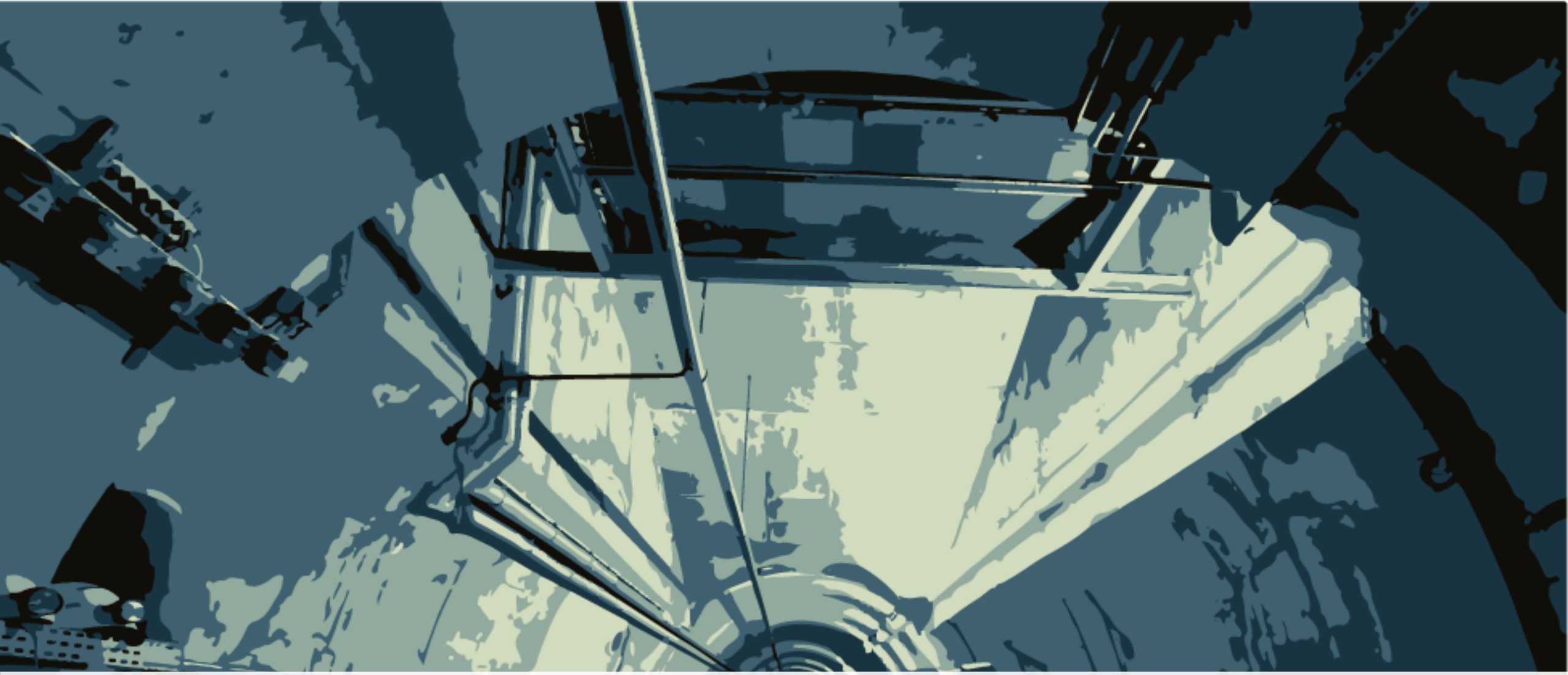




SURFACE & UNDERGROUND BASED LOW BACKGROUND NOISE INTERDISCIPLINARY RESEARCH LABORATORY, RUSTREL

current status of LSBB development and inter-disciplinary activities

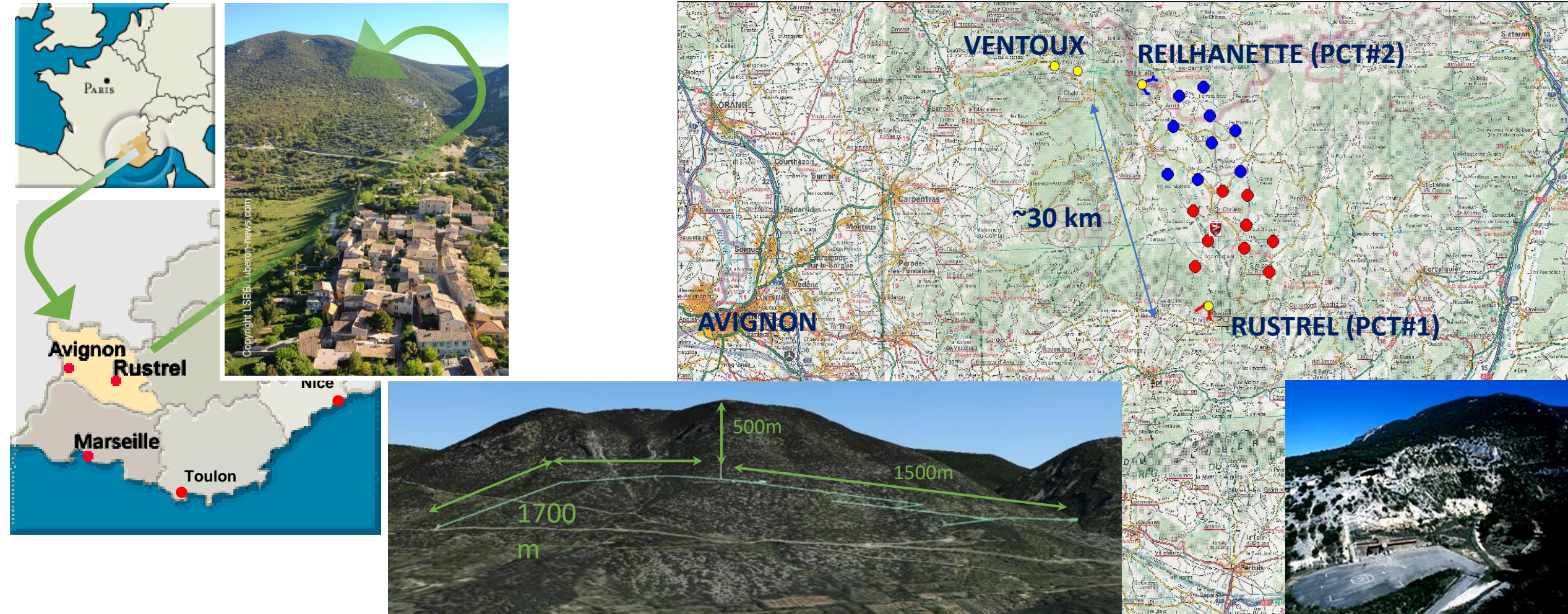




LEGACY FROM HISTORY



Reconversion of a Cold War nuclear weapon system toward interdisciplinary research and sustainable development of knowledge



GMS ALBION → LSBB UNDERGROUND RESEARCH LABORATORY (KEY DATES)



→ **IN OPERATION FROM 1971 TO 1997**

→ **DECOMMISSIONING in 1996**

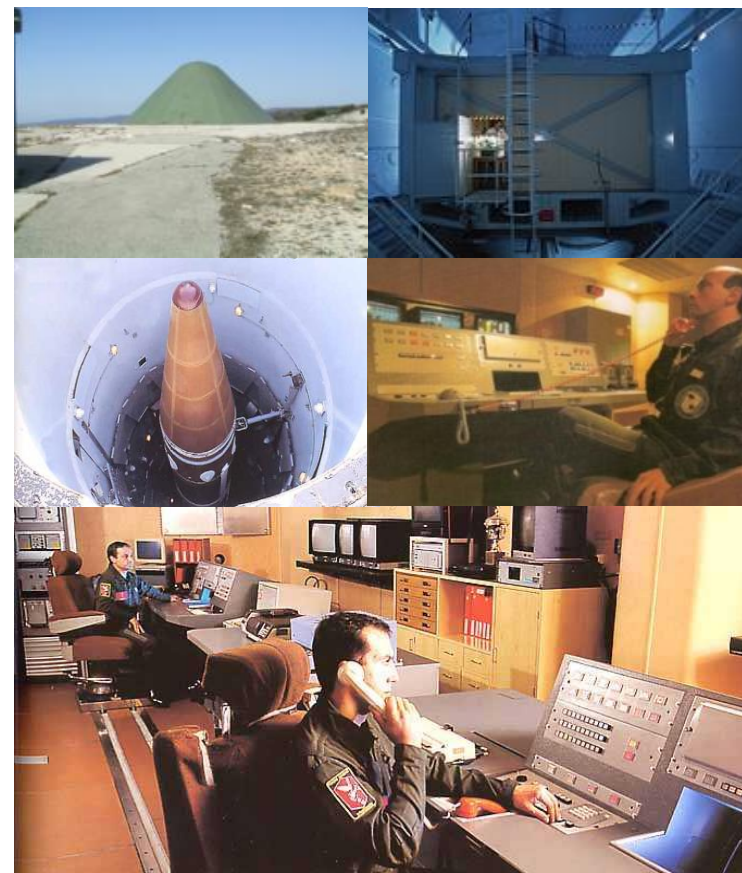
« le retrait du service de la composante sol-sol du plateau d'Albion dont les missions ne se justifient plus dans le contexte actuel et dont la modernisation aurait été, en tout état de cause, extrêmement coûteuse » (President Jacques Chirac, speech to the armed forces delivered at the Ecole Militaire in Paris on Friday, February 23, 1996).

The dismantling of the GMS system (grouping of strategic missiles) on the Plateau d'Albion began in 1996 and was completed in 1997 (Military Programming Law 1997-2002 adopted on 20 June 1996 by the Senate)

→ **RECONVERSION TO THE LSBB'S UNDERGROUND RESEARCH LABORATORY SINCE 1997**

Supported by

The French Ministry of Defense, the Apt county, The Vaucluse department, The Provence-Alpes-Côte d'Azur region, the Europe, the universities of PACA region, the French DOE, the CNRS and the French Ministry of Research



Verification (transparency) of the conversion of the Albion Plateau military facilities by the Conference on Disarmament

[...] la France a organisé aujourd'hui [18 juin 2015] une visite des installations nucléaires militaires démantelées du plateau d'Albion (Vaucluse). Des représentants d'une trentaine d'États membres de la Conférence du désarmement ont ainsi visité les sites des anciens silos des missiles balistiques intercontinentaux et des installations des commandement et de tir [...]. Ils ont pu constater les effets concrets de la décision prise par la France en 1996 d'abandonner la composante nucléaire terrestre de sa dissuasion [...]

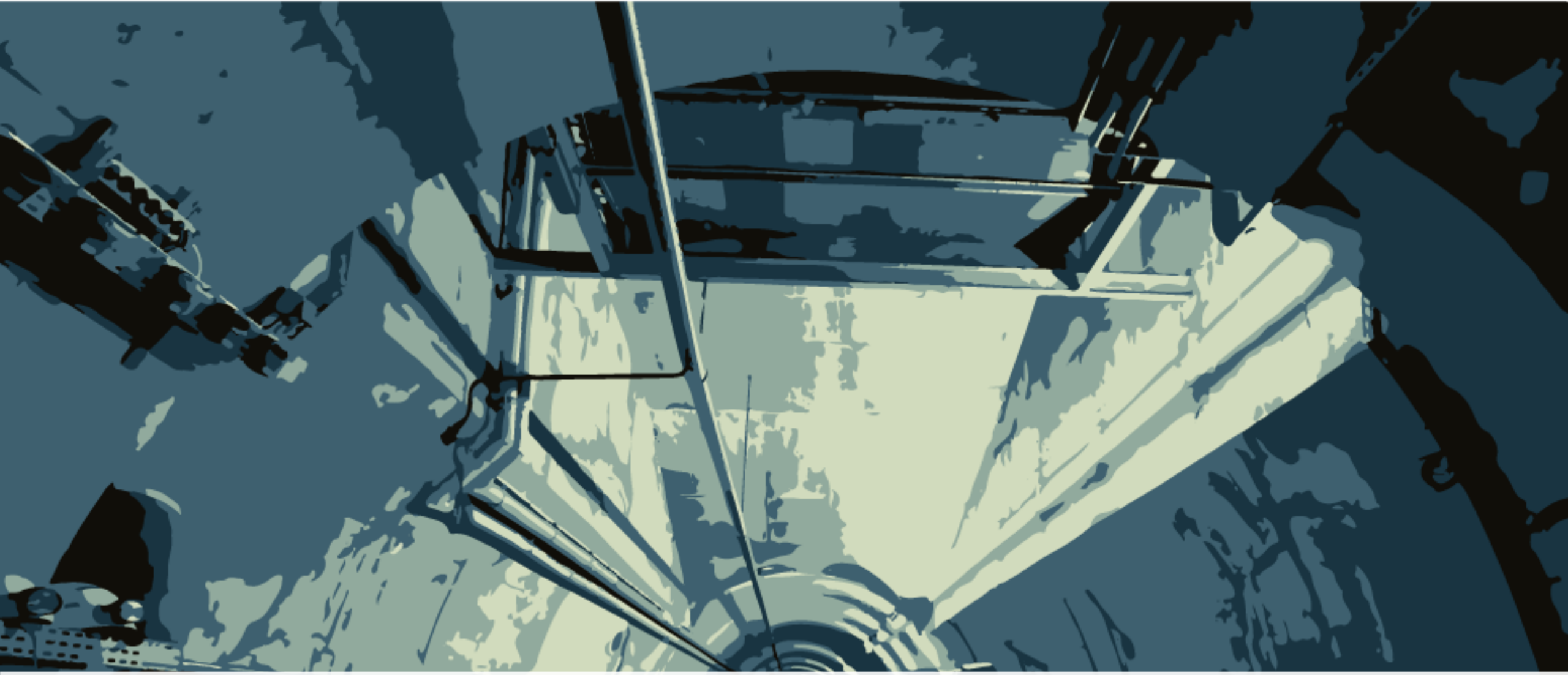


Désarmement - Transparence - Visite des installations militaires reconverties du plateau d'Albion

Le Monde 19 juin 2015 Nathalie Guibert

Opération transparence sur le plateau d'Albion

[...] ce sont les chercheurs du Laboratoire souterrain à bas bruit (LSBB), une structure universitaire, qui font la visite. Ce jeudi 18 juin, la France a convié pour la première fois sur l'ancien site stratégique les ambassadeurs de la Conférence du désarmement, venus de Genève. Lors de son discours sur la dissuasion à Istres le 19 février, François Hollande avait renouvelé les engagements de transparence de la France sur l'arme suprême, et espéré pousser les autres États à la réciprocité [...]



LSBB – ABOVE GROUND & UNDERGROUND BASED LAB.



→ Environment

Low anthropogenic noise within the Luberon Regional Nature Park
 5th largest water resource in the world, 1st in the Mediterranean, fed exclusively by rain
 Major seismogenic region in the South of France
 Geological analogue of the carbonate platforms of the Middle East

+

→ Infrastructure

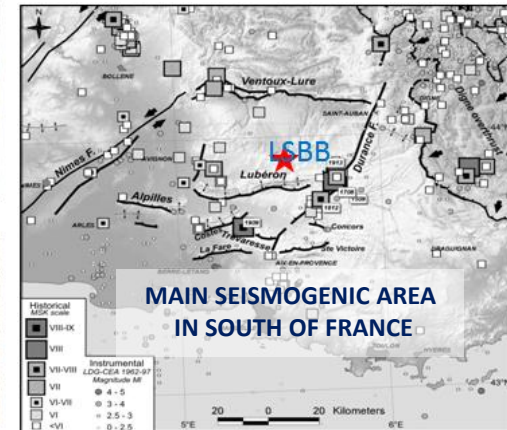
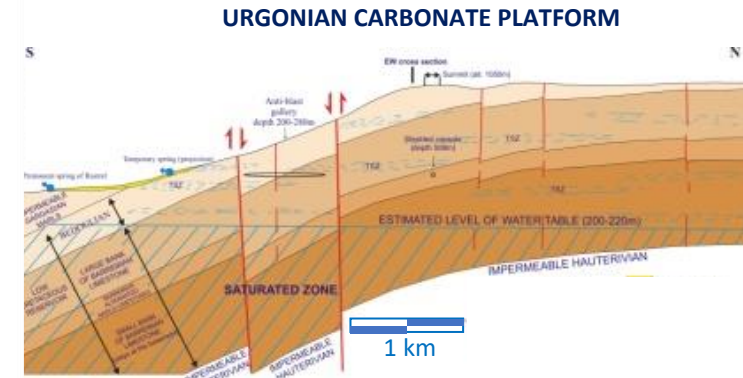
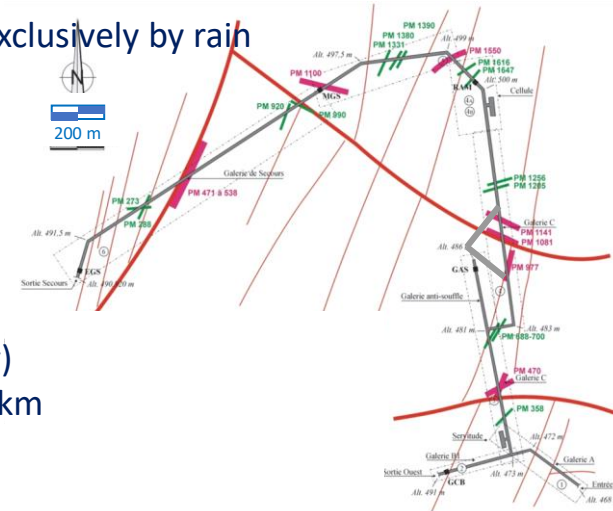
Electromagnetic shielding 28 m × Ø 8 m capsule at a depth of 518 m
 Fully equipped infrastructure on the surface and at depth (E, FO, security)
 Surface access in the Luberon Regional Natural Park and at depth over 4 km
 Boreholes from the surface and from depth accessible to experiments

=

→ A worldwide unique multi-scale Research Infrastructure for ultra-sensitive science

- Observation of the Earth and the Universe
- Accommodation of academic and industrial R&D platforms
- Integration of large scientific instruments
- Synergy of research transdisciplinary research programs

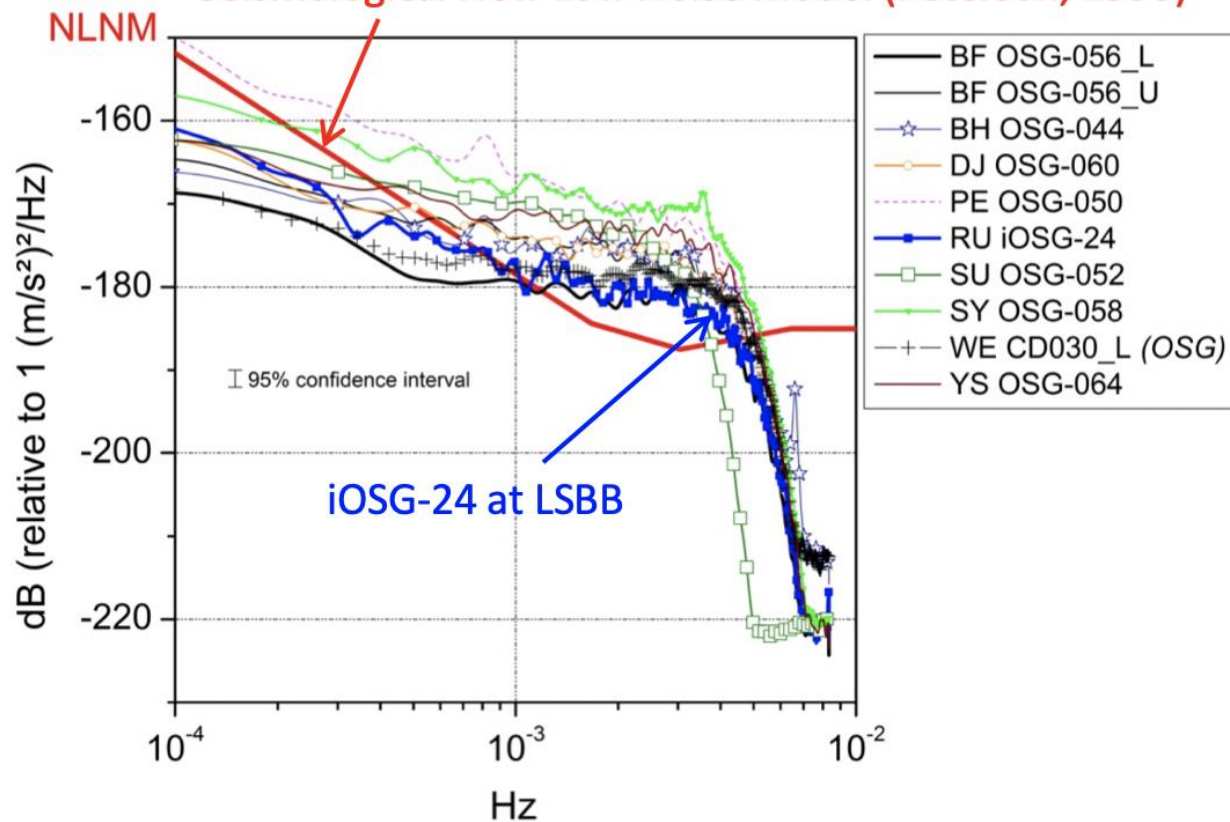
Keywords: Geophysics, geology, physics, astrophysics, biology
 And health, metrology, calibration, characterisation instrumentation,
 carbonate, porous and fractured reservoirs, groundwater resources
 resources, water transfers, critical zone, global changes



Superconducting gravimeters

One of the quietest sites in the world

Seismological New Low Noise Model (Peterson, 1993)



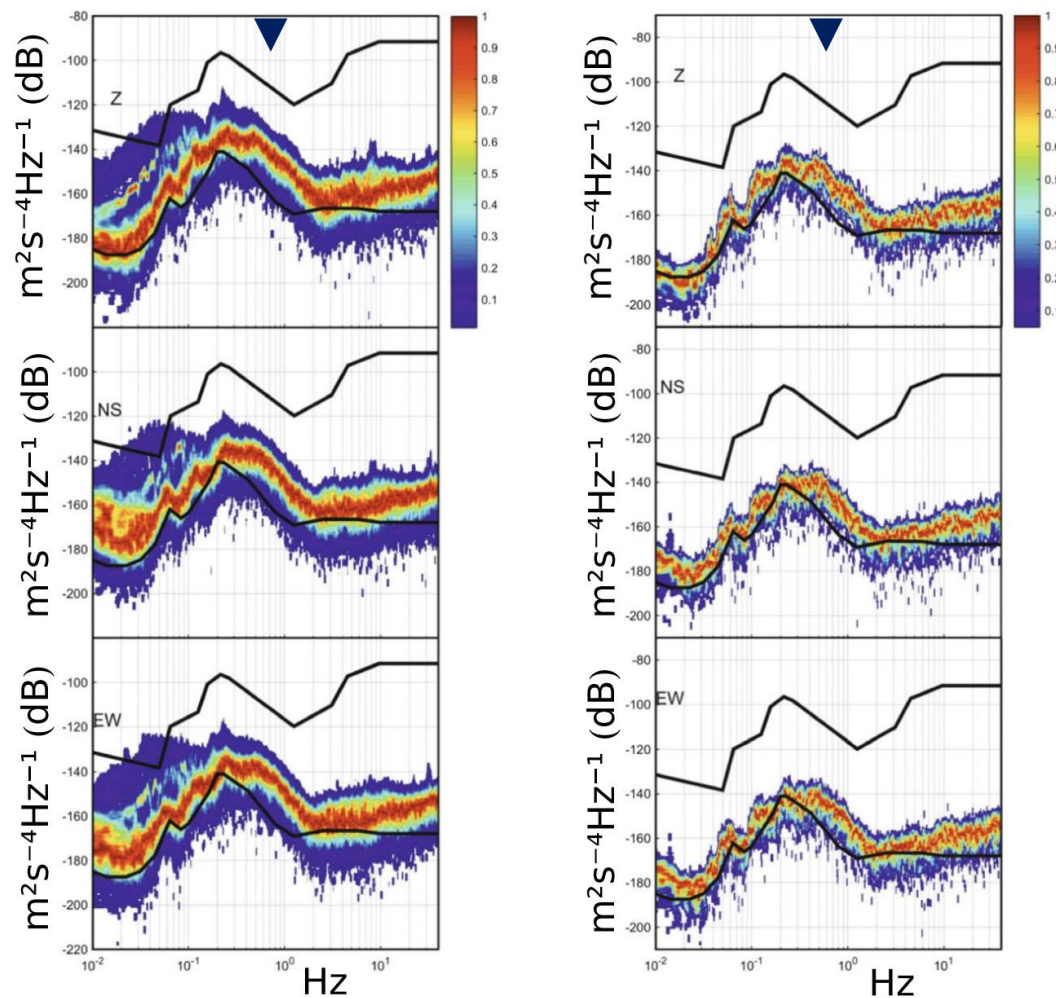
Rosat *et al.* (2018)

Low-noise properties of the seismic environment

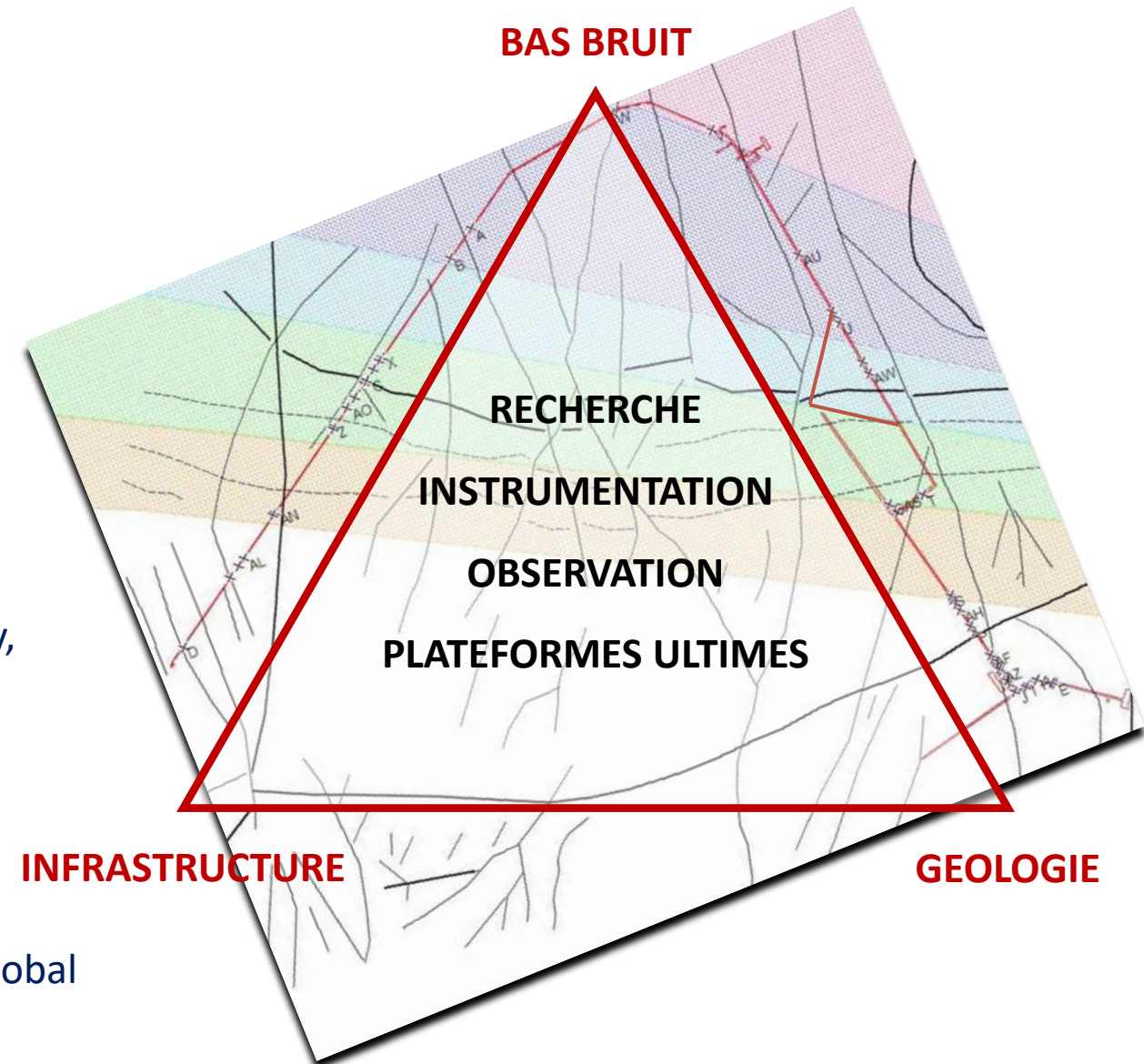
Seismic noise power spectra (high, Z; middle, NS; low, EO) compared to Peterson noise models

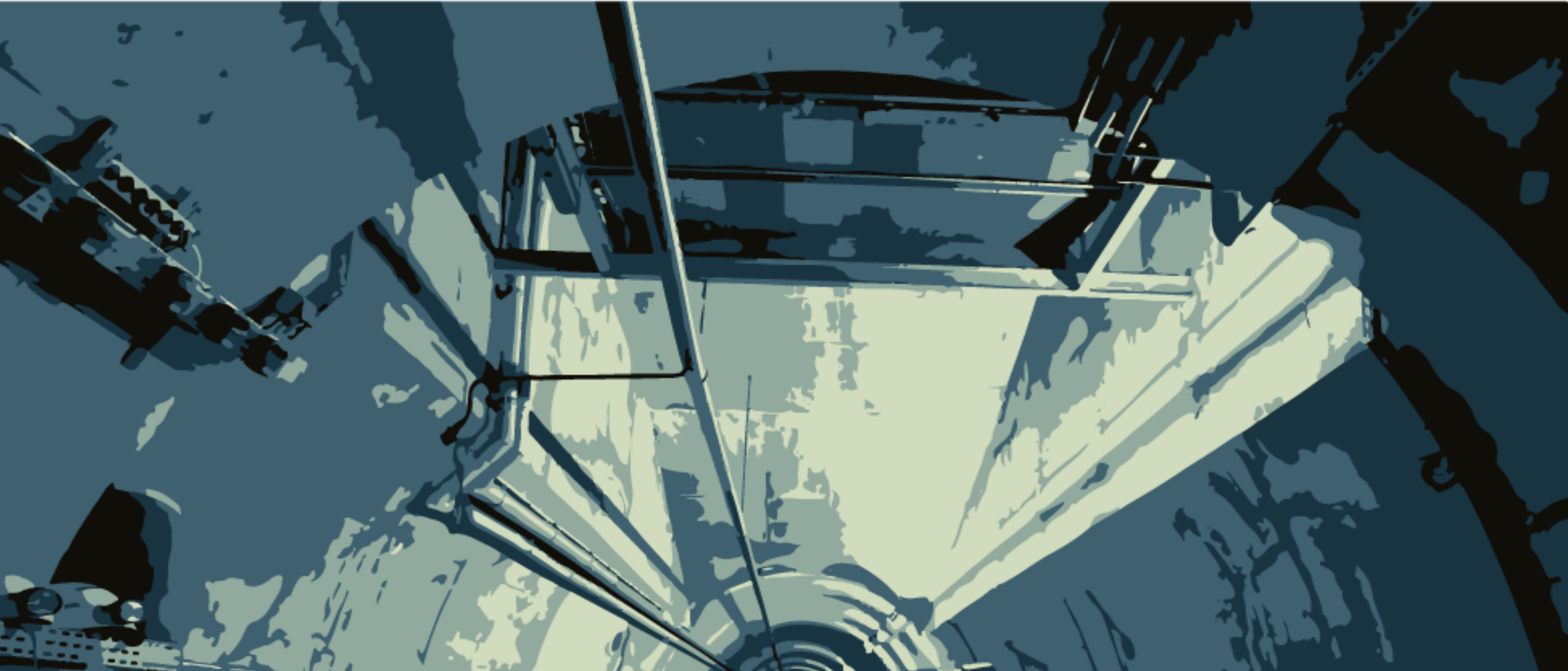
Average noise in 2011

Quiet day



- **Resources & fluid dynamics in the critical zone**
 Karst underground water resource, critical zone, carbonate platform
- **Fluids & medium interactions**
 Thermo-hydro-mechanical & poro-elastic processes, geomechanics
- **Wave physics & radiative environment**
 Seismology, Magnetism, particles Neutrons / Muons
- **High sensitivity metrology & measures**
 Densitometry, Magnetometry, Rotationnal seismometry, Atom interferometry, Optics ...
- **Life**
 Biology, Brain imagery
- **Society & Human Sciences**
 Contemporary History vs Cold War, anthropisation vs Global changes





SCIENCE AT LSBB



→ **HIGH SENSITIVITY INSTRUMENTS & MEASUREMENT METHODOLOGY**

- Instrumentation (Radar, Muon Trackers, ...)
- Electroencephalography (EEG) at Wide Band and High Sensitivity

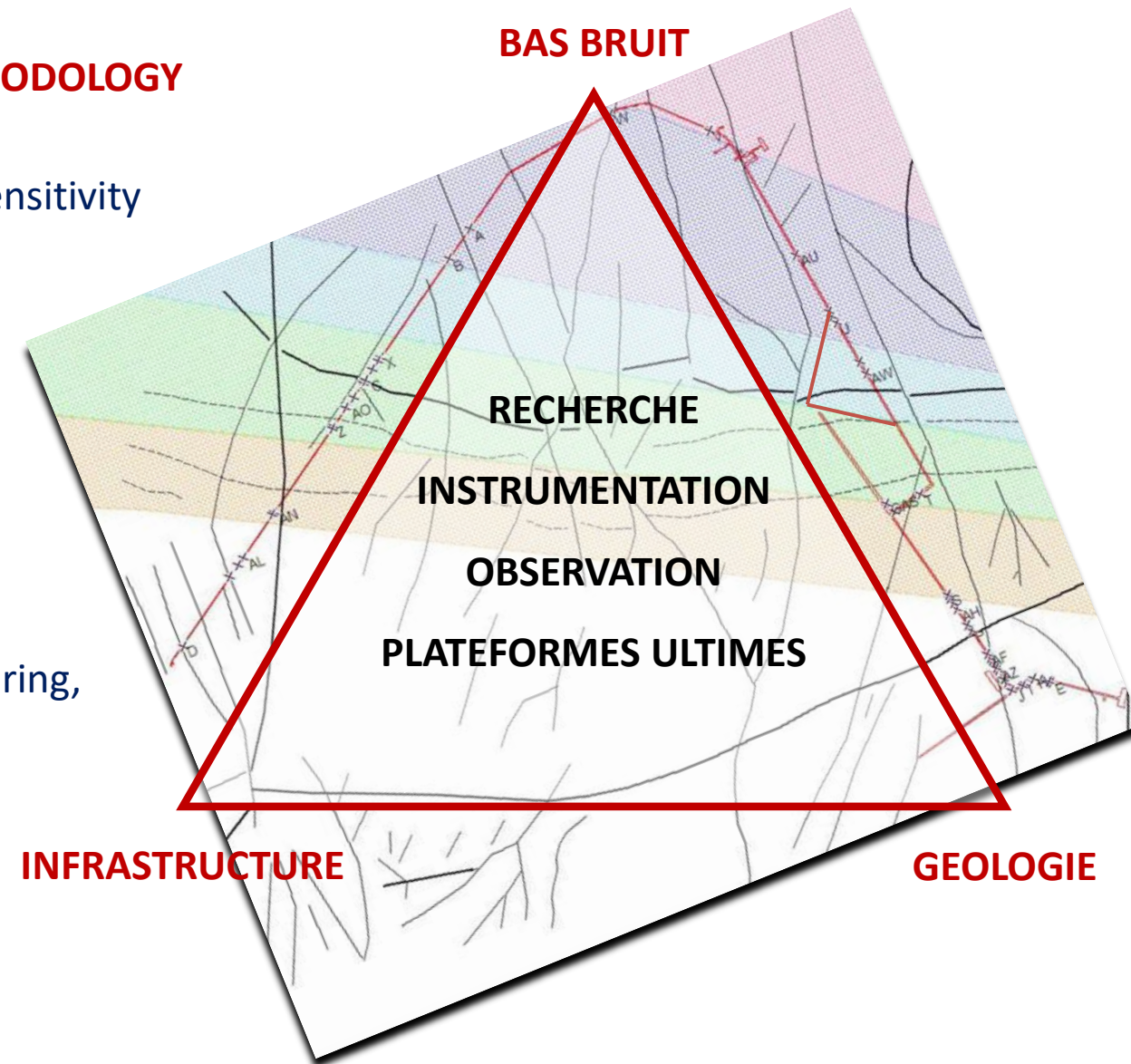
→ **OBSERVATIONS & STUDIES**

- Multi-physics Observatory* (Seismology, Gravimetry, Magnetometry, Hydrogeology, Atmospheric TLE ...)
- Observation and Analysis of Geophysical Phenomena (Earth Interior, Surface, Atmosphere)
- Critical Zone Processes, Hydrodynamics of Geological Reservoirs*
- Couplings and Physics- and Geophysical Processes (Fracturing, Poroelasticity)

→ **R&D PLATFORMS & LARGE INSTRUMENTS**

- Wave Physics and Rotational Seismology
- AI Measurement of Gravitation*
- Ultimate characterisation of mirrors*

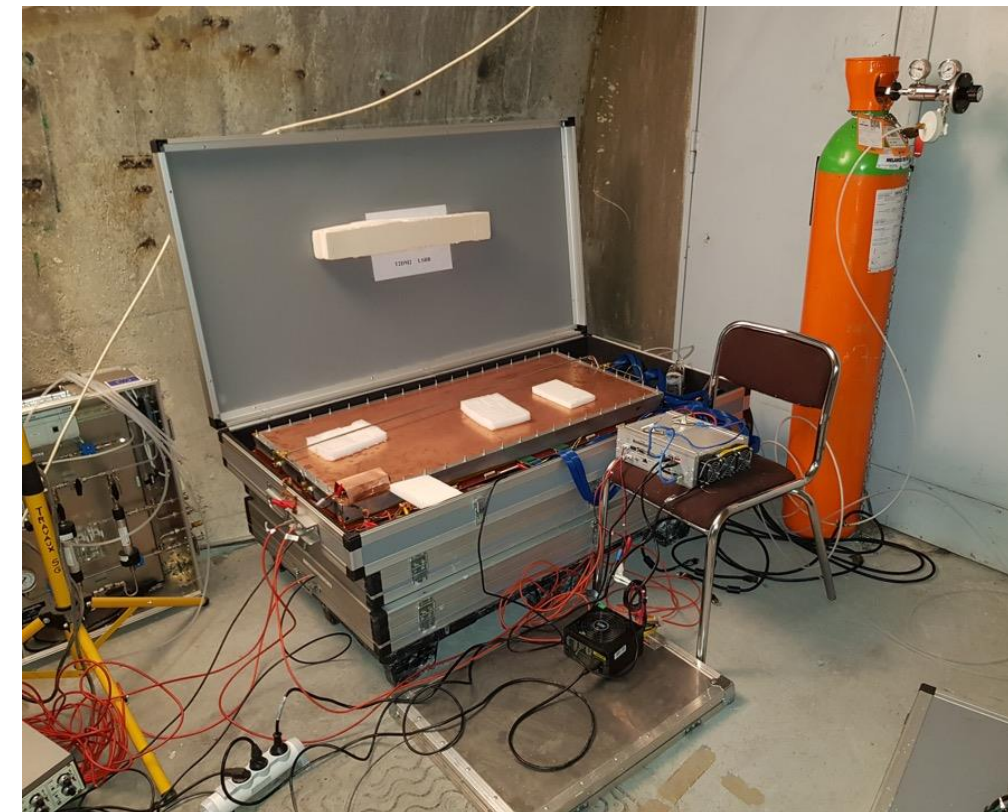
* *Invited talks*



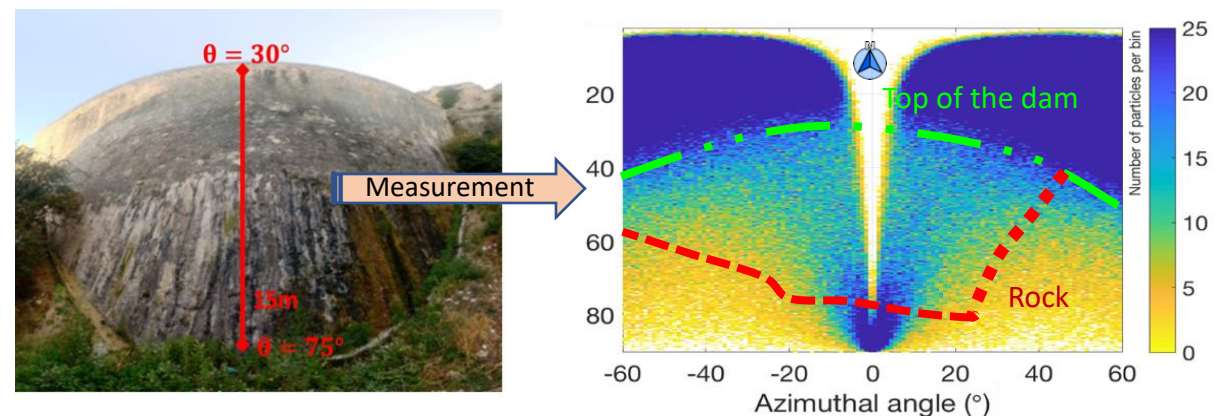
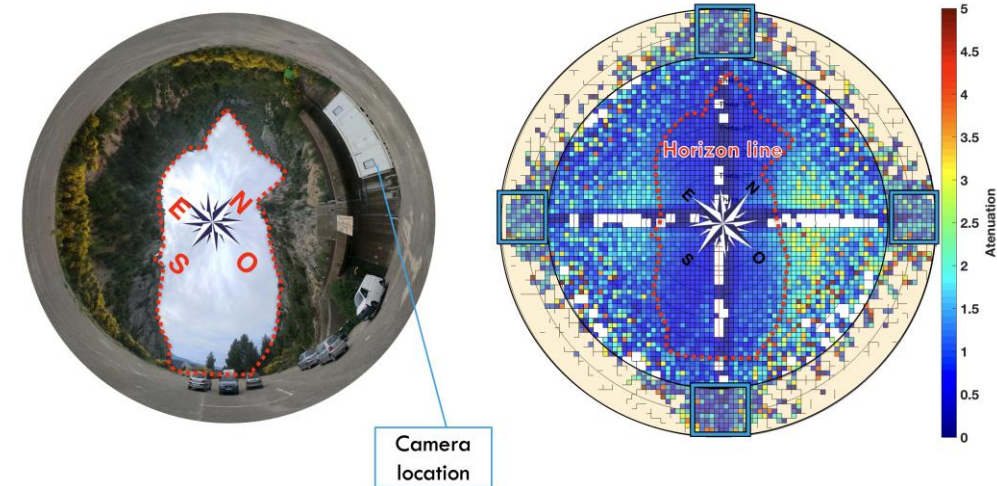
HIGH SENSITIVITY INSTRUMENTS & MEASUREMENT METHODOLOGY

→ INHOUSE MUON TRACKING TECHNOLOGY

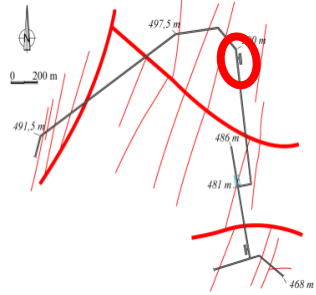
- Patented technology and ongoing valorization
- Network of 20 inhouse, autonomous, detectors
- Permanent setup for groundwater monitoring and mobile muon trackers for large civil structures survey.



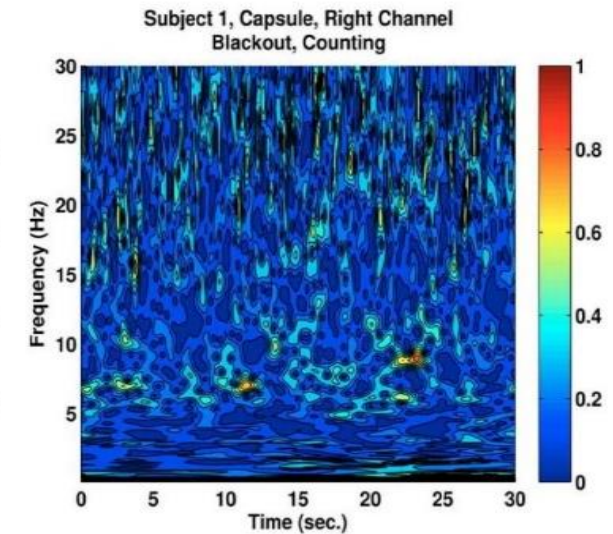
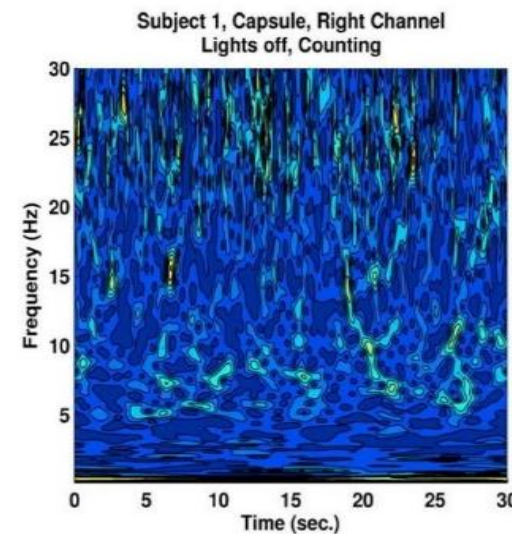
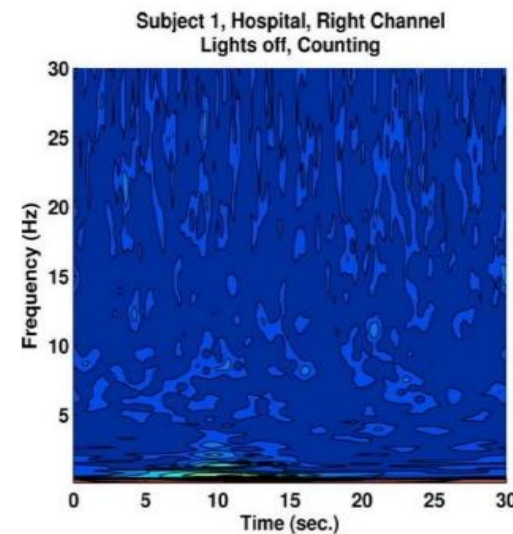
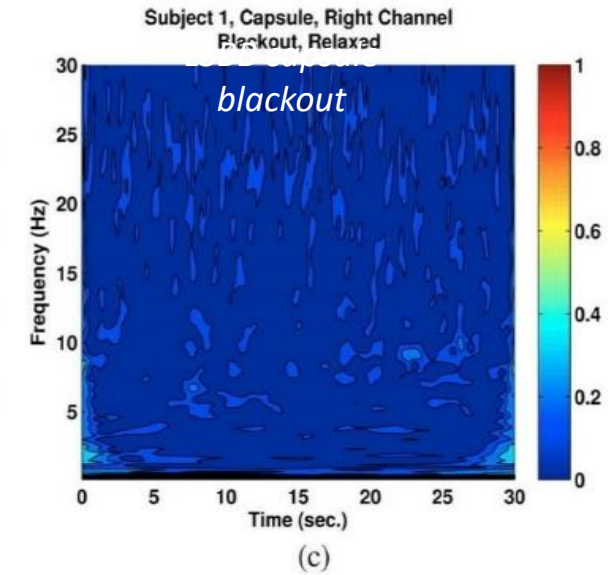
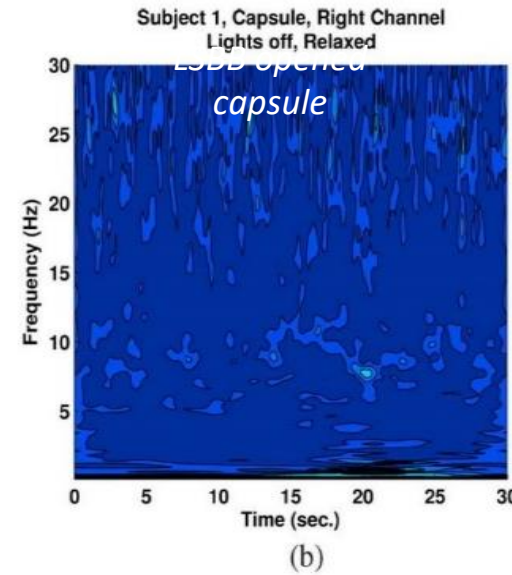
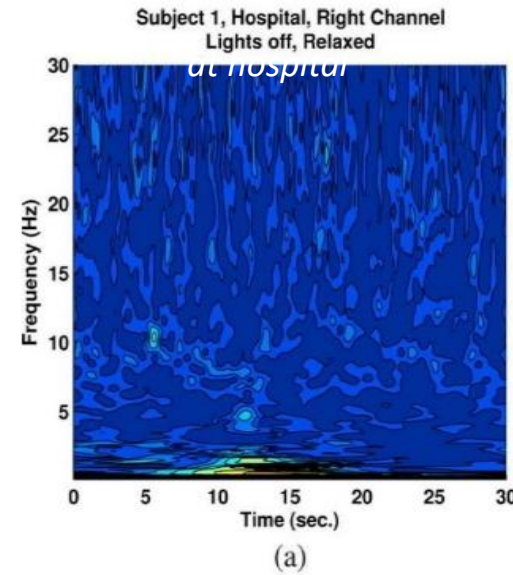
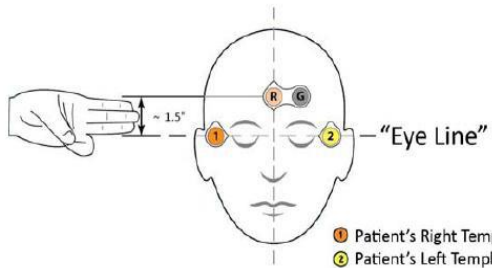
Lázaro Roche et al., 2021



→ **IRP MAXWELL BERGER LABORATORY CNRS-LSBB / UBC-Vancouver**
High sensitivity electroencephalography (EEG)



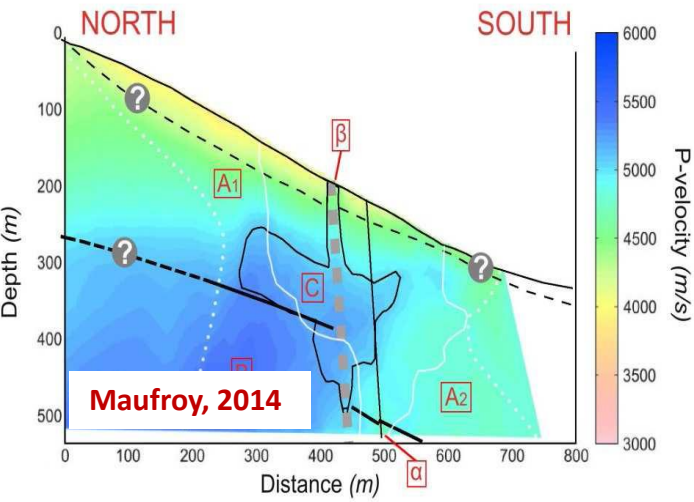
RELAXED SUBJECT



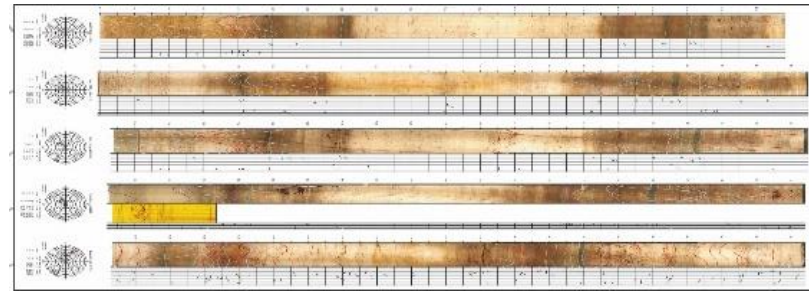
Shahidi Zandi et al., IEEE/TMBE 2011
 Hamzei et al., 2016

COUNTING SUBJECT

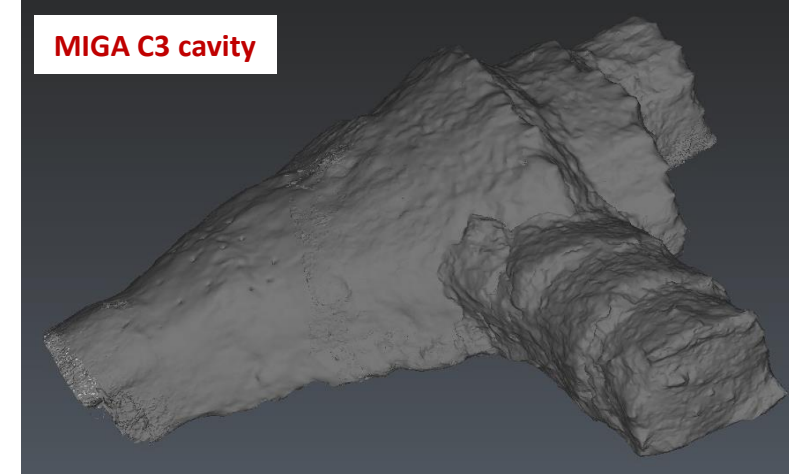
OBSERVATIONS & STUDIES



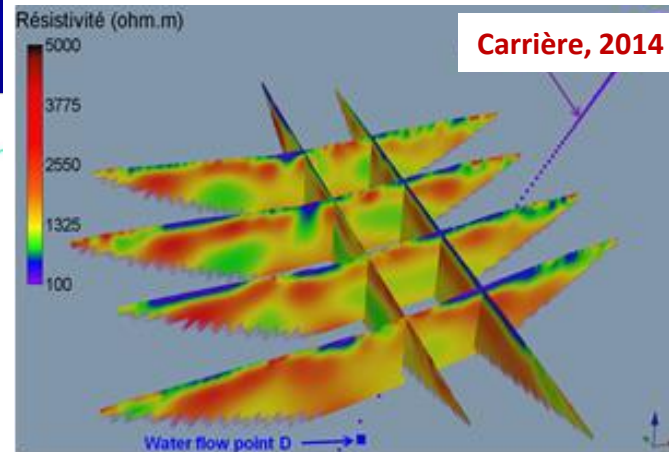
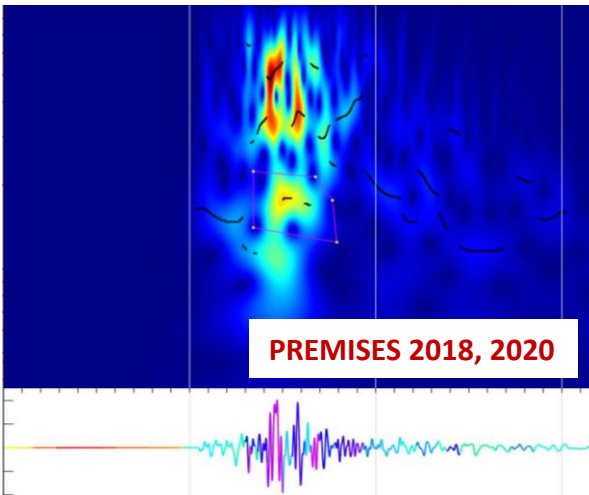
→ **RESERVOIR TRANSDISCIPLINARY INVESTIGATION**



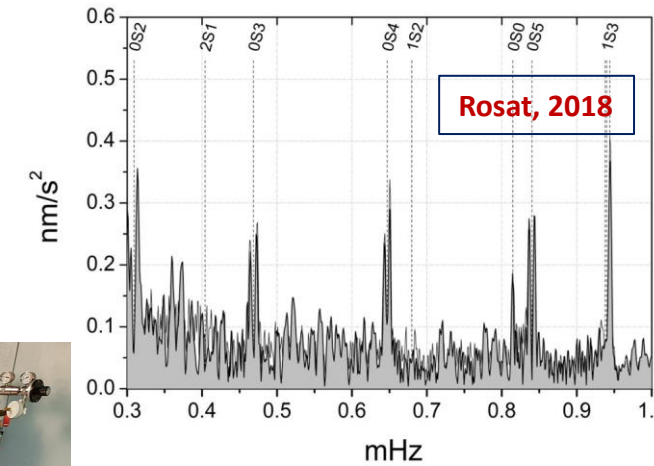
Boreholes & cores (*scale*)



- Photogrammetry (*step-by-step tunnel excavation*)
- Seismology, densitometry (*RESIF, INTERIMAGES, TRUST-ME*)
- Seismic signature vs alteration of the massif (*PREMISES*)
- Gravimetry (*IOSG MIGA/LSBB et CRITEX*)



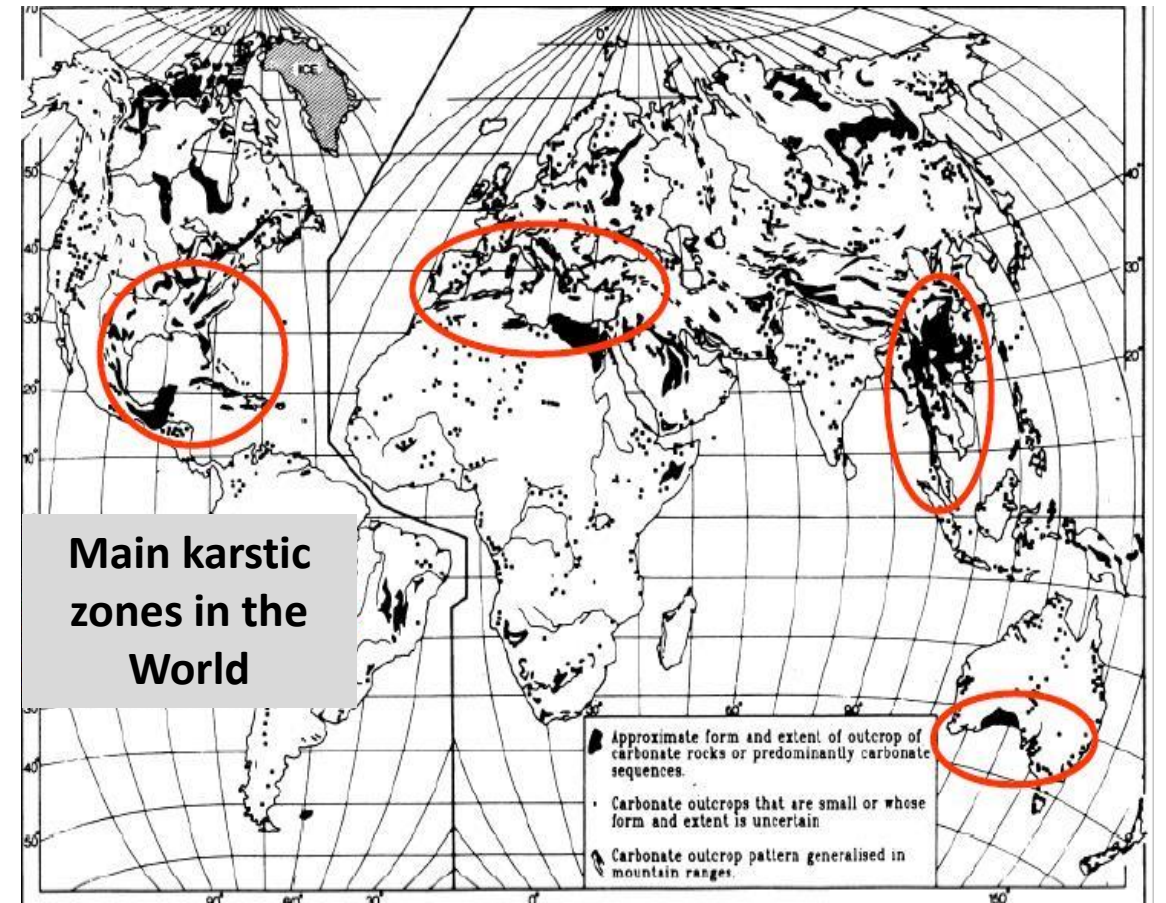
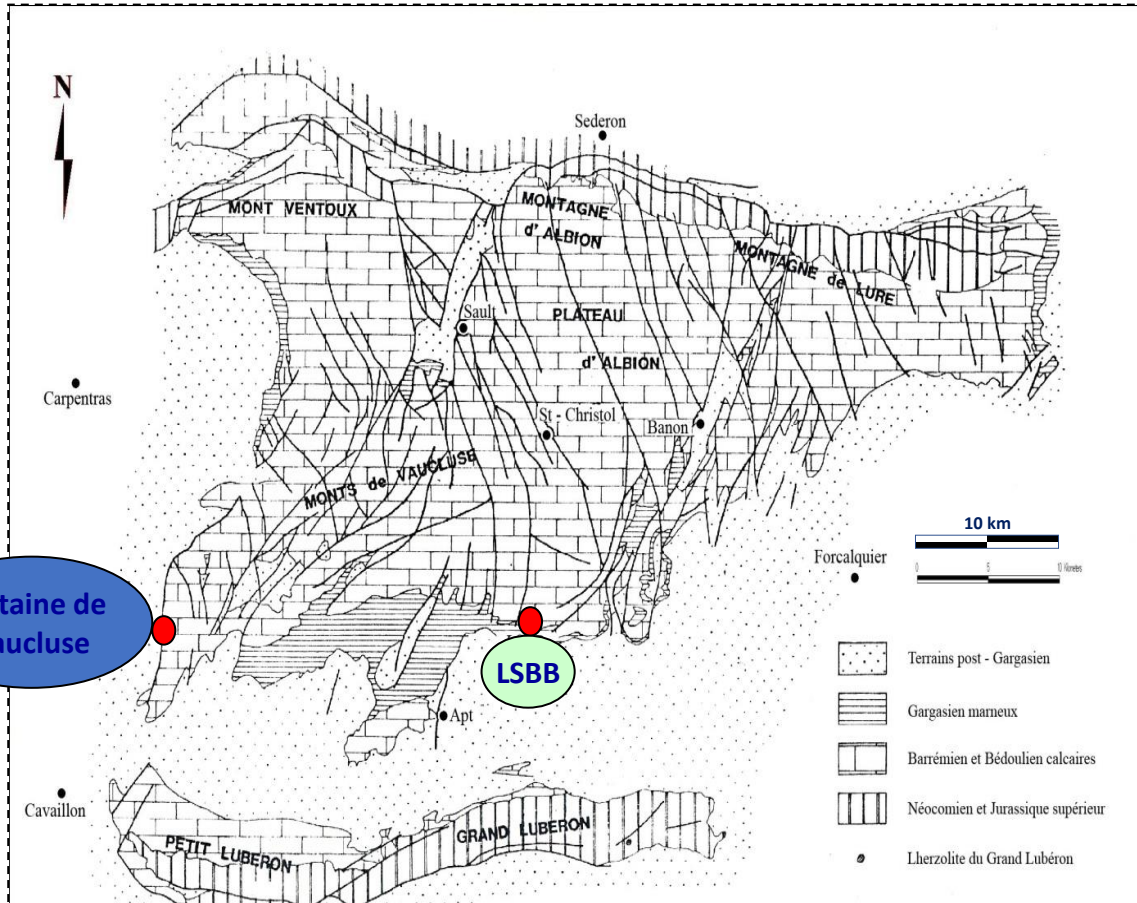
...



→ **WATER RESOURCE & RESERVE IN PERI-MEDITERRANEAN AREA**

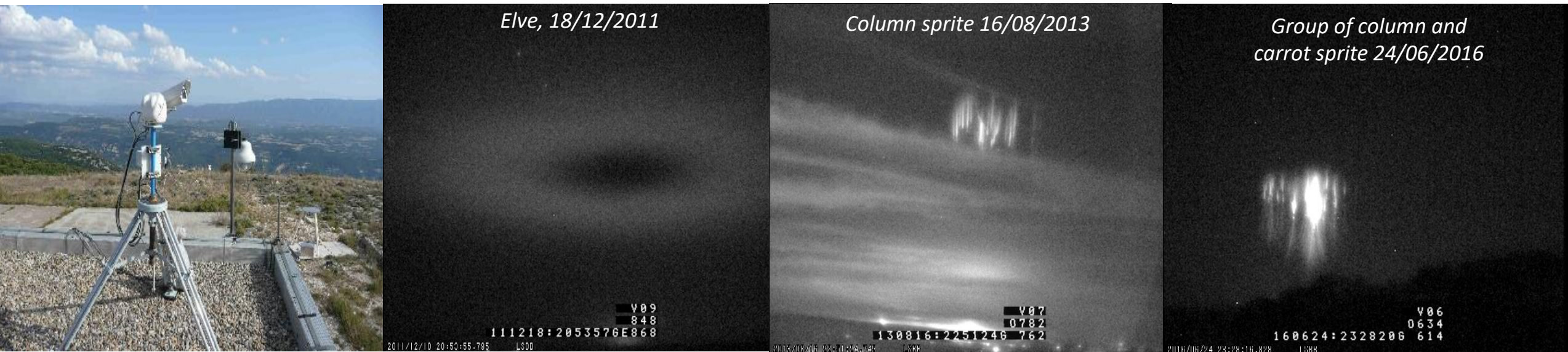
Dynamic of fluid transfer in Karst

- 150 years of flow measurements at Fontaine-de-Vaucluse catchment
- 20 years (2002-2022) of hydrochemical simultaneous measurements at both LSBB and Fontaine-de-Vaucluse
- Easy and « random » access to LSBB flows in the unsaturated area of the karstic aquifer and within the saturated zone towards boreholes



→ **ATMOSPHERE PHYSICS - TRANSIENT LUMINOUS EVENTS (TLE)**
A European collaboration

LSBB top

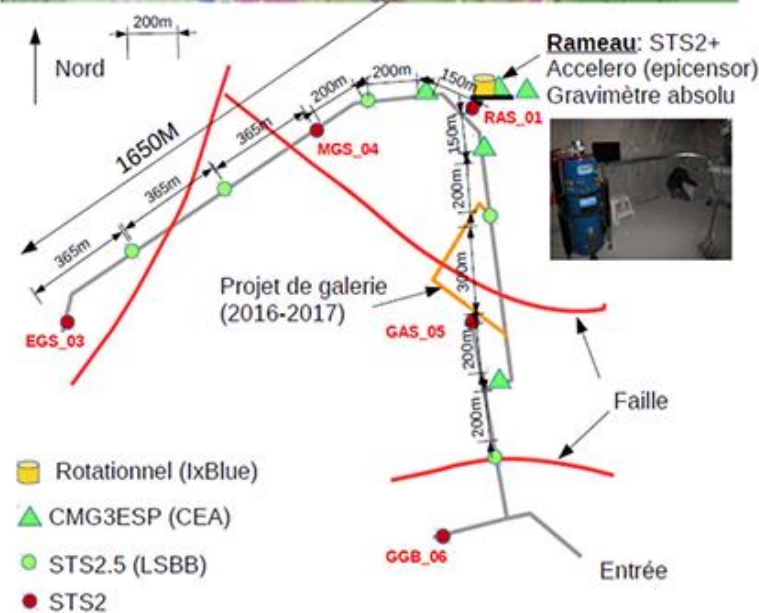
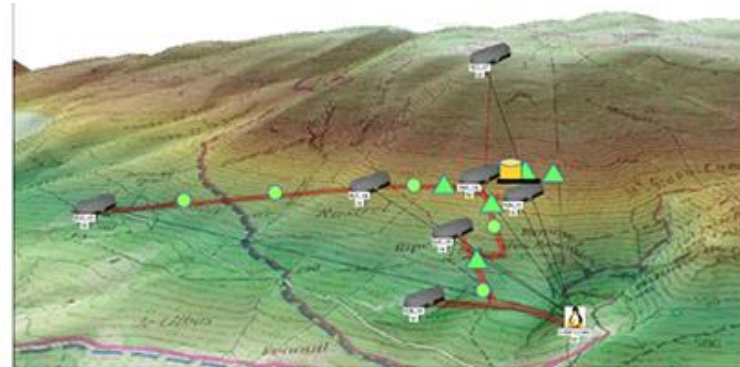
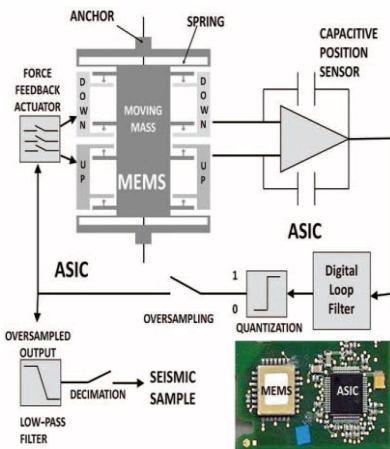


Pizzuti et al., 2021, Kolmašová et al., 2018, Kašpar et al., 2017; Liu et al., 2016; Soula et al., 2016

R&D PLATFORMS & LARGE INSTRUMENTS

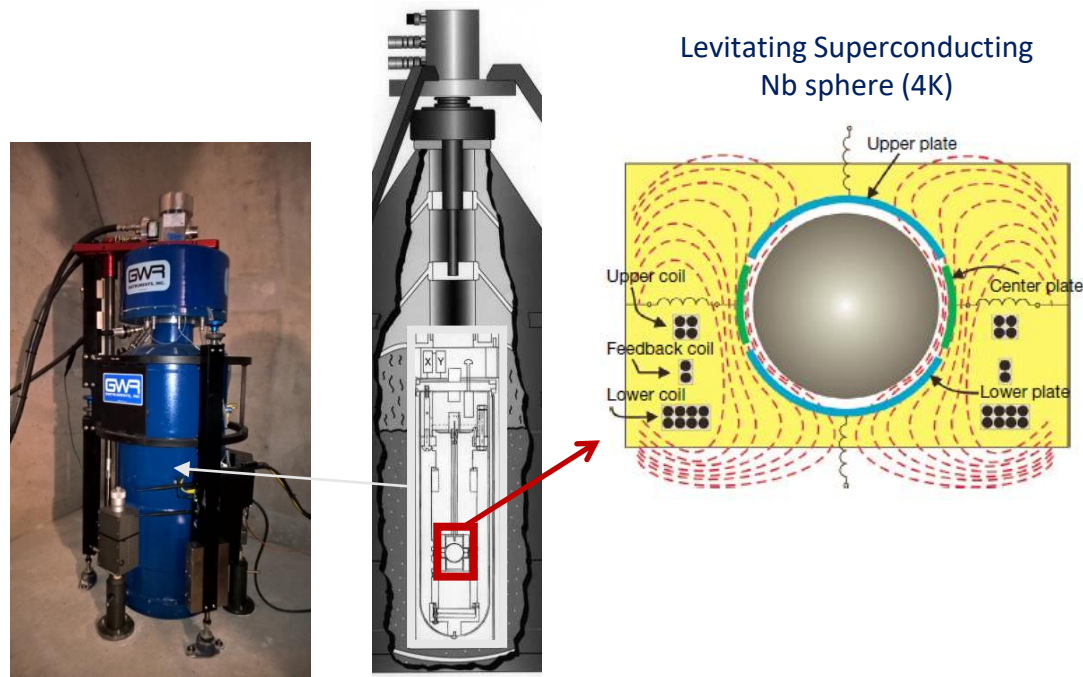
→ **ENABLE 3D CONFIGURATION FOR SEISMIC INSTRUMENTATION, ROTATION FIELD MEASUREMENT**

Comparison of measurements from an interferometric fiber-optic gyroscope and the spatial derivation of the seismic rotation field recorded by a dense network of seismometers



Comparison of gravimetric, micro-barometric, velocimetric, accelerometric measurements in a broad frequency band

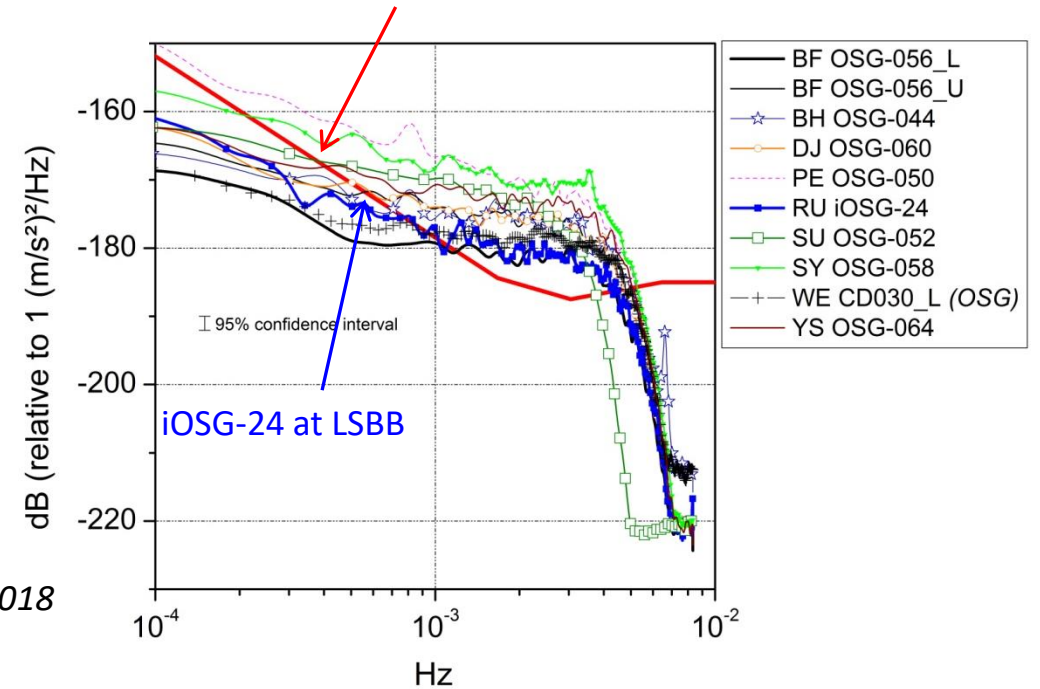
→ **SUPERCONDUCTING GRAVIMETRY @ LSBB SINCE 2015**
 iOSG-24 @ LSBB → one of the quietest site in the world



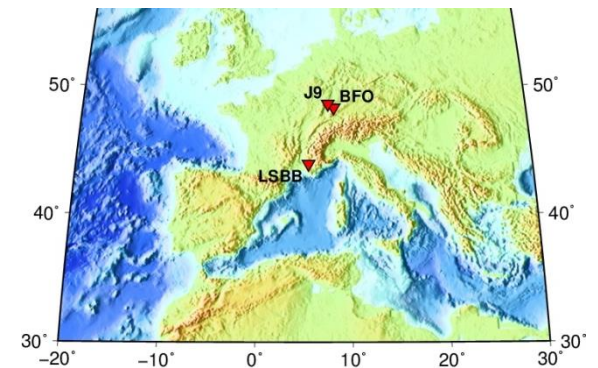
Levitating Superconducting Nb sphere (4K)

Rosat et al. 2016, 2018

Seismological New Low Noise Model (Peterson, 1993)



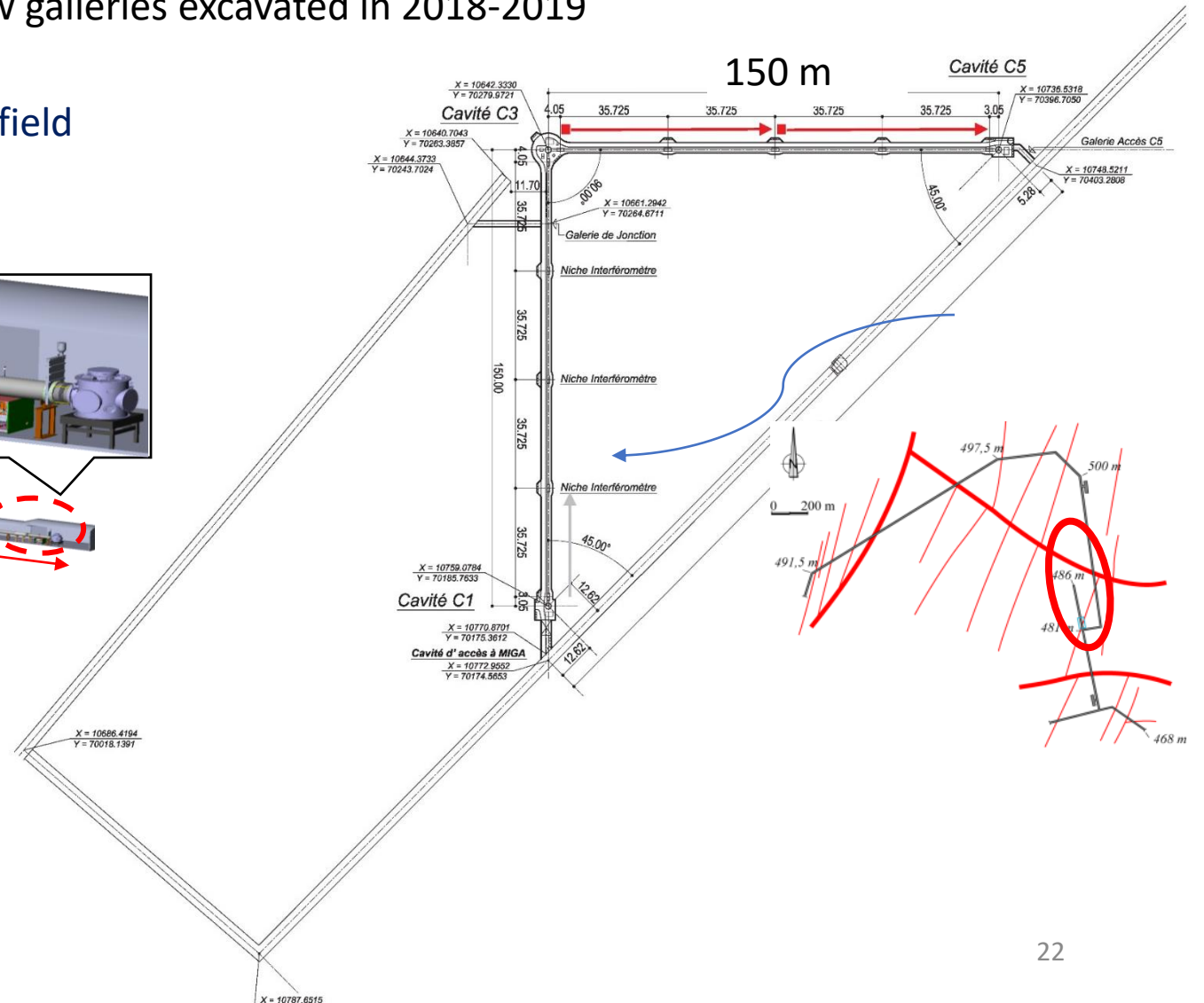
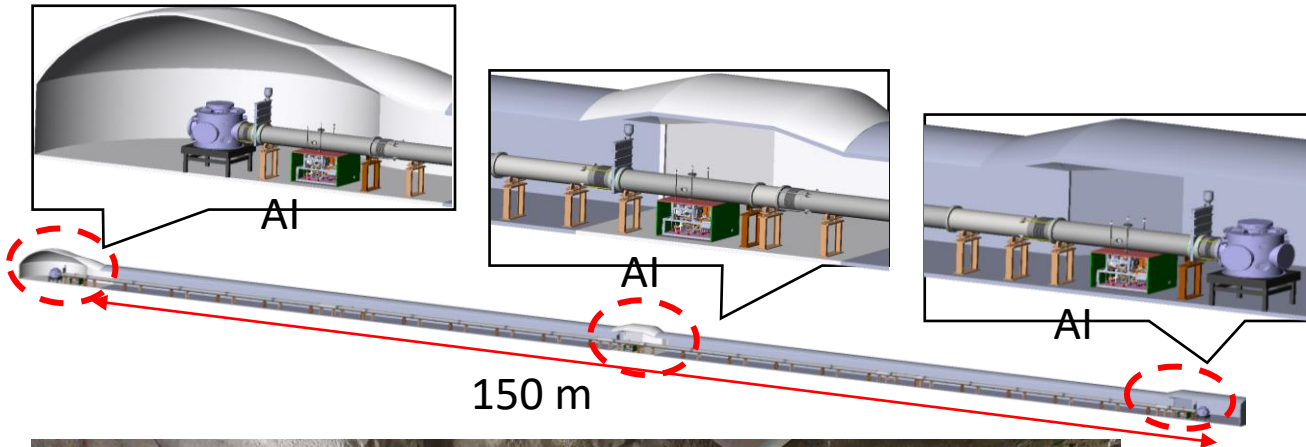
- ✓ Magnetic feedback very low instrumental drift (a few $\mu\text{Gal}/\text{year}$, where $1 \mu\text{Gal} \sim 10^{-8} \text{ m/s}^2$)
- ✓ Very high sensitivity at the nanogal level ($\sim 10^{-12} \text{ g}$)
- ✓ International node (iOSG-24) and continuous measurement of time-varying gravity: to be used for a consistent and rigorous quality check and intercomparison with the MIGA antenna

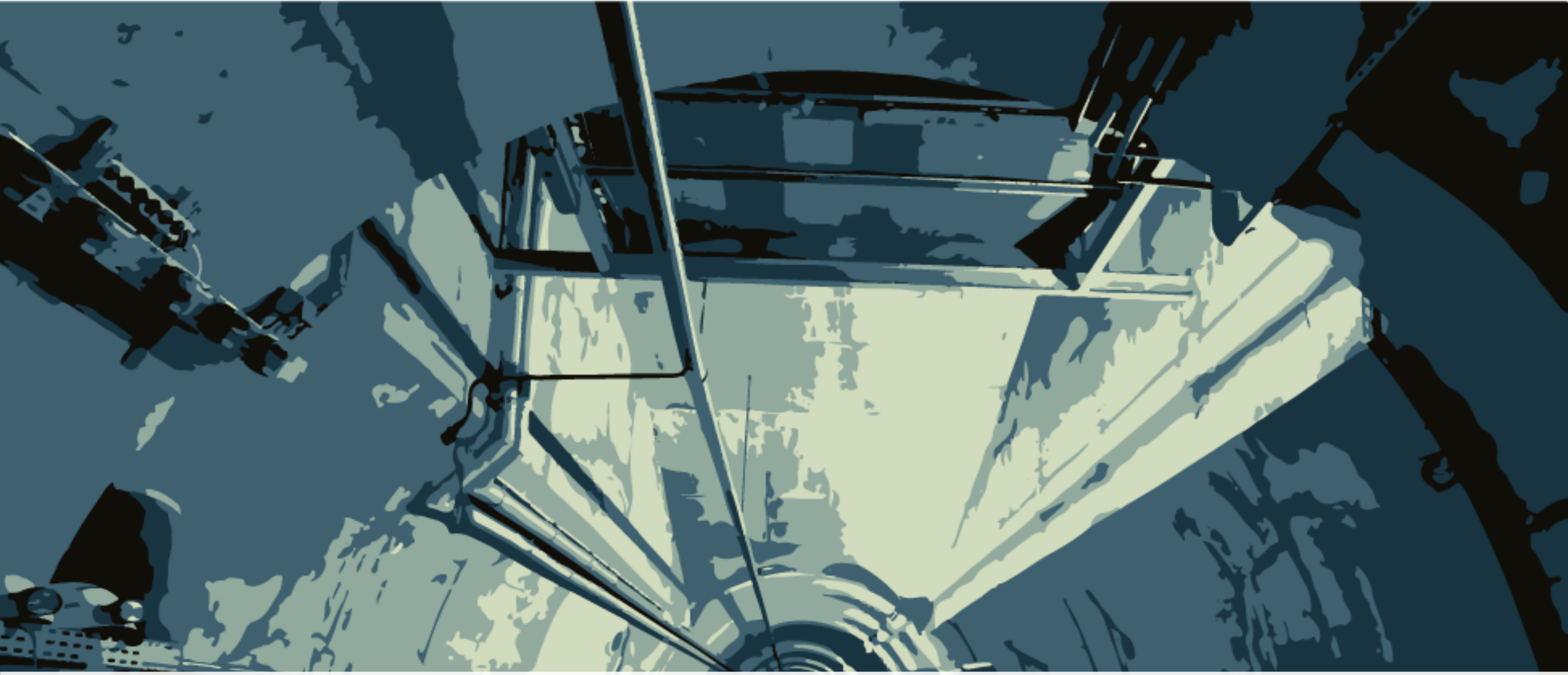


→ **MATTER WAVE - LASER BASED INTERFEROMETER GRAVITATION ANTENNA (MIGA)**

An array of Rb AI in the process of installation in the new galleries excavated in 2018-2019

- GW in astrophysics
- Very small changes and spatialization in local gravity field





STAFF AND ACCESS TO LSBB



DIRECTION

Stéphane GAFFET – Dir.
Gilles MICOLAU – Deputy Sci. Dir.
Daniel BOYER – Deputy Tech. Dir.

ADMINISTRATION

Sébastien GOUT

ENGINEER CREW

Alain CAVAILLOU
Daniel BOYER
Jean-Baptiste DECITRE

PROJECT SUPPORT (TRUST-ME, MIGA)

Ignacio LÁZARO ROCHE
Clément RISSO
Dylan SABULSKY (arriving in July)



→ **HOW TO DEVELOP AN ACTIVITY AT LSBB ?**

Contact mails : contact@lsbb.eu and direction@lsbb.eu

- **COMPLETION OF THE ACTIVITY SHEET** describing the research activity planned (see *lsbb.cnrs.fr* → *PROPOSE AN EXPERIENCE*)
- **ANALYSIS CRITERIA** by the LSBB direction – Compatibility with the low noise, the environment, the capacity of LSBB and with the forthcoming or already underway experiences
- **FEEDBACK AND ADAPTATION** of the activity where appropriate, discussion of the needs and cost of implementation
- **LEGAL AGREEMENT** with the CNRS including compliance to internal rules of LSBB (safety, low noise, dissemination, if necessary, condition for long-term residence defining the modality of maintenance)
- **PLANNING FOR IMPLEMENTATION** at LSBB including the workload of the engineer team of LSBB

**Thank you all for your availability along the *i*-DUST'2022 event
Enjoy the conference**

