Inter-Disciplinary Underground Science and Technology

Report of Contributions

https://indico.cern.ch/e/idust2022

Contribution ID: **6** Type: **Plenary talk**

Monitoring the water stock using two vertically distributed superconducting gravimeters help to quantify evapotranspiration at daily time scale.

Wednesday 8 June 2022 10:40 (20 minutes)

Evapotranspiration (ET) is a major term of the water cycle which remains one of the biggest sources of uncertainty in hydrology. It is necessary to better understand this component and to develop new approaches to improve its quantification. Gravimetry is a geophysical method that measures variations in the Earth's gravity field "g". Superconducting gravimeters (SG) provide continuous and precise measurement of g which can be related to changes in the water storage with a high accuracy. We seek to evaluate the potential of this approach to estimate the ET from daily time series. We chose the Underground Laboratory at Low Noise (LSBB) as it is the only site in the world to have two superposed SG. This unique configuration allows to subtract the deeper signal to the upper one in order to obtain a surface to depth residual where all global effect (e.g., tides, polar motion, atmospheric loading) are removed. We compared this very clean signal to calculated ET values using the SimpKcET model. In favorable conditions (i.e., rain-free days, no disturbances), we observed a significant correlation between the daily gravimetric changes and the karst vadose zone outlets (i.e., modeled ET and measured discharge). The daily variation in gravity signal can be mainly attributed to the daily variation in ET. This approach is then validated for surface-to-depth residuals, but remains more difficult for single surface-based SG. To strengthen this correlation, we are conducting complementary measurements to obtain a more accurate estimation of ET. Through the comparison between gravity signal and direct tree transpiration measurements using sap flow sensors. Determining ET from hydrogeodesy is a real challenge that approaches the technological and signal processing limits of gravimetry. Our ambition is now to work on single SG in order to reproduce and adapt our methodology on other experimental sites equipped with SG.

Primary authors: LOISEAU, Bertille (Sorbonne Université, UMR 7619 METIS, F-75005 Paris, France); Mr CARRIÈRE, Simon Damien (Sorbonne Université, CNRS, EPHE, UMR 7619 METIS, F-75005 Paris, France); Mr GINOUX, Malo (Sorbonne Université, CNRS, EPHE, UMR 7619 METIS, F-75005 Paris, France); Mr CHAMPOLLION, Cédric (Université de Montpellier, UMR 5243 GM, 34095 Montpellier, France); Mrs OLLIVIER, chloé (IRD, UMR 5126 CESBIO, 31401 Toulouse, France); Mr MARTIN-STPAUL, Nicolas (INRAE, URFM, 40509 Domaine St-Paul, France); Mrs LESPARRE, Nolwenn (CNRS, UMR 7063 ITES, 67084 Strasbourg, France); Mr OLIOSO, Albert (INRAE, URFM, 40509 Domaine St-Paul, France); Mrs MAZZILLI, Naomi (INRAE, UMR 1114 EMMAH, 40509 Domaine St-Paul, France); Mr CHALIKAKIS, Kostantinos (INRAE, UMR 1114 EMMAH, 40509 Domaine St-Paul, France); Mr HINDERER, Jacques (CNRS, UMR 7063 ITES, 67084 Strasbourg, France); Mr JOUGNOT, Damien (Sorbonne Université, CNRS, EPHE, UMR 7619 METIS, F-75005 Paris, France); MERCIER, Vincent (INRAE, UMR 1114 EMMAH)

Presenter: LOISEAU, Bertille (Sorbonne Université, UMR 7619 METIS, F-75005 Paris, France)

Session Classification: #2 Session (I. Kolmasova/B.Canuel)

Track Classification: Critical Zone

Contribution ID: **7** Type: **Plenary talk**

Asymmetric Backward Peaking Radiation Patterns from an Accelerated Relativistic Bremsstrahlung Particle In High Density Mediums

Wednesday 8 June 2022 16:00 (20 minutes)

Radiation patterns of combined parallel and perpendicular motions from the accelerated relativistic particle at low and high frequencies of the bremsstrahlung process with an external lightning electric field were explained. The primary outcome was that radiation patterns have four relative maxima with two forward peaking and two backward peaking lobes. The asymmetry of the radiation pattern, i.e., the different intensities of forwarding and backward peaking lobes, is caused by the Doppler effect. A novel outcome is that bremsstrahlung has an asymmetry of the four maxima around the velocity vector caused by the curvature of the particle's trajectory as it emits radiation (Yücemöz & Füllekrug, 2021). Further extended work reports another novel asymmetry in the overall radiation pattern from a single particle. Previously stated bremsstrahlung asymmetry, R was an asymmetry in the radiation lobe pairs about particle's velocity vector. Bremsstrahlung asymmetry used to occur at the same level (Same magnitude) in both forward radiation lobe pairs and backward radiation lobe pairs. However, in high-density mediums where the emitted wave can lag behind the speed of the particle, symmetry of the magnitude of bremsstrahlung asymmetry, R differs between forward peaking radiation lobe pairs relative to backward peaking radiation lobe pairs. This is another novel asymmetry and it causes bremsstrahlung asymmetry, R to be larger in the forward peaking compared to backward peaking radiation. Furthermore, bremsstrahlung asymmetry, R determines the magnitude of the Doppler effect in each radiation lobe which in turn enhances the increase in the difference in radiation length and increases the bremsstrahlung asymmetry further. A higher density medium causes backward peaking radiation length to decrease. Shrink in radiation length is higher in the backward direction as backward peaking lobes are always at a lower intensity and have low energies due to the Doppler effect. The effect of Doppler effect is larger on radiation lobes when the separation angle between two radiation lobes decreases. This is because decreasing the separation angle between two lobes brings two lobes closer into the line of direction of motion. Another conclusion is that forward and, backward peaking radiation patterns are not symmetrical around the particle's velocity vector in the case of bremsstrahlung asymmetry, R exists in straight-line trajectories. This extended mathematical modelling of the bremsstrahlung process into different high-density mediums helps to better understand the physical bremsstrahlung processes of a single particle's radiation pattern, which might assist the interpretation of observations with networks of radio receivers and arrays of γ-ray detectors.

Primary author: Dr YUCEMOZ, Mert (University of Bath)

Presenter: Dr YUCEMOZ, Mert (University of Bath)

Session Classification: #3 Session (L. Ottaviani/I. Lázaro)

Track Classification: Astrophysical measurements in the terrestrial environment

Contribution ID: **8** Type: **Plenary talk**

Portable Resistive Plate Chambers for muography in confined environments

Tuesday 7 June 2022 15:20 (20 minutes)

Muography (or muon radiography) is an imaging technique that relies on the use of cosmogenic muons as a free and safe radiation source. It can be applied in various fields such as archaeology, civil engineering, geology, nuclear reactor monitoring, nuclear waste characterization, underground surveys, etc. In such applications, sometimes deploying muon detectors is challenging due to logistics, e.g. in a narrow underground tunnel or mine. Therefore, we are developing muon detectors whose design goals include portability, robustness, autonomy, versatility, and safety. Our portable muon detectors (or "muoscopes") are based on Resistive Plate Chambers (RPC), planar detectors that use ionization in a thin gas gap to detect cosmic muons.
At present, we have two fully assembled and operational muoscopes of active area $16 \times 16\ cm^2$ and $28 \times 28\ cm^2$. Benefiting from the experience gained in building and operating these prototypes, we are proceeding towards the development of an improved muoscope version with more advanced technical layout and readiness. In this presentation we provide the status of our performance studies, and an outline of the direction ahead. We aim at improving the resolution substantially by increasing the number of readout channels, and we are also exploring the option of moving from strips to pixels; as that would imply a large increase in the number of readout channels, we are developing 2D multiplexing algorithms. Moreover, a better gas circulation circuit will be implemented to assure the uniformity of the gas distribution in the chamber.

Primary authors: SAMALAN, Amrutha (Ghent University (BE)); GIAMMANCO, Andrea (Universite Catholique de Louvain (UCL) (BE)); CORTINA GIL, Eduardo (Université catholique de Louvain); AL MOUSSAWI, Marwa; TYTGAT, Michael (Ghent University (BE)); DEMIN, Pavel (Universite Catholique de Louvain (UCL) (BE)); GAMAGE, Ran Muthugalalage Ishan Darshana (Université catholique de Louvain (UCLouvain)); KARNAM, Raveendrababu (Universite Catholique de Louvain (UCL) (BE)); BASNET, Samip (UCL - CP3); YOUSSEF, ayman (Lebanese University)

Presenter: GAMAGE, Ran Muthugalalage Ishan Darshana (Université catholique de Louvain (UCLouvain))

Session Classification: #1 Session chaired by S. Gaffet

Track Classification: Couplings: Earth, solid, atmosphere, universe

Contribution ID: **9** Type: **Plenary talk**

Tomographic Research of Underground and large STructures with Muographic Expertise (TRUST-ME).

Wednesday 8 June 2022 09:30 (20 minutes)

Transmission muography is a rising technique in domains such as geophysics and civil engineering. It provides dynamic information about the density distribution around the detector thanks to the attenuation of a natural, passive source: cosmic muons. This long-reach technology provides complementary information to classical prospecting tools for the study of active, heterogenous environments.
In that context, the TRUST-ME project aims at validating the LSBB in-house muon tracker technology (MUST²)[1], for two novel applications: groundwater monitoring towards its sustainable management and large infrastructure surveillance.
This contribution presents the interest of the muon tomography for monitoring both the critical zone and hydraulic infrastructures. A versatile network of 20 autonomous muon trackers is currently being deployed at the Low Background Noise Underground Research Laboratory (LSBB) of Rustrel. The work also describes the detector working principle, the improved features after major electronics update and its associated challenges towards the proof-of-concept validation.
Lastly, the European muographic community is making an ambitious collaborative effort in the context of the APOGEIA HORIZON-INFRA-2022-TECH-01 project. The goals of the consortium concerning the Muography work package, the participation of the TRUST-ME project and the implications for the LSBB as host infrastructure will be addressed as well.
1. Lázaro Roche, I., Decitre, J. B., & Gaffet, S. (2020). MUon Survey Tomography based on Micromegas detectors for Unreachable Sites Technology (MUST²): overview and outlook. Journal of Physics Conference Series. 1498: 012048. 10.1088/1742-6596/1498/1/012048

Primary authors: RISSO, Clement Antoine (LSBB - Laboratoire Souterrain a Bas Bruit (FR)); Dr LAZARO ROCHE, Ignacio (LSBB - Laboratoire Souterrain a Bas Bruit (FR))

Presenters: RISSO, Clement Antoine (LSBB - Laboratoire Souterrain a Bas Bruit (FR)); Dr LAZARO ROCHE, Ignacio (LSBB - Laboratoire Souterrain a Bas Bruit (FR))

Session Classification: #2 Session (I. Kolmasova/B.Canuel)

Track Classification: Couplings: Earth, solid, atmosphere, universe

Contribution ID: **10** Type: **Plenary talk**

ArchéMuon: A Gallo-Roman archaeological site as a "sandbox" for testing muography and geophysical imaging techniques

Wednesday 8 June 2022 14:30 (20 minutes)

During the last 20 years muon tomography has been recognized for its contributions to various domains of science like Volcanology, Hydrology, Archaeology and many more. Its impact is especially prominent in the case of Volcanoes either as a standalone remote imaging technique or in combination with other more traditional Geophysical methods. Being non-invasive, muography, has no adverse impact on the studied object and this makes it an excellent tool for the imaging of archeological sites. The discovery of the previously unknown void in the Great Pyramid of Giza by the ScanPyramids project proved how capable muography can be as standalone probe of smaller-scale targets. Most sites of archaeological interest are not completely excavated and remain buried or quasi-buried for long periods after their discovery and while the excavations are being performed. This gives rise to formations where muon tomography and near-surface Geophysics could work together to map the subsurface structures. In 2018 we conducted a 3-month muography survey in the excavated tumulus of Apollonia in Chalkidiki (Greece) with goal to evaluate the discovery potential for the buried tomb. Based on the findings and conclusions of that expedition a controlled environment was deemed imperative for the evaluation of joint measurements with other methods. The courtyard of the Gallo-Roman Museum of the Saint-Romain-an-Gal community hosts one of the largest and best preserved Roman residential districts discovered in France and is perfect for this kind of studies. In the ArchéMuon project three laboratories[1] join forces to create a field test-bench where different near-surface imaging techniques can be tested in comparison to and in conjunction with muon tomography. A network of different sensors like electrodes (electric resistivity), optical fibers (seismic imaging) and gravimeters will be placed on the surface while muon detectors will continuously be taking measurement underground. A comparative analysis between methods is expected to provide valuable insights on the optimal synergetic approach for archaeological studies and other applications of similar scale. Furthermore, the long-term monitoring of the region will be an excellent opportunity to extract conclusions for the weather impact (mainly through water retention/drainage) on the archaeological site and on the imaging efficiency itself.

[1] Institut de Physique des 2 Infinis de Lyon (IP2I), Laboratoire de Géologie de Lyon: Terre, Planète, Environnement (LGL-TPE), Laboratoire Archéorient Maison de l'Orient et de la Méditerranée (MOM)

Primary authors: Dr TAUZIN, Benoît (LGL-TPE UCB Lyon1); Dr BENECH, Christophe (UMR Archéorient); Dr MARTEAU, Jacques (Universite Claude Bernard-Lyon); Mr AVGITAS, Theodore (IP2I Lyon)

Presenter: Mr AVGITAS, Theodore (IP2I Lyon)

Session Classification: #3 Session (L. Ottaviani/I. Lázaro)

Track Classification: Couplings: Earth, solid, atmosphere, universe

Contribution ID: **11** Type: **Plenary talk**

Lightning initiation seen by the magnetic loop antennas installed at LSBB

Wednesday 8 June 2022 11:00 (20 minutes)

Sequences of bipolar pulses, which are believed to identify the initiation of the majority of both cloud-to-ground (CG) and intracloud lightning flashes in electromagnetic recordings, have been regularly detected by magnetic loop antennas installed at the external site of LSBB at Vestale on the Plateau d'Albion. Since 2013, numerous studies on lightning initiation based on the LSBB data acquired by different antenna configurations have been already published. We present a few examples of our research on lightning initiation including the thundercloud charge structure derived from the electromagnetic recordings.
Energetic pre-stroke pulse sequences (called also preliminary breakdown (PB) pulses) were found in broadband electromagnetic recordings from a multi-cell summer thunderstorm. Combined analysis of electromagnetic and radar data placed the lightning initiation in small, short living cells outside or on edges of the main convective line. This observation can be explained by a presence of strong negative charge pockets and a strong lower positive charge region inside the thundercloud. In another study of PB processes, we found unexpectedly fast evolution of summer negative CG lightning strokes, which we could explain by the presence of a strong negative charge centre inside the thundercloud. By combining the magnetic field data with the electric field measurements located several hundred kilometres from LSBB, we found that PB pulses can be detected at distances up to 600 km from their source and that there was a significant sky wave energy from PB pulses in the signal beyond about 500 km. Recently we aimed at initial stage of energetic negative CG winter lightning flashes. We found specific patterns in the time evolution of PB pulse amplitudes and inter-pulse intervals and hypothesize that this pattern reflects a spatial arrangement of dense pockets of negative charge inside the thundercloud.

Primary author: Dr KOLMASOVA, Ivana (Institute of Atmospheric Physics, Czech Academy of Sciences and Faculty of Mathematics and Physics, Charles University)

Co-author: Prof. SANTOLIK, Ondrej (Institute of Atmospheric Physics, Czech Academy of Sciences and Faculty of Mathematics and Physics, Charles University)

Presenter: Dr KOLMASOVA, Ivana (Institute of Atmospheric Physics, Czech Academy of Sciences and Faculty of Mathematics and Physics, Charles University)

Session Classification: #2 Session (I. Kolmasova/B.Canuel)

Track Classification: Couplings: Earth, solid, atmosphere, universe

Contribution ID: **12** Type: **Plenary talk**

Very first observation data from a giant loop antenna at the LSBB

Tuesday 7 June 2022 16:30 (20 minutes)

A giant magnetic antenna has been installed at the mountain top surface of the LSBB site since 2010, initially dedicated to excite a SQUID magnetometer situated 520 meter underground. The antenna is a 300 meter long domestic cable laying on the ground and covering an area of 5600 m². Its unusual size and its location on a pluri-disciplinary instrumented site allows to make it an original and unique instrument dedicated to environmental observations. For two years, we have worked on modifying this device into a giant standalone magnetic sensor, based on appropriated technologies which ensure remote control, versatility of use and flexibility for adding new features. Today, this design offers two operating modes.
The first one consists in monitoring the time evolution of its internal electrical impedance. Basically, we can continuously measure the electrical impedance over a wide range of frequencies (from 20Hz to 10kHz) corresponding to the quasi-static regime and covering the electrical resonance of the loop. The second mode consists in measuring the weak spontaneous electrical voltage induced at the loop endpoints. The monitoring can be performed by time-resolved spectral analysis in this case. On another note, qualitative comparisons with measurements made on a mock-up installed in the galleries of the LSBB tends to show that the time variations observed on electrical impedance characteristics are linked to external disturbances.
In this presentation, we first address the up-to-date available data to discuss the experimental protocols we used and the instrument sensitivity. Then we present significant information extracted from these data. It is the starting point for discussions in view to correlate them with other signals available at the LSBB such as SQUID measurements, gravimeters data, hydric data of the moutain, etc...

Primary author: Mr DEZORD, Clément (Ecole Doctorale 536 Sciences et Agrosciences (Avignon Université), CNRS/UMS 3538 Laboratoire Souterrain à Bas Bruit)

Co-authors: Mr MICOLAU, Gilles (CNRS/UMS 3538 Laboratoire Souterrain à Bas Bruit); Mr MESGOUEZ, Arnaud (AU/INRAe UMR 1114 Environnement Méditerranéen et Modélisation des Agro-Hydrosystèmes); Mrs POZZO DI BORGO, Elisabeth (CNRS/UMS 3538 Laboratoire Souterrain à Bas Bruit); Mr ABBAS, Chahine (AU/INRAe UMR 1114 Environnement Méditerranéen et Modélisation des Agro-Hydrosystèmes)

Presenter: Mr DEZORD, Clément (Ecole Doctorale 536 Sciences et Agrosciences (Avignon Université), CNRS/UMS 3538 Laboratoire Souterrain à Bas Bruit)

Session Classification: #1 Session chaired by S. Gaffet

Contribution ID: **14** Type: **Plenary talk**

Coupling of atmospherics and the ionosphere observed from LSBB

Thursday 9 June 2022 10:40 (20 minutes)

All lightning strokes generate electromagnetic pulses –atmospherics– which can travel over distances of thousands of kilometers. Night-side atmospherics show typical frequency dispersion signatures caused by sub-ionospheric propagation. Their analysis can be used to determine the distance to the source lightning, and therefore it represents a safe tool for investigation of distant thunderstorms, as well as for indirect observations of the lower ionosphere.

We have developed a method based on a deep learning approach to automatically obtain the type of atmospherics, their exact time, and the frequency range from the frequency-time spectrograms using the data recorded on the external site of LSBB at Vestale. The method that employs convolutional neural networks is designed to be adaptable to scientific needs and provide reliable results according to the requirements on the sensitivity to events, computation performance, and precision of extracted details.

We have also captured unusual daytime atmospherics with dispersion signatures originating from strong thunderstorms which occurred during winter months 2015 in the North Atlantic region. Using newly developed analysis techniques for 3-component electromagnetic measurements we are able to determine the source azimuth and to attribute these rare atmospherics to both positive and negative lightning strokes in northern Europe. We consistently find unusually large heights of the reflective ionospheric layer which are probably linked to low fluxes of solar X rays and which make the dayside subionospheric propagation possible. Although the atmospherics are linearly polarized, their dispersed parts exhibit left handed polarization, consistent with the anticipated continuous escape of the right-hand polarized power to the outer space in the form of whistlers.

Primary author: SANTOLIK, Ondrej (Institute of Atmospheric Physics, Czech Academy of Sciences and Faculty of Mathematics and Physics, Charles University)

Co-author: KOLMASOVA, Ivana (Institute of Atmospheric Physics, Czech Academy of Sciences and Faculty of Mathematics and Physics, Charles University)

Presenter: SANTOLIK, Ondrej (Institute of Atmospheric Physics, Czech Academy of Sciences and Faculty of Mathematics and Physics, Charles University)

Session Classification: #4 Session (G. Micolau / K. Coulié)

Track Classification: Couplings: Earth, solid, atmosphere, universe

Contribution ID: **15** Type: **Plenary talk**

Near subsurface density reconstruction by full waveform inversion in the frequency domain

Wednesday 8 June 2022 11:20 (20 minutes)

The work proposed in this presentation is part of a global project dealing with the characterisation of heterogeneous media by both electromagnetic and mechanical full waveform inversion. Indeed Full Waveform Inversion (FWI) of seismic reflection (SR) or Ground Penetrating Radar (GPR) data is an efficient approach to reconstruct subsurface physical parameters with high resolution. We focus here on the mechanical part and more specifically on quantitative imaging of nearsurface density in the context of water content characterization, as analogous to relative dielectric permittivity involved in the electromagnetical approach. Processing field data is challenging because the nature of the source and the sensors used impact the signal-to-noise ratio as well as the frequency range embedded in the recorded data. From then it becomes interesting to process the data in the frequency domain, by working on a few representative frequencies of the recorded temporal signal. Field data are simulated by noisy synthetic data. Different frequency strategies are used and their results are compared with each other. The inverse problem involved consists in assessing the density in the probed medium, from the data on the displacement field measured at the detectors. Such a problem is known to be nonlinear and ill-posed. It is solved iteratively by a regularized Gauss-Newton algorithm (RGN), which relies on the Fréchet derivative obtained through the generalized reciprocity principle which is equivalent to the well-known adjoint method. The numerical results obtained show an optimal strategy, for which the convergence rate and the computation time are reasonable, the spatial resolution is improved and the density is well reconstructed.

Primary author: Mr DIDIER, Quentin (Avignon Université)

Co-authors: Dr ARHAB, Slimane (Avignon Université); Prof. LEFEUVE-MESGOUEZ, Gaëlle (Avignon Université)

Presenter: Mr DIDIER, Quentin (Avignon Université)

Session Classification: #2 Session (I. Kolmasova/B.Canuel)

Track Classification: Critical Zone

Contribution ID: **16** Type: **Plenary talk**

3-axis unshielded HTS SQUID geomagnetic sensor in an urban environment

Tuesday 7 June 2022 16:10 (20 minutes)

A commercial 3-axis high temperature SQUID system, cooled with liquid nitrogen, is currently operating unshielded as a geomagnetic sensor in an aluminium dewar at SANSA Space Science, South Africa. The collaborative project between South Africa (SANSA), France (LSBB) and Czech Republic (CTU) is aimed at continuous, low-noise geomagnetic space weather measurements. The environment is urban with commercial installations [1]. The vertical SQUID is a M2700 from Cryostar (white noise < 300 fT/√Hz) and the two horizontal SQUIDs are HTM-8 from FZ Jülich (white noise <65 fT/√Hz). The SQUIDs are controlled with Magnicon SEL-1 electronics, and output is digitized with National Instruments 24-bit card. There is provision for a non-magnetic environment, isolation from mains power noise and a low noise reference fluxgate magnetometer, running simultaneously at a distance of 3 m. SQUID measurements under different environmental circumstances reveal significant noise due to interference from the commercial environment –RF and/or magnetic. Also, the manual process of cryogen refilling results in instability of the SQUIDs due to temperature settling in the dewar [2]. Furthermore, between refills we recently observed 5 mHz oscillations of up to 2 nTptp amplitude in the HTM-8 SQUIDs, which are shown to correlate to 6 mKptp temperature variations of the liquid nitrogen [3]. The frequency and amplitude of these oscillations are functions of cryogen level and compromise system operation as a geomagnetic sensor even in the FLL loop. We discuss the investigation of mitigation techniques; the high sensitivity of the HTM-8 SQUIDs to these temperature oscillations is currently unexplained.

[1] E.F. Saunderson, M. Dressler and M. Janosek, "Practical aspects of an HTS SQUID operating as a Geomagnetic sensor", SCSSM2021, Prague, 2021
[2] F. P. Milliken et al, "The response of high-Tc SQUID magnetometers to small changes in temperature", Journal of Applied Physics, vol: 82, 6301, 1997
[3] D.J. Blundell and B.W. Ricketson, "The temperature of liquid nitrogen in cryostat dewars", Cryogenics, January 1979, pp 33-36

Primary author: SAUNDERSON, Elda (South African National Space Agency)

Co-authors: Mr DRESSLER, Michal (Czech Technical University in Prague); Dr JANOSEK, Michal (Czech Technical University in Prague); Prof. FOURIE, Coenrad (Stellenbosch University)

Presenter: SAUNDERSON, Elda (South African National Space Agency)

Session Classification: #1 Session chaired by S. Gaffet

Track Classification: Noise as signal, advanced metrology

Contribution ID: **17** Type: **Plenary talk**

Full-wave Radar Tomography for Astrophysics: Interior structure of small body vs. carrier effects

Wednesday 8 June 2022 15:20 (20 minutes)

There are over 27, 313 known Near Earth Asteroids (NEAs), i.e., asteroids within 4.488 × 107 km from Earth, out of which 1, 254 are on risk list according to ESA's Near Earth Object Coordination Centre (NEOCC). Hence, advancing the knowledge of mineral composition, interior structure, and potential threats of planetary bodies is very important and has been the motivation behind space explorations over years. The first space mission to observe the deep interior of a small Solar System Body (sSSB) was Comet Nucleus Sounding Experiment by Radio Transmission (CONSERT) by European Space Agency's (ESA's) Rosetta mission which rendezvoused comet 67P/Churyumov–Gerasimenko in 2014. ESA will continue Radar Tomography (RT) exploration as a part of the HERA mission [2, 3], the European component of AIDA (Asteroid Impact and Deflection Assessment), whose Juventas Radar (JuRa) [1] carried by a CubeSat with the same name (Juventas CubeSat), will perform RT measurements with the asteroid moon of the binary asteroid Didymos as its target. Reconstructing an SSSB's interior permittivity distribution (structure) via RT is an ill-posed inverse problem and utilising the full-waveform approach, i.e., maintaining the complete wavefield information of the forward simulation, is essential with respect to the reconstruction quality.

In this presentation, we examine the goals of JuRa by applying the methods of Ground penetrating radar (GPR) modelling and inversion in the presence of noisy signal which necessitates filtering with methods such as Truncated singular value decomposition (TSVD) and robust inversion of incomplete spectral data, e.g., through sampling and error marginalisation. We utilise these techniques in numerical simulations with a complex test domain (containing a stratified surface layer, voids and cracks) and laboratory experiments with an analogue object. Based on the aforementioned, we estimate the feasibility of the JuRa experiment under mission-based payload and instrument constraints such as the 60 MHz centre frequency, 20 MHz bandwidth, and monostatic signal configuration with regards to its aim of detecting subsurface structure of the asteroid Didymos.

[1] Alain Herique, Dirk Plettemeier, Hannah Goldberg, and Wlodek Kofman. Jura: the juventas radar on hera to fathom didymoon. In European Planetary Science Congress, pages EPSC2020–595, 2020.
[2] Alain Herique, Dirk Plettemeier, Wlodek W Kofman, Yves Rogez, and Hannah Goldberg. Direct observations of didymos'regolith and internal structure with lfr radar on juventas cubesat for esa hera mission. In AGU Fall Meeting Abstracts, volume 2019, pages NH51C–0789, 2019.
[3] Patrick Michel, Michael K¨uppers, and Ian Carnelli. The hera mission: European component of the esa-nasa aida mission to a binary asteroid. 42nd COSPAR Scientific Assembly, 42:B1–1, 2018.

Acknowledgements: This work was supported by the Academy of Finland Centre of Excellence in Inverse Modelling and Imaging, 2018-2025.

Primary authors: YUSUF, Oluwatoki Yusuf (Aix-Marseille Université, CNRS, Centrale Marseille, Institut Fresnel, Marseille, France); DUFAURE, Astrid (Aix-Marseille Univ., CNRS, Centrale Marseille, Institut Fresnel, Marseille, France); SORSA, Liisa-Ida (Computing Sciences, Tampere University (TAU), P.O. Box 692, 33101, Tampere, Finland); PURSIAINEN, Sampsa (Computing Sciences, Tampere University (TAU), P.O. Box 692, 33101, Tampere, Finland); EYRAUD, Christelle (Aix-Marseille Univ., CNRS, Centrale Marseille, Institut Fresnel, Marseille, France)

Presenter: YUSUF, Oluwatoki Yusuf (Aix-Marseille Université, CNRS, Centrale Marseille, Institut

Fresnel, Marseille, France)

Session Classification: #3 Session (L. Ottaviani/I. Lázaro)

Track Classification: Astrophysical measurements in the terrestrial environment

Contribution ID: **18** Type: **Plenary talk**

Use of natural organic matter fluorescence to illustrate transit time differences in the unsaturated zone of karst hydrosystems. Application to the Low-Noise Underground Laboratory (LSBB) of Rustrel, Pays d'Apt, in France

Thursday 9 June 2022 11:00 (20 minutes)

Karst aquifers contribute significantly to water supply. Sustainable management of karst water resources requires a good understanding of karst recharge processes. Most karst aquifers are fastly reacting systems, in which short transit times (0 to 6 months) are common. However, few natural tracers are usable in this time range. In a recent work currently under review (Serene et al., 2022), we showed that natural organic matter fluorescence has the potential for being a natural tracer of short time range. Identified main fluorescent compounds of karst groundwater from the Fontaine de Vaucluse hydrosystem are humic-like and three different protein-like (P1, Trp and Tyr). These compounds have different degradation rates, so their relative concentration is related to transit time.
In this study, we consider the temporal dynamics of fluorescent natural organic matter at 3 temporary (C, AJ and W) and 3 perennial (A, B, and D) flow points from the LSBB. Correlations between compounds are used to shed light on water dynamics of these flow points. High correlation coefficients between all fluorescent compounds suggest a short transit time. Longer transit time yields a correlation between Trp and P1 only, because of their similar degradation rate. If the transit time is even longer, correlation between Trp and P1 may be lost. Indeed, initial concentration of P1 is generally lower and it may reach detection limits. Compared with mean, maximum and minimum values, the results of these correlation coefficients put in releaf the difference of storage conditions and transit time for the different types of flows. Thus, fluorescence of organic matter appears to be a highly sensitive indicator, providing complementary results to other natural tracers.

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Primary authors: SERÈNE, Leïla (HSM, Univ Montpellier, CNRS, IRD, Montpellier, France); Mrs MAZZILLI, Naomi (UMR 1114 EMMAH (AU-INRAE), Université d'Avignon, 84000 Avignon, France); Mr EMBLANCH, Christophe (UMR 1114 EMMAH (AU-INRAE), Université d'Avignon, 84000 Avignon, France); Mrs BATIOT-GUILHE, Christelle (HSM, Univ Montpellier, CNRS, IRD, Montpellier, France); Mrs BABIC, Milanka (UMR 1114 EMMAH (AU-INRAE), Université d'Avignon, 84000 Avignon, France); Mr DUPONT, Julien (UMR 1114 EMMAH (AU-INRAE), Université d'Avignon, 84000 Avignon, France); Mr SIMLER, Roland (UMR 1114 EMMAH (AU-INRAE), Université d'Avignon, 84000 Avignon, France); Mr BLANC, Matthieu; Mr MASSONNAT, Gérard (TotalEnergies, CSTJF, Avenue Larribau, CEDEX 64018 Pau, France)

Presenter: SERÈNE, Leïla (HSM, Univ Montpellier, CNRS, IRD, Montpellier, France)

Session Classification: #4 Session (G. Micolau / K. Coulié)

Track Classification: Geological reservoirs

Contribution ID: **19** Type: **Plenary talk**

Muography with Micromegas detectors : Main features and results and future prospects in geophysics with new concept telescopes.

Thursday 9 June 2022 09:30 (20 minutes)

Muogarphy applications have been broadened in the last years thanks to the advances on particle detectors used to perform the measurements. Among the different technologies, the Irfu group is using multiplexed Micromegas detectors since almost ten years. Telescopes based on this technology have showed their capabilities and performance in such a different applications as archaeology, civil engineering or nuclear safety. They are capable of providing real-time muography images with an angular resolution of the order of few miliradians while keeping their autonomy and long-term stability.
However, in order to increase the range of applications, the group is developing a new detector concept based on a compact Time Projection Chamber readout by a 2D multiplexed micromegas: the D3DT detector. This instrument will allow the 3D reconstruction of muon tracks with a single instrument with an acceptance of almost 2p in solid angle. The whole detector has an external diameter of about 20 cm. Due to its compactness this instrument can be installed in quite tight places, like boreholes. This makes D3DT especially interesting for geophysical applications like reservoirs localization or overburden characterization for shallow depth installations. The potential of this TPC has been evaluated for these applications by Monte Carlo simulations. Besides, different laboratory prototypes have been developed paying special attention to the Micromegas characterization. Tests with these prototypes have also allowed to define and evaluate data analysis tools for track reconstruction.
In this presentation a general summary of the muography activities carried out by Irfu will be presented paying special attention to the development and potential applications of D3DT, including the most relevant results obtained from the above-mentioned simulations and prototypes.

Primary authors: Mr LEFEVRE, Baptiste (Université Paris-Saclay (FR)); ATTIE, David (CEA/DSM/DAPNIA/SPP); GOMEZ MALUENDA, Hector (Université Paris-Saclay (FR)); MANDJAVIDZE, Irakli (Université Paris-Saclay (FR)); LEHURAUX, Marion (Université Paris-Saclay (FR)); Mr PHILIPPE, Mas (Université Paris-Saclay (FR)); PROCUREUR, Sebastien (Université Paris-Saclay (FR))

Presenter: GOMEZ MALUENDA, Hector (Université Paris-Saclay (FR))

Session Classification: #4 Session (G. Micolau / K. Coulié)

Track Classification: Geological reservoirs

Contribution ID: **20** Type: **Plenary talk**

Investigation of the metabolic versatility of a new bacterium isolated from sediments affected by hydrothermal circulations in Vulcano Island, Italy.

Tuesday 7 June 2022 16:50 (20 minutes)

Vulcano is the southernmost of the seven islands forming the Aeolian volcanic archipelago. This island harbors a developed hydrothermal system and is the place where the first hyperthermophilic marine archaeon, Pyrodictium occultum was isolated. Shallow hydrothermal systems have been recently the subject of numerous investigations as they constitute easy access extreme environments, and may be actual analogues of places where life appeared. Indeed, due to the mixing of hot, reduced and sometimes metal/sulfur rich fluids with oxygenated seawater, these environments are characterized by high gradients of temperature and fluid chemistry. Here we describe the taxonomic and physiological properties of strain V6Fe1T, a novel anaerobic bacterium, isolated from shallow subsurface sediments on the seashore. Cells were thin, non-motile, Gram-negative flexible rods. 16S rRNA gene sequence showed that strain V6Fe1T was a member of the unwell characterized Deferribacteraceae family. This strain showed substantial metabolic versatility, fermenting organic substrates, using various electron acceptors (ferric iron, manganese, sulfur, nitrate, nitrous oxide) to perform respiration, growing autotrophically (e.g without organic carbon sources) with molecular hydrogen as an electron donor and Fe(III), Mn(IV), S° or NO3- as electron acceptors. Thermodynamical calculation demonstrated that among terminal electron acceptors, nitrate may be the most suitable for anaerobic chemolithotrophic and chemoorganotrophic lifestyles in Vulcano hydrothermal systems. Nitrate reduction pathways were investigated according to the growth conditions. Unlike the most closely related strains, strain V6Fe1T performed both dissimilatory nitrate reduction to ammonium (DNRA) and denitrification, nitrate being reduced to dinitrogen. The genome consisted of a 2,358 kbp long chromosome. Genomic data were used to decipher which genes were involved when nitrate reduction took place. Comparison with genomes of closely related strains suggested that DNRA and denitrification pathways should be leveraged by cyclic AMP receptor protein (CRP) paralogues according to electron donor/acceptor availability.

Primary authors: Prof. ERAUSO, Gaël (MIO); GALES, Gregoire (MIO UM110); Dr GUASCO, Sophie (MIO UM110); Mr HANNOUN, Maverick (MIO UM110)

Co-author: POSTEC, Anne (MIO UM 110)

Presenters: GALES, Gregoire (MIO UM110); POSTEC, Anne (MIO UM 110)

Session Classification: #1 Session chaired by S. Gaffet

Track Classification: Living

Contribution ID: **21** Type: **Plenary talk**

Reaching ultra-high vacuum for a large vacuum vessel in an underground environment

Wednesday 8 June 2022 15:40 (20 minutes)

Located far from anthropological disturbances and with low seismic and magnetic background noise profiles, the LSBB facility is the ideal location for a new hybrid detector for the study of space-time strain. This new concept, the MIGA infrastructure \cite{Canuel2018}, utilizes an array of atom interferometers manipulated by the same beam, the resonant optical field of a 150 m long optical cavity. The infrastructure constitutes a new method for geophysics, for the characterization of spatial and temporal variations of the local gravity, and is a demonstrator for future decihertz gravitational wave observation. Such an infrastructure requires ultra-high vacuum (10^{-9} mbar) on a size (150 m) and scale (about 30 m^3) not previously seen in underground laboratories, and especially in underground environments with high humidity and significant dust contamination. Here, we detail the status of the MIGA infrastructure and describe the ongoing generation and analysis of the vacuum works - this comes from tests of the prototype vacuum vessel (see \ref{fig:1}), focusing on heating cycles, residual gas and resonant frequency analysis, as well as demonstrating an understanding of the thermal inertia of the system.

Primary authors: Dr BERTOLDI, A. (LP2N); SABULSKY, Dylan (LP2N); Dr LANDRAGIN, A. (LNE-SYRTE); Dr CANUEL, B. (LP2N); Mr BOYER, D. (LSBB); Dr JUNCA, J. (LP2N); Prof. PREVEDELLI, M. (Universit\‘{a} di Bologna); Prof. BOUYER, P. (LP2N); Dr BEAUFILS, Q. (LNE-SYRTE); Prof. GEIGER, R. (LNE-SYRTE); Dr GAFFET, S. (LSBB); Mr ZOU, X. (LP2N); Dr LAZARO ROCHE, Ignacio (LSBB - Laboratoire Souterrain a Bas Bruit (FR))

Presenter: SABULSKY, Dylan (LP2N)

Session Classification: #3 Session (L. Ottaviani/I. Lázaro)

Track Classification: Industrial development in low background noise environments

Contribution ID: **22** Type: **Plenary talk**

The PREliminary MIga Seismic Experiment - PREMISE

Thursday 9 June 2022 09:50 (20 minutes)

In 2020, a temporary seismic experiment has been conducted by the CEA/DAM and the CNRS/LSBB with the support of more than 18 different academic laboratories or companies. During this experiment, the seismic wave field generated by several small active sources has been recorded in 3 dimensions on the site of the Laboratoire Souterrain Bas Bruit (LSBB), Rustrel, France. Taking advantage of the particular environment of the LSBB infrastructure (underground galleries, low seismic noise and a well-known geology), several kind of sensors have been installed at surface and in tunnels. The deployed instruments include about 100 SmartSolo seismometers from the DENSAR array - EOST, 200 DSU3- SERCEL accelerometers and more than 4km of optic cable for Distributed Acoustic Sensing (DAS) measurements with a FEBUS A1-R instrument. This 3D seismic data set provides opportunities to study the effect of the free surface (topography) and of local heterogeneities on the seismic wave field and its source signature. With a fiber total length of 10.5km, including loops and spools, several ground coupling conditions of the DAS fiber have been considered in order to evaluate the performance of this new seismic instrument in comparison to classical seismic sensors. After a detailed description of the experiment geometry and installed sensors, several examples of recorded signals and some preliminary analysis of this original data set will be presented.

Primary authors: SÈBE, Olivier (CEA, DAM, F-91297 Arpajon, France); GAFFET, Stéphane (LSBB, Laboratoire Souterrain Bas Bruit, CNRS, La grande combe, 84400 Rustrel, France)

Co-authors: AUGUSTE, Michel (I.E.M, Les Agachons, 84480 Buoux); BAYOUA, Fortuné (FEBUS Optic, Technopole Hélioparc, 2 av. Président Pierre Angot, 64000 Pau, France); BESSON, Michel (Ets BESSON Michel, 127 rue des Cayssines, 46000 CAHORS); BOYER, Daniel (LSBB, Laboratoire Souterrain Bas Bruit, CNRS, La grande combe, 84400 Rustrel, France); BROUCKE, Céleste (Université de Strasbourg, CNRS, EOST, UMS830, F-67000 Strasbourg, France); CARRÉ, Sylvain (CEA, DAM, F-91297 Arpajon, France); CAVAILLOU, Alain (LSBB, Laboratoire Souterrain Bas Bruit, CNRS, La grande combe, 84400 Rustrel, France); DECITRE, Jean-Baptiste (LSBB, Laboratoire Souterrain Bas Bruit, CNRS, La grande combe, 84400 Rustrel, France); FOUQUET, Daniel (CEA, DAM, F-91297 Arpajon, France); LALLEMAND, Charly (CEA, DAM, F-91297 Arpajon, France); LANTICQ, Vincent (FEBUS Optic, Technopole Hélioparc, 2 av. Président Pierre Angot, 64000 Pau, France); LAPORTE, Marine (CEA, DAM, F-91297 Arpajon, France); LAZARO ROCHE, Ignacio (LSBB, Laboratoire Souterrain Bas Bruit, CNRS, La grande combe, 84400 Rustrel, France); LESCOAT, Antoine (SERCEL, 16 rue de Bel Air, BP 30439, Carquefou, France); MIOSSEC, Bertrand (CEA, DAM, F-91297 Arpajon, France); MORLENS, Anne-Sophie (CEA, DAM, F-91297 Arpajon, France); OLIVIER, Serge (CEA, DAM, F-91297 Arpajon, France); ROUILLÉ, Guillaume (CEA, DAM, F-91297 Arpajon, France); SOMMIER, Line (CEA, DAM, F-91297 Arpajon, France); VALLAGE, Amaury (CEA, DAM, F-91297 Arpajon, France)

Presenter: SÈBE, Olivier (CEA, DAM, F-91297 Arpajon, France)

Session Classification: #4 Session (G. Micolau / K. Coulié)

Track Classification: Couplings: Earth, solid, atmosphere, universe

Contribution ID: **23** Type: **Plenary talk**

Electromagnetic geophysical measurements using SQUID sensors in low noise unshielded environment

Wednesday 8 June 2022 09:50 (20 minutes)

Geophysical measurements using highly sensitive Superconductive Quantum Interference Device (SQUID) sensors have been in use since more than two decades. Owing to their extreme sensitivity, SQUIDs require very low noise environment for stable operation. The requirement of unshielded environment for geophysical data acquisition further pushes the need to find ways to reduce unwanted cultural noise including those of the powerline frequency, wind as well as other high-frequency noise. Electromagnetic geophysical measurements with low temperature SQUID sensors have been performed in different environmental conditions in India, and a comparison of various interferences that made SQUIDs unstable in unshielded environments was noted. Working with the SQUIDs in an unshielded environment outside the laboratory did not yield consistent stable operation due to random variations. The powerline noise, being periodic in nature, could be easily removed using suitable processing techniques but the random noise due to wind and high frequency interferences corrupted the data. Later, the cryostat containing the sensor probe was semi-buried into the earth in a remote location far away from any cultural noise. This led to reduction in the fluctuations due to wind and random vibrations and stable operation was ensured throughout an entire day. This easy, cost-effective way was used to perform transient electromagnetic measurements in an external unshielded environment for a long period of time. We discuss the difficulties in measurements in unshielded environment and present results showing transient electromagnetic data that could be obtained during the experiments.

Primary authors: MOHANTY, Ijee; Ms BISHT, Lata (Indira Gandhi Centre for Atomic Research); Dr R., Nagendran (Indira Gandhi Centre for Atomic Research)

Presenter: MOHANTY, Ijee

Session Classification: #2 Session (I. Kolmasova/B.Canuel)

Track Classification: Couplings: Earth, solid, atmosphere, universe

Contribution ID: **24** Type: **Plenary talk**

Conference introduction. The LSBB, above- and underground based low background noise interdisciplinary research laboratory.

Tuesday 7 June 2022 14:30 (20 minutes)

Created in 1997, the LSBB is located in the heart of the Luberon Regional Nature Park in the Vaucluse. Initially a military facility, the LSBB has been converted into a research laboratory whose activities have been contributing to the development of knowledge and know-how in many scientific fields for nearly 25 years. A Support and Research Unit under the supervision of Avignon University and the CNRS, the LSBB is a remarkable infrastructure with exceptional physical and environmental characteristics listed as a 20th century architectural heritage site.

Located in the heart of the largest karstic aquifer in Europe, the LSBB enables the in-situ study of the effects of global changes on underground water resources. Inherited from its military history, its physical environment with very low anthropogenic noise offers unique conditions for carrying out high quality measurements and observations and for developing and implementing extremely sensitive sensors and experimental techniques.

Key dimensions of the LSBB interdisciplinary research facility:

Carbonate geological reservoirs and karst water resources - The LSBB opens up major fields of investigation, the challenges of which concern, for example, the sustainable management of groundwater resources in all peri-Mediterranean countries, the modelling of carbonate reservoir dynamics, and the understanding of multi-physical and multi-scale physical processes in the critical zone.

Experimentation in a low noise underground and on the surface environment - The LSBB benefits from an environment with very low anthropic, electromagnetic and pollution disturbances, a rare combination of qualities favourable to scientific and technological activities whose stakes concern (i) the experimentation of physical processes, the Earth and near Universe observation, and the measurement of very low amplitude signals, and (ii) the R&D activities including the development and the characterization of sensors, and the implementation of innovative measurements or imaging protocols aiming at ultimate sensitivities and resolutions.

Primary author: Dr GAFFET, Stéphane (LSBB, Laboratoire Souterrain Bas Bruit, CNRS, La grande combe, 84400 Rustrel, France)

Presenter: Dr GAFFET, Stéphane (LSBB, Laboratoire Souterrain Bas Bruit, CNRS, La grande combe, 84400 Rustrel, France)

Session Classification: #1 Session chaired by S. Gaffet

Contribution ID: **25** Type: **Plenary talk**

Welcome speech from Avignon University

Tuesday 7 June 2022 14:15 (15 minutes)

Session Classification: #1 Session chaired by S. Gaffet

Contribution ID: **26** Type: **Plenary talk**

Closing remarks

Thursday 9 June 2022 11:40 (15 minutes)

Primary author: COULIÉ, Karine

Presenter: COULIÉ, Karine

Session Classification: #4 Session (G. Micolau / K. Coulié)

Contribution ID: **27** Type: **Plenary talk**

Water flow within the underground critical zone: multi-physcis and multi-scale insights from LSBB platform.

Thursday 9 June 2022 09:00 (30 minutes)

Primary authors: Dr DANQUIGNY, Charles; EMBLANCH, Christophe (UMR 1114 EMMAH (AU-INRAE), Université d'Avignon, 84000 Avignon, France); CHALIKAKIS, Kostantinos (INRAE, UMR 1114 EMMAH, 40509 Domaine St-Paul, France); MAZZILLI, Naomi (INRAE, UMR 1114 EMMAH, 40509 Domaine St-Paul, France)

Presenter: EMBLANCH, Christophe (UMR 1114 EMMAH (AU-INRAE), Université d'Avignon, 84000 Avignon, France)

Session Classification: #4 Session (G. Micolau / K. Coulié)

Track Classification: Critical Zone

Contribution ID: **28** Type: **Plenary talk**

AstroParticle Observatories and GEoscience Innovative Actions (APOGEIA)

Tuesday 7 June 2022 14:50 (30 minutes)

The main objective of APOGEIA is the development of three types of interdisciplinary and mutually related
groundbreaking technologies: the use of fibre cables or mobile systems as distributed sensors, the use of particle detectors as prospection instruments, and the extremely low noise sensors developed in the European (worldwide) underground laboratories. These technologies build the capacity to deploy large sensor networks at extreme and hostile sites (e.g, volcano, underground, deep sea, space) but also serve as climate monitoring and natural catastrophe alert systems of urban areas. They also profit from extreme timing, advanced digital solutions, and artificial intelligence developments coming from the elaboration of leading astrophysics / astroparticle and geoscience / atmospheric Research Infrastructures (RI). These two domains started interdisciplinary synergies 10 years ago, paving the way to innovative solutions to societal challenges (e.g. climate change and catastrophe alerts) and new industrial applications, products and services. APOGEIA will further promote these synergies and lead to far- reaching applications for the benefit of both scientific fields and the society. It proposes the development, coordination of the many European separate efforts, preparation of the next generation RI and in fine industrialisation of the above sensor systems, their dense synchronised networking and development of advanced digital solutions for RI upgrade and monitoring, enabling solutions even for the most demanding scientific and societal challenges.

Primary author: KATSANEVAS, Stavros

Presenter: KATSANEVAS, Stavros

Session Classification: #1 Session chaired by S. Gaffet

Track Classification: Couplings: Earth, solid, atmosphere, universe

Contribution ID: **29** Type: **Plenary talk**

MIGA, a large scale gravity antenna using quantum technology

Wednesday 8 June 2022 09:00 (30 minutes)

Primary author: CANUEL, Benjamin (LP2N, Laboratoire Photonique, Numérique et Nanosciences, Université Bordeaux-IOGS-CNRS:UMR 5298, 1 rue F. Mitterrand, F-33400 Talence, France)

Presenter: CANUEL, Benjamin (LP2N, Laboratoire Photonique, Numérique et Nanosciences, Université Bordeaux-IOGS-CNRS:UMR 5298, 1 rue F. Mitterrand, F-33400 Talence, France)

Session Classification: #2 Session (I. Kolmasova/B.Canuel)

Track Classification: Astrophysical measurements in the terrestrial environment

Contribution ID: **30** Type: **Plenary talk**

Winlight System upcoming underground operations.

Wednesday 8 June 2022 14:00 (30 minutes)

Primary author: Dr COMPAIN, Eric (Bertin Technologies)

Presenter: Dr COMPAIN, Eric (Bertin Technologies)

Session Classification: #3 Session (L. Ottaviani/I. Lázaro)

Track Classification: Industrial development in low background noise environments

Contribution ID: **31** Type: **Plenary talk**

Origin and evolution of the French nuclear deterrence system during the cold war.

Thursday 9 June 2022 11:20 (20 minutes)

The deterrence ground-to-ground force has to be ready to answer to the President's order in all time and at the highest rate of availability.
In order to guarantee the counter efficiency, this system must be invulnerable. For this purpose, the substructure of the different facilities meets very severe requirement for protection and security. We are the heirs of this doctrine.

Primary author: BOYER, Daniel (LSBB, Laboratoire Souterrain Bas Bruit, CNRS, La grande combe, 84400 Rustrel, France)

Presenter: BOYER, Daniel (LSBB, Laboratoire Souterrain Bas Bruit, CNRS, La grande combe, 84400 Rustrel, France)

Session Classification: #4 Session (G. Micolau / K. Coulié)

Track Classification: Industrial development in low background noise environments