

# Environmental noise studies

Irene Fiori, Federico Paoletti, Roberto Passaquieti, Maria C.Tringali

**Swedish Academy Physics Class visit**  
European Gravitational Observatory - June 15 2022

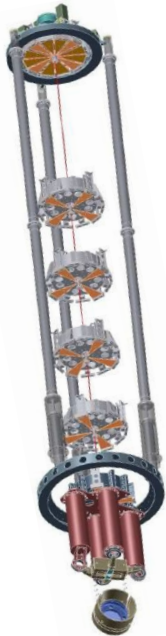
Contact:  
[irene.fiori@ego-gw.it](mailto:irene.fiori@ego-gw.it)

# Environmental influences

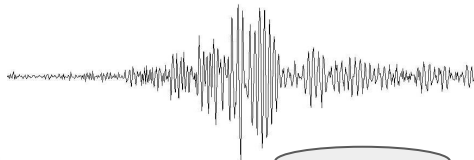
Radio waves  
(6MHz, 8MHz, 56MHz)



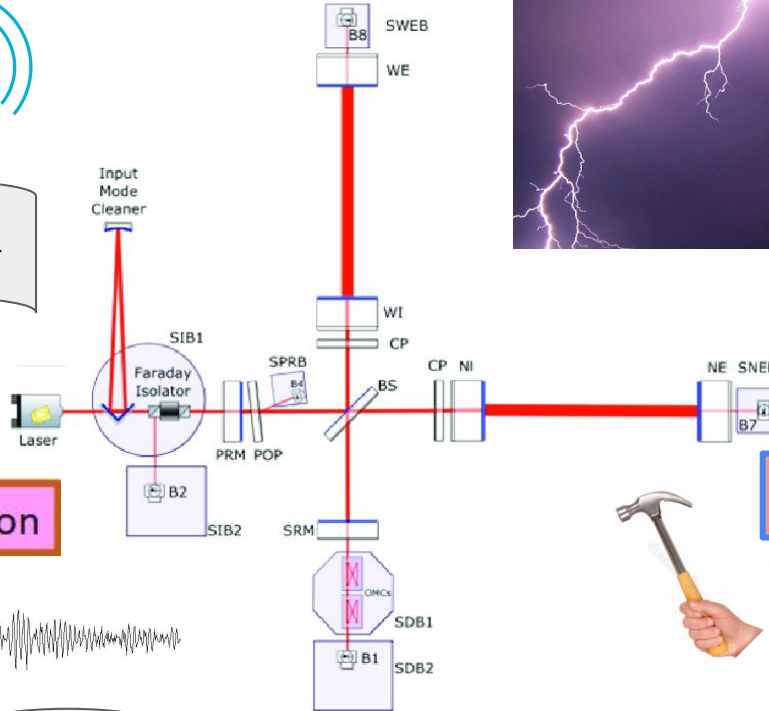
Couple with RF laser modulation used for angular and longitudinal controls



Slow ground motion



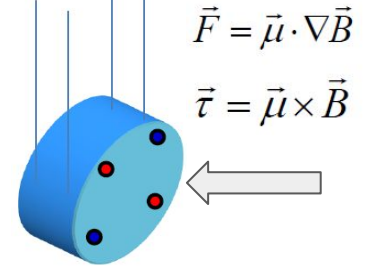
Excite mechanical modes of mirrors and optical benches suspensions



Magnetic fields



Force on magnetic actuators



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

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

Sounds and Vibrations



Imprint phase noise on scattered light beams

Excite vibrations of vacuum chambers, in-air optical benches

# The EGO environmental team

Monitor and characterize the noisy environment

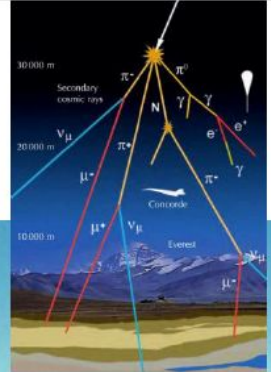
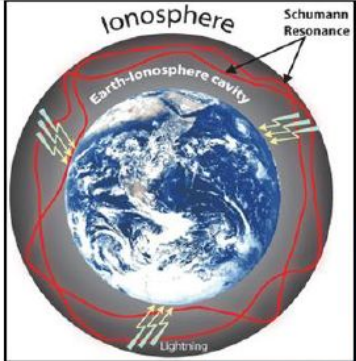
Identify and model noise sources and noise paths

Implement mitigation solutions

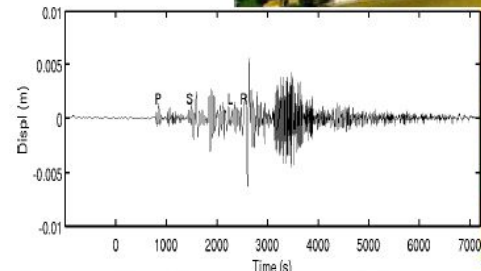
in tight collaboration with other EGO teams and the Virgo community



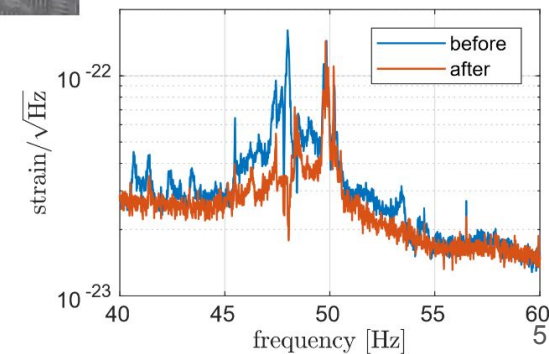
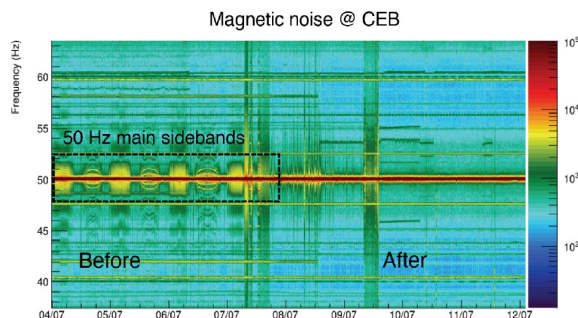
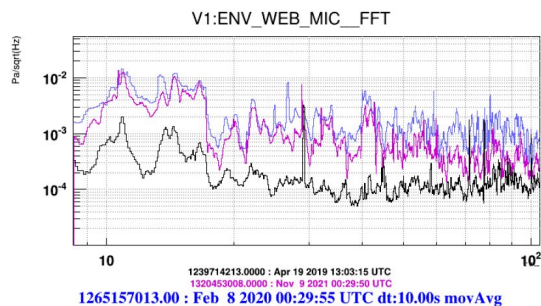
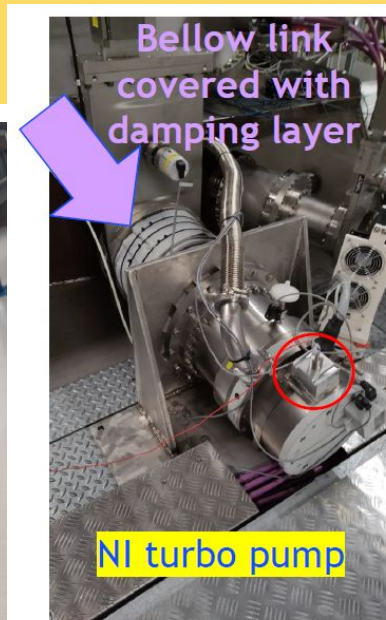
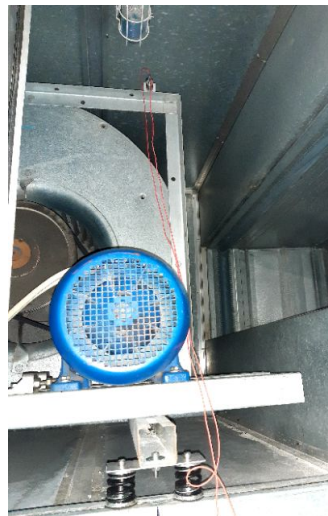




Plenty of sources



# Infrastructure noises

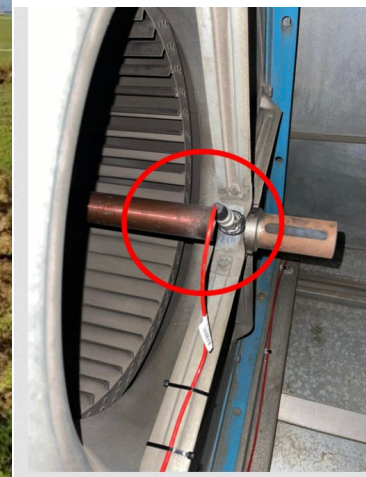
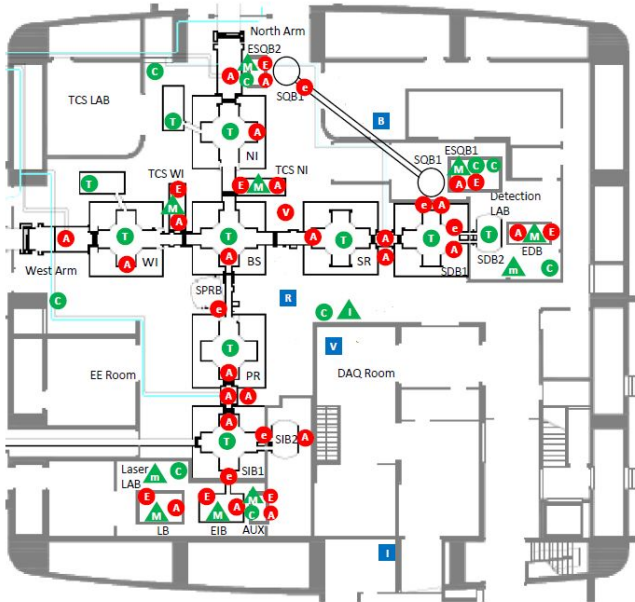




# Extensive monitoring

- Probes close to the interferometer: ~600 (accelerometers, microphones, magnetometers, RF antennae, power grid monitors, temperature, humidity, pressure, etc.)
- External monitors: magnetic fields, wind, lightnings, seism, cosmic muons

ENV sensors  
CEB



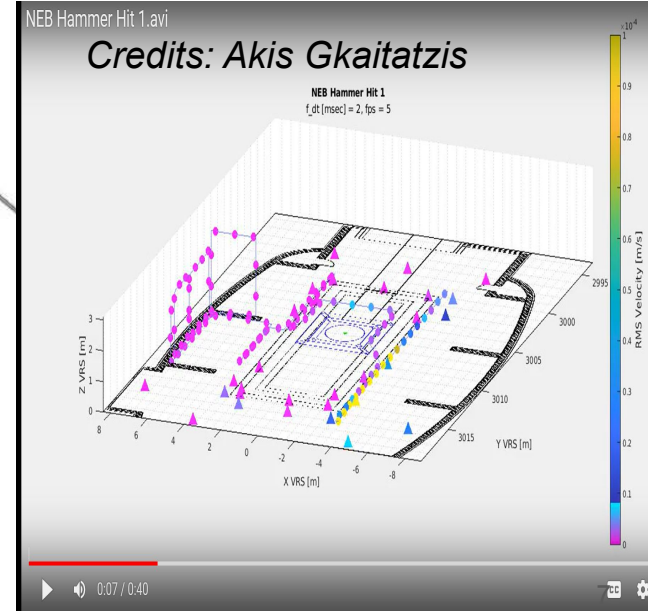
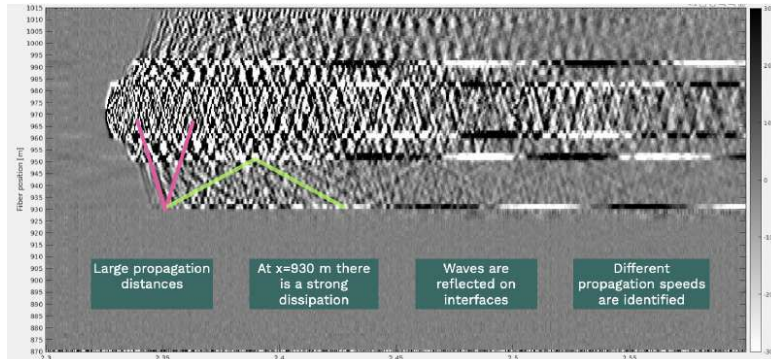
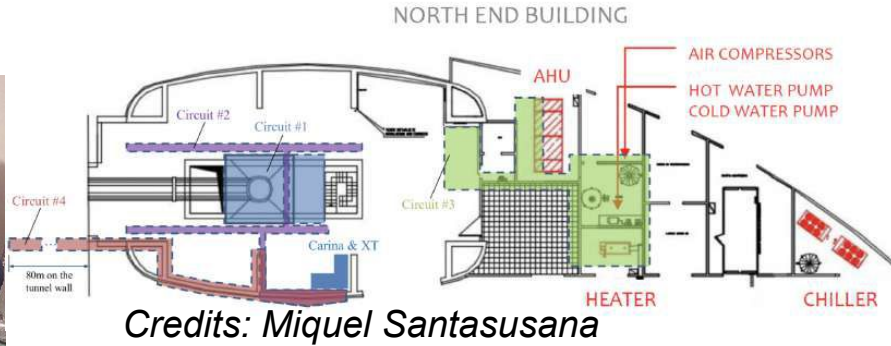
ACC-3 on fan pulley left bearing



# Distributed fiber sensing

1km fiber installed at Virgo North End building for evaluation study ([SILIXA](#)'s engineered *DAS* fiber).

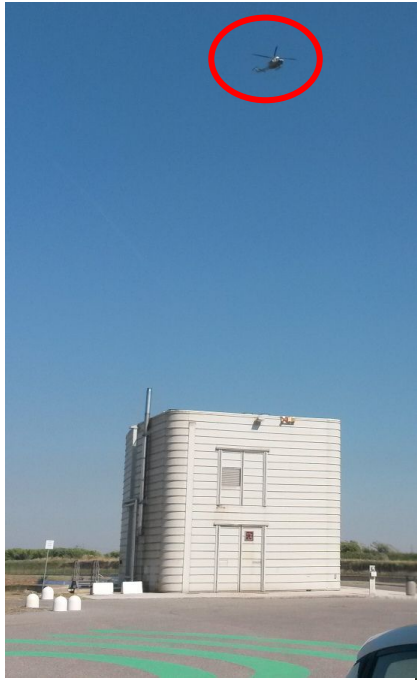
Promising for use in the extensive monitoring of the underground laboratory infrastructure of future GW detectors.



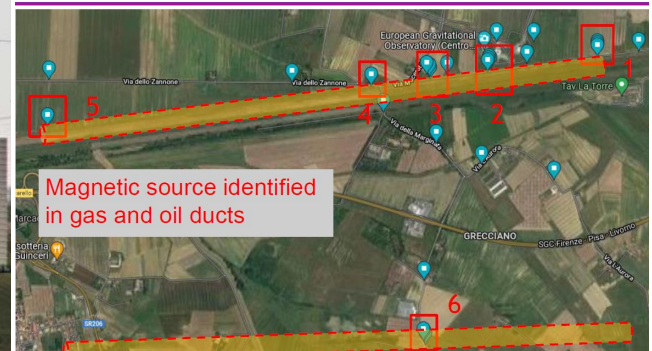


# Noise from human activities

- Study anthropic sources in the EGO surroundings and influences on the Virgo detector
- Preserve the noise climate of the EGO site: [agreement signed with the local administration authorities](#) (Province of Pisa)



## Mysterious Magnetic Noise

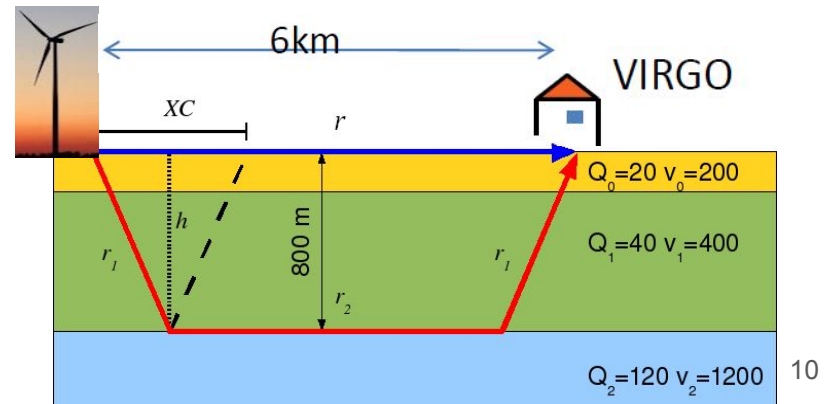
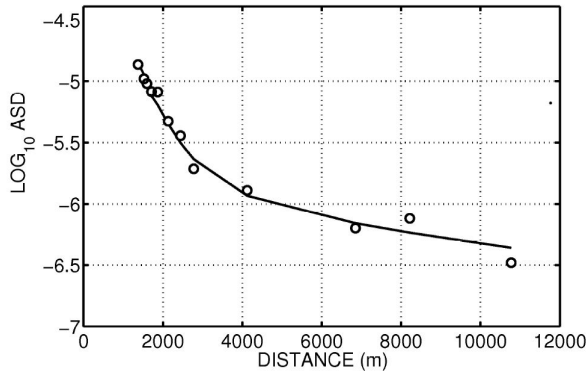
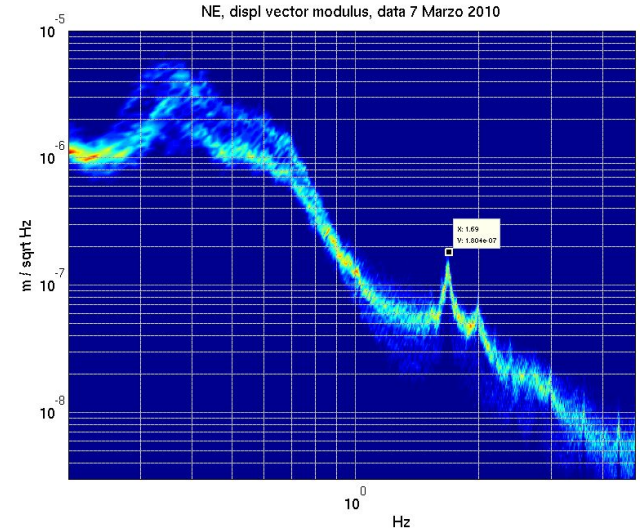




# A selection of case studies

# Noise from a wind park

- Pontedera wind park is 6 km from us. Detect vibration noise at  $\sim 2\text{Hz}$ . INGV-EGO study. Deep layer propagation model explains the small attenuation observed. G.Saccorotti et al. <http://dx.doi.org/10.1785/0120100203>
- Soil model used to predict impact of other wind-park proposed projects.

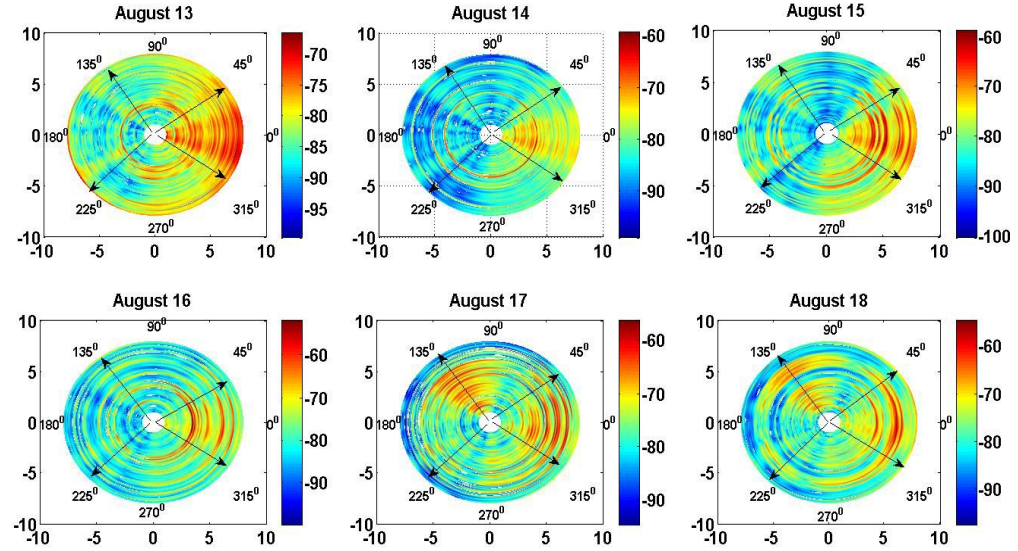
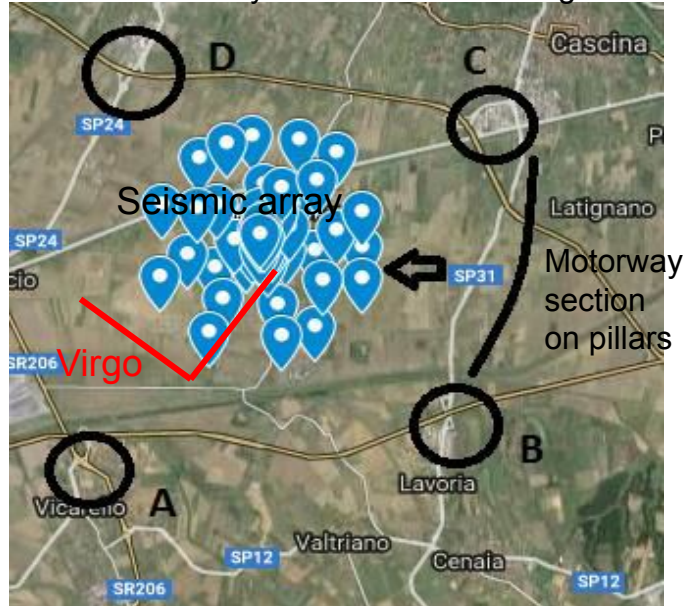


# Truck noise



- Seismic wave transients at 2-3Hz match heavy vehicle transits on nearby viaducts. Corresponds to mechanical modes of the pillar structure. <https://tds.virgo-gw.eu/?content=3&r=1463>
- 100-seismometer array deployed in between Virgo arms. Beamforming analysis confirms seismic wave-field direction. S.Koley et al. <https://doi.org/10.1190/segam2017-17681951.1>

FI-PI-LI motorway viaducts close to Virgo





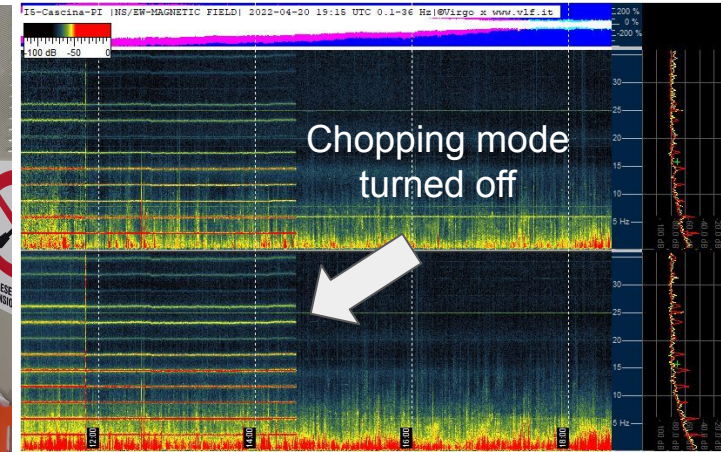
# Magnetic noise from gas pipelines



Magnetics field at 5Hz and harmonics was polluting the EGO-Virgo magnetic environment

The noise was found associated to anti-corrosion galvanic current flows in natural gas pipelines located in the area around the site. The source was a DC power supply module, located 4km from us, used to keep the pipe at a voltage with respect to the soil ground. The module was erroneously set in chopping mode.

Virgo

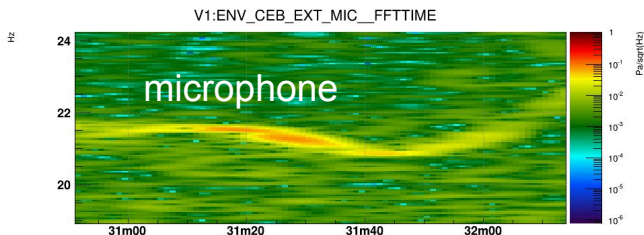


# Aircraft noise

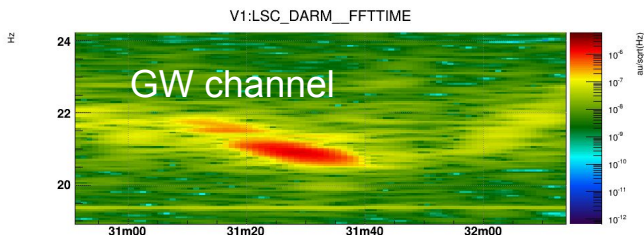


- Airplanes and helicopters produce sound pressure waves and vibrations. Their typical signature is a Doppler chirp. Close-by fly-over can produce a transient noise in the Virgo GW channel.
- These events are typically tagged and removed from the data analysis pipelines. Michael Coughlin et al. <https://arxiv.org/abs/1108.1521>
- March 2019 - with the help of the 46-air brigade we performed flyover test and enforced no-fly zones (cylindrical volumes 2000ft x 2000ft) around Virgo's experimental buildings

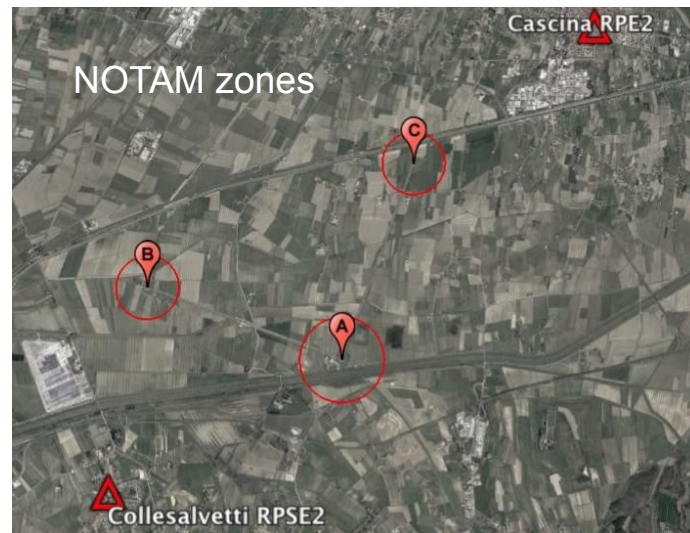
Agusta-Bell  
412 helicopter,  
1000 ft above  
CEB



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

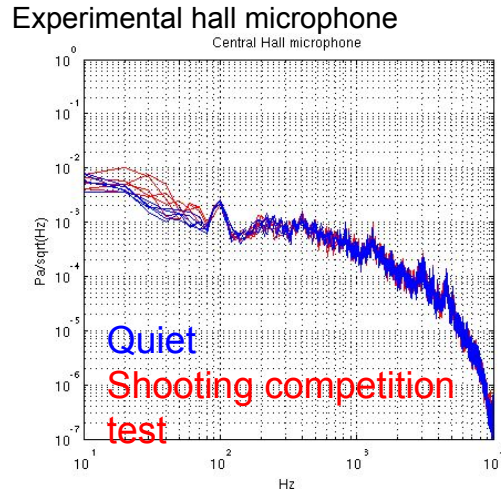
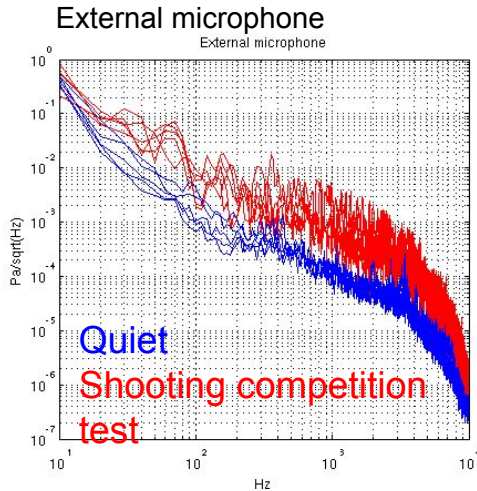


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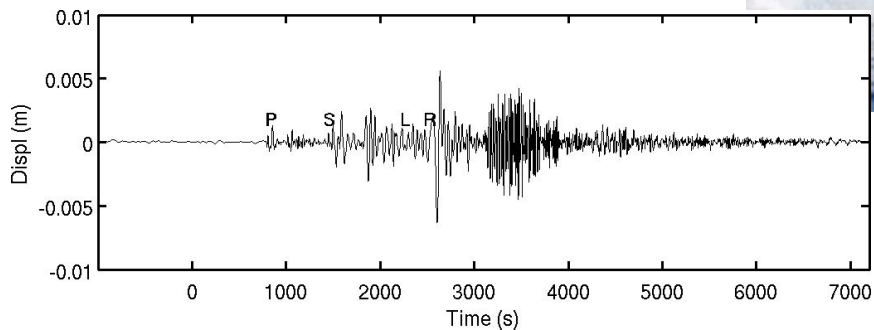
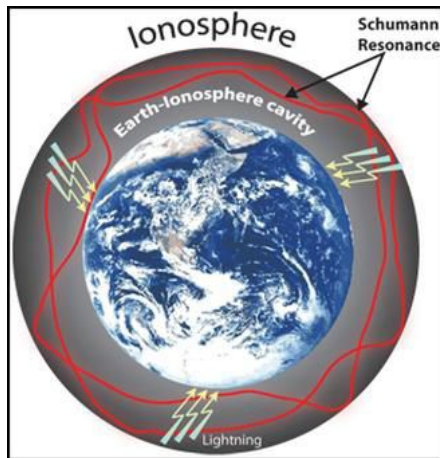
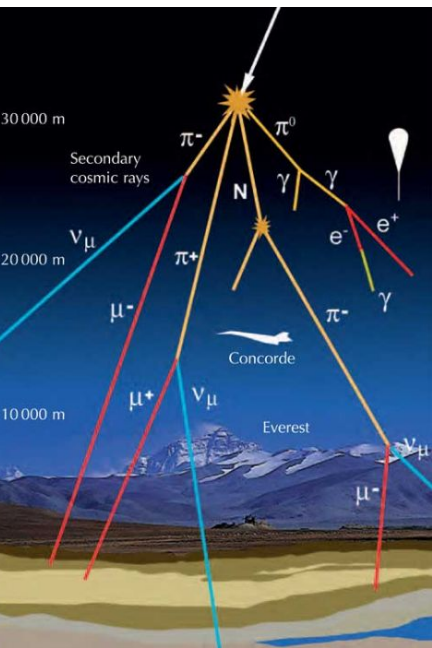
# Noise from a skeet shooting facility

- Following the Noise limit agreement with the Province of Pisa, several installation proposals in the Virgo surrounding have been submitted to a noise evaluation by EGO for approval.
- One example is a skeet shooting sport facility at 600m from us
- Best practice is, when possible, to rely on measurements based on a realistic test.
- In this case, a series of shooting practice and competitions were organized with the customer, and the acoustic noise produced at Virgo was measured.





# Geophysical noises

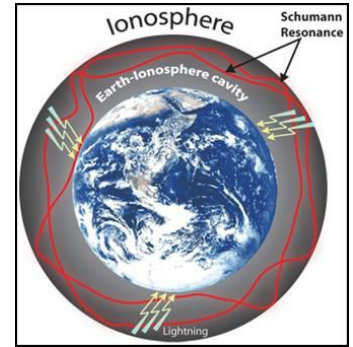


# A selection of case studies

# Schumann's magnetic field

Schumann resonances (SR): a world-wide electromagnetic field sustained by the lightning discharges in the EM cavity between the Earth surface and the ionosphere.

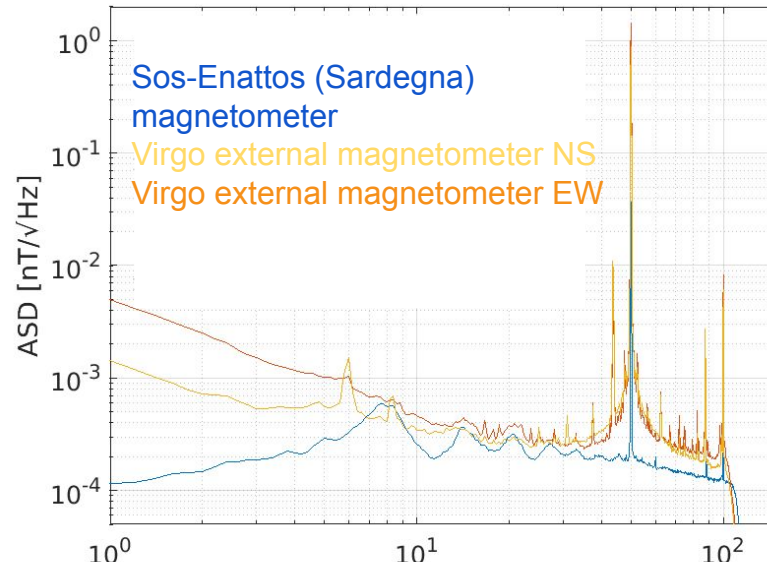
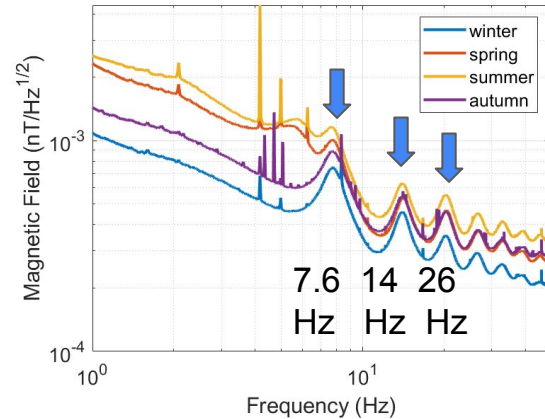
SR constitute a correlated noise for the measurement of the stochastic GW background. LIGO-Virgo Collaborations: [arXIV:1903.02886](https://arxiv.org/abs/1903.02886)



External magnetometers @EGO are used as witness sensors for subtracting SR correlated magnetic noise. M.Coughlin, A.Cirone, et al <https://doi.org/10.1103/PhysRevD.97.102007>

Measured at Sos-Enattos

Credits. R.De Rosa



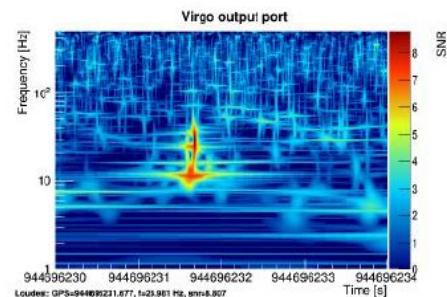
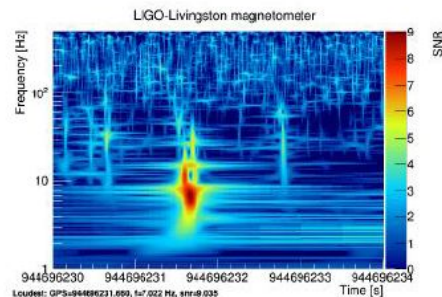
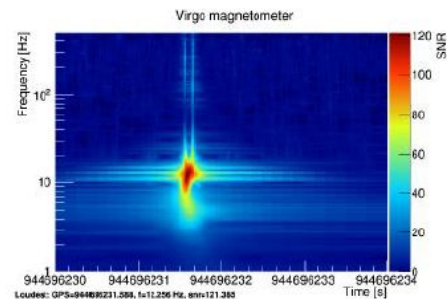
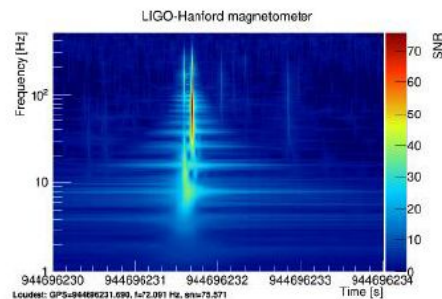
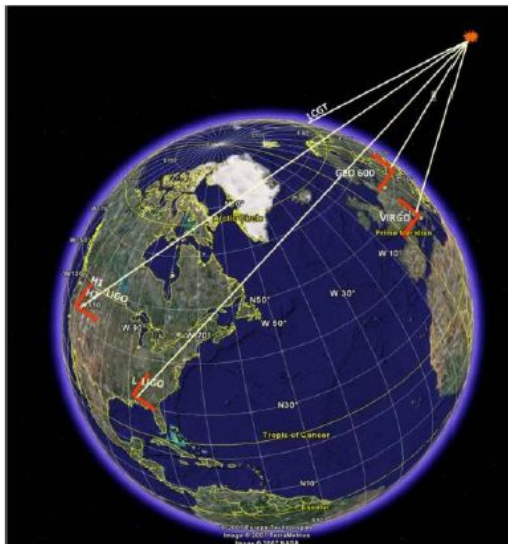


# Geomagnetic pulses

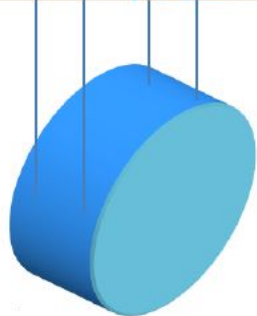
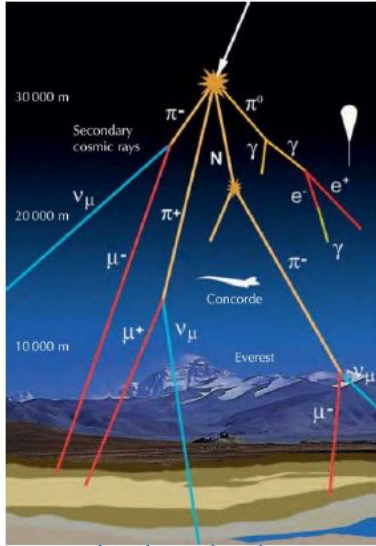
- ❑ Very energetic electric discharges in atmosphere can produce “coincident” (light-speed separated) noise transients in world-wide detectors
- ❑ Can mimic a GW signal
- ❑ Magnetometers are used to select and veto

**Gigantic-jet** of December 12 2009, near Corsica  
Detected by magnetometers at LIGO and Virgo  
and by the Virgo detector

I.Kowalska, et al., <https://arxiv.org/abs/1612.01102>



# Cosmic rays



Interactions cosmic ray shower  $\leftrightarrow$  mirror test masses:

- **Elastic interaction**: direct momentum transfer
- **Inelastic interaction**: heating  $\rightarrow$  distortion of mirror surface
- Muons are charged  $\rightarrow$  **charge deposit on mirror**  $\rightarrow$  Coulomb force fluctuations



Braginsky et al. *Notes about noise in GW antennas created by cosmic rays*,  
2006 Phys. Lett. A 350,1 arXiv:gr-qc/0509058

Some effect can be observed for  $> 2\text{TeV}$  showers  
 $h \approx 10^{-22}$  (just a few / year)

Certainly of relevance for future GW detectors  
Acquiring experience now helps!

One muon detector installed at EGO, during O3 science run  
(courtesy of Jacques Marteau – IPN Lyon)

Diaphane Detector at EGO



# Earthquakes

Intense or close earthquakes can cause Virgo to lose its controlled state (in gergo, *lock loss*) and thus reduce the Virgo duty cycle.

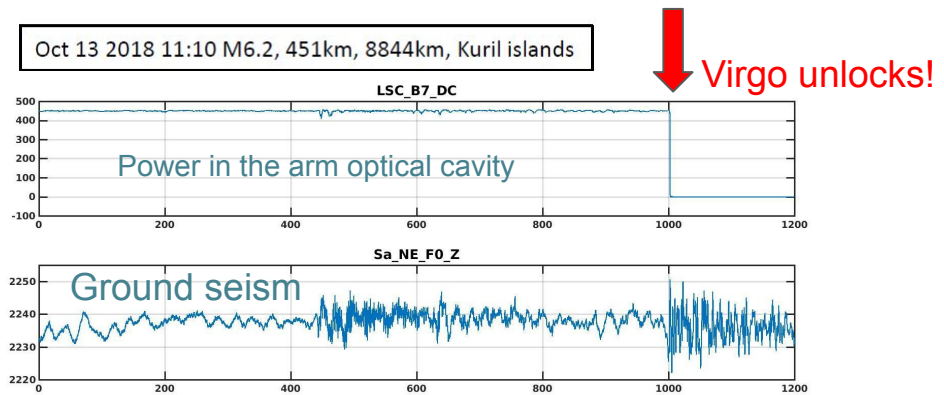
Virgo EQ warning is based on the *Seismon* software which receives alerts from USGS seismic network and predicts arrival times of P and S waves at Virgo. M.Coughlin LIGO

<https://iopscience.iop.org/article/10.1088/1361-6382/aa5a60>

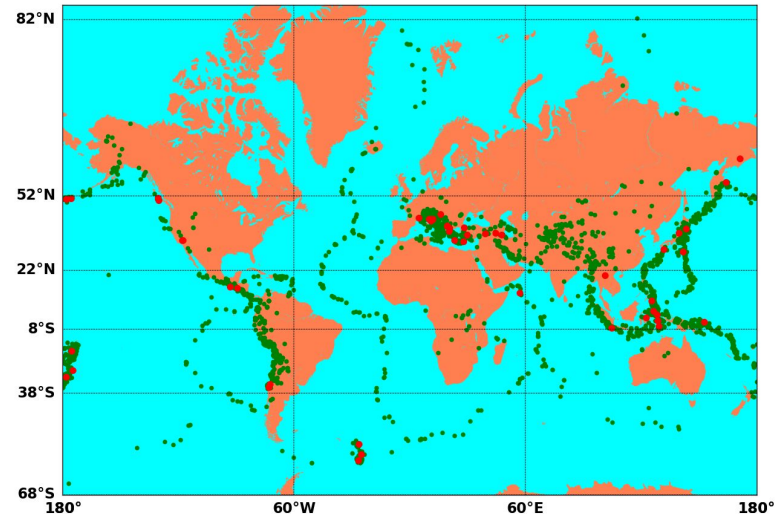
Collaboration project with INGV (Italian institute of Geophysics and Volcanology) to improve coverage and reduce alert time by adding local sensors

M.Olivieri et al APPEC workshop at IPGP Paris

[https://indico.in2p3.fr/event/18287/contributions/67510/attachments/52191/67313/PosterParis\\_Final\\_Olivieri.pdf](https://indico.in2p3.fr/event/18287/contributions/67510/attachments/52191/67313/PosterParis_Final_Olivieri.pdf)



Earthquakes during O3 run (1 year long)  
RED ones caused Virgo lock losses

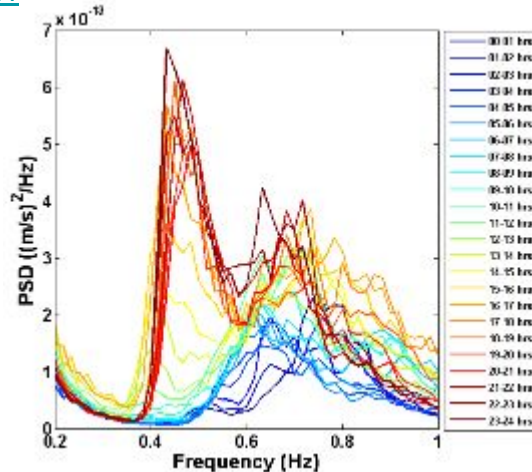
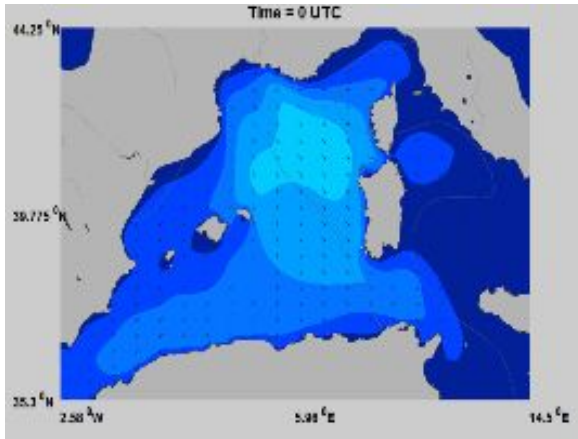




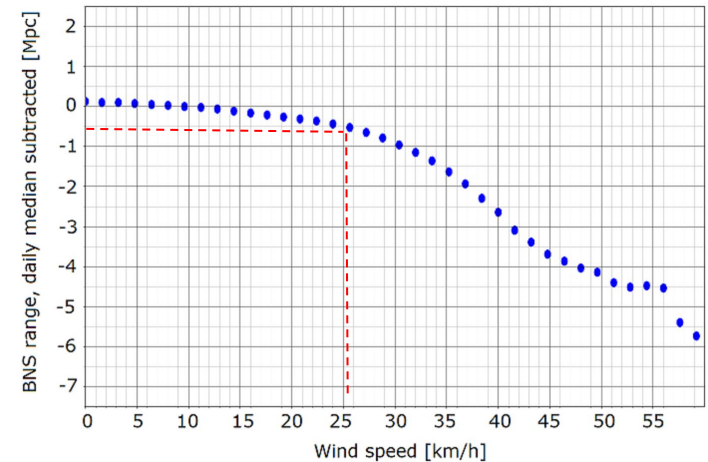
# Sea and wind

- Sea activity at Virgo cause ground microseismic noise typically peaked at 0.4Hz.
- Wind produces tilt of the experimental buildings floor, which to be compensated, sometimes requires too large corrections in the mirror suspensions.
- The impact of sea and wind on the interferometer was studied during the 1-year long O3 science run - The Virgo Collaboration <https://arxiv.org/abs/2203.04014>
- While the interferometer proved robust against sea activity, wind speeds  $\geq 25\text{km/h}$  produced a sensible degradation of the sensitivity and the duty cycle.

Effect at Virgo of a storm in the Mediterranean sea, Soumen Koley et al, <https://doi.org/10.1190/segam2017-17681951.1>



Observation range as function of wind speed (Virgo O3 data)



*Thank you for your attention!*

