





LSBB Laboratoire Souterrain à Bas Bruit Low Noise Inter Disciplinary Underground Science & Technology

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UNION EUROPÉENNE Fonds Européen de Développement Régional









Vacuum Fluctuations at Nanoscale and Gravitation: theory and experiments Or

Orosei, Sardegna

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Outline

- Legacy from history
- Current status
- Geological context
- Science at LSBB
 - Instrumental and Methodological Developments
 - Observations and Studies
 - Instrumental Platform and Big Instruments
 - Integration in Networks, Associations and Projects
- Conclusion



LEGACY FROM HISTORY



Creation of GMS « ALBION » in 1965 Operational since 1971





Access by mountain side, in a narrow valley over the RUSTREL village



South



Schema of the military infrastructure





LSBB inherited military infrastructure in its landscape





RECONVERSION...



→ DISMANTLING DECISION IN 1996

 « ...unjustified mission in the actual context and very costly modernisation anticipated... » President Jacques Chirac

French nuclear deterrence is now based on submarines: nobody knows *—in principle!* where they are, at the contrary of LSBB...

→ ALERT SENT TO THE FRENCH RESEARCH COMMUNITY WORKING IN UNDERGROUND LABS IN 1996

→ CONVERSION IN A RESEARCH LABORATORY IN 1997

→ PARTIAL DISMANTLING COMPLETED IN 1998

With help of...

Defense Ministery, Restructuration Funds for Defense Estates

Common Communities of Pays d'Apt, Vaucluse Dept., Provence-Alpes-Côte d'Azur Region Europe

Universities of Nice, Avignon, Marseille

CEA, CNRS and Research Ministery



CURRENT STATUS



CURRENT STATUS & GOVERNANCE





CURRENT STATUS & GOVERNANCE









THE GEOLOGICAL CONTEXT



GEOPHYSICAL AND HYDROGEOLOGICAL ENVIRONMENT





- Within one of the main seismogenic region of France
- Access to the unsaturated and saturated zone of the catchment of Fontaine-de-Vaucluse aquifer
- Easy access to a carbonate platform, geological analog of middle east Urgonian oil fields





THE SEISMIC FRANCE





Underground Labs





En couleur : épicentres des séismes d'origine naturelle dans la zone SI-Hex (France métropolitaine et zone économique exclusive en mer (ZEE), avec élargissement de 20 km), ainsi que les séismes ressents en France avec une intensité EMS-98 \geq IV (BCSF). En grisé : épicentres des séismes hors zone pour lesquels une magnitude M₄ a été calculée dans le cadre du projet SI-Hex.

100 km



→ Environment

Low anthropic noise (within the Regional Nature Park of Luberon) A geological analog of the carbonated oil-fields exploited in the Middle East 5th water resources in the World, 1st in Mediterranean supplied only by rains Major Seismogenic Region South of France

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→ Infrastructure

EM Shielded Capsule 28 m × \emptyset 8 m at 518 m depth Fully equipped (energy, Optical Fibers, safety) at surface and underground Access to surface access (\approx 50 ha) and depth (4 km) Boreholes for instrumentation from surface and galleries

=

A multi-scale laboratory and ultra-sensitive experiments

Geophysics, geology, physics, astrophysics, life and health Metrology, calibration, characterization and instrumentation Carbonate, porous and fractured reservoirs Underground water resources, fluid transfers, global changes



European underground labs (•active/•future)

Open to everyone respecting the environment necessary to other experiments



SCIENCE AT LSBB



An Underground –and Surface– Laboratory Dedicated to Interdisciplinary Academic and Industrial Researches

- → RESSOURCES
 - Karst, Underground Water Resources, carbonated platform
- → INTERACTIONS OF ENVIRONMENT AND FLUID Processes and thermo-hydro-mechanical couplings, poro-elasticity, geomechanics
- → PROPAGATION OF WAVES AND RADIATIVE ENVIRONMENT Seismology, Magnetism, Gamma / Neutrons / Muons / WIMPs (DM) radiations
- → INSTRUMENTATION & HIGH SENSITIVITY MEASUREMENTS Gravimetry, Densitometry, Magnetometry, Seismometry, Rotation & Clinometry
- → LIFE In situ Biology, Brain Imaging
- \rightarrow HUMAN SCIENCE & SOCIETY
 - Contemporary History vs Cold War, Anthropization vs Global Changes



Instrumental and Methodological Developments

High Sensitivity Instrumentation (Radar, Muon Cameras, ...) Earth Imaging, Earth's Critical Zone Dynamics, Characterization of Geological Reservoirs Electroencephalography (EEG) at Wide Band and High Sensitivity

Observations and Studies

Multi-physics Observatory (Seismology, Gravimetry, Magnetometry, Hydrogeology, ...) Observation and Analysis of Geophysical Phenomena (Earth Interior, Surface, Atmosphere) Multidisciplinary Approach of Geophysical Processes (Fracturing, Poro-elasticity)

> Instrumental Platforms and Big Instruments Instrumental Comparison (seismic) Instrumentation for the Measurement of Gravitation



SCIENCE AT LSBB

INSTRUMENTAL AND METHODOLOGICAL DEVELOPMENTS



- ightarrow Broad Band High Sensitivity Radar Imaging of subsoil (ightarrow-20m)
- \rightarrow Inversion of properties (permittivity, conductivity)



Sénéchal et al., NSG 2013 Berès et al. JAG 2013



IMAGING AT INTERMEDIATE SCALES

ightarrow Geophysical Characterization of the geological environment of LSBB









HEALTH HIGH SENSITIVITY ELECTROENCEPHALOGRAPHY (EEG)



Shahidi Zandi et al., IEEE/TMBE 2011 Hamzei et l., 2016 LIA LSBB-LEAT-UBC Ground & Brain Ultimate Low Noise Imaging Lab.



SCIENCE AT LSBB

OBSERVATIONS AND STUDIES



WAVE PHYSICS POLARISATION OF SEISMIC WAVES





\rightarrow Water resource & reserve in peri-Mediterranean area

- o 140 years of flow measurements at Fontaine-de-Vaucluse catchment
- **o** 16 years (2002-2018) 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





TRANSIENT LUMINOUS EVENTS (TLE)

\rightarrow A European collaboration

Observatoire Midi-Pyrénées, CEA, LSBB (Fr), Inst. of Atm. Physics (Prague, Cz), DEEE Oxford (Uk)



LSBB, top

preparing the Taranis satellite mission (CNES, 2019)





Kašpar et al., 2017; Liu et al., 2016; Soula et al., 2016



SCIENCE AT LSBB

INSTRUMENTAL PLATFORM AND BIG INSTRUMENTS





Single Event Upset (SEU) expected rate due to alpha contamination in the tested device for 1 year was **4 events** Only **1 event** has been detected : **the rate is at least 4 times better** than expected !



Possible explanation for the observed error :

Rosetta at

LSBB

1500 m.w.e.

.e. -550m in calcite

- 1) alpha associated with a solder bump
- 2) **bad bit** in the part. If so, the same bit should have upset again
- 3) **signal integrity** (noise) : power supply, cross talk, read-disturb ...

Fernandes et al., 2016; Castellani et al., 2008; Lesea et al., 2005, 2006, 2007, 2008



PLATFORM 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





Laine & Mougenot, SEG 2014 EGU 2018





Comparison of gravimetric, microbarometric, velocimetric, accelerometric measurements in a broad frequency band



ULTRA-SENSITIVE MAGNETOMETRY \rightarrow ADDRESSING EARTH/IONOSPHERE COUPLINGS...

The capsule and the cabin



SQUID² 3D magnetometer @ LSBB (SQUID in a Shielding QUalified for Ionosphere Detection) Noise level ~ 3 fT/ \sqrt{Hz}





Sichuan-Wenchuan Earth Quake, May 12, 2008 (Mw 8.1)

G. Waysand et al (2011) CR Phys. 12 , 192 See also Mangin & Kahn, 2018, EDP Sciences



« SUPERCONDUCTING » GRAVIMETRY **@ LSBB SINCE 2015**







~ Magnetic feedback \rightarrow very low instrumental drift a few μ Gal/year, where 1 μ Gal ~ 10⁻⁸ m/s²

Center plate

Very high sensitivity at the nanogal level ($\sim 10^{-12}$ g) \checkmark International node (iOSG-24) \checkmark and continuous measurement of time-varying gravity: to be used for a consistent and rigorous quality check and intercomparison with the MIGA antenna

S. Rosat et al. 2016, E3S, i-Dust2016



 $iOSG-24 @ LSBB \rightarrow$ one of the quietest site in the world



A NEW UNDERGROUND INFRASTRUCTURE ATOMIC INTERFEROMETER FOR GRAVIMETRY (MIGA)

 \rightarrow See Benjamin Canuel's presentation at this workshop





SCIENCE AT LSBB

Integration in (Inter-)National NETWORKS, ASSOCIATIONS AND PROJECTS



Integration in (inter-)national NETWORKS, ASSOCIATIONS & PROJECTS

Research fields	Network name or Project	Collectivity	Comments
Seismology	ORFEUS, RAP RESIF (equipex)	Europe, France	Observatories and Research Facilities for EUropean Seismology French Accelerometric Network
Gravimetry	IGETS	World Wide (node @ EOST Strasbourg, Fr)	International Geodynamics and Earth Tide Service
Gravitation and cold atoms	ELGAR	Design Study Eu, 17 partners	European Laboratory for Gravitation and Atom-interferometric Research (next design study call nov 2019)
Hydro Geology Water ressources	SOKARST	Fr	Drainage basin of Fontaine de Vaucluse
Astroparticles	DULIA underground labs	Europe (APPEC)	With LNGS(It), LSM(Fr),LSC(E) & BUL(UK) + a joined Research Infrastructure LSBB_ LSM (CNRS INSU &IN2P3) ?
Muon tomography	RD51	CERN (Eu)	Sharing technology
Earth magnetic field	"Geo SQUID"	LSBB(Fr) HMO(SA)	Two first nodes !
Medicine	Brain studies (EEG)	UBC, CA	\rightarrow International Associated Laboratory with CNRS ?



CONCLUSION

LSBB, a new research infrastructure offering, thanks to its Low Noise conditions

- ✓ Multi-physical Observations of the Earth (from internal Earth to Ionosphere)
- ✓ the Hosting of Academic and Industrial Experiments
- \checkmark the Hosting of Instrumental Platforms
- ✓ the Hosting of Big Experiments

✓ the Training of Students (44 PhDs defenses involving LSBB since its creation)
 ✓ ...

with strong societal commitments :

✓ Water resource monitoring	(global climate change, local agriculture,)
 Optimization of oil exploitation 	(oil-field analogue of Middle East)
✓ Magnetic monitoring	(earth quake prevention ?)
✓ Interdisciplinary International Conferences	(i-DUST, every 2 years)

LSBB short-term priority

✓ Make the MIGA experiment a success

✓ To contribute to the design study of a future European infrastructure devoted to the common observations of GW and gravimetric perturbations (\rightarrow ELGAR project)

LABORATOIRE SOUTERRAIN À BAS BRUIT DE RUSTREL PAYS D'APT LUBERON

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THANK YOU !