetic, Electric power (based on 90th percentile values)

Define **limits on noise produced at Virgo** (not too stringent, but safe for us):

- Simple rules: i.e. “noise with source on must not exceed  $\frac{1}{3}$  of noise with source off”
- Penalty for periodic sources
- Transients: limit on peak value evaluated over 1s with 20 kHz sampling
- Acoustic: for high frequency (> 100Hz) rely upon acoustic classification (presently Class III, to be made more stringent)

Define the **size of the protected area**

List **critical frequencies**

**It was meant to be a first step, to be subsequently improved.**

**Main objective was to add Virgo among the necessary evaluation steps to get build authorization**

# Preserving the site noise

<https://www.provincia.pisa.it/argomenti/ptc/approvazione-definitiva-2022/ptc-vigente>

In compliance with this agreement:

- Any proponent of a noisy activity potentially critical for Virgo (as described in the Annex) is asked to contact EGO
- EGO evaluates the noise impact of the project:
  - meet the proponents to get specific information
  - perform measurements on similar installation (usually agreed with the proponents)
  - projections using noise propagation models to the site and possible couplings to the ITF
- Eventually, EGO gives a response to the “Ufficio Ambiente” about the feasibility of the project or possible concerns.

**13.1.5** Il Comune di Cascina ed i Comuni limitrofi in relazione alle attività presenti e da sviluppare nell'area di ricerca, d'importanza internazionale, dell'antenna interferometrica “VIRGO”, in località S. Stefano in Macerata (Cascina), dovranno vietare l'insediamento, la realizzazione, il funzionamento, la trasformazione e l'effettuazione di attività, impianti ed attrezzature che possano modificare i valori di campo magnetico ed elettrico, sismico ed acustico attualmente rilevati, attorno ai laboratori, superando i valori massimi ammissibili come definiti nel Doc.P 7 e successive elaborazioni in relazione alle diverse tipologie di sorgenti, (continue, impulsive, periodiche), pertanto, i Comuni, sulla base di analisi di studio specifiche firseranno rispettivamente nei loro Piani Strutturale la distanza minima di rispetto dall'area di ricerca, al fine di tutelare l'area da possibili interferenze.

### **68.2.3 Eolico**

**68.2.3.1** Gli impianti di produzione di energia elettrica mediante lo sfruttamento del vento possono essere ubicati anche in zone classificate agricole dai vigenti Piani Urbanistici fatte salve le aree agricole prossime all'area di ricerca scientifica Virgo, in località S. Stefano a Macerata in Comune di Cascina, per un intorno adeguato, previsto dalle prescrizioni contenute all'art 13.1.5

# Preserving the site noise

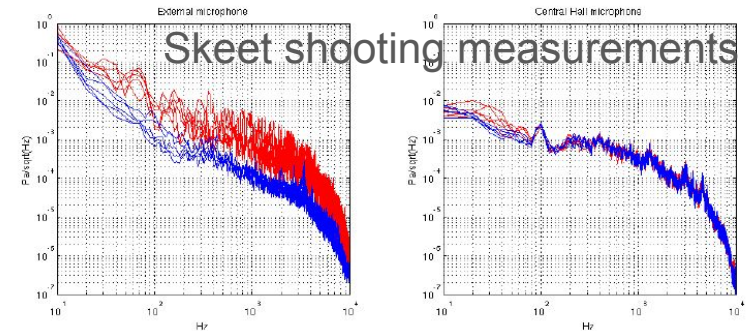
Since 2006, 9 projects have been evaluated

- 1 speedway
- 1 enlargement of the existing wind park
- 1 new wind park
- 1 earth quarry
- 1 trash compactor
- 1 skeet shooting plant
- 1 shooting plant
- 2 photovoltaic plants

Evaluation was done with the help of noise propagation models or by performing measurements on similar installations

Most projects turned out to be not critical

Some projects (1 speedway and 2 wind parks) were dismissed because of other reasons.



# Conclusions

Anthropogenic sources, like wind farms, road traffic and trains contribute to the Virgo site environmental noise up to 10-20 Hz.

Observed magnetic transients from trains can be associated to telluric currents in the ground. This noise is potentially relevant for ET and must be evaluated at the candidate sites.

In order to preserve the noise levels at the site, EGO defined agreements with the authorities in charge, like the Air Force and the Provincia di Pisa.

Proposed projects so far have been evaluated by EGO based on noise models and measurements on similar plants.

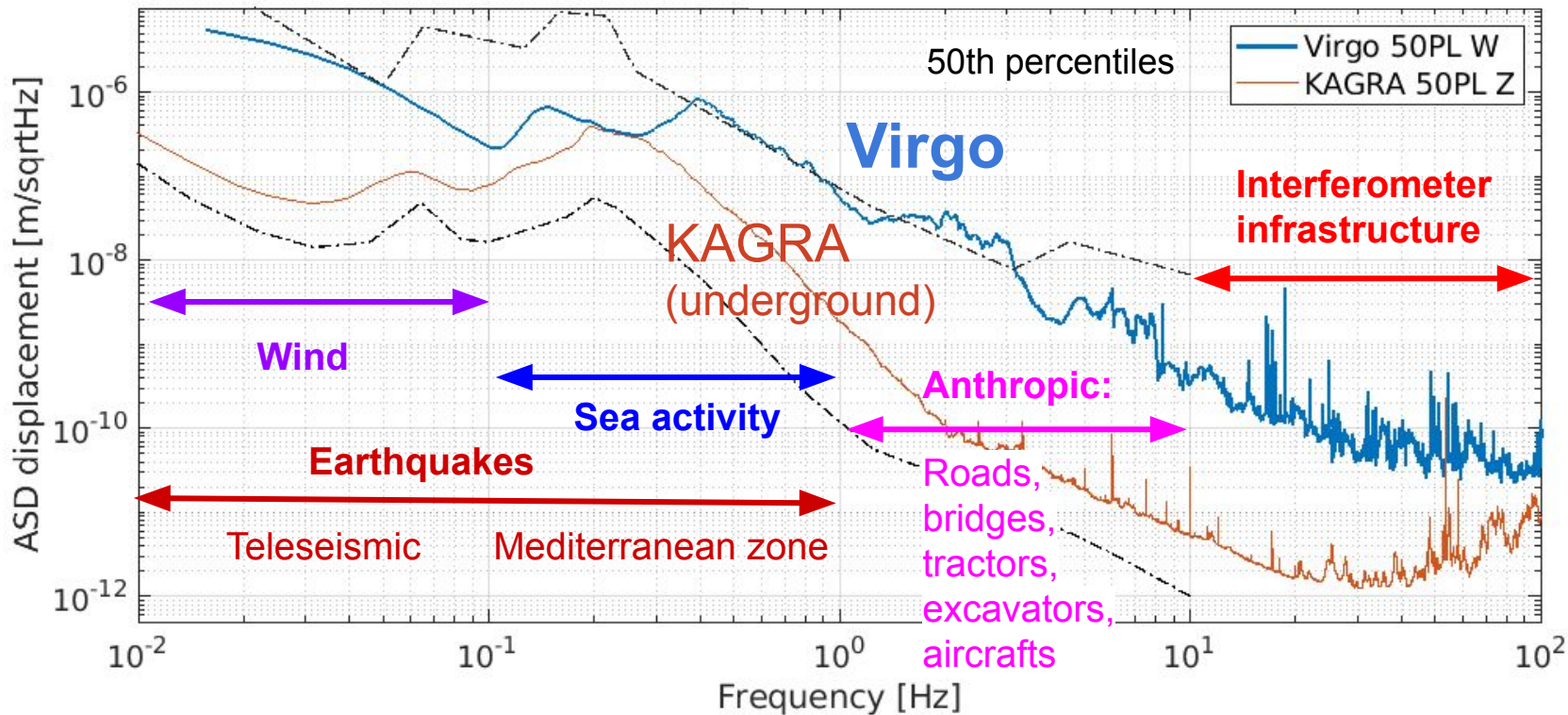
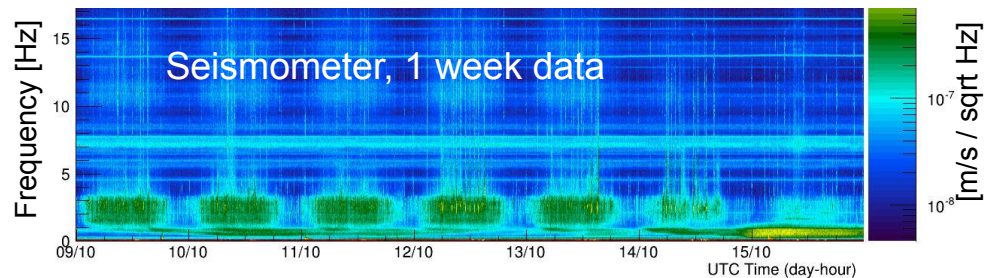
Establishing reliable models for predicting the noise decay at a distance from the sources is crucial for this evaluation and for the definition of respect zones.

*Thank you for your attention*



Spare slides

# Seismic sources



# Magnetic sources

