AHEAD 2020

EGO European Gravitational Observatory

Influences of environmental noise in the Virgo detector

Irene Fiori

AHEAD2020 Workshop on the Synergies between Astroparticle and Geoscience

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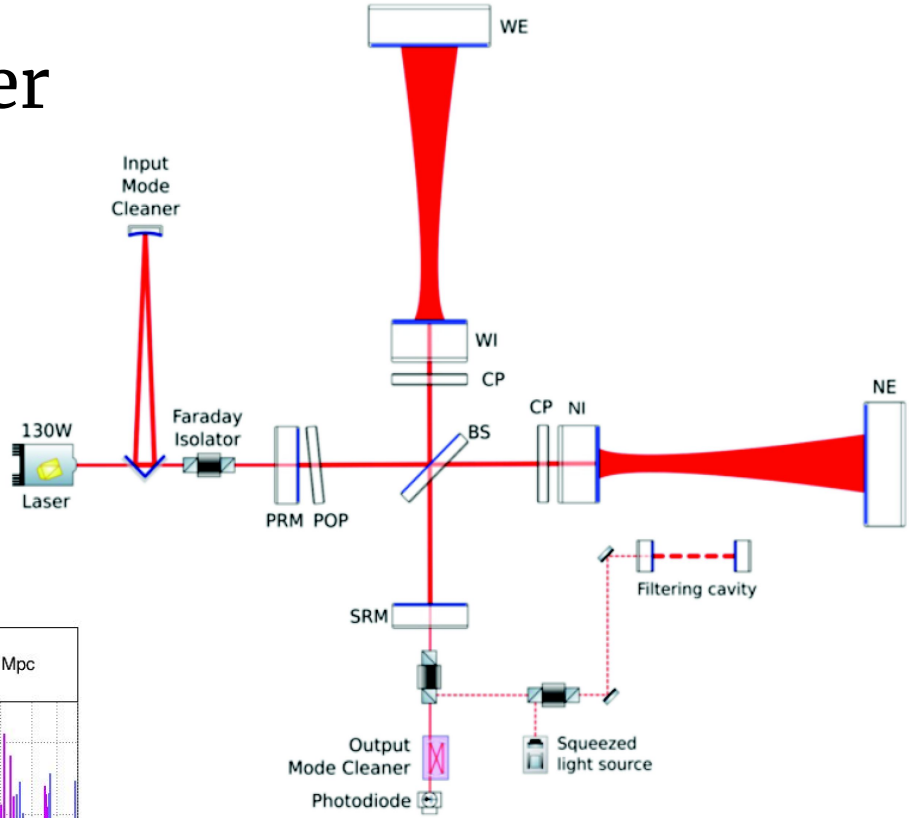
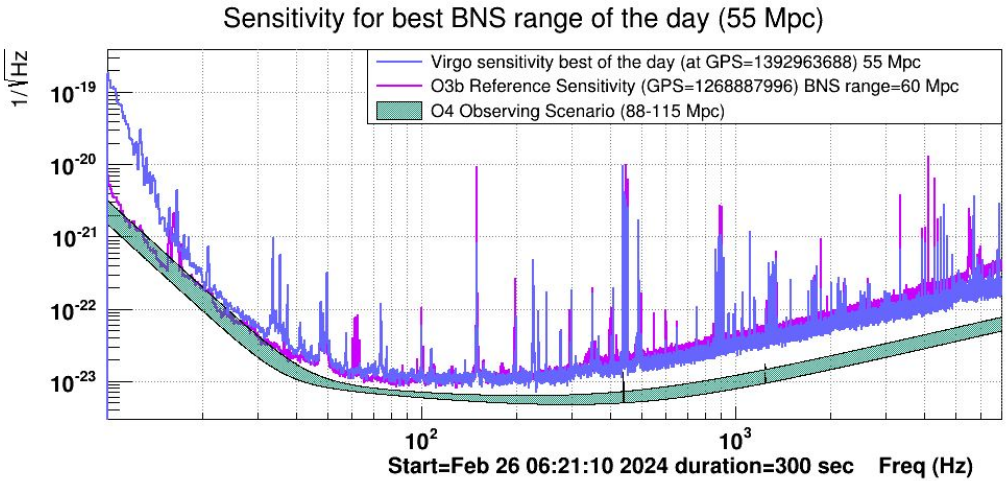
North End building (NEB)
West End building (WEB)
You are here
Central building (CEB)
EGO@PHOTO

The Virgo GW interferometer

- 3 km arms
- 10-10000 Hz range
- 7000 m^3 Ultra High Vacuum system
- Seismic attenuation of Test Masses, 10^{12} from a few Hz
- Absorbing baffles to catch Stray light beams





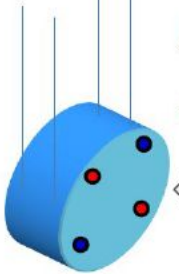
Environmental influences

Magnetic fields

Force on magnetic actuators

$$\vec{F} = \vec{\mu} \cdot \nabla \vec{B}$$

$$\vec{\tau} = \vec{\mu} \times \vec{B}$$



Radio waves (6MHz, 8MHz, 56MHz)

Couple with RF laser modulation used for angular and longitudinal controls

Super-Attenuator suspension

Slow ground motion

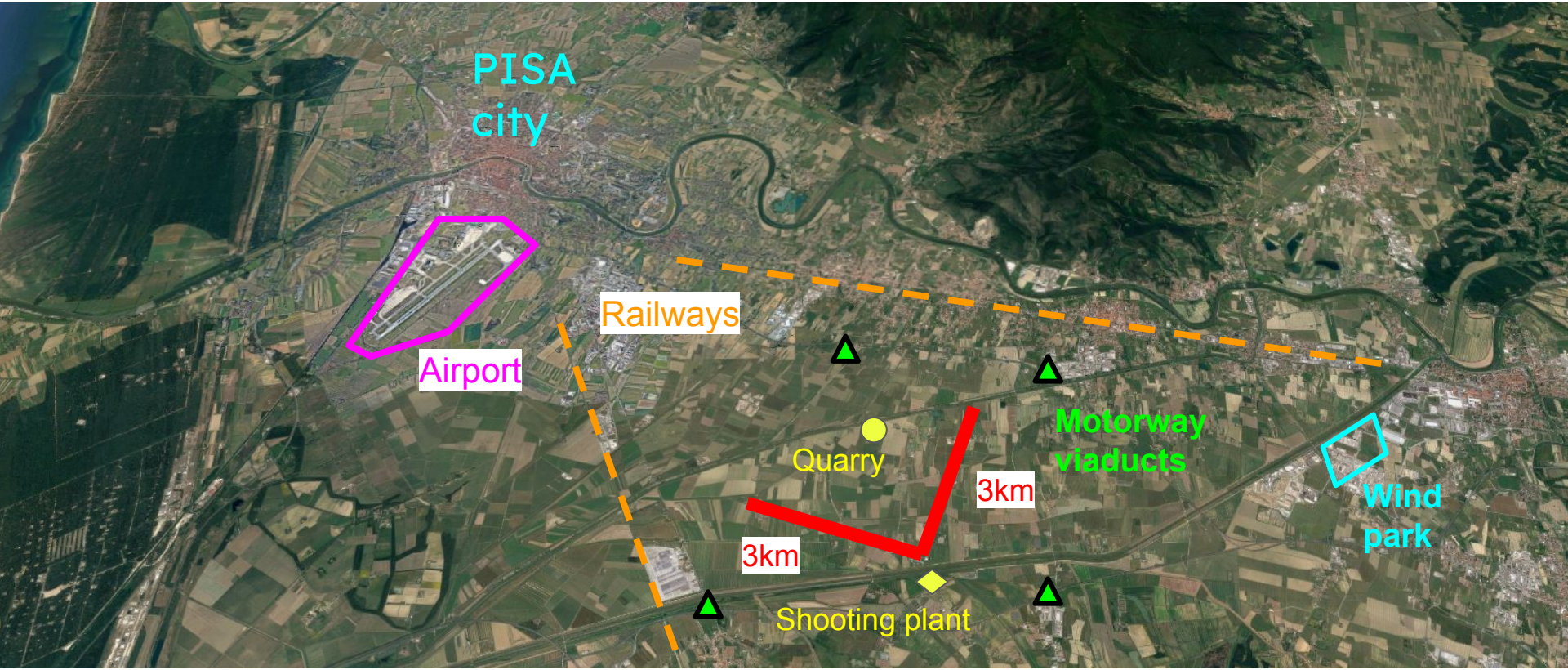
Excite mechanical modes of mirrors and optical benches suspensions

Sounds and Vibrations

Imprint phase noise on scattered light beams

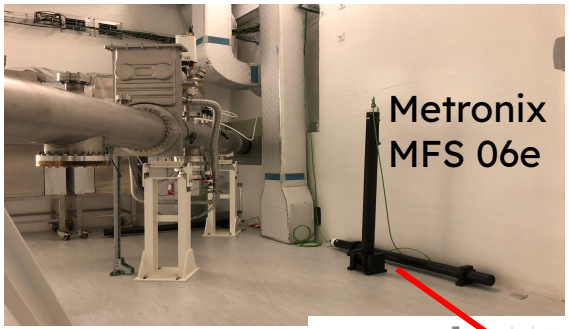
Excite vibrations of vacuum chambers, in-air optical benches

The Virgo environment

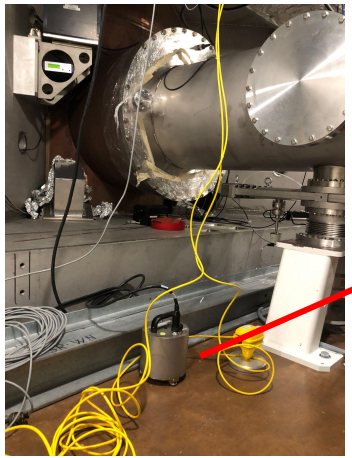


Environmental monitors

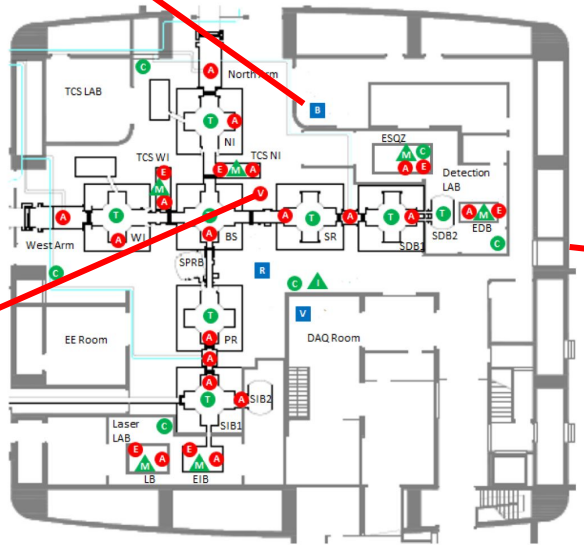
Several (~250) fast probes inside Virgo buildings

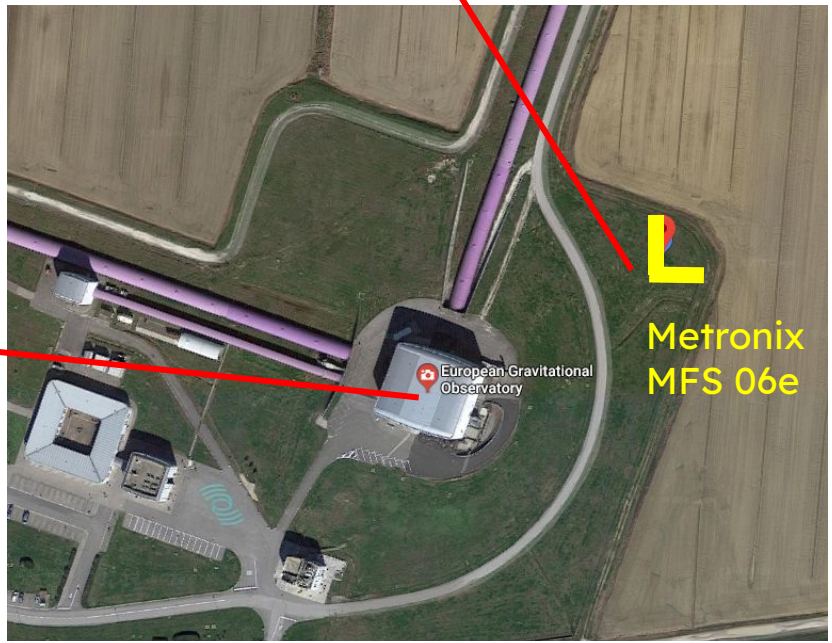


Central Building

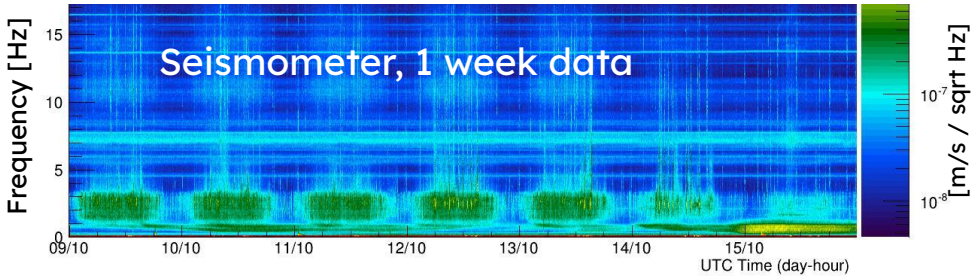


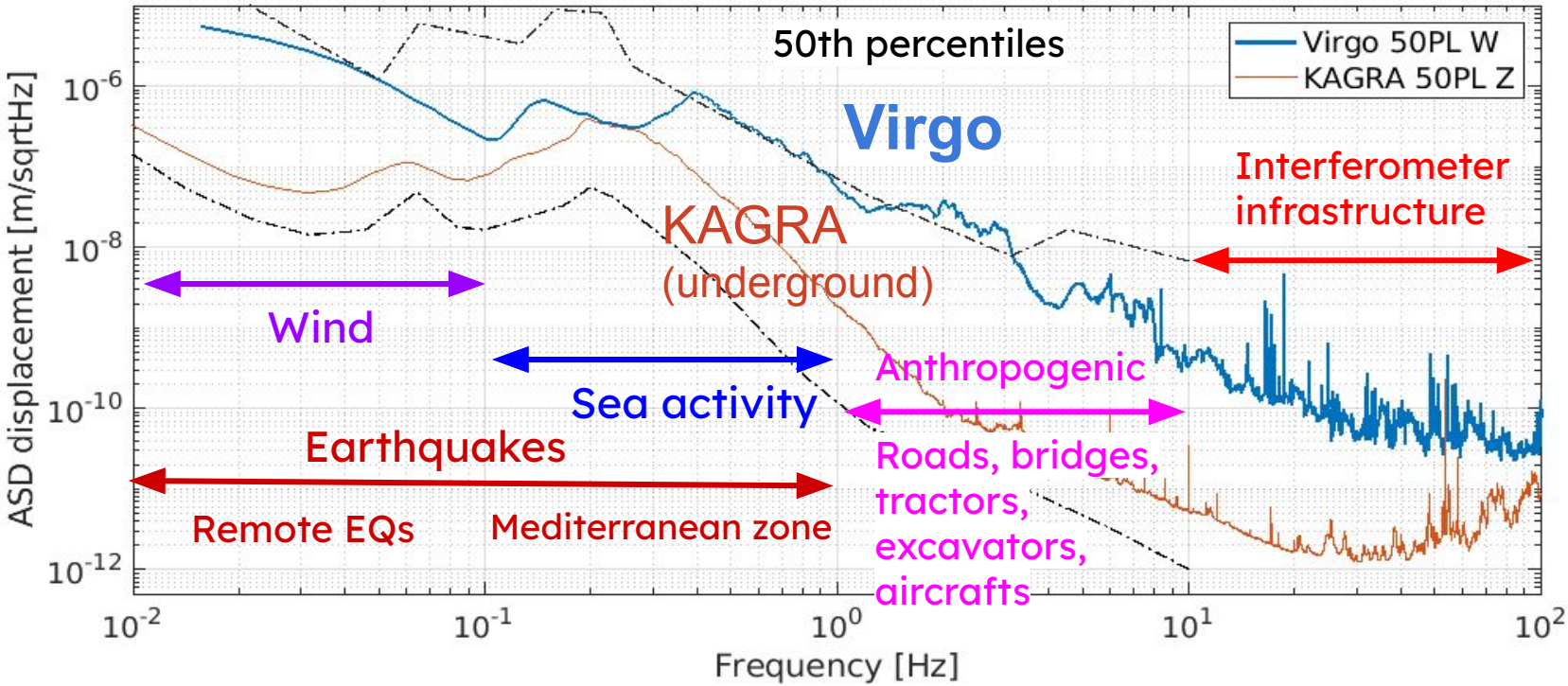
Guralp 40T-60s



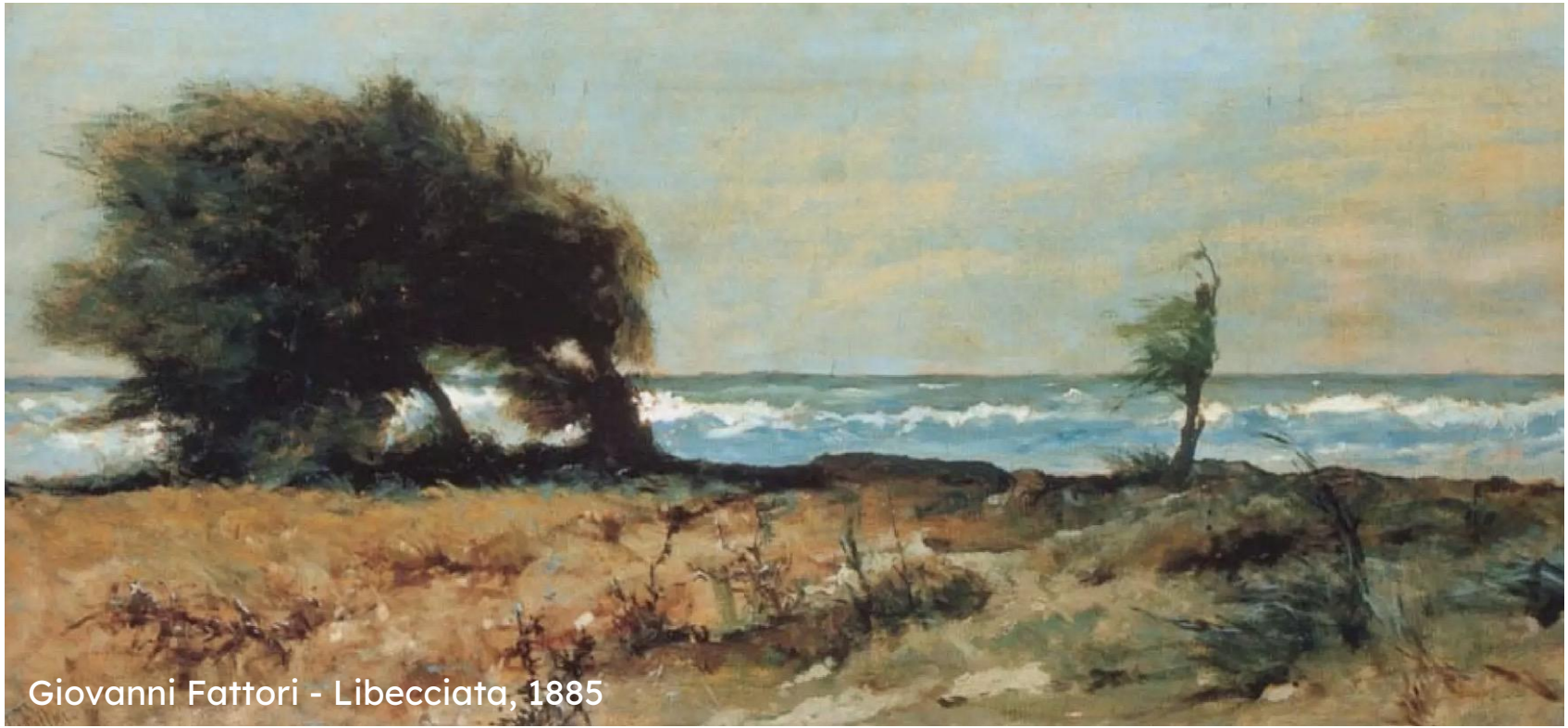


Virgo seismic sources





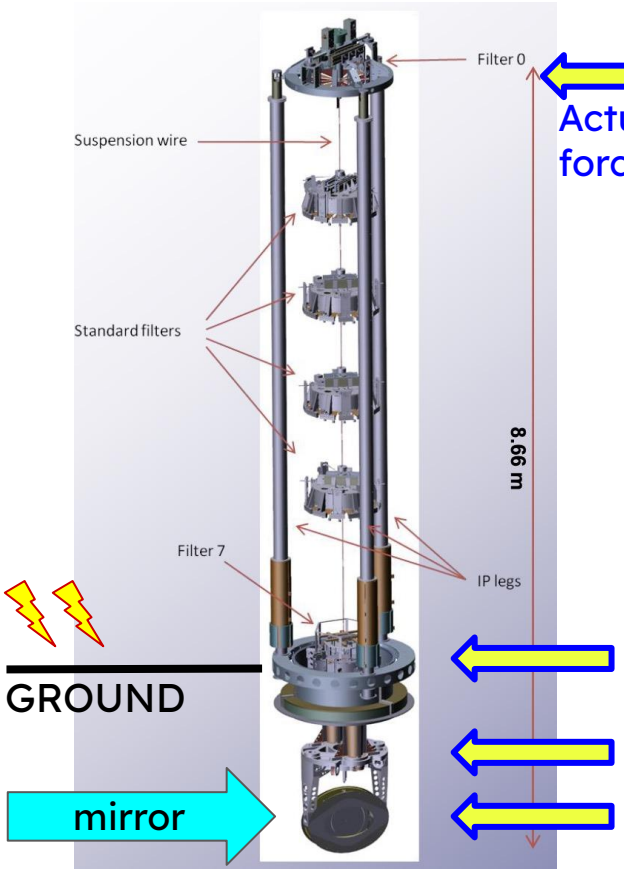
Sea, Earthquakes and Wind



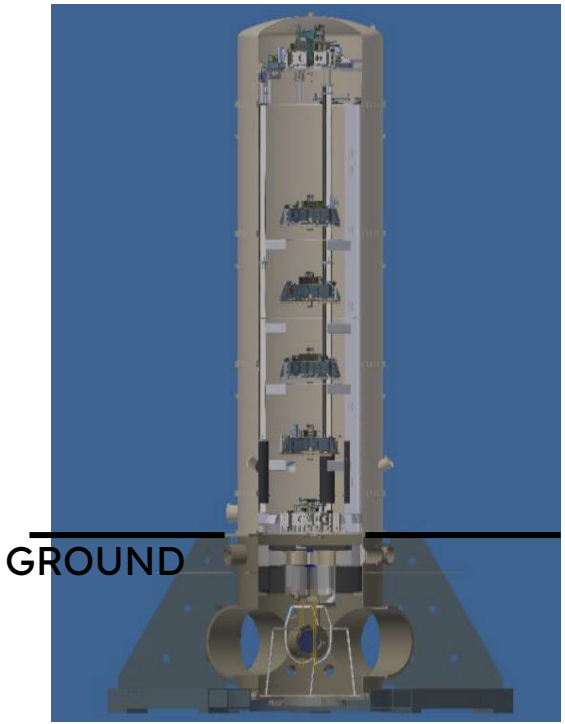
Giovanni Fattori - Libecciata, 1885

SuperAttenuators

- One pre-isolation stage (inverted pendulum, 3 legs, 30mHz) and chain of 5 stage pendula
- Attenuation factor of 10^{12} from a few Hz
- Actively controlled



Actuation force



Robustness:

[V.Boschi, P.Ruggi, E.Majorana - GWADW 2016]

- **Sea activity**

Global Inverted Pendulum Control (GIPC) technique allows to keep the control even for very strong micro-seismic activity

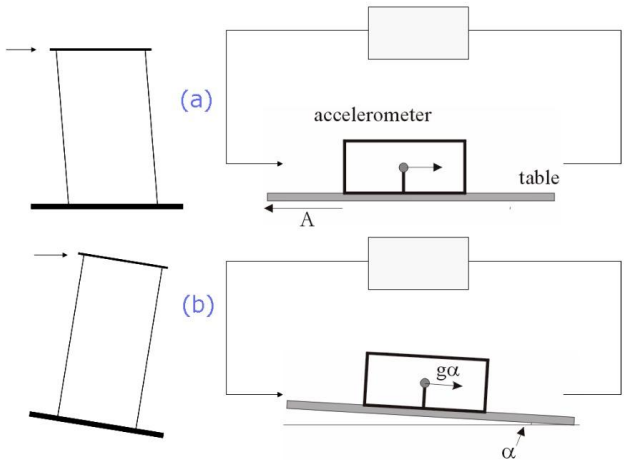
- **Earthquakes**

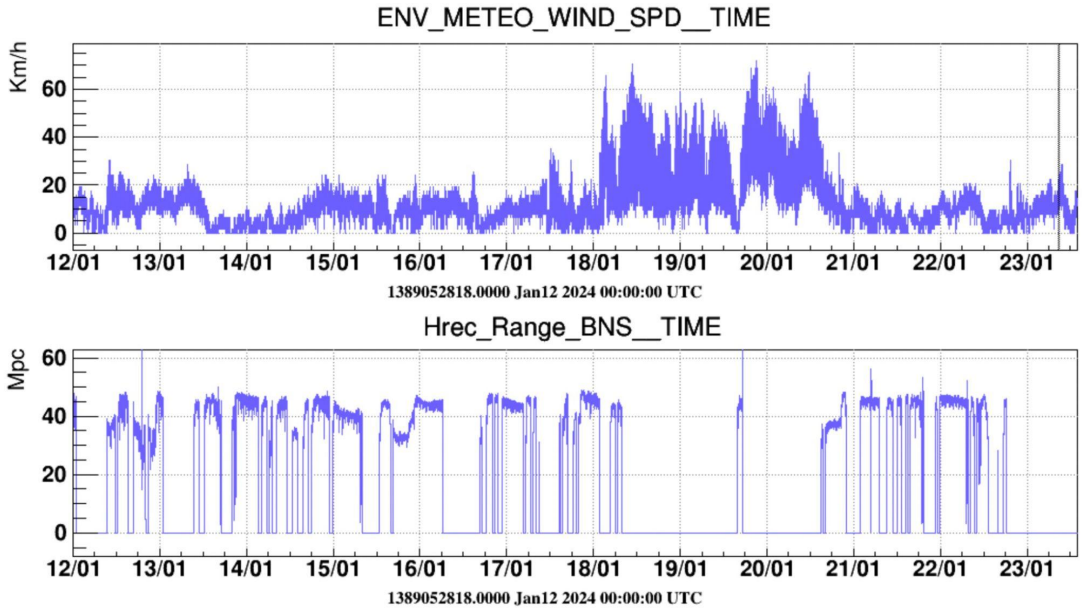
Control strategy (GIPC and reallocation of force to marionette stage) allow to survive distant EQ up to Magnitudo 6.5. ***Seismon*** alert

- **Wind (!)**

Low duty cycle in windy days!

Wind → Tilt of the ground below ~100 mHz: accelerometer sensors on SA top stage wrongly interpret it as acceleration and fail to apply the right correction





G.Losurdo D.Passuello P.Ruggi - VIR-NOT-FIR-1390-318

Wind noise - solutions?

Add tilt sensors to SA control:

- Extremely accurate tiltmeter needed ~nrad/√Hz @ 10mHz
- Beam-balance tiltmeter - A.Allocca VIR-0957A-20, https://publications.cnr.it/doc/461738

LIGO solution: wind fence (LIGO-E1800261)

LIGO-Hanford

LIGO wind fence efficiency

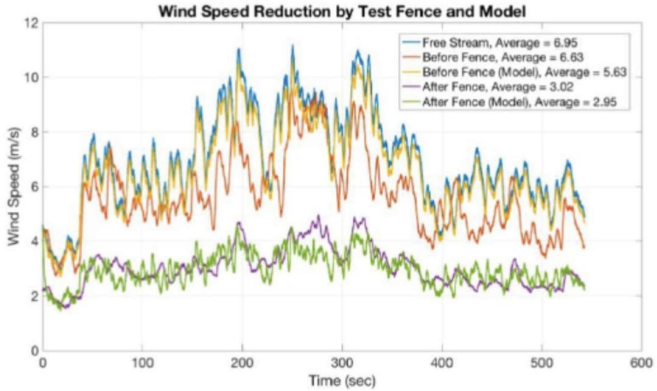


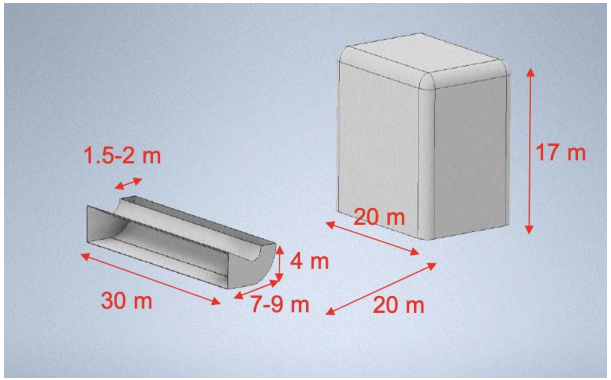
Figure 22: Comparison between CFD Model and Prototype Wind Fence (Time Series)

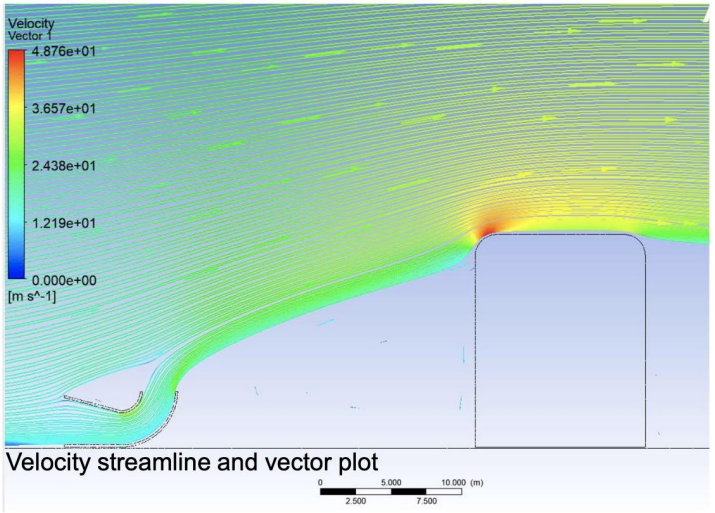
A wind shield for Virgo - a conceptual design

R.Passaquieti
VIR-0429A-22

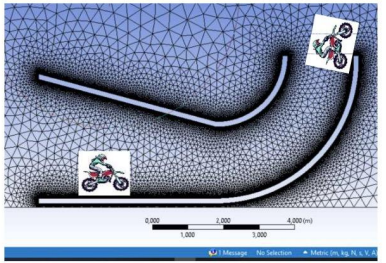
The first Quiet CFD result !

- The CFD 3D model and 2D meshing (96875 nodes)
- The flow of wind definitely climbs to the top of the building !!!



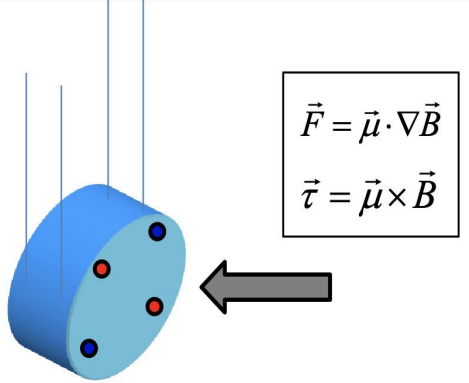


Velocity streamline and vector plot



Magnetic noise

Magnetic couplings



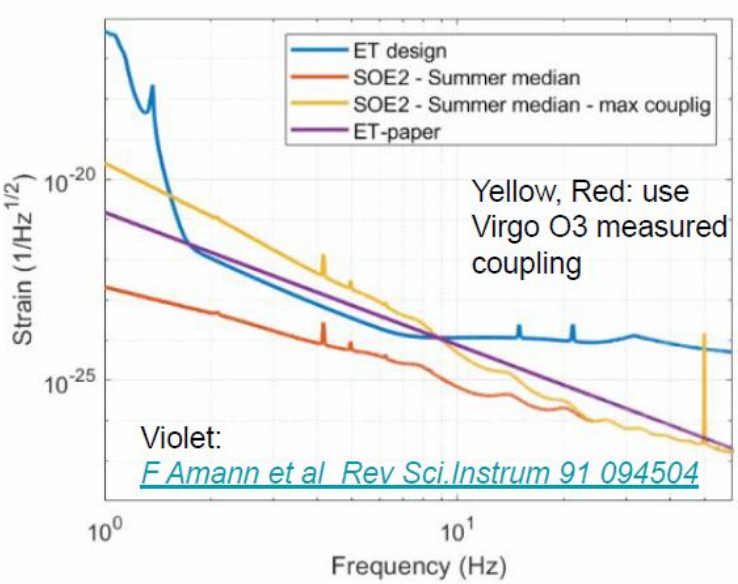
Force on magnetic components in Virgo:

- Magnet actuators on mirror test masses, and along SuperAttenuators
- Faraday isolators (~1T permanent magnet) placed on suspended optical benches

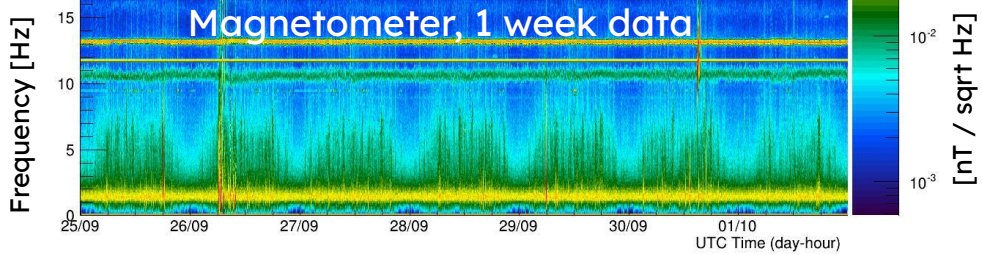
Critical for the Einstein Telescope

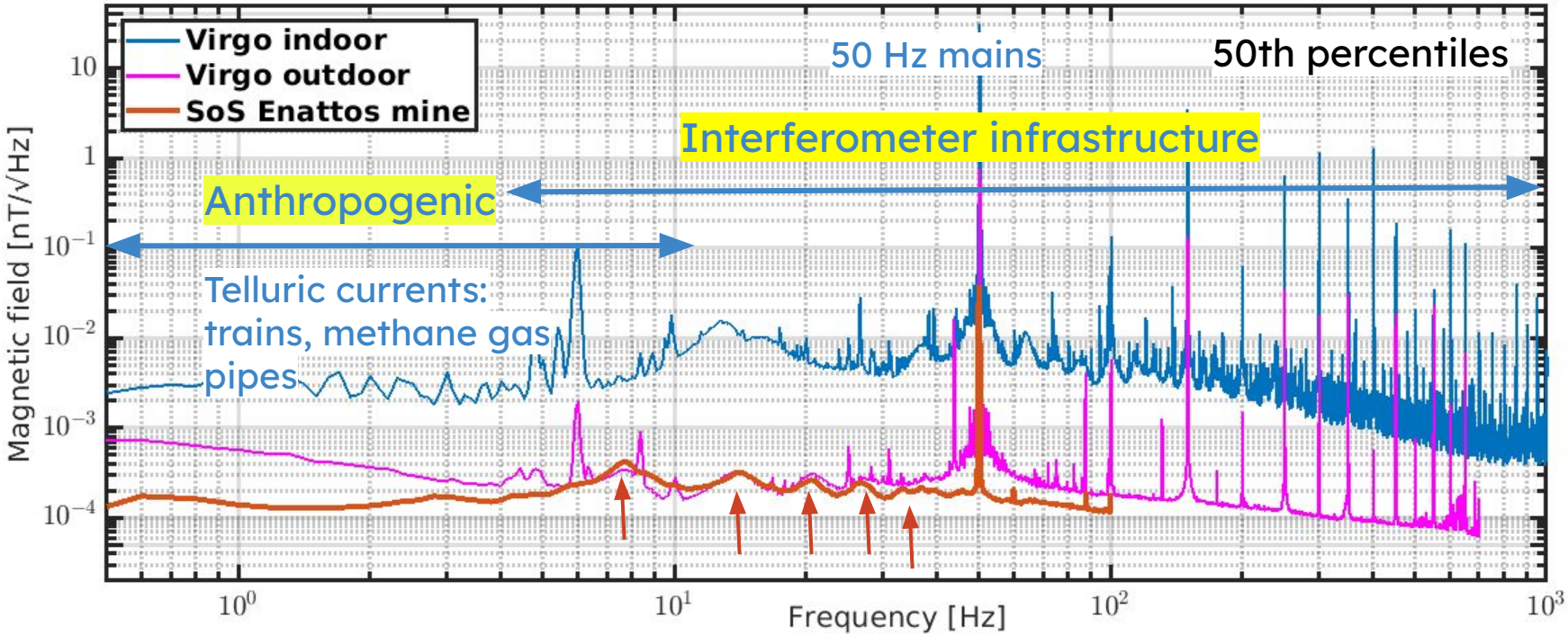
Careful characterization of candidate sites is needed:

- Measure magnetic properties of soil
- Identify anthropogenic sources



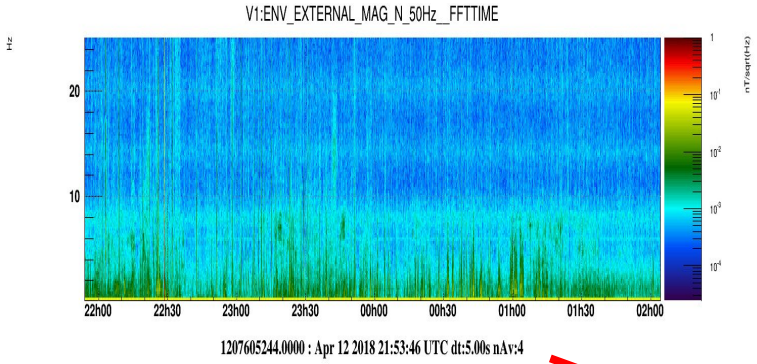
Virgo magnetic sources

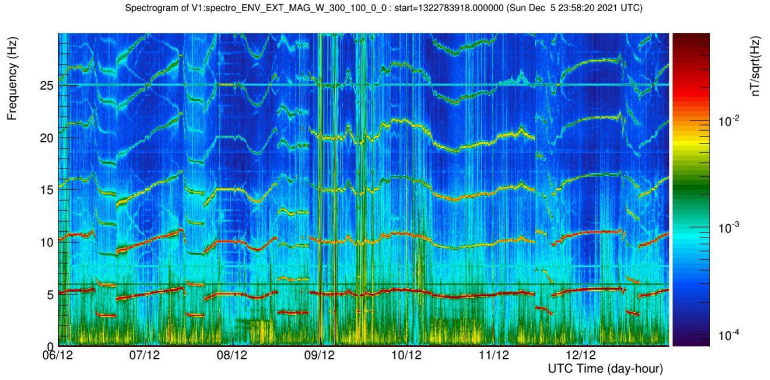


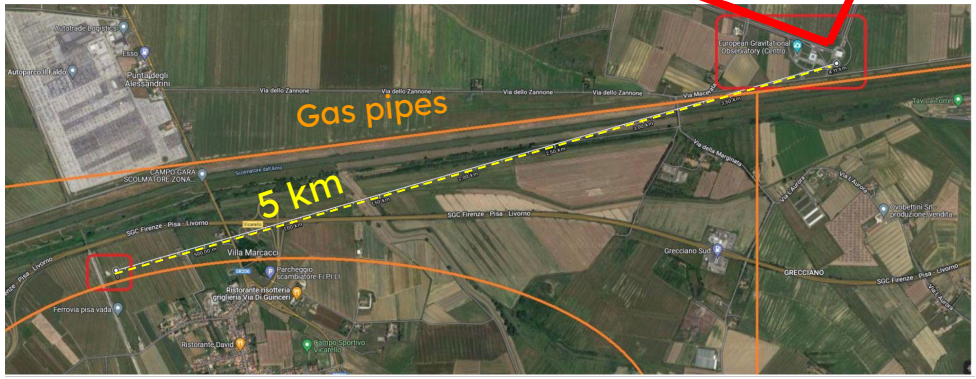


Magnetic noise from methane gas pipes at Virgo

External magnetometers:







Similar magnetic field (much magnified) is found radiated by Virgo arms vacuum pipes

Investigation tracked this noise to the PWM power generator of galvanic (anti-corrosion) currents into the methane gas pipes surrounding the site

Working hypothesis - Telluric currents flow in the soil and also into Virgo arms vacuum pipes

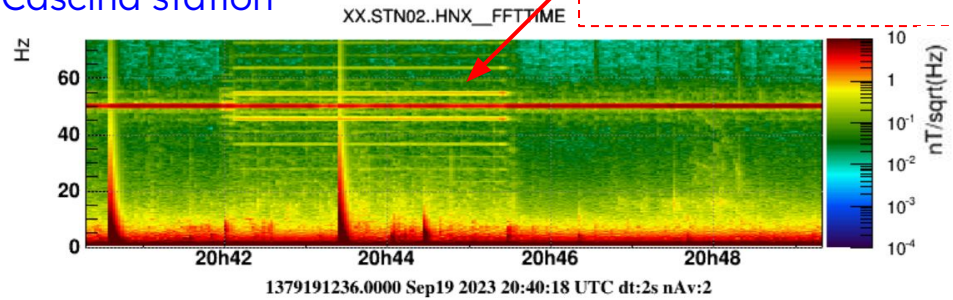
Trains noise

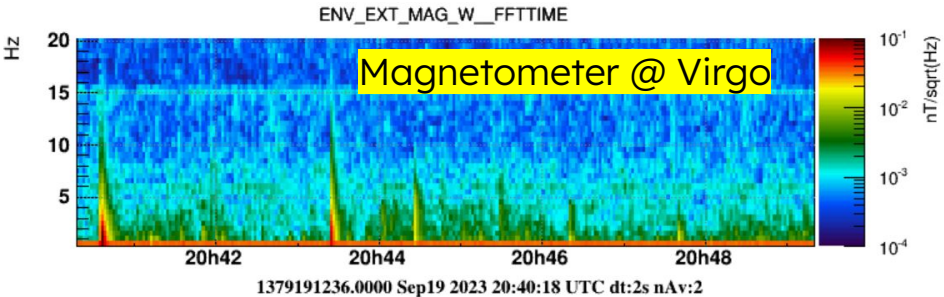
Observed magnetic transients site-wide

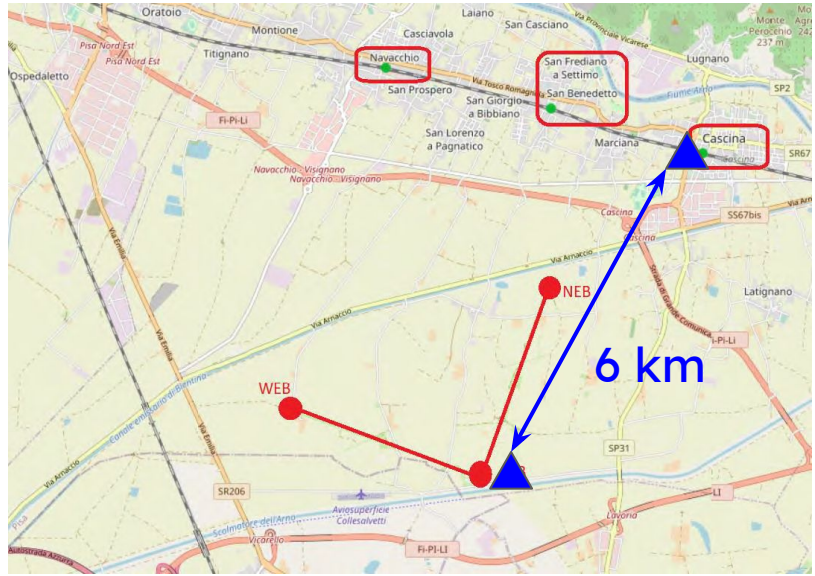
Investigation tracked it to railway lines, at about 2 km from Virgo site.

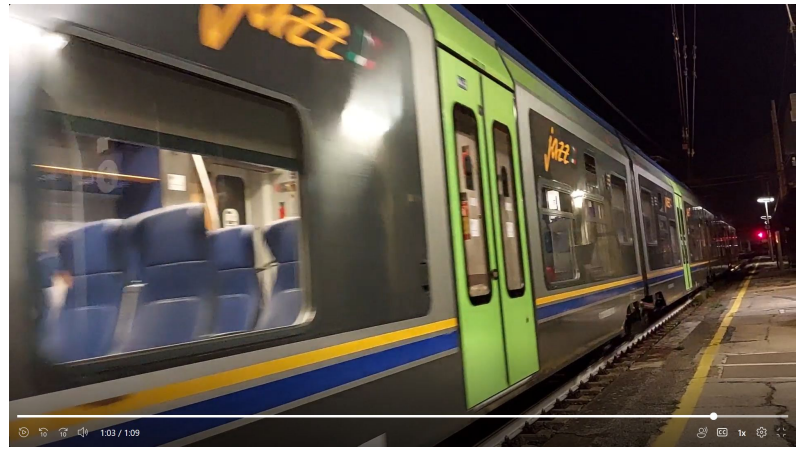
Magnetometer @ Cascina station

BAcc signals, codified currents for automatic block



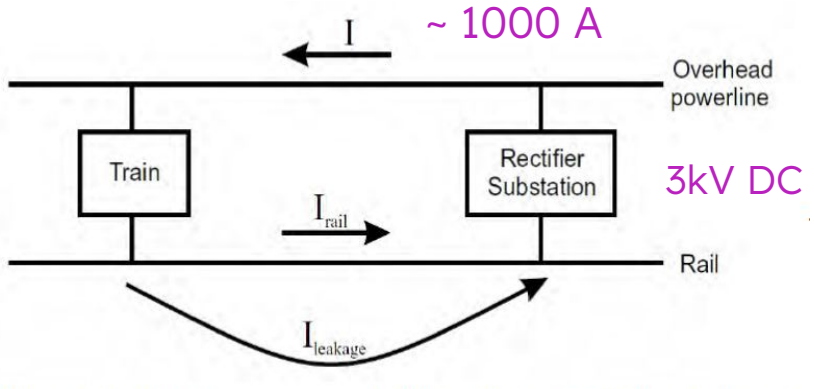






Trains noise - how is it produced?

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 (~1kA) flow in the loop between the overhead power line and the rail
- Current leakage propagates through the soil and radiates magnetic fields
- Also, induction from the current loop (... but fast decay with distance)
- How deep in the ground? Crucial issue for future underground laboratories, like the Einstein Telescope.

Fast glitches - when trains are crossing powering substations (every ~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.

Final remarks

- Natural and anthropogenic noises have some impact on Virgo sensitivity and duty cycle
- Noises from the detector site infrastructure (not in this talk) play a major role !!
- Experience with Virgo and present GW detectors provides important lessons for the future detectors sites