The PhD students of the STEP'UP doctoral school present

The 27th edition of the

CONGRÈS DES DOCTORANT·E·S

March 23rd – 27th 2020

With a special day on a journey to

EXOPLANETS

More info on: cdd.ens.fr

Institut de physique du globe de Paris - 1 rue Jussieu, 75005 Paris - Métro Jussieu

Contents

Congrès des doctorant·e·s 2020

Welcome to the ”Congrès des Doctorants”, the annual meeting organized for and by the PhD students of the STEP'UP Doctoral School. In this 27th annual edition, the meeting will cover research in Physics of the Universe and Earth and Environmental Sciences and will fully express the thematic diversity of our doctoral school with great opportunity for the exchange of ideas and for interdisciplinary collaboration. It will be a unique opportunity for doctoral students to share their science with their colleagues and place their activity at the center of a community of scientists from Université of Paris (which includes Institut de Physique du Globe de Paris), Sorbonne Université and Paris Sciences et Lettres.

This week is the time to celebrate research and innovation in a myriad of fields including geology, geophysics, (bio-)geochemistry, geomagnetism, volcanology, tectonics, geodynamics, astrophysics, cosmology, particle physics and planetary sciences. All communications, including 56 oral and 102 poster presentations, can be a new source of inspiration for your future studies and allow you to learn from colleagues, develop strategies and gain visibility in your growing scientific network. By exchanging with your peers, you will develop new skills and participate in the construction of projects that will enable you to better contribute to the sustainable development of terrestrial and planetary environments.

The direction of the STEP'UP doctoral school would like to thank and congratulate the first-year PhD students for organizing this meeting and for the quality of the program. Despite the number of participants, they have taken advantage of the experience of second and third-year PhD students to maintain the level of excellence that has been achieved in recent years. All together, they are now fully involved in the advancement of their research as a first step in their career.

This year will have its specific aspects. Following the success of the last year “Congrès” which for the first time gathered the PhD students of both components (Earth and Environment and Physics of the Universe), the D1 PhD students who organize the “Congrès” decided to invite 11 PhD students from Italy, Great Britain, Spain and Switzerland. These exchanges are of particular interest because they enable the doctoral degree to be promoted at a European level. On the other hand, we will also have 19 more popularized talks, a last year initiative which appeared to be a very fruitful way to introduce the scientific domains of a given component to the Phd student of the other one. The last part of the meeting will be dedicated to Exoplanets : a wonderful opening for both communities.

We would also like to thank AIM, APC, ENS geology laboratory, IPGP, LPNHE and LPTHE laboratories for their financial support and the involvement of their researchers and administrative staffs in the day-to-day management of the “Congrès des doctorants”. A special acknowledgment to the Communication department of IPGP, for their help in preparing the poster and the website for this meeting.

This is your meeting, make it great and enjoy this week of scientific exchanges.

Christophe Balland, Yannick Giraud-Héraud, Hélène Lyon-Caen, Clément Narteau, Alessandra Tonazzo,
Director and deputy directors of the STEP'UP Doctoral School

MONDAY 23TH

OT Outreach Talk IS Invited Speaker NT Normal Talk

From a small scale to a larger scale

presented by Jorge Jara and Francisco Delgado in Amphithéâtre

9:30–10:00	**Breakfast in the main hall**		
10:00–10:15	**Opening presentation**		
10:15 – 10:35	OT	**Sophie Debaecker** IPGP	Seismic history of the Ryukyus megathrust: insights from coral microatolls
10:40–11:00	OT	**Matthieu Ribot** IPGP	The vertical deformation along the southern end of the Dead Sea fault system highlighted by tectonic markers on Tiran Island, Red Sea, Saudi Arabia
10:40–11:00	**Coffee break in the main hall**		
11:00–11:15	NT	**Sarah Hegedus** IPGP	Iron sequestration in microalgae and ocean acidification
11:20-11:35	NT	**Matthieu Buisson** IPGP	δ^{11}B and B/Ca ontogenetic variability within Globigerina bulloides
11:40-11:55	NT	**Edith Kubik** IPGP	Iron isotopes ratios disparity in the solar system
12:00–14:00	**Lunch**		
12:30–14:00	**Poster session in P07**		

Outreach talks: astrophysics

14:00–14:20	IS	**Laura Giacoppo** Department of Aerospace and Mechanical Engineering, Sapienza, Rome	Realization of the control systems of a small scale suspended interferometer for quantum noise reduction in gravitational wave detectors
14:25–14:45	OT	**Raphaël Mignon-Risse** AIM	How do (massive) stars form?
14:50-15:10	OT	**Marine Martin-Lagarde** AIM	New challenges in transiting exoplanet atmosphere observations with JWST
15:15–15:35	OT	**Marta Colomer** APC	Observing core-collapse supernova neutrinos in the Mediterranean sea

Particle physics

presented by François Vannucci in Amphithéâtre

15:40–15:55	IS	**Eleanor Jones** Department of Physics, University of Warwick, UK	Electroweak-QCD interference in hadronic vector boson decays at the LHC
16:00-16:15	NT	**Yang Han** APC	JUNO with dual calorimetry
16:15–16:30	**Coffee break in the main hall**		
16:30-16:45	NT	**Alexander Leopold** LPNHE	A timing detector for the high luminosity upgrade of ATLAS
16:50-17:05	NT	**Yufeng Wang** LPNHE	Search for new resonances in high-mass diphoton final states using 139/fb of proton-proton collisions collected with the ATLAS detector
17:10-17:25	NT	**Florian Reiss** LPNHE	Testing lepton universality with semileptonic beauty meson decays
17:30-17:55	NT	**Luis Pascual Domínguez** LPNHE	Search for new phenomena in low-mass diphoton final states with proton-proton collisions collected at $\sqrt{s} = 13$ TeV with the ATLAS detector
18:00–20:00	**Welcoming party**		

TUESDAY 24TH

OT Outreach Talk IS Invited Speaker NT Normal Talk

Volcanoes

presented by Guillaume Baby and Yacine Benjelloun in Amphithéâtre

9:00–9:30	**Breakfast in the main hall**		
09:30–09:45	NT	**Jie Chen** IPGP	780-thousand years of volcanic seafloor accretion at a melt-rich segment of the ultraslow-spreading Southwest Indian Ridge 50°28’E
09:50–10:05	NT	**Tara Shreve** IPGP	Caldera ring-faulting during the 2015 Ambrym dike intrusion and the search for the missing deflation source
10:10–10:25	NT	**Benoit Vittecoq** ENS	Hydrogeological functioning of Martinique island revealed by helicopter-borne geophysical survey
10:30–10:45	IS	**Zhongwei Zhao** Department of Earth and Environmental Sciences, University of Manchester	Submarine platform development by erosion of a surtseyan cone at Capelinhos, Faial Island, Azores
10:45–11:00	**Coffee break in the main hall**		

Cosmology and astrophysics

presented by Clément Leloup in Amphithéâtre

11:05–11:20	NT	**Gabriel Moreau** APC	Quantum fields in de Sitter spacetime
11:25–11:40	NT	**Vo Hongh Minh Phan** APC	CRIME: Cosmic Ray Interactions in Molecular Environments
11:45-12:00	NT	**Gabriel Emery** LPNHE	Variability of active galactic nuclei at very high energy with H.E.S.S.: the flaring activity of PKS 2022-077 in 2016 and 2017
12:00-12:15	NT	**Lisa Bugnet** CEA	The impact of magnetic fields on dipolar mixed mode frequencies inside red giants
12:15–14:00	**Lunch**		
12:30–14:00	**Poster session in P07**		

Outreach talks: cosmology and particle physics

presented by Clément Leloup in Amphithéâtre

14:00–14:20	IS	**Laura Iacconi** University of Portsmouth, UK	Interferometer constraints on the inflationary field content
14:25–14:45	OT	**Clara Vergès** APC	Probing Universe's first light
14:50–15:10	OT	**Jean-Phillipe Zopounidis** LPNHE	Direct detection of leptophilic dark matter with XENON1T
15:15–15:35	OT	**Da Yu Tou** LPNHE	Test of Lepton Universality: study of $b \to sl^+l^-$ in LHCb

Earth magnetic field

presented by Mouloud Kessar in Amphithéâtre

15:40–15:55	NT	**Martin Fillion** IPGP	Derivation of the full current density vector in the Earth's ionosphere low- and mid-latitude F region using ESA's Swarm satellites
16:00–16:15	IS	**Mohammad Paknia** Department of Science, University of Roma Tre, Rome, Italy	An integrated paleomagnetic, rock magnetic, anisotropy of magnetic susceptibility, stratigraphy, structural and sediment provenance analysis to investigate the evolution of the Northern Iranian Plateau: insights from Miocene synorogenic red beds from Tarom Basin, NW Iran
16:15–16:30	**Coffee break in the main hall**		
16:30–16:45	IS	**Colin Hardy** University of Leeds, UK	Constraint on the magnetic field within a stratified outer core
16:50–17:05	NT	**Tobias Schwaiger** IPGP	Force balance in numerical geodynamo simulations: a systematic study

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presents

CAREERS IN SCIENCE

Wednesday, March 25th

9:00 - 9:30	**Accueil et café**
9:30 - 9:45	**Présentation de la journée**
9:45 - 10:15	**Passer l'agrégation ? - Théo Tassin (IPGP)**
10:15 - 10:45	**Pause café**
10:45 - 12:30	**Table ronde « Après la recherche : des horizons variés »** Léa Bello (vidéaste et journaliste scientifique freelance), Tugdual Ceillier (EarthCube), Frédéric Guattari (iXblue), Marios Karouzos (Nature Astronomy), Franck Smektala (INGEN)
12:30 - 14:15	**Déjeuner & Forum avec les intervenants**
14:15 - 16:00	**Table ronde « Poursuivre une carrière académique »** Nikolaos Karnesis (CNES), Joseph Martino (APC), Milena Marjanovic (IPGP), Leïla Haegel (APC/SNSF)
16:00 - 17:00	**Forum avec les intervenants**

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9:00 - 9:30	**Welcome coffee**
9:30 - 9:45	**Presentation of the Day**
9:45 - 10:15	***Passer l'agrégation ?* - Théo Tassin (IPGP)**
10:15 - 10:45	**Coffee break**
10:45 - 12:30	**Roundtable « After academic research: various horizons »** Léa Bello (freelance video maker and scientific journalist), Tugdual Ceillier (EarthCube), Frédéric Guattari (iXblue), Marios Karouzos (Nature Astronomy), Franck Smektala (INGEN)
12:30 - 14:15	**Lunch & Forum with the guests**
14:15 - 16:00	**Roundtable "Follow an academic career"** Nikolaos Karnesis (CNES), Joseph Martino (APC), Milena Marjanovic (IPGP), Leïla Haegel (APC/SNSF)
16:00 - 17:00	**Forum with the guests**

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THURSDAY 26TH

OT Outreach Talk IS Invited Speaker NT Normal Talk

Data science

presented by Sabrina Sacerdoti and Leïla Haegel in Amphithéâtre

9:00–9:30	**Breakfast in the main hall**		
9:30–9:50	OT	**Giovanni Stagnitto** LPTHE	Lighting the black box: use and validation of machine learning techniques in high-energy theoretical physics
9:55–10:15	OT	**Marc Arène** APC	How to walk on a mountain in order to characterize gravitational waves?
10:20–10:35	NT	**Salma Barkaoui** IPGP	Martian signal automatic clustering and event's detection using SEIS data in continuous records with an unsupervised deep scattering network

Geomorphology

10:35–10:50	NT	**Yukun Liu** IPGP	The deposition pattern of linear dunes using a cellular automaton (CA) model
10:50–11:05	**Coffee break in the main hall**		
11:05–11:20	NT	**Cyril Gadal** IPGP	Spatial and temporal development of the dune instability at White Sands Dune Field, New Mexico, USA
11:25–11:40	NT	**Olivier Rozier** IPGP	Elongation and stability of a linear dune
11:45–12:00	NT	**Benjamin Wheeler** IPGP	In situ monitoring and modelling of near seafloor hydrothermal dynamics and formation of diffuse vents at the Lucky Strike hydrothermal field, mid-Atlantic ridge
12:00–14:00	**Lunch**		
12:30–14:00	**Poster session in P07**		

Seismic waves

presented by Amicie Delahaie in Amphithéâtre

14:00–14:15	NT	**Alexander Smirnov** IPGP	Similarities and differences of microseism and microbarom source regions reconstructed from the seismo-acoustic Kazakhstani network
14:20–14:35	NT	**Amin Kahrizi** ENS	Using 2D long-streamer seismic data waveform tomography to decipher sedimentary record of fault activity

14:40-14:55	NT	**Alister Trabattoni** IPGP	Orienting and localising ocean bottom seismometers from ship noise analysis
15:00–15:15	IS	**Saulé Simuté** ETH Zurich, Department of Earth Sciences, Zurich, Switzerland	Seismic source inversion using Hamiltonian Monte Carlo and a 3-D Earth model in the Japanese Islands
15:20–15:35	NT	**Pauline Bonnet** IPGP	Understanding the dynamics of glacier front and iceberg capsize through analysis and modelling of seismic waves
15:40–15:55	NT	**Venkata Vaddineni** IPGP	Effect of Chain transform fault on the lithosphere-asthenosphere boundary
16:00–16:15	**Coffee break in the main hall**		

Cosmo- and Geochemistry

Presented by Dylan Wilmeth in Amphithéâtre

16:15-16:35	OT	**Arnaud Duverger** IPGP	Deciphering the mechanisms of pyrite formation in pure cultures of sulfate-reducing bacteria
16:40-17:00	OT	**Ke Zhu** IPGP	The short-lived ^{53}Mn-^{53}Cr chronology and its application in the origin of angrite parent body
17:05-17:20	IS	**Marie-Noëlle Decraene** Institut des Sciences de La Terre, Université de Lausanne, Suisse	Tracking microbial signatures in stromatolites at micrometer scale through in situ iron isotope analyses
17:25 –17:40	IS	**Filippo Formoso** University of St Andrews, School of Earth and Environmental Sciences	The speciation of fluorine in silicate melts
17:45 – 18:00	NT	**François Mathon** IPGP	Chemical signature of magnetotactic bacteria

Friday 27th

OT Outreach Talk   IS Invited Speaker   NT Normal Talk

Earth's history

presented by Tatiana Savranskia in Amphithéâtre

9:00 -9:30	**Breakfast in the main hall**		
9:30–9:50	OT	**Delphine Tardif** IPGP	Modelling the climate and vegetation changes induced by the Earth's orbital variations under decreasing CO_2 concentration across the Eocene-Oligocene transition
9:55–10:15	OT	**Marie Troyano** IPGP	Constraining the evolution of the Earth's magnetic field from archeological artefacts: new archeointensity results obtained in Bukhara (Uzbekistan, Central Asia)
10:15–10:30	**Coffee break in the main hall**		
10:30–10:50	OT	**Arnaud Montabert** ENS	Characterizing past earthquakes ground motion
10:55–11:10	NT	**Laetitia Allibert** IPGP	Impact-induced Bulk Silicate Earth changes in chemical composition during accretion

Rivers and sediments

presented by Guillaume Baby and Yacine Benjelloun in Amphithéâtre

11:15–11:35	OT	**Chloé Daudon** IPGP	Rivers analysis from a redefined topographic map on Saturn's largest moon, Titan
11:40-12:00	OT	**Marc Peruzzetto** IPGP	Modeling of major cliff collapse and subsequent lahars in the Prêcheur catchment, Martinique
12:05-12:20	IS	**Nikhil Sharma** Department of Earth Sciences, University of Geneva	Upstream versus downstream changes in a natural sediment routing system from source to sink, south-central Pyrenees, Spain
12:20–14:00	**Lunch**		
12:30–14:00	**Poster session in P07**		

Exoplanets conference

presented by

14:00 – 14:45	IS	**Dr Amaury Triaud** School of Physics and Astronomy, University of Birmingham	Planetary investigations beyond the Solar system
14:50 – 15:35	IS	**Dr Benjamin Charnay** Observatoire de Paris	Atmospheres and habitability of exoplanets
15:35–15:50	**Coffee break in the main hall**		
15:50 – 16:35	IS	**Dr Adrienne Kish** Muséum National d'Histoire Naturelle	(Exo)Biology: What we can learn from a sample size of one ?
18:00–22:00	**Poster award ceremony and closure party organized by Hekla**		

What is Hekla ?

Hekla is a first year PhD-students association. Its aims to

- settle in new PhD students and foreign students in the doctoral school,
- enhance interactions between students, researchers and laboratory staff during events.

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EXOPLANETS CONFERENCE

Friday, March 27th

IPGP Amphithéâtre

Chairman:

14:00 - 14:45 **Dr Amaury Triaud**
School of Physics and Astronomy - University of Birmingham
"Planetary investigations beyond the Solar system"

14:45 - 15:30 **Dr Benjamin Charnay**
Observatoire de Paris
"Atmospheres and habitability of exoplanets"

15:30 - 15:45 ***Coffee Break***

15:45 - 16:30 **Dr Adrienne Kish**
Muséum national d'Histoire naturelle
"(Exo)Biology: What can we learn from a sample size of one ?"

16:30 - 17:30 **Round Table**

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Monday 23th

From small scale to a larger scale

Maylis de La Serve How to improve the International Terrestrial Reference Frame?

Clément Demasy Solubility and bioavailability of Patagonian dust in the future Southern Ocean

Ana Sanchez Spatio-temporal evolution of the Greenland ice sheet and associated deformation of the Earth

Arefeh Moarefvand Experimental study of the effect of stress on $\alpha \rightarrow \beta$ quartz transformation at lower continental crust pressure and temperature conditions

Manon Dalaison Continuous monitoring of seismic and aseismic slip along the Chaman fault system from InSAR

Solène Antoine High-resolution displacement field for the 2019 Ridgecrest earthquake (California): first considerations in terms of fault zone structure and near-fault deformation processes

Geochemistry

Mickaël Tharaud Capabilities of spICPMS as a tool for the identification of colloidal mineral phases in natural samples. Sequential vs simultaneous acquisition

Charlotte Dejean Structural and chemical controls for biomineralization in bacterial bio lm observed in situ in Liquid-Cell Scanning Transmission Electron Microscopy

Shengyu Tian An improved method for the determination of high precision stable Zr isotope ratios of geological reference materials using a PFA inert sample introduction system

Xiaoquan Qin Geochemistry of trace metals associated with Fe-Mn nodules in red soil profiles in China

Particle physics

Raphaël Bajou A dual-phase argon detector for the long-baseline neutrino experiment DUNE

Reem Hani Taibah Performance of pixel planar sensors for ATLAS inner Tracker to operate at High-Luminosity LHC

Romain Bouquet B-jet energy scale calibration using top-antitop lepton+jets events in ATLAS

Thomas Grammatico Extracting γ from three-body charmless B-meson decays

Yajun He Identification of boosted Higgs bosons for searches of new physics and improvement of the ATLAS tracker for the high luminosity phase of the LHC

Thien Nhan Chau Atmospheric neutrino oscillation with KM3NeT/ORCA

Astrophysics

Christelle Levy Tests of Lorentz Invariance and intrinsic time delays in Active Galactic Nuclei with H.E.S.S./CTA

Luca Giunti PeVatron metrics with gammapy

Makarim Bouyahiaoui High-energy neutrinos from cosmic ray interactions in the Local Bubble

Ion Cojocari Development of a prototype Compton telescope for space-borne gamma-ray polarimetry

Francesco Carotenuto Relativistic jets from a new Black Hole transient in our Galaxy

Yoann Gatelet Multimessenger astronomy to study the origin of the very-high-energy astrophysical neutrinos

Sylvain Breton Interest of low-frequency modes in helio- and asteroseismology

Samuel Zouari The very high energy emission of the galactic center

Mathilde Espinasse Relativistic X-ray jets in the black hole candidate MAXI J1820+070

Tuesday 24th

Cosmology

Hamza El Bouhargani Estimating the microwave sky from data of multi-kilo-pixel CMB experiments

Theodoros Papanikolaou Induced gravitational waves from a universe filled with primordial black holes

Louise Mousset Latest calibration results from QUBIC: the Q&U Bolometric Interferometer for Cosmology

Julianna Stermer Using mock quasar spectra to study systematics in eBOSS and DESI Lyman-alpha analyses

Guillaume Stankowiak TES detection-chain operation of the QUBIC instrument dedicated to the CMB observation

Michelangelo Traina A simulation-based background model in DAMIC search for Dark Matter

Baptiste Jost Probing the Universe's beginning and testing fundamental physics with Simons Array and Simons Observatory cosmic microwave background polarization data sets

Guy Augarde Characterization of dark energy with Subaru and HST

Pierre Auclair Gravitational waves from cosmic strings : relics of the early Universe

Thomas Montandon Isocurvature modes: a joint analysis of the power spectrum and the bispectrum of the CMB

Hugo Roussille Modified gravity theories and future observations in astrophysics and cosmology

Bastien Arcelin Separation of overlapped galaxies with Variational Autoencoder for weak gravitational lensing

Particle physics

Sid El Moctar Ahmed Maouloud Direct dark matter search with XENON Project

Julie Rode Searching for dark matter with dark side experiment

Etienne Chardonnet Signal and trajectory reconstruction in a dual-phase liquid Argon time projection chamber

Lukas Maderer Earth tomography with KM3NeT/ORCA

Quoc Viet Nguyen TPCs test beam analysis for T2K experiment

Astrophysics

Georgios Papadopoulos Development and characterization of novel CCD readout electronics for the search of dark matter with DAMIC-M

Léon Vidal Experimental validation of LISA interferometric performances

Thibault Vieu Modelling cosmic ray acceleration in stellar clusters

Mikel Falxa Detecting low frequency gravitational waves

Baptiste Faure Hierarchical fragmentation in high redshift galaxies revealed by hydrodynamical simulations

Catherine Nguyen Reducing quantum noise in gravitational-wave detectors using squeezed states of light

Aurélien Chalumeau Gravitational wave confusion problem across frequency bands

Alexandre Toubiana Mimicking black hole mimickers

Quang Nam Dam Simulation for realistic LISA configuration

Thursday 26th

Geomorphology

Amande Roque-Bernard Suspended load transport in a small tropical catchment: data analysis and modeling

Pablo Poulain Submarine granular flows and generated tsunami waves: from laboratories experiments to simulation of Montagne Pelée flank collapses

Souradeep Mahato Effect of mass wasting on the topographic evolution of a mid-ocean ridge detachment fault footwall

Earth's history

Cyril Sturtz Experimental modeling of the cooling of partially crystallized magma ocean: application to the thermal history of terrestrial bodies

Tania Habel Unraveling the contribution of the western margin of the Altiplano plateau in North Chile (20°S) to Andean mountainbuilding

Alexandre Janin Imaging the past and present Owen transform fault: preliminary results from the VARUNA seismic cruise

Data Science

Emilie Pirot Machine Learning applied to Greenland seismic signals

Alexis Falcin Classification of seismo-volcanic signals of La Soufrière of Guadeloupe by supervised learning

Claudia Hulbert Neural Network Interpretation as a denoising tool for automatic tremor location

Earth magnetic field

Robin Heraibi Towards a high resolution paleosecular variation records of the last interglacial-glacial cycle in Central Europe: the loess-paleosol sequence of Dolni Vestonice

Théo Tassin Geodynamo modelling of double diffusive convection

Guillaume Ropp Modelling and interpretation of the fast variations of the Earth's magnetic field

Christian Laag New insights into changing palaeoenvironmental conditions in a sub-profile of the Nussloch loess-palaeosol sequence (P9), detected by in-depth environmental magnetic and diffuse reflectance spectrometry methods

Volcanoes

Giulia Del Manzo Marine tephrostratigraphy: a powerful geological tool to better understand the eruptive history of Montagne Pelée in Martinique, Lesser Antilles

Léa Ostorero Dynamics of the magmatic reservoir leading to the 2010-2013 eruption of Kizimen volcano in Kamchatka (Russia)

Abigail Metcalfe Understanding the link between timescales of magmatic processes and unrest at La Soufrière de Guadeloupe

Fei Zhou Magnetic signature of a tectonic dominated hydrothermal area (49.25°E) at the ultra slow spreading ocean ridge, SWIR

Etienne Le Glas Development of chlorine stable isotopes as a new tool to unravel the variations of hydrothermal activity on volcanoes: application to la Soufrière de Guadeloupe

Geochemistry

Sandeep Thapa Characterization of black schist occurences and sulfur emissions in the upper Trishuli Valley, Central Nepal

Isabelle Genot Uncovering the sulfur isotopic composition of fluids from HP-metamorphic slab

Alexandra Perron Thermal analyses of biocarbonates as part of the search for traces of life on Mars

Clara Caurant From carbonates to possible organic compounds at high pressure: the carbon journey at the Monviso meta-ophiolite

Seismic waves

Nassima Belkacem From secondary microseism to body-wave tomography

Léo Petit Towards micromechanics-based numerical models of brittle deformation

Chao Sun Effect of pore collapse and grain crushing on the frequency dependence of elastic wave velocities in a porous sandstone

Zhikai Wang Nature of oceanic lithosphere across the Equatorial Fracture Zones in the Atlantic Ocean using seismic tomography

From a small scale to a larger scale

Alice Dupiau Modeling spectral and directional soil reflectance in the solar domain (400-2500 nm) as a function of soil moisture content

Gaëlle Benatre A main slip partitioning system in the sedimentary wedge of the Lesser Antilles Subduction Zone

Valentine Lefils From Corinth gulf extension to Ionian subduction/collision (W. Greece): micro-seismicity survey to constrain local tectonics and regional geodynamics

Marie Bouih Mass transfers associated with the 2010 Mw 8.7 Maule earthquake by the GRACE mission

Geochemistry

Antoine Boutier High pressure serpentinization and abiotic methanogenesis in metaperidotite from the Appalachian and Alpine subduction

Deze Liu Tracking the origin of the depletion volatile element of the Earth with indium isotopes

Robin Bonnet Study of a Biodeterioration process of Cementitious Matrices: Application to Asbestos-Cement Wastes

Kun Zheng Siderophores assisted Biorecovery of Technology Critical Elements: Gallium (Ga), germanium (Ge) and indium (In) from end-of-life products

Evelyne Adjei Mensah Isotopic fractionation of chromium during transfer in mining impacted paddy soils

Huma Ilyas Performance comparison of different types of constructed wetlands for the removal of pharmaceuticals and their transformation products

Seismic waves

Serena Panebianco Detection, location and characterization of induced seismicity in the High Agri Valley, southern Italy

Gaspard Farge Sounds of the deep subduction zone plumbing system: modeling non-volcanic tremor activity in a fault-valve, pore-pressure diffusive system

Louise Cordrie Simulation of the 2004 tsunami of Les Saintes in Guadeloupe (Lesser Antilles)

Angèle Laurent Detection, location and characterization of VLF events during the 2018-2019 seismovolcanic crisis in Mayotte

Cyril Journeau Detection, classification, and location of seismovolcanic tremors with multi-component seismic data, example from the Piton de la Fournaise volcano (La Réunion, France) and Klyuchevskoy Volcanic Group (Kamchatka, Russia)

Sabrina Menina Comparison of attenuation and scattering of Lunar and Martian structures

Alice Jacob Searching for seismic sources around the InSight landing site: focus on sol 173 and 235 marsquakes

Keisuke Onodera Investigation of seismic excitation of Martian dust devil vortices using 3D seismic wave propagation simulation

Roxane Tissandier Towards a dynamic vision of the slip along faults

Ariel Gallagher Comparison of the elastic properties of reservoir rocks in the field and the laboratory: link between seismic, sonic and ultrasonic measurements

Marine Laporte Improvement of focal depth estimations from combination of local and teleseismic data: Application to Far-Western Nepal

Soumya Bohidar Orientation of short period OBS from P-wave polarisat

Nirmit Dhabaria Elastic Full-waveform inversion using Hamiltonian Monte Carlo approach for imaging the Moho transition zone

Ssu-Ting Lai Numerical simulation on small-scaled granite during compression deformation

Rihab Sassi Surface Rupture from dynamic earthquake modeling

Monday

OT Outreach Talk IS Invited Speaker NT Normal Talk

Seismic history of the Ryukyus megathrust: insights from coral microatolls

Sophie Debaecker[1], *Nathalie Feuillet*[1], *Kenji Satake*[2], *Kohki Sowa*[3], *Masaki Yamada*[4], *Atsushi Watanabe*[2], *Mamoru Nakamura*[5], *Chuan-Chou Shen*[6], *Tsai-Luen Yu*[7], *Jean-Marie Saurel*[1], *Ayaka Saiki*[2] *and Giovanni Occhipinti*[8]

OT

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[3] Japan Agency for Marine-Earth Science and Technology, Kanagawa, Japan,
[4] Shinshu University, Matsumoto, Japan,
[5] Ryukyus University, Okinawa, Japan,
[6] National Taiwan University, High-Precision Mass Spectrometry and Environment Change Laboratory (HISPEC), Taipei, Taiwan,
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To complete the contributions of geodetic tools in the understanding of the megathrust behavior of the Ryukyu Trench, we chose to use coral microatolls. At the intermediate time scale in the Southern Ryukyus, the seismic potential is debated since GPS data reveal low seismic coupling, and few $M_w \geqslant 8$ earthquakes, with uncertain origin, have been reported in the past 350 years. Using coral microatolls, we sought to reconstruct relative sea-level (RSL) changes, due to an interaction between climate and tectonic events over several thousand years.
Using satellite and drone imagery, we identified and investigated a total of 9 sites in Miyako, Ishigaki, Iriomote and Hateruma islands, where we sampled 4 fossils and 7 living coral of variable shape. We used U/Th dating to estimate the age of our fossil slices, and the age vary between 4711 and 2270 BP. We retrieved the RSL changes from our 11 samples which lead us to records over the last 230 years, and 320 years cumulated between 2270 BP and 4711 BP.
Living microatolls show slight submergence of around $0.7\,\mathrm{mm.yr}^{-1}$ for those past 150 years. Some local slow and sudden events can be observed for each sample, but only few of them can be related to each other between sampling sites or even islands. The fossil microatolls from Nagura Bay in Ishigaki witnessed two sudden emergences: one of $28\,\mathrm{cm}$ around 2273 BP and one of $29\,\mathrm{cm}$ around 4290 BP.
The intake of the climatic component of the RSL, brought by satellite altimetry and local tide gauges data, lead to several interpretations. At local scale first, the microatolls confirm their use as natural tide gauge, as same short events are recorded by both instrument and corals. At larger scale, the use of satellite altimetry reveals an absolute sea-level rise of $3\,\mathrm{mm.yr}^{-1}$ since 1992, meaning that the apparent $0.7\,\mathrm{mm.yr}^{-1}$ submergence of the microatoll records reflects a tectonic uplift of around $2\,\mathrm{mm.yr}^{-1}$, probably for more than 250 years. Those results call for a reassessment of the seismic hazard of the subduction zone.

The vertical deformation along the southern end of the Dead Sea Fault system highlighted by tectonic markers on Tiran Island – Red Sea, Saudi Arabia

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Defined as a transform plate boundary between the Arabian plate and Sinai micro-plate, the Dead Sea Fault (DSF) extends from the compressive Taurus mountains in the north to the Red Sea extensive system (RSS) in the south. Tiran Island, located near the southernmost end of the DSF, shows clear evidence of active tectonic uplift. More specifically, the southern side of the island seems to be highly affected by active tectonics and exhibits at least 16 levels of uplifted coral terraces.
In this study, we used high-resolution tri-stereo Pleiades satellite imagery to build a Digital Surface Model (DSM) at 0.5 meter resolution and mapped in detail the extent and heights of the uplifted coral terraces. The terrace heights range from one meter to almost five hundred meters above the mean sea level and they are tilted towards the east. Combining our DSM, the eustatic curve, and the Marine Isotopic Stage (MIS) variations, we derive the relative age for each terrace level. Assuming a constant uplift rate through the last 5 Myrs, we calibrate an age model consistent with an uplift rate close to $0.2 \pm 0.02\,\mathrm{mm.yr}^{-1}$, which indicates that Tiran Island has recorded at least 2.3 Myrs of tectonic uplift.
In parallel, we combined high resolution multibeam bathymetric datasets acquired by R/V Thuwal in June 2018 and September 2019 with the Beautemps-Beaupré dataset (2004) into the first complete high-resolution bathymetric map of the area. South of Tiran Island, we trace the location of the main strike-slip Tiran fault along the western side of the Hume deep pull- apart basin, as well as a normal fault oriented NW-SE along the southern edge of Tiran Island. Hence, we propose that the Tiran fault and the normal fault as the key fault structures responsible for the tectonic uplift of Tiran Island.

Iron sequestration in microalgae and Ocean acidification

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The oceans play a major role in the global carbon cycle. Indeed, they contribute to the absorption of about one quarter of the total CO_2 emitted by anthropic activities [1]. When CO_2 is dissolved in the ocean, it acidifies surface waters, and thus disturbs the oceanic ecosystem including marine phytoplankton. Microalgae absorb metallic elements, especially iron for photosynthesis, through their surfaces. Iron complexation on the micro-organisms cell walls is the first step before its subsequent internalization into the cell. Ocean acidification is expected to change both the metal availability and the microalgae surface properties, which can drastically impact the global iron uptake. The main goal of this project is to anticipate the impacts of ocean acidification on the iron adsorption capacity on the microalgae. For this purpose, surface charge variations are monitored as a function of pH, by acid-base titrations, onto various model species of microalgae representative of the marine environment: *P. tricornutum* and *T. oceanica*. Iron complexation on cell walls is then studied by titration experiments to construct sorption isotherms. Given the low concentration expected in oceanic system, we use a $57Fe$ spiking approach during our experiments. Those experiments allow to model sorption of proton and iron onto the cell surfaces. Thus, different parameters can be established: acid-base titrations allow acquiring density and protonation constants for the binding sites, and iron sorption experiments provide affinity constants values for these binding sites.

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$\delta_{11}B$ and B/Ca ontogenetic variability within *Globigerina bulloides*

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Understanding the atmosphere-continent-ocean carbon cycle and its associated oceanic carbon system is one of the keystones to face the Anthropocene's climate change. Since the 1990s the isotopic ratio of boron ($\delta_{11}B$) in calcitic shells of planktic foraminifera has proven to be a powerful geochemical proxy to determine the oceanic paleo-pH and its link to atmospheric CO_2 level over geological times [1], whereas the ratio B/Ca as proxy of the seawater carbonate chemistry is still questionable [2,3]. However, the use of planktonic foraminifera in paleoclimatic reconstructions requires calibrations of the pH-$\delta_{11}B$ relationships to correct what is known as "vital effect" [4]: each species controls differently its calcification process and consequently slightly modifies the seawater chemistry during biomineralization [5,6]. Moreover, shell size effect on $\delta_{11}B$ has been reported for some symbiont-bearing species due to photosynthetic increase of pH [7,8]. Calibrations for the symbiont-barren *Globigerina bulloides* have been already determined [9,10] but sparse data have been reported so far for the test size effect on $\delta_{11}B$ [11]. Here we measured the $\delta_{11}B$ of three different fractions (250-315, 315-400 and >400 μm) of *G. bulloides* sampled along the coretop PS97-122 from the Chilean margin (54.10°S, 74.91°W), by using a new protocol developed at IPGP and dedicated to small samples which couple a microsublimation technique and a micro-direct injection device (μ-dDIHEN [12]). Our preliminary results show significantly higher $\delta_{11}B$ values for the large fractions compared to the small ones, as found for symbiont-bearing planktonic species such as *Globigerinoides sacculifer* [7] and *Globigerinoides ruber* [8].

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Iron isotopes ratios disparity in the solar system

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Iron is the third most abundant element on Earth (McDonough 2003), and is present as a major element in both the core and the mantle. Iron isotopes are therefore well suited to record fractionating processes that occurred during the formation and differentiation of the Earth. The Bulk Silicate Earth (BSE), and the mantle of other bodies of the solar system such as the Moon, Mars and Vesta, present heavier iron isotope compositions than the chondrites. Several processes could explain such an isotopic signature. First the enrichment in heavier isotopes in the mantle could be the result of volatile loss of iron during the earlier stages of the Earth by degassing of a deep magma ocean. A second possibility is the preferential storage of the lighter iron isotopes into the core during the Earth's differentiation. Recent study by Elardo and Shahar (2017) propose that this heavy BSE signature is the product of both light Fe enrichment of the mantle during core formation and heavy Fe isotope enrichment during the subsequent magma ocean crystallization and mantle melting. Their model is based on an experimentally determined core-mantle isotopic fractionation that increases with the nickel content of the core. This raises questions regarding the generally accepted assumption evinced by Huang and Badro (2018) that Fe-Ni alloys are ideal and that the nickel content of the core has no effect on its physical (*e.g.* density, compressibility) and chemical properties. We therefore performed novel measurements of experimental iron isotopic fractionation between metal and silicate for a range of Ni content of the core from 0 to 70 wt.$\%$. We show that the isotopic composition of the silicate part of experiments could be influenced by the capsule material and that it is possible that the nickel content of the metal is not a valid explanation for the variations of iron isotopes between different solar system materials.

Realization of the control systems of a small scale suspended interferometer for quantum noise reduction in gravitational wave detectors

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In 2015, the first direct observation of a gravitational wave (GW) event has been possible by the second generation of ground-based GW detectors: Advanced Virgo and Advanced LIGO. In the following years, many other events have been detected by Virgo and LIGO. The sensitivity improvement which allowed these detections, is leading these instruments to face the limit imposed by the quantum nature of light: the Standard Quantum Limit (SQL). Hence, any further upgrade should imply quantum noise (QN) reduction techniques. Virgo and LIGO already adopt frequency independent squeezers, which reduce QN in the high frequency range where shot noise is dominant (above 200Hz). In the very near future, GW detectors will be also limited by QN in the low frequency range (below 100Hz), where radiation pressure noise (RPN) is dominant. Therefore, it is crucial to develop table-top experiments aiming at testing broadband quantum noise reduction (10Hz-1kHz): frequency dependent squeezers (FDS). We are developing a small-scale interferometer with monolithic suspensions of the main optics, named SIPS, that will be sensitive to RPN in the audio frequency band of GW detectors. Since SIPS will be RNP-limited by design, it constitutes a suitable test bench for a FDS setup based on the Einstein Podolsky Rosen (EPR) principle, which needs to be preliminary tested in a RPN-limited cavity before any possible integration in Virgo. Hence, it is fundamental to finalize SIPS experiment with the study and realization of the local and global control system to keep the interferometer in its working point. This is quite challenging because the Fabry- Pérot cavities of SIPS have an extremely high finesse (23000), implying very narrow bands for the realization of the global control. This research activity is mainly devoted to the realization of LabView-based feedback loops designed to damp and control the position of suspended elements, by means of optical lever read-out system and coil-magnet actuators. This initial control is meant to drive the optical degrees of freedom of the interferometer within the accuracy range required to lock the operation setpoint. In this talk I will present the status of SIPS and its integration with EPR experiment, focusing on our preliminary work on local controls using optical levers.

How do (massive) stars form?

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The sun was here way before humankind, hence nobody witnessed its birth. How did it happen? Star formation is a central brick in the galactic ecosystem, it gives initial conditions for planet formation and it is an active topic of research. I will present the current theory of star formation, then I will add a challenging ingredient: what about stars much (>8) more massive than the sun? Shouldn't it be even easier, due to their stronger gravitational field? One new character comes into play: the photon, and its radiative pressure. Massive stars start radiating while still accreting, and at a much higher luminosity as their mass increases. In a first simple 1D approximation their radiative pressure feedback can exceed the gravitational force and reverse the accretion flow. Spherical symmetry has been broken in multidimensional simulations, and disk accretion (2D) and Rayleigh-Taylor instabilities (3D) have emerged. Radiation must be treated accurately, in particular its frequency-dependent nature has to be captured because the gas-radiation coupling varies on orders of magnitude between the stellar photons (UV) and the medium photons (infrared), thus it strongly impacts its force and absorption by the surrounding gas. In my thesis, I have been coupling two radiative transfer methods in the RAMSES code: the first one is adapted to the direct stellar radiation (RAMSES-RT, M1) and the second one is a correct approximation for absorbed-and-reemitted radiation (Flux-Limited Diffusion). This hybrid approach brings big improvements for the gas temperature and the radiative force. I will present the impact of this approach in the formation of a massive star, and particularly the enhancement of radiative outflows. I will use a specific refinement strategy to observe the presence (or not) of these controversial Rayleigh-Taylor instabilities, and I will show how this result is of physical (and not numerical) origin. Finally, I will present preliminary outcomes when including magnetic field together with this method to investigate the origin (radiative or magnetic?) of outflows.

New challenges in transiting exoplanet atmosphere observations with JWST

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Since the first exoplanet detection in 1995, more than 4000 planets have been discovered. In the past tweny five years, the observations tools have greatly improved, increasing the statistics and revealing the diversity of planets. With the upcoming space telescopes such as James Webb and Ariel, detailed knowledge of exoplanet atmospheres will become possible. This opens up new challenges in data treatment, to detrend the signal of planets atmosphere from other sources of signal, especially systematic noise and drifts from the instrument. Good knowledge and modelling of these characteristics are necessary, in addition to that of the astrophysical properties. To meet this challenge, new methods are being developed in the community. In order to evaluate their performances and to study the ultimate performance of the instrument, we created realistic synthetic observations. This includes detailed astrophysical properties, as well as the detector response and the systematic behaviour of the instrument. This work allows us a better understanding of the influence of the instruments behaviour on the data quality and sensitivity of the observation. With this information, we can investigate which physical properties of the star and the planet are significant for the expected performance. The synthetic data produced will be used for the MIRI-ERS data challenge next year.

Observing Core-Collapse Supernova neutrinos in the Mediterranean sea

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The next observation of MeV neutrinos from a Core Collapse Supernova (CCSN) will provide important new probes on the physical mechanism driving these extreme phenomena of the Universe. The KM3NeT neutrino telescopes deployed in the Mediterranean Sea, with the multi- PMT optical module technology and a large instrumented volume, will be able to detect neutrinos from a Galactic CCSN as an overall increase on the PMT counting rate. The detection principle and expected sensitivity will be presented in this contribution, as well as the real-time performances. The capability of the KM3NeT detectors to resolve the neutrino light-curve and energy spectrum, which can be of major importance for discriminating between the different models, will be also discussed on this presentation.

Electroweak-QCD interference in hadronic vector boson decays at the LHC

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Vector boson resonances are often used as ”standard candles” for precision mass measurements. However, in analyses considering hadronic vector boson decays, experimental collaborations at the LHC neglect interference terms that arise between the background and signal processes with identical final states.
The large number of interactions that occur at each bunch crossing in the LHC results in many different processes, all of which require accurate simulation in order to analyse the data precisely. The approach taken in the case of hadronic vector boson decays is to simulate the electroweak production of these vector bosons separately to the QCD background. The consequence of this is that the interference between these two processes is not simulated and thus ignored in analyses. The impact of this interference between the QCD background and the electroweak signal is potentially very large as it can cause shifts in the reconstructed peak po-sitions of the W and Z bosons of up to several GeV$/c^2$. These effects depend largely on the kinematics involved and are also expected to scale inversely with the square-root of the signal-to-background ratio. Therefore, in boosted regimes, where the vector bosons are produced with large transverse momentum, it is found that the effects are very small. As a result, the use of vector boson resonances as reference points is not affected by neglecting interference. Currently, the areas where the effects could have a large impact are inaccessible experimentally, but this may not be the case in the future.
The work that will be presented are studies on these interference effects for a variety of different processes and the potential impact on experimental analyses will be discussed. In particular, interference in boosted vector bosons and diboson production are presented for the first time. The work has been documented in a paper: `https://arxiv.org/pdf/1908.08330.pdf`.

JUNO with Dual Calorimetry

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The Jiangmen Underground Neutrino Observatory (JUNO) is a multipurpose neu- trino experiment currently being built in Kaiping, Jiangmen, Guangdong, China. JUNO has broad physics potential. By studying the reactor neutrinos, JUNO is able to de- termine neutrino mass ordering greater than 3-sigma significance which is its primary physics goal, and JUNO will measure precisely three neutrino oscillation parameters with sub-percent precision. Beyond the reactor neutrinos, JUNO is capable to observe also supernova neutrinos, solar neutrinos, atmospheric neutrinos, geo-neutrinos and search for proton decay, etc. It will provide a unique opportunity to address some unsolved crucial questions in particle physics and astrophysics.

JUNO is going to be the world's largest ever liquid scintillator detector filled with 20,000 ton target mass, viewed by 2 photon detection systems: 18,000 20-inch (large) photo-multiplier tubes (LPMT) and 25,000 3-inch (small) photo-multiplier tubes (SPMT). The two PMT systems form the dual calorimetry for achieving the unprecedented 3% energy resolution at 1MeV and 1% energy scale uncertainty.

In this talk, I will introduce briefly the JUNO physics program and the detector design. Then I will focus on the dual calorimetry design in which the SPMT system is introduced to help conquering the 1% energy scale uncertainty challenge, and then 3% at 1MeV energy resolution challenge for the mass ordering determination.

A timing detector for the high luminosity upgrade of ATLAS

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At the high luminosity version of the LHC, which will start data taking in 2026, background from additional p-p interactions (pile-up) will be one of the main experimental challenges. High precision timing measurements provide a powerful tool to distinguish particles originating from the hard scatter (HS) vertex from those coming from pile-up collisions. The High Granularity Timing Detector (HGTD) - an ATLAS upgrade detector - will cover the pseudo-rapidity (η) range between 2.4 and 4.0, where the inner tracking detector (ITk) is no longer capable of resolving the longitudinal impact parameter of tracks at high resolution.

Search for new resonances in high-mass diphoton final states using 139/fb of proton-proton collisions collected with the ATLAS detector

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Since the discovery of the 125 GeV Higgs boson at the LHC, studies of the Higgs sector have become an important topic of the ATLAS physics program. There are many potential extensions of the Standard Model (SM) that predict new high-mass states decaying into two photons. Among which, two types of signal models are considered: a spin-0 resonance which was predicted in theories with an extended Higgs sector such as the two-Higgs doublet models (2HDM), and a spin-2 graviton excitation of a Randall-Sundrum model with one warped extra dimension. The diphoton final state played an important role when the H(125) Higgs boson was discovered, and is chosen for this search as it provides a clean experimental signature with excellent invariant mass resolution and moderate backgrounds.

This talk presents the search for new resonances decaying into two photons, using pp collisions collected with the ATLAS detector at LHC. 139/fb of pp collision data at a centre-of-mass energy of 13 TeV collected in 2015, 2016, 2017 and 2018 is used, bringing around a factor 2 improvement compared to the previous result. Pairs of isolated photon candidates with invariant mass above 150 GeV are selected. Further analysis improvements come from the reoptimisation of the event selection, which is harmonized between the spin-0 and spin-2 searches.

Testing lepton universality with semileptonic beauty meson decays

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The Standard Model (SM) of particle physics describing the fundamental particles and their interactions has been very successful, but is known to be incomplete. One of the most exciting hints for physics beyond the SM are seen in tests of lepton flavor universality (LFU). In the SM charged leptons (electron, muon, tau) have the same interaction coupling strength and differ only by their masses. The relative ratios of decays to final states differing only by the involved charged lepton can therefore be predicted with good precision. Measuring a deviation from the predicted value would give a clear hint of physics beyond the SM. Here we show such a ratio measurement performed with data recorded by the LHCb experiment utilizing the semileptonic decay of beauty mesons to charmed particles with final states involving a muon or an electron and the corresponding neutrino:

$$R_{e\mu} = \frac{\mathcal{B}(B^0 \to D^{*-} e^+ \nu_e)}{\mathcal{B}(B^0 \to D^{*-} \mu^+ \nu_\mu)}$$

Measuring this ratio with the LHCb experiment poses several challenges. The neutrino remains undetected and consequently the decay can not be fully reconstructed, due to the missing energy and momentum it carries away. Furthermore, the efficiency of reconstructing an electron in the detector must be treated as a special case, because of the Bremsstrahlung it emits, and has to be carefully calibrated using data-driven methods.

We will discuss the current status of this analysis and how these challenges can be addressed.

Search for new phenomena in low-mass diphoton final states with proton–proton collisions collected at $\sqrt{s} = 13$ TeV with the ATLAS detector

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The Higgs boson discovery by ATLAS and CMS collaborations relied mainly on resonance searches in two different channels, one of them being the diphoton channel. Since then, both experiments have extended the resonance search range towards lower and higher diphoton invariant masses up to limits driven by experimental limitations.

This talk focuses on a novel diphoton resonance search in the invariant mass range below 60 GeV using all Run2 data from pp collisions collected with the ATLAS detector at the Large Hadron Collider. Some perspectives on future analyses in the same mass region will be discussed.

OT Outreach Talk IS Invited Speaker NT Normal Talk

780-thousand years of volcanic seafloor accretion at a melt-rich segment of the ultraslow-spreading Southwest Indian Ridge 50°28'E

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The ultraslow spreading (∼14 mm/yr) Southwest Indian Ridge (SWIR) has a thick axial lithosphere, as confirmed by earthquakes depths, and its melt supply has been shown to vary from enough to produce a fully volcanic seafloor, to nearly amagmatic, leading to widespread faulting of mantle-derived ultramafic rocks onto the seafloor. A substantial melt supply at segment #27 (central SWIR, 50°28'E) has been inferred from bathymetric, gravity, and geochemical data. Seismic data confirms that the crust in the center of this segment is up to ∼9.5 km-thick, with a low-velocity anomaly (-0.5 km/s) in the lower crust that suggests a hot and/or melt-rich zone (Jian et al., 2017, JGR). Yet, microearthquakes occur down to 10 km, indicating a thick brittle lid on or very close to the ridge axis (Yu et al., 2018, JGR), and faults that control the axial valley in the adjacent, less magmatically active ends of the segment can be followed to the segment center. This setting is similar to that of several magmatically robust segment centers at slow and ultraslow ridges. The construction of the magmatic crust, and specifically the interplay between magma emplacement and faulting, are not well understood in this context. We address this question with a study of volcanic morphologies and faulting revealed by high resolution bathymetry and reflectivity data acquired by the AUV QianLongII (DY40 cruise; 2016) over the center of segment #27, covering ∼780 thousand years of crustal accretion. Mapping of volcanic facies ranging from smooth to hummocky terrains, fault scarps and fissures leads us to discuss the recent eruptive history of this melt-rich region, and its possible relation with faulting, both local and adjacent segment ends regions. Combining with other melt-rich ridge segments at slow and ultraslow spreading ridges, we interpret our observations into that 3-D melt focusing results in a complex magma plumbing system under the context of thick brittle lid.

Caldera ring-faulting during the 2015 Ambrym dike intrusion and the search for the missing deflation source

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During dike intrusions, co-eruptive surface displacements have shown discrepancies between the magma volume evacuating a volcano's reservoir and the magma volume injected into the dike. In some cases, the intruded volume can be up to 5 times greater than that of the reservoir volume loss. Such differences are explained by shape effects of a stiff ellipsoidal reservoir compared to a compliant crack, in combination with magma compressibility. As a result, co-eruptive surface displacements do not always provide unambiguous insights into the volcano's plumbing system, leaving lingering questions regarding the reservoir's depth, geometry and size.
On February 21^{st} , 2015 at Ambrym volcano (Vanuatu), a dike intrusion produced up to 2 meters of line-of-sight shortening (co-eruptive uplift), as measured by InSAR, SAR correlation, and Multiple Aperture Interferometry (MAI). Using a 3-D Mixed Boundary Element (BE) forward model, combined with a Monte Carlo neighbourhood inversion algorithm, we solve for the dike overpressure and geometry that produces the best-fitting surface deformation. However, this pressure source alone cannot explain a portion of the co-eruptive uplift. The residual deformation is instead modelled by caldera ring-faulting. Using the BE forward model, the stress change imposed by the opening dike on a passive, frictionless fracture (fault) is explored. We find that the dike opening clamps the fault, resulting in reverse slip, as opposed to observed normal faulting. Including a deflating pressure source beneath Ambrym's caldera allows for producing up to $30\,\mathrm{cm}$ of normal fault slip at the surface. At Ambrym, the existence of a deflating reservoir and coeval ring-faulting was confirmed with InSAR measurements during a large-scale rift zone intrusion in 2018.
The 2015 co-eruptive surface displacements at Ambrym can be modelled by a dike and a normal fault, but the missing deflation source is only identified once taking into account the mechanical interactions between the pressure sources and the caldera ring fault. In volcanic systems, especially those with an interplay between dike migration, reservoir deflation, and ring-faulting, the stress change induced by multiple sources should be considered in order to improve conceptual models of the volcano's plumbing system.

Hydrogeological functioning of Martinique Island revealed by helicopter-borne geophysical survey

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Water resources exploration on volcanic islands is challenging as these territories frequently face high population densities with increasing water demands. Improving the hydrogeological knowledge of these islands is thus a major objective in order to achieve a sustainable management of their water resources. We take advantage of a SkyTEM helicopter-borne geophysical survey over Martinique Island (Lesser Antilles) which allow, overcoming dense vegetation and steep slope constraints, providing information's on the first 200 m depth. We conducted multidisciplinary studies at different spatial scales in order to interpret resistivity data in terms of hydrogeological structures and properties for constraining hydrogeological conceptual models. We firstly demonstrated, at the aquifer scale, that heterogeneous hydrodynamic properties and channelized flows result from aquifer compartmentalization along structural directions imaged by resistivity and magnetic maps. Furthermore, we show that the most fractured compartments have lower resistivity and higher transmissivity. Compartmentalization and transmissivity contrasts thus protect the studied coastal aquifer from seawater intrusion. At the watershed scale, we put in evidence that the main geological structures lead to preferential flow circulations and that hydrogeological and topographical watersheds can differ, influencing river flowrates. Correlation between resistivity, geology and hydraulic conductivity data of four aquifers also reveals that the older the formation, the lower its resistivity and the older the formation, the higher its hydraulic conductivity. Finally, our approach allows characterizing the properties of aquifer and aquitard units of Martinique, leading to the proposition of hydrogeological conceptual models that suits the complexity of the island at different scale, with heterogeneous geological formations presenting high lateral and vertical variability. Moreover, our study offers new guidelines for addressing relations between resistivity, geology and hydraulic conductivity for volcanic islands.

Submarine Platform Development by Erosion of a Surtseyan Cone at Capelinhos, Faial Island, Azores

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Erosion of volcanic islands ultimately creates shallow banks and guyots, but the ways erosion proceeds to create them over time and how coastline retreat rate relates to wave conditions, rock mass strength and other factors are unclear. The Capelinhos volcano was formed in 1957/58 during a Surtseyan and partly effusive eruption that added a $\sim 2.5\,\mathrm{km}^2$ tephra and lava promontory to the western end of Faial Island (Azores, central North Atlantic). Subsequent coastal and submarine erosion has reduced the subaerial area of the promontory and created a submarine platform. This study uses historical information, photos and marine geophysical data collected around the promontory to characterize how the submarine platform developed following the eruption. Historical coastline positions are supplemented with coastlines interpreted from 2004 and 2014 Google Earth images in order to work out the progression of coastline retreat rate and retreat distance for lava- and tephra-dominated cliffs. Data from swath mapping sonars are used to characterise the submarine geometry of the resulting platform (position of the platform edge, gradient and morphology of the platform surface). Photographs collected during SCUBA and ROV dives on the submarine platform reveal a rugged surface now covered with boulders. The results show that coastal retreat rates decreased rapidly with time after the eruption and approximately follow an inverse power law relationship with coastal retreat distance. We develop a finite-difference model for wave attenuation over dipping surfaces to predict how increasing wave attenuation contributed to this trend. The model is verified by reproducing the wave height variation over dipping rock platforms in the UK (platform gradient 1.2° to 1.8°) and Ireland (1.8°). Applying the model to the dipping platform around Capelinhos, using a diversity of cliffs resistance predicted from known lithologies, we are able to predict erosion rate trends for some sectors of the edifice. We also explore wider implications of these results, such as how erosion creates shallow banks and guyots in reef-less mid-oceanic archipelagos like the Azores.

Quantum fields in de Sitter spacetime

Gabriel Moreau

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The standard model of cosmology offers a very successful description of the history of the universe at very large scales. It is based on the theory of General Relativity, which gives a unified picture of the geometry of spacetime and gravity. However, it comes in direct conflict with some observational facts, such as the Cosmic Microwave Background (CMB), an electromagnetic radiation coming from the early stages in the history of the universe. This tension can be cured by the inclusion of an inflationary phase (i.e. a phase of accelerated expansion), which also provides an elegant explanation for the observed spectrum of the CMB, at the intersection between quantum physics and general relativity. During this talk I will try to explain in more details the reason for studying inflation as well as why it motivates the study of quantum fields in de Sitter spacetime, and possibly some hints of the specificity of this setup.

CRIME: Cosmic Ray Interactions in Molecular Environments

Vo Hong Minh Phan

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Cosmic rays are believed to play an essential role in determining the chemistry and the evolution of molecular clouds. This is because they are usually considered to be the main ionization agent of these star-forming regions. Recent theoretical estimates have found that the predicted ionization rate of many cosmic-ray transport models using the local cosmic-ray spectra is about 10 to 100 times smaller than the one inferred from the observational data. This seems to indicate that the observed spectrum is local and, thus, it opens up new possibilities to model properly the Galactic cosmic-ray spectrum at low energy to better understand the ionization rate which is of critical importance to pave the way for future research in Star Formation. More interestingly, a few molecular clouds in the vicinity of cosmic-ray sources are observed to have an enhanced ionization rate which seems to be of cosmic-ray origin and might allow us to put some constraints on the low energy part of the cosmic-ray spectrum around these sources. In this talk, we will briefly discuss some of the theoretical investigations of cosmic-ray transport in molecular clouds and the possible interpretations of observed ionization rates on both the diffuse Galactic cosmic ray spectrum and the one around cosmic accelerators down to energy below 1 GeV.

Variability of Active Galactic Nuclei at Very High Energy with H.E.S.S.: the flaring activity of PKS 2022-077 in 2016 and 2017

Gabriel Emery

LPNHE - Sorbonne Université

Active Galactic Nuclei (AGN) are powerful photon and particle emitters located at the center of some galaxies. Emissions from AGNs are powered by the accretion of matter on a central super massive black hole. In some AGNs, a fraction of the infalling matter is ejected in a relativistic jet. This jet is a beam of particles moving at speeds close to the speed of light. Emissions by particles in the jet are concentrated in the jet direction by relativistic effects. Hence, high energy emissions can only be observed if the jet point in Earth direction. PKS 2022-077 is a Flat Spectrum Radio Quasar, a sub-category of AGN, located at a redshift z=1.388, farther than any source currently detected at Very High Energy (VHE, E>100 GeV). At such energies, absorption by the Extragalactic Background Light (EBL) renders the detection of distant sources particularly challenging. The High Energy Stereoscopic System (H.E.S.S.) observed the source following reports from AGILE (April 2016) and Fermi-LAT (April 2016, October and November 2017) on high flux states in gamma-rays. The H.E.S.S. experiment is an array of Cherenkov telescopes located in Namibia. This experiment is designed to indirectly detect VHE photons reaching Earth atmosphere over a large effective area. During each of the three flaring periods, near-simultaneous observations were obtained with H.E.S.S., Fermi-LAT and multiple telescopes at other wavelengths. Though the source was not significantly detected by H.E.S.S., upper limits were derived for each observation period. Through constraints given by Fermi-LAT in the MeV-GeV domain and upper limits by H.E.S.S., we searched for an intrinsic cutoff in the EBL corrected gamma-ray spectrum of PKS 2022-077.

The impact of magnetic fields on dipolar mixed mode frequencies inside red giants

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Stars more massive than $\sim 1.3\mathrm{M}_\odot$ are known to develop a convective core during the main-sequence: the dynamo process due to this convection could be the origin of a strong magnetic field, trapped inside the core of the star for the rest of its evolution. If such field exists, it should affect the mixed modes inside red giants as they are sensitive to processes affecting the most intern layers of the stars. The impact of a magnetic field on dipolar oscillation mode of the Sun was studied in the context of the SOHO/MDI mission. The investigation of the solar acoustic oscillation modes did not provide any hint of the existence of a magnetic field in the solar core. We generalise this work to evolved solar-like stars: today we have access to the core of evolved stars thanks to the observation of mixed modes from the Kepler, K2 and TESS missions. We investigate the theoretical effect an axisymmetric magnetic field with poloidal and toroidal components on the mixed modes frequencies of simulated sub-giants and red giants. This theoretical perturbative study enable us to estimate the magnetic perturbation on the frequencies of mixed dipolar modes, depending on the magnetic field strength and the evolutionary stage of the star.

Interferometer constraints on the inflationary field content

Laura Iacconi IS

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With an energy scale that can be as high as 10^{14} GeV, inflation may provide a unique probe of high-energy physics. Both scalar and tensor fluctuations generated during this early accelerated expansion contain crucial information about the particle content of the primordial universe. The advent of ground- and space-based interferometers enables us to probe primordial physics at length-scales much smaller than those corresponding to current CMB constraints. One key prediction of single-field slow-roll inflation is a red-tilted gravitational wave spectrum, currently inaccessible at interferometer scales. Therefore, interferometers probe directly inflationary physics that deviates from the minimal scenario and, in particular, additional particle content with sizeable couplings to the inflaton field. We adopt here an effective description for such fields and focus on the case of extra spin-2 fields. We find that a time-dependent sound speed for the extra modes can generate primordial gravitational waves with a blue-tilted spectrum, potentially at reach at interferometer scales. To define current exclusion limits on the parameter space, we combine bounds from the model inner consistency checks with those originating from (i) the upper limit on the tensor-to-scalar ratio r at CMB scales (ii) ultracompact minihalos, (iii) primordial black holes, (iv) big bang nucleosynthesis, and (v) the Laser Interferometer Gravitational-Wave Observatory (LIGO). We explore the possibility of a detection by the Laser Interferometer Space Antenna (LISA) and its constraining power on this very general set-up.

Probing Universe's first light

Clara Vergès OT

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The Cosmic Microwave Background (CMB) is the first light ever emitted in the Universe, only 380 000 years after the Big-Bang. Since its discovery by Penzias and Wilson in 1964, the CMB has been observed, measured and studied by many scientists and many experiments, around the globe and even from space.
Although it looks extremely homogeneous at first sight, the CMB in fact presents small variations depending on the direction of observation, called anisotropies. These anisotropies carry information about the structure of our universe, its energy content and its evolution, making the CMB one of the best probe we have to study the universe. Recent experiments, in particular the Planck mission, have measured the total intensity of the CMB and its variation across the sky with a very high precision, allowing us to confirm and measure the parameters of the standard cosmology model with a very high accuracy. Total intensity is however not the only source of information carried by the CMB, since its light is also polarised. This polarisation potentially contains hint for a new physics, in particular of a hypothetical phase called inflation. This phase has been proposed by cosmologists to resolve problems arising in the standard model of cosmology. Polarisation anisotropies are however several order of magnitude below those of total intensity, making them hard to measure.
Cosmologists are therefore building new experiments to observe CMB polarisation with an unprecedented precision, looking for a particular signature in this signal, which would be a smoking gun for inflation.
I will give an overview of Universe history, CMB science, and operation of current and future CMB experiments.

Direct Detection of Leptophilic Dark Matter with XENON1T

Jean-Philippe Zopounidis

OT

Laboratoire de Physique Nucléaire et des Hautes Énergies, CNRS/IN2P3, Sorbonne Université, Université de Paris, Paris, France

Despite the great experimental efforts, that have been undertaken in recent years, there has been no indication as to the particle nature of dark matter (DM). However, its existence is dictated by a multitude of astronomical and cosmological observations which receive a natural interpretation if seen in the light of a "**Physics Beyond the Standard Model**".

Indeed, from a theoretical point of view, one of the most attractive attempts to elucidate this profound open question of modern physics emerges through supersymmetry theory, under the generic name of **Weakly Interacting Massive Particles** (WIMPs). Nevertheless, all relevant experimental efforts, based on underground detectors, have only excluded part of the parametric space of the theory.

It seems, then, that the mystery's answer could be sought in alternative theories predicting other DM candidates. For instance, there are so-called, "**hidden sector**" models, predicting a leptophilic DM, *i.e.* a DM particle that could interact with atomic electrons causing inelastic atomic processes such as ionization.

But it happens that underground detectors, like the double-phased TPC of XENON1T, filled with liquid xenon (LXe), are characterized by an exceptional sensitivity for detection of small charge signals derived from ionization of xenon atoms, down to the level of one electron! Therefore, the detector is sensitive to the inelastic quantum processes occurring at the atomic level and, *par excellence*, to the ionization process of even a single atom.

And yet, it is in this very region of the leptophilic DM expected signal, that a huge and, so far, incomprehensible background arises, driven by the so-called **single electrons**, small charge signals that appear to derive from a multitude of quantum processes in the atomic level of LXe, for many and yet unknown reasons.

Can we classify the processes that create these backgrounds? What can we infer about leptophilic DM without the possibility of background subtraction? How can state-of-the-art machine learning techniques like Neural Networks mitigate such backgrounds, making use of partial knowledge of them in conjunction with the topological characteristics of the corresponding events? These are some of the questions, about this exciting topic of direct DM detection, that I will try to answer in my presentation.

Test of Lepton Flavour Universality: Study of $b \to sl^+l^-$ in LHCb

Da Yu Tou

OT

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The Standard Model is a relativistic quantum field theory description of the subatomic world. In this model the world is made up of fermions - quarks and leptons. Their interaction proceeds via the electromagnetic, weak or strong forces mediated by the gauge bosons. The Standard Model has stood the test of precision measurements so far. Yet its predictive power does not extend to astrophysical observations: it offers no explanation for gravity, dark matter, dark energy and matter-antimatter asymetry.

In the search for physics beyond the Standard Model, the LHC accelerator was built to collide protons at 13TeV centre-of-mass energy. One experiment collecting LHC collision data is the LHCb experiment. LHCb has a pseudorapidity region of $2 < \eta < 5$, optimised to study the decays of b and c quarks. A new physics search in b decays is test of lepton flavour universality - Standard Model decay rates are independent of lepton flavour. In particular, the rare b quark decays into an s quark and a di-lepton pair ($b \to sl^+l^-$) are studied.

This talk focuses on LHCb lepton flavour universality measurements in $B^0 \to K^{*0}l{+}l^-$, $B^+ \to K^+l{+}l^-$ and $\Lambda_b^0 \to pK^-l{+}l^-$ decays.

Derivation of the full current density vector in the Earth's ionosphere low- and mid-latitude F region using ESA's Swarm satellites

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[3] NOAA National Centers for Environmental Information

A new multi-spacecraft method to recover estimates of the average three- dimensional current density in the Earth's ionosphere is presented. It is demonstrated using the ESA's Swarm satellite constellation and by taking advantage of the favorable geometrical configurations during the early phase of the mission. The current density vector is calculated inside prisms whose vortices are defined by the satellite positions. The mathematical formalism differs from previous approaches such as the one known as the "curlometer". It makes use of the well-known curl-B technique and involves an inverse problem which allows for error propagation through the calculation. Data from the vector field magnetometers of the three satellites are used and special care is taken to characterize the errors on these data. The method is applied in the low- and mid-latitude F-region on 15 February 2014. It provides latitudinal profiles of the full current density vector together with the associated error bars in the morning and evening sectors. We observe several dynamical features such as clear signatures of field-aligned interhemispheric currents, potential signatures of the wind dynamo current system as well as mid-latitude east-west currents.

An integrated paleomagnetic, rock magnetic, anisotropy of magnetic susceptibility, stratigraphy, structural and sediment provenance analysis to investigate the evolution of the Northern Iranian Plateau: insights from Miocene synorogenic red beds from Tarom Basin, NW Iran

Mohammad Paknia[1], *Paolo Ballato*[1], *Massimo Mattei*[2], *Ghasem Heidarzadeh*[2], *Francesca Cifelli*[1], *Jamshid Hassanzadeh*[3], *Joshua Feinberg*[4], *Mike Jackson*[4], *Bruce Moskowitz*[4], *Dario Bilardello*[4], *Andy Wickert*[4] and *Mohammad R. Ghassemi*[5]

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Sedimentary basins represent first-order geological archives that can provide information on the evolution of the sediment source regions, the growth and the erosional history of adjacent topography, the evolution of the depositional settings and the paleoenvironmental conditions. In this study, we focus on the intermontane Tarom Basin located on the upper plate of the Arabia- Eurasia collision zone at the transition between the northern margin of the Iranian Plateau and Alborz Mountains. This basin was filled with synorogenic red beds that allow investigating puzzling aspects of the collision zone, such as the timing and mechanisms of plateau margin (Tarom range) uplift, its lateral extension and link with the adjacent growing Alborz Mountains. The basin fill also offer the possibility to better understand the tectono-stratigraphic evolution of the basin, depositional environments, paleoenvironmental conditions and sediment provenance areas. To achieve these goals, we performed an integrated paleomagnetic, rock magnetic, anisotropy of magnetic susceptibility (AMS), geochronologic, magnetostratigraphic, structural, sedimentologic, and sediment provenance study on three sedimentary sections exposed in the basin. This approach allowed documenting for the first time the termination age of Eocene arc volcanism in this region at $38-36$ Ma, an age for the synorogenic red beds of 16.5 to 7.6 Ma with sedimentation accumulation rates range between $0.025-0.29\,\mathrm{mm.yr}^{-1}$, the occurrence of an early stage of late Eocene deformation followed by higher magnitude of deformation from ~ 16.5 Ma, a complex evolution of the drainage system with several episodes of efficient and reduced to absent fluvial connectivity with the Caspian Sea, changes in the depositional setting as well as in the sediment source area, and the occurrence of post 7.6 Ma intrabasinal deformation event which had a localized impact in the magnetic fabric of sediments. We also obtained detailed information about type of magnetic minerals, main ferromagnetic carriers, magnetic domains/grain-size and the other magnetic characteristics of the sediments associated with changes in past climate, sediment source areas and in the depositional settings. Overall, our data indicate that the northern basin margin accommodated a greater magnitude of deformation and exhumation than the southern one, which experienced limited deformation and erosional exhumation.

Constraints on the magnetic field within a stratified outer core

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IS

University of Leeds

Mounting evidence from both seismology and experiments on core composition suggests the existence of a layer of stably stratified fluid at the top of Earth's outer core. In this work we examine the structure of the geomagnetic field within such a layer, building on the important but little known work of Malkus (1979). We assume (i) an idealised magnetostrophic spherical model of the geodynamo neglecting inertia, viscosity and the solid inner core, and (ii) a strongly stratified layer of constant depth immediately below the outer boundary within which there is no spherically radial flow. Due to the restricted dynamics, Malkus showed that with stratification the geomagnetic field must obey a certain condition which is a more restrictive version of the condition of Taylor (1963). The nonlinear nature of these constraints makes finding a magnetic field that obeys them, here termed a Malkus state, a challenging task. Nevertheless, such Malkus states when constrained further by geomagnetic observations have the potential to probe the interior of the core. By focusing on a particular class of magnetic fields for which the Malkus constraints are linear, we describe a constructive method that turns any purely-poloidal field into an exact Malkus state by adding a suitable toroidal field. We consider poloidal fields following a prescribed smooth profile within the core that match observation-derived models of the magnetic field in either epoch 2015 or the 10000-yr time averaged field. Multiple possible solutions for the toroidal field exist, hence we determine the Malkus state of minimum toroidal energy and we find that it has a strong azimuthal toroidal field, larger than the observed poloidal component at the core-mantle boundary. For the 2015 field for a layer of depth 300 km, we estimate a root mean squared azimuthal toroidal field of 3 mT with a pointwise maximum of 8 mT occurring at a depth of about 70 km.

Force balance in numerical geodynamo simulations: a systematic study

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Dynamo action in the Earth's outer core is expected to be controlled by a balance between pressure, Coriolis, buoyancy and Lorentz forces, with marginal contributions from inertia and viscous forces. Current numerical simulations of the geodynamo, however, operate at much larger inertia and viscosity because of computational limitations. This casts some doubt on the physical relevance of these models. Our work aims at finding dynamo models in a moderate computational regime which reproduce the leading-order force balance of the Earth. By performing a systematic parameter space survey with Ekman numbers in the range $10^{-6} \leq E \leq 10^{-4}$, we study the variations of the force balance when changing the forcing (Rayleigh number, Ra) and the ratio between viscous and magnetic diffusivities (magnetic Prandtl number, Pm). For dipole-dominated dynamos, we observe that the force balance is structurally robust throughout the investigated parameter space, exhibiting a quasi-geostrophic (QG) balance (balance between Coriolis and pressure forces) at zeroth order, followed by a first-order MAC balance between the ageostrophic Coriolis, buoyancy and Lorentz forces. At second order this balance is disturbed by contributions from inertia and viscous forces. Dynamos with a different sequence of the forces, where inertia and/or viscosity replace the Lorentz force in the firt-order force balance, can only be found close to the onset of dynamo action and in the multipolar regime. Our study illustrates that most classical numerical dynamos are controlled by a QG-MAC balance, while cases where viscosity and inertia play a dominant role are the exception rather than the norm.

OT Outreach Talk IS Invited Speaker NT Normal Talk

Lighting the Black Box: Use and Validation of Machine Learning Techniques in High-Energy Theoretical Physics

Giovanni Stagnitto OT

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Machine learning (ML) techniques, in particular neural network (NN) architectures, are increasingly used in high-energy physics. After a general introduction, I will present two applications of ML techniques in theoretical high-energy physics. i) Machine learning techniques are used to determine the Parton Distribution Functions (PDFs) which describe the quark and gluon content of protons. PDFs are crucial ingredients in the precision calculations of hadronic-initiated processes, such as the proton- proton collisions of the LHC. They are intrinsically non-perturbative objects, and thus have to be determined by fitting experimental data to the theory. In these cases, using the universal approximation property of NN allows for an unbiased PDF fitting. ii) ML techniques are also used to study of the pattern of quark and gluon radiations in the final state of a collider event. The distribution of radiation around a particle is tightly linked to the nature of the particle. For example, the distribution would different if the initiating particle was a quark or a gluon, i.e "quark vs. gluon discrimination". This is a typical case of a classification problem and because it requires a large number of input variables it calls for the use of ML techniques. I will also discuss some tests used to validate the ML framework both for i) and ii). These tests compare the NN outputs with known solutions for a specific input.

How to walk on a mountain in order to characterize gravitational waves ?

Marc Arène OT

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Imagine you are blind and your task is to report the map of a complex shaped mountain. It has secondary peaks, steep slopes and plateaus, many bumps etc. Even though you cannot see, you are able to walk anywhere on that mountain and record the height of every point on your way. What would be the strategy to adopt in order to render a trustworthy picture of the mountain as quickly as possible?
In the context of gravitational waves data analysis, we are facing an ill- shaped mountain living in a 17 dimensional space. Indeed when such a ripple of space time has been detected by ground-based interferometers, the next step is to estimate the parameters of its source, in our case the coalescence of a compact binary system (eg an orbiting pair of neutron stars and/or black holes). Doing so requires having a deep knowledge of the posterior distribution of the parameters which is a function of 17 variables in the most complete model given by General Relativity.
The main purpose of my PhD is to develop an efficient algorithm, the Hamil- tonian Monte Carlo (HMC), which should converge to a satisfactory picture of our mountain several times faster than currently used methods.
In this talk I will pursue the mountain metaphor to explain the reason behind the use of Markov Chain Monte Carlo algorithms, then describe their set-up, their relevance in the context of gravitational waves and finally explain why the HMC is a promising algorithm in this field.

Martian signal automatic clustering and event's detection using SEIS data in continuous records with an unsupervised deep scattering network

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InSight (Interior Exploration using Seismic Investigations, Geodesy, and Heat Transport) lander had successfully deployed onto Mars' surface the SEIS (Seismic Experiment for Internal Structure) instrument; a six-axes seismometer equipped with both a long-period three-axes, very Broad Band (VBB) instrument and a three-axes short-period (SP) instrument. These six sensors will cover a broad range of the seismic bandwidth, from 0.01 Hz to 50 Hz, with possible extension to longer periods. It's the first broad-band instrument monitoring Mars's seismic noise and activity in order to estimate the interior structure of Mars.

However, planetary seismology is still far from providing models with high precision due to the high sensitivity of the seismological features used in the inversion process. In fact, SEIS is a very sensitive instrument ; noise in an octave bandwidth around 1 Hz is expected to be in the range of 2–3 10^{-9} m/s^2/Hz$^{\frac{1}{2}}$, thus, they may nevertheless be hidden into noise, or may escape from analysis due to the limitations imposed by the current methodologies.

Therefore, the aim of this study is to overcome this problem by well extracting, recognizing and classifying the SEIS signals using Deep Learning and Machine Learning strategies . In fact, this tool has recently proved to be powerful in signal processing, data automatic feature extraction and may even be helpful to detect new types of signals. Those new signals can reveal unknown processes and lead to new discoveries about Mars physical processes. The method used in this study is a new adapted version of the unsupervised representation learning approach for clustering and detection of seismic signals in earth continuous seismic records [2]. It's inspired from the deep scattering network [1]. This technic is divided into two steps. The first one, to make an automatic feature extraction using the scattering transfrom network. The second step is to cluster them using the Gaussian Mixture Model. This technique was tested on the blind test data provided by the Marsquake Service (MQS) and by the Mars Structure Service (MSS). It is also used to analyze the first data recorded data by the co-located broadband and short period seismometers and has shown to be able to detect so many events that can be classified into an instrumental events (noise, glitch,...) and Nature events (Dust devils, seismic noise, seismic events,...)that is going to be discussed in detailed in this paper.

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The deposition pattern of linear dunes using a cellular automaton (CA) model

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Although linear dunes are abundant on the Earth and found on other planets, like Mars and Titan, their internal structure remains not commonly recognized in the field. Here a CA model is employed to simulate the deposition pattern of elongating linear dunes under bidirectional wind regimes. Dunes initiate and evolve on a bare, non-erodible bed from a fixed source of sand. Sediment supply along the linear ridge is modelled with two types of boundary conditions: open boundaries for a zero supply, and periodical boundaries that compensate the outflux (Rozier, et al. 2019). With tracking the deposition time at the minimal scale, both the historical sedimentary structure and detailed deposition patterns within a cycle are investigated in respect to the wind duration ratio N.

As the dune reaches a steady-state, the overall architecture consists of a core permanently buried beneath an active layer mobilized by the wind oscillation. Within the core, the wind ratio N is reflected by the asymmetry of the strata dipping from the crest to both sides. Under open boundary conditions, the oldest sand within a cross section indicates that the elongation rate does not significantly vary with N at the early stage. The case is different under periodical boundaries. The track of oldest sand indicates that the increase of N causes earlier deposition to be preserved, whilst the instantaneous tip elongates approximately at the same rate. In all cases, there is a delay between the time when the dune tip extends to a section and when the first grain is preserved in it. The along-ridge sand supply under the periodical condition is considered as the driver. In addition to the historical dynamic recorded by the core, we also identify phases of deposition within one wind cycle. The phase is also determined by the wind ratio N on this small time scale.

Spatial and temporal development of the dune instability at White Sands Dune Field, New Mexico, USA

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In zones of loose sand, the emergence of sand dunes results from a linear instability of a flat sediment bed. This instability has largely been studied in spatially homogeneous conditions in experiments and numerical models, but rarely in-situ due to the time and length scales involved. In inhomogeneous conditions, such as the upwind edge of dune fields, the convective aspect of flat bed instability can express as migrating surface waves of spatially increasing amplitude. We present here the case of the upwind margin of White Sands Dune Field, and document the development of incipient dunes over 4 years using high-resolution lidar-derived topography data. In addition to the dune wavelength, growth rate and celerity, we also measure the characteristic length scale associated with the spatial growth of dunes. We show that all these quantities are consistent with those predicted by the linear stability analysis. The exponential growth of dunes in space and time may therefore provide useful constraints on wind regimes and sediment properties where direct measurements are not available.

Elongation and stability of a linear dune

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Compared to barchan dunes, the morphodynamics of linear dunes that elongate on a non-erodible bed have barely been investigated by means of laboratory experiments or numerical simulations. Using a cellular automaton model, we study the elongation of a solitary linear dune from a sand source and show that it can reach a steady state. This steady state is analyzed to understand the physical processes at work along the dune. Crest reversals together with avalanche processes control the shape of transverse sections. Dune width and height decrease almost linearly with distance downstream until the minimum size for dune is reached. This is associated with a constant sand loss along the dune, which eventually compensates for the sediment influx and sets the dune length. This sand budget is discussed to distinguish an elongating linear dune from a barchan dune and to explain the complexity of linear dune fields in nature.

In situ monitoring and modelling of near seafloor hydrothermal dynamics and formation of diffuse vents at the Lucky Strike hydrothermal field, mid-Atlantic ridge.

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Km-scale convection cells at the origin of focused, black smoker vents have been the focus of most previous studies of hydrothermal circulations in the oceanic lithosphere at mid-oceanic ridges. These hot hydrothermal fluids are modified in the highly permeable domain that lies just below the seafloor. Mixing with secondary seawater circulations and chemical reactions lead to the formation of diffuse effluents that vent mid to low temperature fluids. These diffuse vents release larger heat and chemical fluxes than the high temperature black smokers, and host most of the chemiosynthetic biological activity at mid-ocean ridges vents but remain poorly studied. In situ studies of the characteristics of diffuse mid-ocean ridge hydrothermal fluids over long time period are scarce. We use data generated at the multidisciplinary EMSO-Azores observatory for the 1 km^2 Lucky Strike basalt-hosted hydrothermal field (Mid-Atlantic Ridge 37°17$'$N). We use these data to constrain physical models of fluids circulation in the shallow seafloor. Our in-situ observations and monitoring data focus on two vent sites showing typical characteristics of hydrothermal mounds: a massive sulphide deposit structure, up to 20 meters in diameter, with several black smokers, set in a semi-elliptical domain of diffuse venting up to 20 to 70 m in diameter. In our modelling approach, we focus on the upper 100 m of the basement with a physical model using heat conduction and Darcy's porous flow laws, with a central pipe of hot fluid (modelled as hot seawater). The pipe size and fluid speed at the base of the model are among the model's unknowns. We test plausible values for these parameters which we constrain by running larger scale models of the black smoker hydrothermal circulation. We find that secondary seawater circulations generated in our small scale models prevent the high temperature ($>$300°C) fluids to reach the seafloor and to form black smokers. In order to form these focused vents, we need to introduce minerals precipitation leading to local permeability variations that insulate part of the hot fluids all the way to the seafloor.

Similarities and differences of microseism and microbarom source regions reconstructed from the seismo-acoustic Kazakhstani network

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The monitoring network of the Kazakhstani Institute of Geophysical Researches includes seismic and infrasound arrays. The PMCC method helps identifying microseisms in seismic records and microbaroms in infrasound records effectively. Simulation of the microbarom strength, propagation path and signal attenuation are well developed for the moment, and for microseisms as well. However, the bathymetry effect on the source intensity shall be taken into account to model microseisms. Results of the source parameter simulations and microbaroms and microseisms detections are compared at 7 Kazakhstani seismic and infrasound arrays. These comparisons are also carried out between collocated seismic and infrasound arrays. Similarities and differences between the reconstructed source regions of microseisms and microbaroms are discussed. Beside this study, the advantages of integrating the infrasound and seismic methods have been shown for studying seismoacoustic signals from severe storms.

Using 2D long-streamer seismic data waveform tomography to decipher sedimentary record of fault activity

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Acoustic full-waveform inversion (FWI), involves use of both phase and amplitude of the recorded compressional waves to obtain a high-resolution P-wave velocity model of the propagation medium. Application of FWI in the academic domain has, so far, been limited, mostly because of the lack of adequate seismic data. Only modern long-streamer data have offsets that, in some cases, enable constraining subsurface velocities at a significant enough depth to be useful for structural or tectonic purposes. In this study, we show how FWI can help decipher the record of a fault activity through time at the Shumagin Gap in Alaska. The MCS data were acquired on RV Marcus G. Langseth during the ALEUT cruise in the summer of 2011 using two 8-km-long seismic streamers and a 6600 cu. in. tuned airgun array. One of the most noticeable reflection features imaged on two profiles is a large, landward-dipping normal fault in the overriding plate; a structural configuration making the area prone to generating both transoceanic and local tsunamis, including from landslides. This fault connects to the plate boundary fault at $\sim$35 km depth, near the intersection of the megathrust with the forearc mantle wedge. The fault system reaches the surface at the shelf edge 75 km from the trench, forming the Sanak basin where the record of the recent activity of the fault is not clear. Indeed, contouritic currents tend to be trapped by the topography created by faults, even after they are no longer active. Erosion surfaces and onlaps from contouritic processes as well as gravity collapses and mass transport deposits results in complex structures that make it challenging to evaluate the fault activity. Refraction arrivals in the target continental slope area permitted running streamer traveltime tomography followed by FWI to produce coincident detailed velocity profiles to complement the reflection sections. FWI imaging of the Sanak basin reveals low velocities of mass transport deposits and velocity inversions indicate mechanically weak layers linking some faults to gravity sliding on a décollement. These details question previous interpretation of a present-day active fault.

Orienting and localising Ocean Bottom Seismometers from ship noise analysis

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As they are deployed on the ocean floor, Ocean Bottom Seismometers (OBS) loose their orientation during their descent and can drift hundreds of meters relative to their surface dropping point. In order to quantify the OBS orientation on the ocean floor, existing methods based on teleseismic polarization analysis give consistent results with precision rarely better than $5\circ$. Analyzing the data coming from the RHUM-RUM (Réunion Hotspot and Upper Mantle - Réunions Unterer Mantel) OBS deployment around La Réunion, it has been observed that the noise radiated from the numerous ships passing by in the area is well recorded at distances up to $100\,\mathrm{km}$ by both the hydrophone and the three component seismometer in the $5-50$ Hz frequency band. Based on the known ship trajectories provided by their Automatic Identification System, we propose new fully automatic methods allowing to quantify the OBS orientation and location on the seabed. In a first step, we combined data issued from both seismic and hydroacoustic channels to develop a method based on energy flux analysis that allows retrieving the orientation of the OBS with a precision of about 1°. A second method based on cepstrum computation is then introduced to analyze multiple path interference patterns and allows retrieving the actual OBS location on the ocean floor with a precision of about 100 m. To encourage the use of those new tools, codes have been published in a python package named Obsea. We therefore demonstrate that ship-induced anthropogenic noise can provide a useful observable that could be broadly and easily used in marine seismology to provide at no cost a robust estimate of the OBS location and orientation.

Seismic source inversion using Hamiltonian Monte Carlo and a 3-D Earth model in the Japanese Islands

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We present a proof-of-concept catalogue of full-waveform seismic source solutions for the Japanese Islands area. Our method is based on the Bayesian inference of source parameters and a tomographically derived heterogeneous Earth model, used to compute Green's strain tensors. We infer the full moment tensor, location and centroid time of the seismic events in the study area.
To compute spatial derivatives of Green's functions, we use a previously derived regional Earth model. The model is radially anisotropic, visco-elastic, and fully heterogeneous. It was constructed using full waveforms in the period band of 15–80 s.
Green's strains are computed numerically with the spectral-element solver SES3D. We exploit reciprocity, and by treating seismic stations as virtual sources we compute and store the wavefield across the domain. This gives us a strain database for all potential source-receiver pairs. We store the wavefield for more than 50 F-net broadband stations. By assuming an impulse response as the source time function, the displacements are then promptly obtained by linear combination of the pre-computed strains scaled by the moment tensor elements.
With a feasible number of model parameters and the fast forward problem we infer the unknowns in a Bayesian framework. The fully probabilistic approach allows us to obtain uncertainty information as well as inter-parameter trade-offs. The sampling is performed with a variant of the Hamiltonian Monte Carlo algorithm, which we developed previously. We apply an L2 misfit on waveform data, and we work in the period band of $15––80$ s.
We jointly infer three location parameters, timing and moment tensor components. We present two sets of source solutions: (1) moment tensor solutions, where the trace is free to vary away from zero, (2) moment tensor solutions with the isotropic part constrained to be zero. In particular, we study events with significant non-double-couple component. Preliminary results of $M_w \sim 5$ shallow to intermediate depth events indicate that proper incorporation of 3-D Earth structure results in solutions becoming more double-couple like. We also find that improving the Global CMT solutions in terms of waveform fit requires a very good 3-D Earth model and is not trivial.

Understanding the dynamics of glacier front and iceberg capsize through analysis and modelling of seismic waves

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One current concern in climate science is the estimation of the annual amount of ice lost by glaciers and the corresponding rate of sea-level rise. Greenland ice sheet contribution to the global ice-mass losses is about 30%. Ice loss in Greenland is distributed approximately equally between loss in land by surface melting and loss at the front of marine-terminating glaciers that is modulated by dynamic processes. Dynamic mass loss includes both submarine melting and iceberg calving. The processes that control ablation at tidewater glacier termini, glacier retreat and calving are complex, involving interactions between bedrock, glacier, icebergs, ice-mélange, water and atmosphere. Moreover, the capsize of huge icebergs of cubic-kilometer scale can destabilize the glacier triggering its basal sliding, generate tsunami waves, and induce mixing of the water column which can impact the local fauna and flora.
The objective of this project is to improve our understanding of capsize using a mechanical modeling of iceberg capsize in contact with a deformable glacier, which interacts with the solid earth through frictional contact. This investigation is constrained by the analysis the generated seismic waves recorded at teleseismic distances. To achieve this objective we make an attempt to simulate the entire system involving solid earth, glacier, capsizing iceberg and their interaction with water. Even though state of the art fluid-structure interaction models enable accurate simulation of complex fluid flows in presence of deformable solids floating near the free surfaces, such models are computationally very expensive. Therefore, our strategy is to construct a simple solid dynamics model involving contact, friction and fluid-structure interaction, which is governed by parametrized forces and moments. We fine-tune them with the help of reference direct numerical simulations of fluid-structure interactions involving full resolution of Navier-Stokes equations. We assess the sensitivity of the glacier dynamics to the glacier-bedrock friction law and the conditions for triggering sliding motion of the glacier due to iceberg capsize. The seismogenic sources of the capsizing iceberg in contact with a glacier simulated with our model are then compared to recorded seismic signals of well documented iceberg-capsize events.

Effect of Chain Transform fault on the Lithosphere-Asthenosphere Boundary

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The Lithosphere – Asthenosphere boundary (LAB) is an elusive boundary in that it can be defined in terms of differences in mechanical, thermal, rheological and compositional properties of lithosphere and asthenosphere. The LAB is at Moho depth near ridge axis and deepens with age, but the actual depth of the boundary is still a topic of debate. Previous results using multi-channel seismic (MCS) reflection data at St. Paul fracture zone have revealed a melt-rich sub-lithospheric low velocity channel that deepens from 72 km at 40 Ma to 88 km at 70 Ma, thins from 18 to 12 km respectively and roughly corresponds to 1300 $^{\circ}$C isotherm. But the LAB is unconstrained in the areas where the lithosphere is influenced by the three dimensional thermal structure of transform faults and plate boundaries. We present the results of reflection events observed on ocean bottom seismometers (OBS) along 800 km long profile 40 km south of Chain Transform fault that we interpret to be the upper bounds of the LAB. These events have offsets of 200 km up to 450 km indicating sub-moho reflector depths. We also present the velocity structure of the crust and upper mantle along the whole profile obtained from the first arrival travel time tomography. In the region close to the transform fault, sea floor is almost flat and the usual half-space cooling model could not explain the observed lack of subsidence which indicates that the region is influenced by deeper thermal anomalies. The sea floor then becomes more rugged and uplifted at the edge of the transform fault probably due to the ridge-transform intersection. We observe that the Moho depth suddenly decreases from $\sim$5.5 km to 3.5 km starting from 23 Ma and attribute this crustal thinning to the presence of a propagator which intersects our profile around 30 Ma. There is a low velocity anomaly in the crust and Mantle near the Ridge-Transform intersection (RTI) which could explain the topography in the region. We have used travel-time mapping method to migrate the reflection events and find that the events roughly correspond to 1250°C isotherm and interpret them to be the upper bound of the LAB. We discuss the effect of thermal structure of Chain transform fault on the crustal and upper mantle velocity structure and implications of unusual LAB observed in the region.

Deciphering the mechanisms of pyrite formation in pure cultures of sulfate-reducing bacteria

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Pyrite (FeS_2) is the most abundant metal sulfide at Earth's surface and is ubiquitous in modern and ancient sediments. As sulfide production is mainly driven by sulfate-reducing microorganisms, it is assumed that pyrite found in the past sediment record is biogenic and could be used as a biosignature. However, most of the studies of sulfate-reducing bacteria in pure cultures report the formation of metastable iron sulfides such as mackinawite (FeS) or greigite (Fe_3S_4), instead of pyrite. Hence, we lack an understanding of the role played by sulfate-reducing bacteria in sedimentary pyrite formation. Here, we present results from pure cultures of *Desulfovibrio desulfuricans* in the presence of different sources of iron (dissolved Fe^{2+} or amorphous Fe^{III}-phosphate nanoparticles). We monitored iron and sulfur speciation, as well as phosphate and organic acid concentrations over one month. Moreover, we characterized the minerals produced in the cultures down to the atomic scale, using a multi-analytical approach including X-ray diffraction, Fe K-edge Xray Absorption Spectroscopy, Scanning and Transmission Electron Microscopy and Scanning Transmission X-ray Microscopy at C K-edge and Fe L$_{2,3}$-edges. As reported in the literature, a rapid precipitation of amorphous iron sulfide occurred in the cultures. But noteworthy, biogenic sulfide reduced Fe_{III}-phosphate leading to the formation of vivianite ($Fe_3^{II}(PO_4)_2 \cdot 8H_2O$) in addition to iron sulfides. We identified conditions upon which amorphous FeS evolved into well-crystallized mackinawite then greigite and finally pyrite. We will discuss the mechanisms of pyrite formation and implications for the search of biosignatures.

The short-lived ^{53}Mn-^{53}Cr chronology and its application in the origin of angrite parent body.

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Chromium (Cr) isotopes is probably one of the best suited system to study the timing and genetic relationships. The short-lived nuclide ^{53}Mn, with a half-life of 3.7 $\pm$ 0.2 Myrs, decays to ^{53}Cr (radiogenic origin) and therefore the ^{53}Mn-^{53}Cr decay system is a useful chronometer to date early Solar System events. On the other hand, the variation of ^{54}Cr/^{52}Cr ratios (nucleosynthetic origin) can be a good tracer to track the kinship of Solar System materials.

Angrite meteorites are some of the oldest materials in the solar system. They provide important information on the earliest evolution of the solar system and accretion timescales of protoplanets. Here, we show that the ^{54}Cr/^{52}Cr ratio is homogeneously distributed among angrite meteorites within 13 parts per million, indicating that precursor materials must have experienced a global-scale melting such as a magma ocean. The ^{53}Cr/^{52}Cr and Mn/Cr ratios are correlated which is evidence for an initial ^{53}Mn/^{55}Mn ratio of (3.17 $\pm$ 0.21) × 10 -6 . When anchored to the U-corrected Pb-Pb age for the D'Orbigny angrite, this initial ^{53}Mn/^{55}Mn corresponds to an absolute age of 4563.3 $\pm$ 0.4 Ma, i.e. 4.0 $\pm$ 0.4 Ma after CAI-formation. This age is distinct from the one of the volatile depletion events dated by the ^{87}Sr/^{86}Sr initial ratio and therefore must correspond to the age of crystallization of the magma ocean and crust formation of angrite parent body (APB), which can also constrain a bigger size of APB than that of Vesta. Furthermore, this age is similar to those obtained from internal isochrons of the oldest volcanic angrites that cooled rapidly at the surface of the parent body (with ages of 4564 $\sim$ 4563 Ma), while older than those obtained from plutonic angrites (4561 $\sim$ 4556 Ma) that cooled down slowly, located deeper within the parent body. This implies that cooling of the angrite parent body took at least $\sim$8 Myrs after its formation.

Tracking microbial signatures in stromatolites at micrometer scale through in situ iron isotope analyses

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Stromatolites are laminated organosedimentary structures formed under the influence of microbial consortium. The study of actual stromatolites helps to constrain chemical reactions at the biofilm scale and the role of microbial metabolisms on mineralization ([1] Dupraz et al., 2005). However, the microbial origin of Archean stromatolites is still discussed due to the absence of diagnostic fossil evidence for photosynthesis and chemolithotrophy.
Micrometric syngenetic sedimentary pyrites (FeS_2) closely associated with organic matter are widespread in Archean stromatolites and modern microbial mats. Iron isotope compositions recorded in sedimentary pyrites are used as a proxy of paleoredox conditions of the ocean because change of the redox state of iron (between Fe^{2+} and Fe^{3+}) led to important isotope fractionations ($\Delta_{Fe(III)-Fe(II)} = +3‰$, [2] Welch et al., 2003). This reaction can be driven abiotically through a redoxcline or induced by microbial metabolisms such as Dissimilatory Iron Reduction ([3] DIR, Johnson et al., 2005). Dissimilatory Iron Reduction is thought to be one of the earliest metabolisms on the Earth ([4] Vargas et al., 1998) and can fractionate Fe isotopes up to $3‰$during Fe-oxide reduction. We therefore propose to explore Fe isotope signatures of pyrites as a proxy of the early traces of redox microbial activity using in situ SIMS equipped with a Hyperion Radio Frequence Plasma source. This technique, applied on Archean (2.7 Ga stromatolites of the Tumbiana Formation, Western Australia) and Triassic (250 Ma sediments of the Sonoma Basin, USA), allows to obtain a spatial resolution of $3\mu\mathrm{m}$ and a reproducibility better than $0.25‰(2\sigma)$. The comparison of these data yields a unique view of the evolution of the iron isotope signatures through geological time and provides original constraints on pyrite formation at a biofilm scale.

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The speciation of Fluorine in silicate melts

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Understanding the behaviour of the halogens (F, Cl, Br, I) is required to explain the dynamic interplay between the silicate interior and volatile-rich hydrospheres and atmospheres of planets, moons, and exoworlds (Clay et al., 2017; 2019). We identify fluorine as a starting point because it is the most abundant and compatible of the halogens in the Earth system, and can directly impact the nature of Earth's interior. For example, fluorine affects the thermal stability of mineral phases and the viscosity of silicate melts (Webster et al., 2018). Fluorine is a highly electronegative, monoisotopic, negatively charged atom with a low boiling point and ionic radius similar to both oxygen and hydroxyl ions (OH^-) (Crepisson et al., 2014; Dalou et al., 2012). Therefore, understanding the pathways followed by fluorine might illuminate the pathways followed by water within silicate systems (McCubbin et al., 2015). Thus, the mechanics of fluorine dissolution in silicate melts (speciation) require attention.

We have conducted experiments at high temperatures (1250°C) across a range of pressures ($0 - 3$ GPa) in a simple $Ca - Mg - Al - Si - O$ system (CMAS) which reproduces the viscosities of intermediate to mafic silicate melts. The speciation of fluorine is studied using solid-state nuclear magnetic resonance (NMR) spectroscopy. Our results show most of the fluorine is bound with aluminium in the melt structure, but minor abundances of $Mg - F$ and $Ca - F$ are also observed in the 19^F NMR spectrum. There is no observable effect of pressure and/or temperature. These observations challenge the assumption that fluorine and hydroxyl ions are kin, because OH^- form stable compounds with Mg^{2+} (*i.e.* as $Mg(OH)_2$, Mookherjee et al. 2008). These data predict decoupling of F^- and OH^- irrespective of their similar ionic radius and charge. Therefore, assuming the relative behaviours of F^- and OH^- follow an equilibrium exchange relationship might be (counterintuitively) flawed.

Chemical signature of magnetotactic bacteria

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Magnetotactic bacteria (MTB) are ubiquitous aquatic microorganisms that synthesize intracellular nanocrystals of magnetite $[Fe(\text{II})Fe(\text{III})_2O_4]$ or greigite $[Fe(\text{II})Fe(\text{III})_2S_4]$ in organelles called magnetosomes. They live under microoxic or anaerobic conditions. Magnetosomes allow MTB to swim along the Earth's geomagnetic field lines toward oxygen optimum conditions. This ability might have been preserved through geological time since their putative emergence 2.5-3 Ga ago, according to phylogenetic, genetic and proteomic studies [1]. Banded iron formations (BIFs) dating to the Great Oxidation Event ($\sim$2.45 Ga) and carbonate globules from the Martian meteorite ALH84001 ($\sim$3.9 Ga) host nanocrystals of magnetite that have been suggested to be produced by MTB. However, criteria used for MTB identification in these rocks are essentially limited to morphological description (e.g. size and shape) of nanomagnetite. In this study, we aim at establishing specific chemical signatures of MTB magnetites to distinguish them from abiotic ones as well as from extracellular magnetite produced by other iron-metabolizing bacteria [Fe(II)-oxidizing and Fe(III)-reducing bacteria]. We measured major and traces elements concentration in biological magnetites produced by an oceanic MTB, *Magnetovibrio blakemorei*, strain MV-1 in various conditions of laboratory cultures. The calculated partition coefficents (K_D) representing the enrichment of chemical elements in the magnetite relative to the growth medium show a strong distinction between biotic and abiotic magnetite for Molybdenium ($K_{D,MV-1}(Mo)$ = 2.10^{-4} ($\pm$ 1.10^{-5}) while $K_{D,abiotic}(Mo)$ = 9.10^{-9} ($\pm$ 3.10^{-9})) and Tin ($K_{D,MV-1}(Sn)$ = 5.10^{-2} ($\pm$ 2.10^{-2}) while $K_{D,abiotic}(Sn)$ = 1.10^{-8} ($\pm$ 6.10^{-10})). A previous study showed similar enrichments in Mo and Sn in the freshwter *Magnetospirillum magneticum* (AMB-1) [2], which may indicate that these two elements could be jointly used as a tracer of MTB species. We are now exploring a range of elements to properly define the chemical composition of nanomagnetites produced by MTB, including some bacteria from natural environments with different morphotypes of magnetosomes.

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Modelling the climate and vegetation changes induced by the Earth's orbital variations under decreasing CO_2 concentration across the Eocene-Oligocene transition

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The shift from the Paleocene/Eocene warm and ice-free "greenhouse" (~65-33 Ma) to the colder and dryer Oligocene "icehouse" (~33-24 Ma) is usually referred to as Eocene-Oligocene Transition (EOT). It is marked by an important decrease in pCO_2 (from ~4 Preindustrial Atmospheric Levels - or PAL - to ~2 PAL), the inception of the Antarctic ice sheet and is coeval with important paleogeographic changes: notably the retreat of the Paratethys sea and the uplift of the Tibetan Plateau. If the EOT is abruptly marked in the oceanic $\delta_{18}O$ record, its translation into contrasted biomes (assessed through pollens, fossil woods and leaves) over land is less straightforward. While some sites display important shifts in biomes (*e.g.* from tropical forest in the Eocene to temperate forest in the Oligocene), many regions present ambiguous signal (*e.g.* presence of tropical and temperate forest in nearby sites at the same period). This variability can have many origins: uncertainties in dating and paleo-location, preservation biases, or inappropriate calibrations methods. The issue we aim at tackling here is the potential overprinting of a "short time noise" induced by the Earth's orbital variations (order of $\sim10^4$ to 10^5 years) on the long trend climatic signal ($\sim10^6$ years). Using the IPSL-CM5A2 Earth System Model, and the dynamic vegetation ORCHIDEE model, we propose a reconstruction for each of the orbital parameters end-members (eccentricity, precession and obliquity). Our results highlight regions of high biome stability under contrasted orbital forcing and, on the contrary regions of extreme biome variability. The main outcomes are discussed.

Constraining the evolution of the Earth's magnetic field from archeological artefacts: new archeointensity results obtained in Bukhara (Uzbekistan, Central Asia)

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The Earth's magnetic field is acting as a giant shield, protecting the atmosphere from the solar wind. It is mainly dipolar ($\sim 90\%$) and is generated within the Earth's liquid outer core by fluid motions. It varies in space and time, and the reconstruction of its variations gives insights on core flow dynamics. Since the middle of the 19th century, instrumental (or direct) measurements of the geomagnetic field, both in intensity and direction, are available, which enables an accurate determination of its space and time variations. Before that time (between 1600 and 1840 AD), only direct directional measurements were possible. The construction of global geomagnetic field models thus requires either a specific treatment of the axial dipole field component or the use of indirect field intensity measurements. Paleo/archeomagnetism provides such information. Any material containing magnetic minerals, heated above a certain temperature (mainly the Curie temperature of magnetite), acquires a thermoremanent magnetization, which constitutes an archive of the geomagnetic field at the place and time of the cooling succeeding the heating. This is the main principle of archeomagnetism, focused on the magnetization of archeological artefacts dated using archeological constraints. In this study, we propose to calibrate the global geomagnetic field models during the historical period from the determination of an accurate archeointensity variation curve in Central Asia. We analyze baked brick fragments sampled in Bukhara (Uzbekistan), dated between the end of the 16tth and the beginning of the 19th century. This city is particularly interesting due to the preservation of old buildings constructed using baked clay bricks, which are precisely dated thanks to documentary sources. We obtain a series of archeointensity results, allowing the recovery of the geomagnetic field intensity variations in Central Asia during the historical period. We compare that evolution with the one predicted by a number of global geomagnetic field models. In good agreement with archeointensity data previously obtained inWestern Europe, the new Central Asian results show a range of axial dipole variations between 1590 and 1840 wider than previously proposed.

Characterizing past earthquakes ground motion

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The energy accumulated over thousands of years by a fault is released in a few seconds. To understand earthquakes over long periods of time, it is not only necessary to study the characteristics of today events, but also to be able to go back in time. However, in spite of many years of research in the archives, many historical earthquakes remain poorly known. Over the last decades alternative approaches have been developed such as historical seismology, archaeoseismology and paleoseismology chasing new sources of information. Among these, historical buildings witnessed earthquakes recorded in their walls as structural disorders, repairs. A multidisciplinary approach involving archaeology, numerical mechanics and seismology is introduced to analyse the seismic ground motions necessary to explain building repairs/disorders. The main steps are setting the evolution of an historic building over time, by identifying the repairs compatible with failure mechanisms due to earthquakes; defining a mechanical model of the building; selecting accelerograms compatible with a given earthquake; reproducing digitally the observed damages.
The test case is the medieval church of Sant'Agata, an exceptional site with many historical sources describing the damages induced by past earthquakes, and their renovation. The site is located in the Mugello basin (central Apennines, Italy), characterized by a moderate seismicity. The largest known events occurred in 1542 ($M_w \sim 6$) and 1919 ($M_w \sim 6.3$).
Two archaeological campaigns have been conducted, along with an in-depth study of historical texts, allowing to reconstruct the building evolution along the centuries (materials, construction phases, repairs) and to identify the mechanical failure modes.
A mechanical model of the church whose geometry is based on the laser scanner data and the constructive phases previously identified has been defined. An *ad hoc* meshing code has been developed to merge archaeological and geometric information. Concerning the mechanical behaviour, instrumental campaigns has been organized to characterise the building vibration modes from the seismic noise recordings. These measurements are used to update the numerical model.
Initial results demonstrate the strength of the proposed methodology. The next steps are the refinement of the mechanical model and the implementation of a first set of dynamic analysis to characterize each historical ground motion.

Impact-induced fractionation in the Bulk Silicate Earth chemical composition during its accretion

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Dynamical scenarios of terrestrial planets formation suggest that the terrestrial planets region was strongly perturbed by the giant-planets, leading to enhanced collision velocities, and thus, collisional erosion. The present paper aims to estimate this effect on the resulting composition of the Earth, and to determine how it could constrain its dynamical formation. The composition of the Bulk Silicate Earth (BSE, Earth's primitive mantle) is often considered chondritic for refractory and lithophile elements (RLE), which should not be affected by volatile loss or core formation. However, with collisional erosion involved in the Earth formation process, this might not be the case.
Here, we simulate the erosion of Earth's crust in the context of Solar System formation scenarios, including the classical model and Grand Tack scenario, which invokes a long-range orbital migration of Jupiter during the gaseous disk phase (Walsh et al., 2011; Raymond et al., 2018). We quantify the effects of erosion in both scenarios on several RLEs and notably on Sm and Nd that are very good tracers of crustal erosion. We find that the nucleosynthetic reservoir hypothesis, that precludes any significant collisional erosion during Earth's accretion, and the Grand Tack model with a late giant impact are mutually incompatible with each other. In conclusion, under currently discussed dynamical scenarios of the Earth accretion, only two options are conceivable: (i) the Grand Tack happened, along with a late Moon forming impact (after 50 Myr), but this requires the initial material reservoir to be homogeneous, thus, excluding nucleosynthetic anomalies or (ii) the initial planetary material reservoir was heterogeneous (due to nucleosynthetic anomalies) but Grand Tack cannot have happened, and only a low erosive dynamical evolution of planets is possible. We estimate the change in BSE composition for an entire set of other chemical elements in these two cases and show that collisional erosion systematically fractionate the BSE compositions. Accordingly, the effects of collisional erosion should be integrated in compositional models of the BSE and could provide insights on the accretionary processes and the nature of Earth's building blocks (*e.g.* by reconsidering the Earth volatile depletion trend).

Rivers analysis from a refined topographic map on Saturn's largest moon.

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After 13 years of observations by the Cassini-Huygens probe, Titan, Saturn's largest moon, has been found to be unique in the Solar System. Singularly similar to the Earth, its surface displays morphologies familiar to us: drainage basins and river systems, lakes and seas, dune fields, and incised mountains.

Titan's methane cycle plays a major role in its climate and geology, driving a wide range of processes that shape the landscape, such as fluvial erosion. Similar to erosion by water on Earth, liquid methane carves into Titan's surface, forming river valleys. These river networks are particularly discernible in images acquired near the equator by the Huygens probe. To improve understanding of the processes at work, one needs a detailed and accurate digital terrain model (DTM) of this region.

Previous studies investigated the river networks near the Huygens landing site but they based their analysis on a DTM that has some limitations that could significantly bias the interpretation of the morphology and the geology of the area. Taking advantage of significant improvements in the quality of Huygens navigation information and of the DISR images, we built a new DTM of the landing site offering a higher spatial sampling and a more reliable topography.

Since we focus our study on the river networks, we hydrologically conditioned our DTM, as is commonly done for terrestrial studies (i.e., HydroSHEDS, MERIT Hydro). Then we used this DTM, which offers the best available resolution of hillslopes and river valleys on Titan, to perform an accurate morphometrical analysis of the terrain.

Modeling of major cliff collapse and subsequent lahars in the Prêcheur catchment, Martinique

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The Prêcheur river is located to the West of Montagne Pelée, in the Northern part of Martinique island. For several decades it has produced numerous lahars that directly threaten the Prêcheur village, at the mouth of the river. In recent years, the most important lahars have been correlated to massive collapses of the Samperre cliff, 9 km upstream from the sea, that create a reservoir of loose material at the bottom of the cliff. In 2010, a lahar started from this reservoir, destroyed a bridge and inundated part of the Prêcheur village. A new major period of collapses of the Samperre cliff started on 2 January 2018, involving more than $4 \times 106\,\mathrm{m}^3$ of material. In the following days, intense rainfalls triggered several lahars that reached the Prêcheur village but remained confined in the river bed. Since then, lahars and collapses have continued to occur, even though their frequency has decreased with time and their intensity is smaller compared to the onset of the crisis. One single lahar overflowed the river bed on 22 February 2018 without significant impact on infrastructures.

In this study, we test different possible scenarios to model the first and most important phase of the collapse of the Samperre cliff, that occurred in early January 2018, with the shallow-water model SHALTOP. We constrain the collapse geometry with photogrammetric 3D models and LIDAR topographic surveys, acquired in 2010 and in late January 2018. We also consider an intermediate volume to take into account a possible retreat of the cliff face between 2010 and 2018. The modeled traveled distances are compared to field observations. Finally, we use geomorphological and geological observations to identify potentially unstable structures within the cliff, and model the associated collapses. These simulations provide insights on the possible geometry (extent and depth) of the debris reservoir at the bottom of the cliff, after a major collapse episode. This is of prior importance in order to estimate the location and volume of future lahars. In order to investigate their dynamics, we model the major 2010 lahar, for which the initial debris reservoir volume is known (about $2\,\mathrm{Mm}^3$). We first simulate the progressive remobilization of the reservoir by water with the r.avaflow numerical code. In a second test, we impose instead a constant flow discharge upstream until the same volume has been released. We test different parameters to identify which ones have the most significant influence on the lahar travel time, from its initiation until it reaches the Prêcheur village.

Upstream versus downstream changes in a natural sediment routing system from source to sink, south-central Pyrenees, Spain

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The Middle Eocene Climatic Optimum (MECO) represents an episode of widespread warming occurring ~ 40 million years ago. It is characterized by gradual warming over a period of 500000 years, leading to a rise in ocean temperatures of about 5° C in the mid and high-latitudes ([1] Sluijs et al., 2013). Contrary to the traditional understanding and consensus that accommodation space or downstream factors control stratigraphic architecture in fluvial successions, we test the hypothesis that upstream factors, rather than downstream factors, control fluvial architecture through changes in the median grain size, sediment supply and water discharge with paleoslope being a measurable proxy to quantify these changes. We test our hypothesis utilizing the natural system of the Escanilla sediment routing system, encompassing the Middle Eocene Climatic Optimum. The Escanilla system is an overall prograding system, consisting of 1000 m thick alluvial and fluvial deposits at the southern-margin of the Tremp-Graus Basin in the south/central Pyrenees, Spain. Multiple lateral measurements for grain size distributions and cross-set measurements, flow direction and channel geometry are taken close to the source (Coll de Vent), at an intermediate location (Lascuarre), and at a distal part (Olson) of the system for paleohydraulic reconstructions. Drone flight missions are also undertaken to capture aerial photographs of the field area, which are required for the construction of 3D photogrammetric models. At Olson, alternating sequences of laterally continuous amalgamated channel bodies and several small sequences of vertically stacked isolated channel bodies have been identified. Preliminary results show distinct values of median grain size, dune height, flow depth and paleoslope for the amalgamated and vertically stacked isolated channel sequences across the MECO; the addition of our 3D models provide further insight into the lateral connectivity of the amalgamated units. Our results suggest different paleohydraulic conditions during the deposition of amalgamated and non- amalgamated units. This data will also be supported by numerical simulations carried out to better understand the response of fluvial systems to changes in upstream factors.

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How to improve the International Terrestrial Reference Frame?

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Plate tectonics, earthquakes, ice melting and so on, are constantly deforming the Earth's surface. How can scientists observe and study those processes using spatial data if the Earth is rotating and globally deforming over time? We need a universal reference that allows us to locate and compare data, no matter where and when it is recorded. The reference recommended by the International Earth Rotation and Reference Systems Service (IERS) for the geo-scientific community that needs precise positioning, is the International Terrestrial Reference System (ITRS). It is an ideal spatial reference system co-rotating with the Earth; its origin is the center of mass of the Earth, its orientation is conventional and its unit of length is the meter. The numerical realization of such a system is a reference frame. Thus, the ITRS realization is called the International Terrestrial Reference Frame (ITRF). It can be seen as a polyhedron of stations that discretize the Earth's surface, where a station is a geodetic instrument. Nowadays, the ITRF model used to describe the time evolution of station positions is a piecewise linear model. However, the Earth's surface does not deform linearly and this simplification has limits for certain applications such as the study of sea level. To reach the required level of precision, a paradigm change might be needed. Would it be relevant to consider a reference frame in the form of time series? Such a frame would in principle allow to fit to the instantaneous shape of the Earth, but is it achievable considering the errors of spatial geodetic techniques?

Solubility and bioavailability of Patagonian dust in the future Southern Ocean

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Trace metals play a significant role in the ocean biogeochemical cycles. They are present at extremely low concentrations in the ocean ($\sim fmol.kg^{-1}$ to $nmol.kg^{-1}$), but are essential for the phytoplankton growth and physiology since they are micronutrients. For instance, they are used for photosynthesis that consumes carbon dioxide and, therefore, they have a large impact upon climate. This process known as the biological carbon pump accounts for about a third of the oceanic carbon pump. The Southern Ocean is the largest HNLC area (High macroNutrients Low Chlorophyll), where low iron inputs are limiting the phytoplankton growth. External sources of trace metals in the surface Southern Ocean are by the atmospheric inputs, which can episodically alleviate the limitation by trace metals. Here, Patagonian dust represents half of the trace metals dust input, and those inputs are expected to increase by two or three times with the global warming, potentially constituting a negative feedback on the atmospheric carbon increase. However, the solubility of the trace metals contained in the Patagonian dust is still unknown, and thus, the bioavailability of the trace metals needs to be explored. In addition, other changes are expected in the future Southern Ocean that should be considered together with the increase of dust inputs. In this context, this study aims to determine the solubility and bioavailability of the trace metals contained in the Patagonian dust under various other changes in the Southern Ocean. Abiotic and biotic experiments will be conducted under different scenario of present and future conditions (dust input, CO_2 level, macronutrient concentrations, temperature and light). The laboratory work will be combined with field experiments in the Southern Ocean. This work could be changing the current view of the climate prediction.

Spatio-temporal evolution of the Greenland ice sheet and associated deformation of the Earth

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Here, we use variations of the Greenland ice-sheet (GIS) elevation derived from satellite altimetry (Icesat), from 2003 to 2009, displacements recorded at regional GNSS stations and time variable gravity measurements from a new GRACE solution where smaller wavelength signals are preserved, to improve our knowledge of the spatial and temporal evolution of the ice sheet. First, we assume an elastic Earth where all the deformation is due to recent melting. We estimate present-day ice variations by combining satellite altimetry and an empirical model of firn densification. To resolve short wavelengths load variations affecting the displacement of nearby GNSS stations, we decompose our ice variations estimates into spherical harmonics up to degree 2700 and predict horizontal and vertical crustal displacements assuming first elastic Earth properties. We show that vertical elastic predictions, while in good agreement with observations in some regions, cannot explain observations overall, and particularly in the Southeast and the North of Greenland. Those differences seem mainly due to viscoelastic deformation induced by glacial isostatic adjustment (GIA). Consequently, we use vertical GNSS residuals to infer potential ice variations in Greenland since the Last Glacial Maximum (LGM). We also investigate, potential viscoelastic deformation associated with short-term rheology of the asthenosphere induced by recent ice melting that could as well significantly affect the observed deformation. For that we use an ice history loading from 1900 to 2009 derived from both in situ and satellite altimetric measurements, and we compute current potential viscoelastic deformation observable. Both the GRACE gravity data and the horizontal component of the deformation add useful constraints on the relative amplitude of these viscoelastic deformations. The combination of altimetric, gravimetric and GNSS data is necessary first to separate the different deformation sources in the region (GIA, deformation induced by recent ice melting and recent viscoelastic deformation), then to constrain short-term (decadal) rheology of the mantle and finally, to improve our knowledge of the present-day ice mass budget over the GIS.

Experimental study of the effect of stress on $\alpha \rightarrow \beta$ quartz transformation at lower continental crust pressure and temperature conditions

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Based on experimental observations, there have been claims that deviatoric stresses are responsible for triggering high pressure phase transitions below their equilibrium transition pressures. This implies that the phase assemblages observed in exhumed rocks may reflect stresses induced by tectonic overpressure rather than mere lithostatic pressure, thus resulting in overestimated maximum depths of burial. Despite the numerous studies that have addressed whether mean or principal stress may trigger polymorphic phase changes, the case is still not completely clear. The aim of this study is therefore to investigate the role of deviatoric stress on phase transitions at high PT conditions. In this study, we investigated, The $\alpha \rightarrow \beta$ transition of quartz, which is one of the most common mineral of the Earth's crust. This transition has a particular importance for the lower continental crust because of the significantly different elastic properties of the two polymorphs. The $\alpha \rightarrow \beta$ quartz transition is also a good experimental candidate because of its displacive and quasi-instantaneous nature.A series of experiments was performed with a new high pressure Griggs-type apparatus equipped with ultrasonic monitoring, at the ENS Paris. Cored rock samples of Arkansas Novaculite (mean grain size of 5.6 μm) were subjected to pressure and temperature conditions of $0.5 - 1.5$ GPa and $\pm 850^{\circ}$C. In all experiments, the mean stress was either equal to or higher than the confining pressure. The deviatoric stress was increased to cross the transition while keeping the temperature constant. Two P-wave transducers were used on top and bottom of the sample as transmitter and receiver to measure travel times across the assembly. The quartz $\alpha \rightarrow \beta$ transition was directly observed by a time-shift of the p-wave arrival in the order of 10 ns. The mechanical data show clearly that the phase transformation is controlled by mean stress. The quartz $\alpha \rightarrow \beta$ transition induce a softening behavior on our sample because of difference of volume between quartz α and β. According to thermodynamic models of elastic properties of α and β quartz, the variation of p wave velocity for the quartz $\alpha \rightarrow \beta$ transition is in the order of 10$\%$ of magnitude. The active monitoring method allows us to calculate the variation of smaller than 5$\%$. We can explain these small variations as a partial transformation because of stress heterogeneities since local stress at the scale of grains can be different than the macroscopic stress that we measure

Continuous Monitoring of Seismic and Aseismic Slip along the Chaman Fault System from InSAR

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The Chaman fault system (Afghanistan, Pakistan) is a major tectonic boundary between the Indian and Eurasian plates, that accommodates 2-4 cm/yr of long-term sinistral slip rate. However, very few large earthquakes have been recorded on this 850 km-long fault system and, thus, a vast amount of slip has to be released aseismically. In order to characterize the recent spatial and temporal distribution of slip, we build and continuously update a time series of ground deformation from 2014 to 2019 using InSAR data from the ongoing Sentinel1 mission (European Space Agency). Efficient monitoring of the fault is performed by a Kalman filter time series analysis, which enables rapid update of pre-existing time series. We identify and characterize the along-fault segmentation of slip with notably an 80 km-long segment creeping at 7$\pm$2 mm/yr. Moreover, we identify the signature of three Mw 5+ earthquakes and their associated post seismic signal. We discuss the dynamics of fault creep and its interplay with seismic slip along this major plate boundary.

High-resolution displacement field for the 2019 Ridgecrest earthquake (California): first considerations in terms of fault zone structure and near-fault deformation processes

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High-resolution imaging of the deformation field associated with surface ruptures has long been a challenging task while it became a critical information for Fault Displacement Hazard Assessment. Classical methods as InSAR and field studies have a hard time grasping the fine-scale deformation pattern near the surface rupture. Optical image correlation appears as good alternative by making possible the dense measurement of ground deformation very close or even inside of the fault zone, thus going beyond the limitations of the previously cited methods. In this work, we combine 0.5 meters resolution images and MicMac sub-pixel correlator to measure surface displacements associated with the Ridgecrest rupture sequence (California , $M_w 6.5$ on the 4^{th} of July 2019, followed by $M_w 7.1$ on the 5^{th} of July 2019). With this technic, we are imaging with an unprecedented precision of 5 centimeters the displacement pattern in the fault zone, with a spatial resolution of 50 centimeters. Our results reveal very heterogeneous displacement patterns at every scales. Far-field pattern is complex as our correlation window frames the two rupture events that occurred within a 32 hours time slot, on two perpendicular faults. Near-field pattern is complex as well, with very discontinuous and non-linear fault traces that sometimes also divide into several branches. Numerous structures as relays, jumps and bends are visible and are used as a catalogue to be compared with what have been observed in our previous work on the Baluchistan earthquake and with other studies. We also generate high-resolution slip profiles that first, provide a more accurate surface slip budget for the earthquake and second, enable an exhaustive description of the distribution of deformation in the fault zone. All these information will be crucial to the understanding of shallow fault physics and surficial material deformation behaviors.

Capabilities of spICPMS as a tool for the identification of colloidal mineral phases in natural samples. Sequential vs simultaneous acquisition.

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Established techniques such as conventional Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Secondary Electron Microscopy-Energy Dispersive Spectrometry (SEM-EDS) or X-Ray Diffraction (XRD) exist for the identification of the different mineral phases in natural samples. Although these methods are powerful, they present some drawbacks (i.e. bulk analysis, time and/or sample consuming, difficult size distribution characterization…). In this study, using the capability of the ICP-MS for multi-elemental analysis and for single-particle measurement, two qualitative and/or quantitative methodologies are proposed. First, operating single-particle ICP - sector-field – MS, a sequential approach for the distinction of 2 different clay minerals at sub-femtomole per element (i.e. Al, Si, Fe, Ti, Mg, …) per particle was achieved. Then, using an ICP-time-of-flight – MS, the simultaneous multi-elemental analysis allowed determining the distribution of multiple elements in individual colloids.

Structural and chemical controls for biomineralization in bacterial biofilm observed in situ in Liquid-Cell Scanning Transmission Electron Microscopy

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Bacterial cells, mostly in the form of biofilm, are largely widespread in soils (up to 10^9 cells per gram of soil) and can be very reactive with their environment. Indeed, the mineral phases created by biomineralization in the biofilm can be highly reactive with environmental pollutants. However, although in literature, many studies on microbial biomineralization exist, only few of them consider the specific properties of biofilms fine structure. As a result, numerous questions regarding mineralization processes in these structures remain open. For instance, the chromium mining site of Sukinda Valley, India, generates annually a highly toxic Cr(VI) flux. Given the difficulty for oxidizing Cr(III) originally present in ore, the occurrence of bacteria identified on this site is likely to control the Cr(VI) toxic release, by promoting Mn(II) oxidation into MnO_2, a highly oxidant mineral, able in turn to oxidize Cr(III) into Cr(VI). However, given the biofilms complex nature, the dynamics of Cr(VI) release from these metal-rich systems remain poorly understood. We propose here to test two hypotheses to better define the Mn and Cr mineralization mechanisms in biofilms: i) biomineralization is strongly impacted by the extracellular polymers types and 3D organization, ii) biomineralization is dependent on the presence of nucleation sites and not only on local oversaturation in microenvironments. In order to study mineralization in these biofilms, several approaches are used, including Confocal Laser Scanning Microscopy, Scanning Electron Microscopy, Liquid-Cell Scanning Transmission Electron Microscopy (LC-STEM) and Synchrotron techniques. Here we will present you results obtained thanks to LC-STEM technique. We were able to image in vivo bacteria in a medium containing manganese in STEM and to determine how and where the biomineralization of manganese occurs depending on the type of Extracellular Polymeric Substances secreted by the bacteria and constituting the biofilm. This way, we can begin to understand the impact of the structure of biofilms on biomineralization.

An improved method for the determination of high precision stable Zr isotope ratios of geological reference materials using a PFA inert sample introduction system

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Zirconium is a high-field strength element, which plays a central role in geochemistry as one of the most refractory, lithophile and incompatible elements. The main host minerals of Zr, zircon and baddeleyite, are common accessory phases in a wide range of igneous and metamorphic rocks, and are highly resistant to alteration as evidenced by $>$4 Ga terrestrial zircons. Stable Zr isotopic measurements have been recently developed and Zr isotopes have been demonstrated to be a sensitive tracer of magmatic processes on Earth. However, there are currently very limited data for geological reference materials including natural zircon standards. Furthermore, the current method is limited by high instrumental background in the absence of HF in the acid, and prolonged sample washouts between measurements. In order to decrease the washing time and improve the Zr background we developed a new mass spectrometry method using a commercially available inert sample introduction system. In addition, the chemical purification technique, used to isolate Zr from sample matrices, has been altered to improve the separation of Zr from key matrix elements, such as Mo. Using this new method, we report the Zr stable isotopic composition of basalt BHVO-2, diabase W-2a, granodiorite GSP-2, syenite STM-2, manganese nodule Nod-A-1, cody shale SCo-1 and four natural zircon reference materials (Penglai, 91500, GJ-1 and Mud Tank).

Geochemistry of trace metals associated with Fe-Mn nodules in red soil profiles in China

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Red soil is widespread in southern China, covering an area of about 22.7% of China's area. It has experienced intense syndepositional pedogenesis under humid tropical to subtropical conditions. In such soil profile, Fe and Mn oxides are omnipresent and frequently occur in Fe-Mn nodules of varying morphology, size, and shape. Due to their high surface area and high surface charge density, Fe and Mn oxides play crucial roles in concentrating and immobilizing trace metals in red soils. On the other side, Fe-Mn nodules are very sensitive to soil environmental changes, such as moisture, pH, redox potential, and microbial activity. Trace metals may be released due to organic fertilization of the soil or long term saturation with water, leading to contamination of the soil as well as the soil solution and groundwater. Therefore, study on the geochemical behavior of trace metals associated with Fe-Mn nodule in red soil profile could help with improving our knowledge of trace metal cycling and their potential risk in such soil system, and also elucidating soil environmental changing which was recorded by nodules. In this study, two paddy soil profiles with geo-background contamination and two paddy soil profiles with anthropogenic contamination in Southwest China will be selected, where Fe-Mn nodules are widely developed. Fe-Mn nodules and their corresponding soil matrix will be collected from soil profiles according to their pedogenetic horizons. The aims of this study are to (1) examine the distribution, size, mineralogical and physic chemical features of Fe-Mn nodules and their corresponding soil matrix within different pedogenetic horizons of soil profiles; (2) explore the nodule internal structure and chemical features (concentrations, speciation and stable isotope ratios of trace metals, such as Cd, Pb, Cr, etc.) along the section of nodules and in soil matrix as well as soil solutions by using SEM EDS, XPS, LA ICP MS, and MC ICP MS; (3) reveal the possible mechanism of trace metal immobilization and soil environmental changes during nodule formation by comparing the nodule features in soil profiles contaminated from contrasting sources.

A dual-phase argon detector for the long-baseline neutrino experiment DUNE

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More elusive than any other observed particles, neutrinos propagate through any medium (space, earth rock, water, human body, etc.) with a very low probability of interacting weakly with an electron or a nucleus.

Whilst neutrinos are Standard Model particles existing under three types, so-called flavors, not all of their properties have been thoroughly explored. We know that they are massive particles since the discovery of neutrino oscillations, phenomenon that describes the change of flavor along neutrinos propagation. However we only know about how tiny is the sum of neutrinos masses ($\Sigma m_\nu < 0.1$ eV). It is also very likely that neutrinos oscillate differently as anti-neutrinos, meaning that the Charge-Parity (CP) symmetry is violated. Large CP violation, as expected for neutrinos, is one necessary ingredient to explain the matter dominance over anti-matter in our Universe.

The Deep Underground Neutrino Experiment (DUNE) will shed light on this while making precision measurements of neutrino oscillation parameters, by addressing the neutrinos elusiveness with a future gigantic argon detector of 40 kilotons. The neutrinos coming from an intense beam emitted 1300km away at Fermilab, will reveal their presence thanks to a high-resolution 3D imaging of particles tracks produced by neutrinos interactions on argon nuclei.

The design of this final far detector (FD) will be the outcome of an intense R&D program, the ProtoDUNE experiment, currently on-going at CERN. ProtoDUNE aims to demonstrate that the detection technology is able to match the requirements for the rich DUNE physics program.

My thesis fits into the study of a new neutrino detector prototype, called ProtoDUNE Dual-Phase. Among multiple advantages, the Dual-Phase design offers a large, fully active, and uniform liquid argon detection volume, which would maximize the number of neutrino events to be seen in DUNE. This is achieved by the presence of a gaseous argon phase on the top of the liquid phase allowing produced ionization tracks signals to be amplified and well reconstructed.

ProtoDUNE Dual-Phase, commissioned in August 2019, is now taking data coming from cosmic muons, whose analysis will lead to a better understanding of the Dual-Phase performances, and unveil its great detection potential for DUNE.

Performance of pixel planar sensors for ATLAS inner Tracker to operate at High-Luminosity LHC

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In view of the High Luminosity LHC upgrade (HL-LHC), the ATLAS experiment plans to replace the current Inner Detector with an all-silicon Inner Tracker system (ITk). ITk will be instrumented with pixel sensors with an n-on-p silicon technology to achieve tracking requirements with radiation hardness and cost efficiency. A performance study on thin n-on-p planar pixel sensors attached to the readout chip showing testbeam results of hit efficiencies, space resolution and cluster properties are given before and after irradiation.

B-jet energy scale calibration using top-antitop lepton+jets events in ATLAS

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ATLAS is a multi-purpose detector designed to probe Standard Model predictions, perform precision measurements and search for hints of new Physics. It measures energies, momentum and trajectories of particles produced by proton-proton collisions at high center-of-mass energies ($\sqrt{s} = 13$ TeV).

The calibration in energy of ATLAS is therefore crucial especially for b-jets that are very important in many searches and measurements such as the main decay of the Higgs boson into pairs of b-quarks ($\mathrm{H} \to \mathrm{b}\bar{\mathrm{b}}$).

The b-jet energy scale (b-JES) is currently estimated from comparing the b-jets response in different Monte-Carlo simulation samples and is often one of the main sources of experimental uncertainty.

Due to the high cross-section of top pair production at LHC and the large branching ratio of $\mathrm{t}\bar{\mathrm{t}} \to$ lepton+jets events ($\mathrm{t}\bar{\mathrm{t}} \to \mathrm{b}qq' + \mathrm{b}\ell\nu$), b-JES calibration can be carried out comparing data and MC predictions with the so called template method by reconstructing the invariant mass of the hadronically decaying top quark.

This never performed study in ATLAS will enable to correct energy of b-jets in data depending on their transverse momentum/pseudorapidity, determine the associated uncertainties and explore higher momentum regions than other ongoing studies as for instance $\mathrm{Z} + \mathrm{b}$ balanced systems.

Extracting γ from three-body charmless B-meson decays

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The elementary particles and their interactions are well described by the Standard Model. Still, it is not completely satisfactory. For example, the asymmetry between matter and antimatter that is observed is not understood nor well described. B factories such as LHCb or BaBar experiments intend to explore the differences between matter and anti matter in order to explain why the latter is barely seen in our universe. Thus, studying the quarks mixing is an opportunity to mesure the asymmetry between matter and its counter part. It is described by the CKM matrix that contains quarks couplings when they interact through weak interaction. The unitarity of this matrice leads to 6 triangles, one being referred as the Unitarity triangle and containing the three angles: α, β and γ. The last one is the least known of them three. The state of the art gives $\gamma = (73.5^{+4.2}_{-5.1})^{\circ}$. It exists then a natural interest in probing new investigating methods for it. The goal is to check a new process in extracting gamma from B meson decays. One of the method method employed in the previous measurements implies a charm quark in the B decays. Such a process is dominated by Standard Model due to the tree level decay (diagram without loops). In the method developped by Bhubanjyoti Bhattacharya, Maxime Imbeault and David London, charmless B decays are considered, allowing for New Physics to kick in.

Identification of boosted Higgs bosons for searches of new physics and improvement of the ATLAS tracker for the high luminosity phase of the LHC

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The Standard Model (SM) of the particle physics is the theory describing three of the four known fundamental interactions in the Universe, as well as classifying all known elementary particles. So far now, it has been proven a great success with experiments. However, there are some of phenomena which can not be explained by SM, like dark matter, asymmetry of matter and antimatter etc. Physicists are motivated to explore physics beyond SM, called also New Physics (NP). The indirect way to NP is studying properties of SM particles and comparing with SM predictions. Higgs Boson, one of the most important particles in SM could be a leading door to NP.

ATLAS is one of the experiment recording the products of proton-proton collisions created by the Large Hadron Collider (LHC). The analysis of data collected in 2010-2012 allowed ATLAS and CMS collaborations to discover a Higgs boson with mass of about 125 GeV. One part of my work is to develop new tagging algorithms for boosted Higgs bosons, using $\mathrm{H} \to \mathrm{b}\overline{\mathrm{b}}$ process. The new tools are expected to have a good discrimination between signal and QCD background. Some preliminary studies for mass decorrelated identification tools has been done.

Since W/Z/Higgs boson tagging algorithms developed, optimised and evaluated using Monte Carlo simulations, we can not expect simulations to describe all effects (like modelling, detector, etc.) that impact the performance of tagging algorithms accurately. Scale factor is defined as data-to-simulation correction factor. The work of scale factor measurement has started first on boosted $V \to \mathrm{b}\overline{\mathrm{b}}$ final states and extrapolate to $\mathrm{H} \to \mathrm{b}\overline{\mathrm{b}}$ final state.

It is important to mention that LHC will start data-taking with unprecedented collision rates in the coming years, LHC and HL-LHC phase. Inner tracker (ITk), pixel silicon detectors of the ATLAS tracking and vertexing system for HL-LHC, is being developed to cope with the increase in event rate and in pile-up events, and harsh radiation condition. One part of my work is measuring electrical and physical properties of pixel sensors developed in the laboratory LPNHE. Several measurements and data takings have been done.

Atmospheric neutrino oscillation with KM3NeT/ORCA

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KM3NeT/ORCA is the next-generation underwater Cherenkov neutrino detector currently being built in the Mediterranean. The full ORCA array is a single KM3NeT building block of 115 strings or Detection Units (DUs). Each DU hosts 18 digital optical modules (DOMs) which contain 31 small (3”) photomultipliers and the readout electronics. ORCA is designed to detect the Cherenkov light emitted from relativistic charged particles generated from the interaction between neutrinos and nuclei inside or around the detector. The geometry profile of the detector has also been chosen to optimize the performance in measuring atmospheric neutrinos in the energy range of 1-100 GeV.

Atmospheric neutrinos are produced in the decay of secondary particles (π, K,...) originating from the interaction of cosmic rays with the atmosphere. By studying the oscillation pattern of atmospheric neutrinos that cross the Earth with different path lengths (thus, zenith angles), the ORCA detector is primarily dedicated to resolving the question of the neutrino mass ordering and measuring neutrino oscillation parameters (Δm^2_{31} and θ_{23}). The expected sensitivity of full ORCA to the neutrino mass ordering is shown along with the potential of atmospheric neutrino oscillation parameter measurement with just the first sub-array of the detector during the construction phase.

Tests of Lorentz Invariance and intrinsic time lags in active galactic nuclei with H.E.S.S./CTA

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Some of the quantum gravity theories, aiming at unifying gravitation with other fundamental forces, predict that the speed of light in vacuum could be energy-dependent. This would translate into a Lorentz invariance violation (LIV), and take the form of a delay between the arrival times of gamma-ray photons emitted with different energies. LIV studies use the light emitted by specific astrophysical sources, namely flaring blazars which are the most ener- getic objects in the universe, as distant high energy photon sources, observed by Imaging Atmospheric Cherenkov Telescopes.
This project handles two different aspects of time delay studies. On the one hand, it has been shown that there exists intrinsic delays between the time of emission of photons with different energies in blazars. There is hence a need to understand in more details their emission mechanisms in order to be able to predict the delays induced by these sources. On the other hand, despite the previous argument, only one significant delay has been observed so far. A con- sortium between H.E.S.S. and two other similar experiments, namely MAGIC and VERITAS, has been created in order to better constrain the LIV models by combining multiple observations. Furthermore, this work aims at providing a transition between H.E.S.S. and the future CTA observatory, an array of tele- scopes more sensitive than the ones used for LIV studies so far.

PeVatron metrics with gammapy

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Criteria for detecting Galactic accelerators at PeV energies can be applied to the Cherenkov Telescope Array (CTA) simulated instrumen- tal response, in order to assess it's ability to find and characterize these elusive sources. The outputs of this kind of studies are called the Pe- Vatron metrics. Following the example of [1], we computed PeVatron metrics for CTA, assuming an observation livetime of 10 h. This means: (i) simulating the γ-ray emission from sources caracterized by very hard spectra with cutoffs at different energies, (ii) convolving it with a given production of simulated CTA IRFs and then (ii) fitting the data both with simple powerlaws (PL) and exponential-cutoff powerlaw spectra (ECPL). The comparison between the fit statistics in the two cases (TS) allows to determine whether the cutoff can be detected or not, under the given as- sumptions. As a first step, we reproduced the results of [1] using gammapy ([2]), thus providing a crosscheck to the ctools study and also validating our analysis pipeline. Then, we introduced new features that go beyond the reference study: for the first time, we computed the metrics using 3D (space + energy) analysis, instead of standard 1D aperture photom- etry. Furthermore, we introduced realistic hadronic models using naima ([3]-[4]): we simulated and fitted γ-ray models depending directly on the spectral shape of the parent population of CR protons. This way, we built the metrics in the proton's parameter space, i.e. directly in the space of interest for PeVatron searches.

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Vela as a source of Galactic Cosmic Rays above 100 TeV and neutrinos below 100 TeV

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This poster is based on [8, 9] . One of the most prominent features for the cosmic ray spectrum is the knee, a break in the all-particle energy spectrum at the energy $E_k \simeq 4$ PeV. One of the possible explanations for the origin of the knee is that the spectrum below the knee is dominated by a single, nearby source [1, 2]. In [3] the authors showed that to be consistent with B/C ratio, the diffusion should be sufficiently anisotropic and the magnetic field contains a non-zero component perpendicular to the Galactic disk. As a result, the number of sources contributing to the locally observed flux is reduced by two orders of magnitude. Thus only few sources contribute to the local CR flux at energies above 200 GeV.

In the energy range between 200 GeV and 100 TeV a 2–3 Myr old local supernova can dominate the local CR flux, as shown in Refs. [4, 5].

We suggest in [8] that Vela, a 11 kyr old supernova remnant at the distance 270pc, is the source dominating the local CR flux above 200TeV. We study the expected CR flux from Vela, which is connected with the Solar system by a magnetic field line in models of the global Galactic mag- netic field as, e.g., the Jansson–Farrar model [10], taking into account that the Earth is located inside the Local Superbubble. We use a simplified model for the structure of the magnetic field inside the Local Superbubble similar to the one of Refs. [11], and follow individual CR trajectories solving the Lorentz equation. We obtain a good description of the fluxes of individual groups of CR nuclei in the knee region and above. Adding additionally the CR flux from the 2–3 Myr old source, the CR spectra in the whole energy range between 200 GeV and the transition to extragalactic CRs are described well combining the fluxes from only these two local sources.

We study possibility that both excess in IceCube astrophysical neutrino flux and gamma-ray excess at high galactic latitudes come from interactions of PeV cosmic rays from recent nearby source, like Vela in the walls of Local Bubble.

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Development of a prototype Compton telescope for space-borne gamma-ray polarimetry

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Gamma-ray polarimetry is a new domain in full expansion. Already probed by measurements with the INTEGRAL and ASTROSAT missions, this approach can offer us an insight into the emission mechanisms responsible for high energy astrophysical phenomena. Polarimetry was slow to be adopted by the X-ray and gamma-ray astrophysicist community due to the technical constraints this type of measurement entails.
Gamma-ray Polarimetry presents multiple technical challenges. In the soft gamma-ray range, low Z materials sensible to the polarization of photons are foregone for high Z materials that improve photon absorption and simplify design. For higher energies, Compton telescopes become a viable option for polarimetry measurement but mission parameters and particular detector designs haven't been optimized for this type of measurement in the past. Additionally, this is coupled with the fact that the atmosphere is opaque for electromagnetic radiation that is more energetic than 100 eV which means that direct observation can be achieved solely by space-borne instruments.
Our aim is to build a Compton telescope prototype sensible in keV to MeV range. This will be achieved by coupling a scattering layer based on Double Strip Silicon Detectors (DSSDs) developed at CEA with a CeBr3 calorimeter currently developed at CSNSM or a Caliste calorimeter developed by the CEA. A DSSD test-bench is currently in development and the focus of this research. A 9.8cmx9.8cm, 1.5mm thick, and 64 strips silicon detector is coupled with IdeF-X BD ASICs to form the "tracker" portion of the telescope. The performance of the detector will be evaluated at different temperatures before being coupled with a calorimeter. The prototype telescope will then be calibrated at the European Synchrotron Facility in Grenoble in order to evaluate its performance and the achievable scientific goals. This prototype will also be installed in the Nice hospital's experimental area, in order to test its ability to be used for hadron therapy monitoring. Indeed, Compton telescopes are a likely candidate for this as they should be more sensitive than traditional methods, such as PET, and thus reduce the duration of the treatment and the radiation dose administered to the patient.

Relativistic jets from a new Black Hole transient in our Galaxy

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Microquasars are X-ray binary systems containing neutron stars or black holes orbiting around a companion star, that are able to launch spectacular jets of plasma at relativistic speeds. These systems are mostly observed in our Galaxy and allow us to study the jet formation and emission on human timescales, making it possible to unveil the mechanisms that link accretion and ejection in compact objects. Multi-wavelength observations are fundamental to achieve this goal. We present here the monitoring campaign of MAXI J1348-630, a new black hole transient which entered in an outburst phase in January 2019 and that we observed for 11 months in the radio band with the MeerKAT and ATCA interferometers and in X-rays with the MAXI and Swift space telescopes. We tracked the outburst evolution as the system transitioned into different spectral states and we studied of the correlation between the radio luminosity, linked to the presence of synchrotron emitting jet, and the X-ray luminosity, produced by the inner accretion flow, thus being able to probe the accretion-ejection coupling down to very low levels of a black hole transient activity, which are still greatly unexplored. Moreover, we detected two relativistic radio-emitting jets travelling away from the black hole with apparent superluminal speeds, for which we show results on the emission, motion and energetics.

Multimessenger astronomy to study the origin of the very-high-energy astrophysical neutrinos

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The IceCube and ANTARES neutrino telescopes observed a few events with very high energies ($E \geq 10$ TeV) during the last decade. Those observations, together with the recent measurement of the gravitational waves, contribute to the fast development of the ”multimessenger astronomy”. The combination of signals with different natures provides more information than the analysis of these signals separately. Here, we'll discuss about a way to combine the electromagnetic and neutrino signals to better understand the origin of the very-high-energy (VHE) neutrinos. Previous searches show that there might be a Galactic component in this VHE neutrino flux but the statistical significance remains too low to claim a discovery.
In this search, we'd like to find out if such energetic neutrinos could be emit- ted by the Galaxy. Since the neutrinos and the γ-rays are produced by the same astrophysical processes, we can study the most energetic photons observed in the Galaxy to create a VHE neutrino emission model. The combined observa- tion of Antares and IceCube high energy neutrinos will be compared to the counterpart predicted by the γ-ray emission of the Galaxy using a likelihood maximization method, fitting both angular distribution and energy spectrum. If a correlation is found with a sufficiently high statistical significance, it would be the evidence of a galactic component of the VHE neutrino emission, and it might indicate the presence of a PeVatron in the Galaxy.

Interest of low-frequency modes in helio- and asteroseismology

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Context: Asteroseismology aims at probing the interior of a star thanks to the characterisation of its oscillation modes. Those modes can be of two types : acoustic modes (p-modes) for which the restoring force is pressure and gravity modes (g-modes) for which the restoring force is buoyancy. For main-sequence solar- type (MSST) star, p-modes also correspond to higher frequency regions relatively to g-modes. p-modes are trapped between the stellar surface and an inner turning point while g-modes lay in the stratified radiative zones and become evanescent while crossing the convective zone on their journey to the upper regions. Their surface amplitude is thus very low. For MSST stars, g-modes individual structures in the spectra are hidden by the convective noise.
Aims: oscillation modes properties are directly linked to the structure of their resonant cavities. Surface effect being more important on p-modes as the frequency increases, the importance of being able to characterise low-frequency modes appears obvious : low-frequency p-modes allow better constraints on the convective zone structure while an hypothetical observation of the individual structure of the g-modes would directly give us access to the properties of the radiative zone and the stellar core. For MSST stars, F-stars with thin convective zones seem to be the better candidates to observe the g-modes. However, as they are fast rotators, the rotation harmonics can lay in the g-mode region of their spectra. A preliminary analysis of their rotation properties is then necessary.
Method: the sample studied here is constituted with 239 F-stars observed in short cadence by the Kepler satellite. A machine learning pipeline is used to characterise the rotation of those stars.
Results: 91 stars present rotation signals. 23 of them have a rotation period inferior to 5 days.
Conclusion: as expected, the F-stars short cadence sample presents an important proportion of fast rotators. This will have to be taken into account when studying the low-frequency regions in those stars' spectra.

The Very High Energy Emission of the Galactic Center

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Since 2004, the High Energy Stereoscopic System (H.E.S.S) has been observing the sky in energy bands above 100 GeV, using the Vavilov-Cherenkov effect. One of the most noteworthy source at high gamma energies is the point-like source known as HESS J1745-290, which matches the position of the galactic center itself, Sagittarius A*. Since at Sgr A* lies the supermassive black hole of our galaxy, and since compact objects are known to generate very high energy photons, the question of whether or not this gamma-ray source originates from the black hole (more precisely from its surroundings and accretion disk) is a most relevant one. Using the 15 years of H.E.S.S observations at our disposal, and the latest analysis tools of the gammapy python library, we will deepen our description of the galactic central region at those energies, in particular by better describing the diffuse gamma ray emission that surrounds the galactic center. The key elements of the source that need to be investigated are : its extension, its spectral components and its potential temporal variability. Moreover, the thesis will also attempt to model the behaviour of the source phenomenologically. Finally, new tools will be developped for data analysis, especially as we will try to estimate the first results of C.T.A (Cherenkov Telescope Array), the next main project un Cherenkov astronomy.

Relativistic X-ray jets in the black hole candidate MAXI J1820+070

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Jets and outflows are observed in a diverse range of accreting systems such as young stellar objects, galactic X-ray binaries and active galatic nuclei (AGN). The formation of jets, their propagation and their association with accretion processes are still largely unclear. However, their feedback on their immediate environment is now starting to be quantified, as their interaction with the interstellar medium can be observed using high spatial resolution images of X-ray binaries (e.g. Corbel et al. 2002, Migliori et al. 2017).
Here, we report on the black hole candidate MAXI J1820+070, discovered during its 2018-19 outburst and extensively monitored. Radio observations have revealed the formation of relativistic radio jets on both sides of the system (Bright et al. 2020). To constrain the high energy emission from these jets, we conducted four X-ray observations with the Chandra X-ray Observatory between 2018 November and 2019 May. Simultaneously, MAXI J1820+070 was monitored in radio with the VLA and MeerKAT.
The observations reveal the presence of X-ray moving sources associated to the radio counterparts of the jets. The jets are travelling at apparent relativistic velocities, with a possible deceleration at late time, which could be due to shocks with the surrounding environment. In addition, the broadband spectra of the jets are consistent with synchrotron radiation from particles accelerated up to very high energies (above 10 TeV) during shocks, probably between the jets and the interstellar medium. MAXI J1820+070 is the third black hole X-ray binary for which such an interaction is observed at high energy.

Estimating the microwave sky from data of multi-kilo-pixel CMB experiments

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The current inflationary paradigm of early universe cosmology predicts the existence of primordial gravitational waves. These gravitational waves leave a specific imprint on the polarization anisotropies of the Cosmic Microwave Background (CMB), and their detection would deeply impact our understanding of cosmology and fundamental physics. The search for this faint signal as well as its precise characterization require increasingly better sensitivities, which in turn leads to an exponential growth in the size of the data sets being collected by the experiments. Processing these data efficiently requires better numerical tools, able to fully capitalize on the computational power of massively parallel supercomputers. The aim of my current work is to develop novel numerical techniques and code for the first stage of the data analysis pipeline of CMB experiments: we turn the raw data measured by the detectors into estimates of the sky maps (combining signals of different astrophysical origins), where unwanted temporal patterns have been filtered, the noise averaged out, and the loss of cosmological information is minimal. This process is referred to as map-making; it consists in solving a generalized least square problem with non-diagonal weights, and it is a central operation in the CMB analysis for which the main challenge consists in the size and complexity of the full raw data set that we need to process, which is soon expected to reach the Petabytes scale in the forthcoming experiments. At this scale, such an operation can only be performed on massively parallel computing platforms, and the underlying algorithm need to have minimal complexity and to be properly scalable finding suitable solutions to the communication bottleneck problem. I will present my ongoing work on the development of a map-making framework for the next generation of CMB polarization ground experiments (such as Simons Array and Simons Observatory) based on conjugate gradient iterative methods.

Induced gravitational waves from a universe filled with primordial black holes

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As recently argued in the litterature, there may exist some transient matter domination era in the early universe, before Big Bang Nucleosynthesis (BBN), driven by light primordial black holes. These light primordial black holes (PBHs) should have evaporated by BBN and the only way to constrain them is through the gravitational waves produced due to second order gravitational interactions. Thus, in this work we compute the induced second order gravitational wave spectrum sourced by scalar perturbations due primordial black hole formation. In order to do so, we assume randomnly initially distributed pri- mordial black holes, i.e. Poissonian distribution of their number density, and by coarse-graining the PBH energy density field we extract the matter power spectrum upon formation time. Then, we solve the equation of motion for the tensor modes sourced at second order by scalar perturbations and compute the energy density spectrum of gravitational waves, Ω_{GW} , at evaporation time. As we see, the second order gravitational waves are so abundantly produced that primordial black holes should not have formed in the early universe and driven the universe energy content.

Latest calibration results from QUBIC: The Q&U Bolometric Interferometer for Cosmology

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QUBIC is an experiment dedicated to the measurement of polarization B-modes of the Cosmic Microwave Background (CMB) using the novel technology of Bolometric Interferometry. Thanks to its unique spectroimaging capabilities, QUBIC will also be a powerful instrument to constrain foreground contamination. The technical demonstrator has been tested and the concept of this new instrument has been validated.
In this poster, I will explain the instrument architecture, focussing on the optical design. Some of the calibration results will be presented, showing that we actually have a working bolometric interferometer.
The unique design of QUBIC brings new possibilities to CMB polarization mapping including self-calibration and spectroimaging.

Using mock quasar spectra to study systematics in eBOSS and DESI Lyman-alpha analyses

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In 2005 the Baryon Acoustic Oscillation (BAO) provided a new probe for dark energy. The BAO is an imprint left in the matter density field by a propagating sound wave in the primordial universe. It presents itself as a standard separation distance that can be seen between two overdensity regions. Looking at the distribution of matter today, this standard separation can be seen as a peak - the BAO peak - and may be measured in the matter two-point correlation function. Experiments such as eBOSS and its successor DESI are designed to survey stars, galaxies, and quasars and use them as mass tracers. The Lyman-alpha forest is a distinct and useful feature in the spectra of high redshift quasars. Here, we focus on the correlation in Lyman-alpha forests to measure the BAO signal. The analysis is very robust, however, to test its systematics, mock spectra have been developed. We present two sources for systematics, the presence of Damped Lyman-alpha Absorbers in quasar spectra and the distortion introduced by the quasar continuum estimation, and study their effects on the correlation function in mocks.

TES detection-chain operation of the QUBIC instrument dedicated to the CMB observation

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Q U Bolometric Interferometer for Cosmology (QUBIC) is a new ground-based experiment aiming to detect the Cosmic Microwave Background (CMB) B modes. QUBIC is based on bolometric inter- ferometry, a new instrument architecture. This allows to combine together the well known control of systematic effects from interferometers with the high sensitivity of bolometric detectors. It will observe the polarisation of the CMB, the first light emitted after the Big Bang, in two frequency bands (150 and 220 GHz.)
It uses two focal planes of kilo-pixels arrays of Transition Edge Sensors (TES) in addition with Su- perconducting QUantum Interference Device (SQUID) used as amplifiers and switches for mltiplexing system, and Application Specific Integrated Circuit (ASIC) at low temperature. Time-domain multi- plexing using mainly cryogenic readout devices (TES, SQUID, and ASIC) has been developed for the QUBIC detection chain. The original concept combining SQUID multiplexing and additional multi- plexing stage in a cryogenic integrated circuit (ASIC) allows achieving a 128-multiplexing factor.

The full readout system is in operation in the QUBIC cryostat since 2018 and was operated on a par- tially populated focal plan of 256 NbSi TES. Operations and performance using this readout system will be presented. Aliasing noise and limitation of the multiplexing frequency will also be discussed highlighting possible future improvements of performance.

A simulation-based background model in DAMIC search for Dark Matter

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At present, the origin of the universe matter and energy content is mostly unknown, with so-called Dark Matter (DM) amounting to roughly 27% of the total. Among important DM candidates, WIMPs (Weakly Interacting Massive Particles) would have a mass in the 10-to-$10^5 GeV/c^2$ range and would interact with ordinary matter at the weak scale. Experimental efforts of the last decades have been unsuccessful in detecting such objects. This scenario, along with new theoretical developments, has motivated the search for lighter DM ($m_\chi \lesssim 10\, GeV/c^2$) and opened a vast bestiary of candidates: from axion-like particles to hidden-sector gauge bosons with masses as low as a fraction of eV.
DAMIC and DAMIC-M (DArk Matter in CCDs – at Modane) experiments aim for direct detection of light DM by means of CCD (Charge-Coupled Device) semiconductor targets. Scientific fully-depleted CCDs about ten times more massive than conventional ones are used to such end, employing both nuclear recoil and electronic scattering as potential detection processes. With such features, a mass range between 1 MeV and 10 GeV can be probed.
This work presents the background model used for the latest WIMP search in DAMIC (to be extended for DAMIC-M). Such model is constructed using seed-clustered Geant4 simulations, and accounts for contributions from contaminants present in the components of the DAMIC experimental setup. It is an essential ingredient of the likelihood study performed to discriminate possible DM-generated signal.

Probing the Universe's beginning and testing fundamental physics with Simons Array and Simons Observatory cosmic microwave background polarization data sets

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The Cosmic Microwave Background (CMB) is the oldest light observable in the Universe. It was emitted when free electrons combined with nuclei in the primordial plasma. Due to the absence of free electrons the Universe has suddenly become transparent. The photons freed in that process compose the CMB radiation that we see today.
However this signal is not uniform over the sky. The CMB anisotropies are the key to understanding of the primordial Universe and are uniquely characterized by their power spectra.
The current standard model of cosmology is best understood if an era called cosmological inflation is assumed. Inflation naturally leads to the CMB polarisation of the B (curly)-type and detecting it would provide its strong validation. However, B modes anisotropies are very faint - at least 6 order of magnitudes lower in amplitude than temperature anisotropies. New hardware technologies and analysis techniques are required to detect it.
My PhD takes place in this context and is performed within the Simons Observatory (SO) project - a leading, ground-based telescope in the Atacama Desert in Chile. Its first light is expected in 2021 and it is one of the most promising instruments for the detection of primordial B modes.
Photons originating from astrophysical sources contaminate CMB measurements with amplitudes up to 4 orders of magnitude bigger than the expected CMB B mode polarisation. I work on methods to clean such signals to recover the most pristine CMB signal possible. This is one of the biggest challenges in the field. Addressing it will not only allow us to set tight limits on the B-mode signal but also help us constraining effects such as primordial magnetic fields or interactions with axion like particles which could rotate the polarization angle. These effects are one of the goals of my work.

Characterization of Dark Energy with Subaru and HST

Guy Augarde, Nicolas Regnault

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The Nature of Dark Energy, the mysterious component driving the acceleration of cosmic expansion, is still unknown. The main approach to constraint its equation of state is to construct a Hubble diagram, the evolution of luminosity or angular distance with respect to the redshift. Type Ia Supernovae (SN Ia) used as luminosity distance indicators, allowed to create a Hubble diagram allowed the historical discovery, that the expansion of the Universe is now accelerating.
As of today, the state of the art is the Joint Light Curve Analysis (Betoule & al. 2014), a Hubble diagram made of 740 spectroscopically-confirmed SN Ia with redshifts between 0.05 and 1. To improve this results one of the way, followed by the Subaru Strategic Program (SSP), is to get more high redshift SN Ia (0.8 < z < 1.5). The Subaru telescope will discover and follow up , about 300 very high redshift SN Ia. For the moment, ± 150 have been already found.
As the Universe is expanding, the light sent by a SN is redshifted. A key aspect of the study, is, having the flux of the light measured in the observer frame, to reconstruct this flux in the supernova frame. For that, we use an empirical model of the spectrophotometric evolution of those objects. The model currently in use in the community is called Spectral Adaptive Lightcurve Template (SALT2), develop between 2007 and 2010. During my phD, I will develop the new generation of this model , relying on a much larger training set. I will present on this poster, the first part of the creation of the model, considering an simplified model of the supernova flux.

Gravitational waves from cosmic strings: relics of the early Universe

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Gravitational astronomy, which is still in its infancy, offers great prospects for studying the earliest moments in the History of the Universe. Unlike photons and neutrinos, gravitational waves propagated freely from the first moments of the Universe to our detectors, and are a direct probe of primordial cosmology and high energy physics. The Laser Interferometer Space Antenna which is due to be launched in 2034 will be able to observe/constain sources of cosmological orgins, among which cosmic strings. These objects are one-dimensional remnants of the phase transitions that occurred at early times. To this day, cosmic strings have not yet been discovered but their presence should produce a wide range of signatures due to their gravitational and non-gravitational effects.
First we model the formation and the dynamics of the cosmic string network and we quantify its signature in terms of gravitational waves as well as in high energy gamma rays. Second we compare these signals with bounds given by present and planned experiments and assess their ability to constrain extensions of the standard model.

Isocurvature modes: a joint analysis of the power spectrum and the bispectrum of the CMB

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The study of the inflation epoch gives us a unique probe of very high energy physics of order $10^{15} - 10^{16} GeV$. A detection of non-Gaussianities and/or isocurvature modes would be particularly interesting since both could rule out the simple single-field inflation models and demonstrate the presence of multiple fields interacting at very high energy. The measured power spectrum of the Cosmic Microwave Background (CMB) is for now compatible with purely adiabatic perturbations. Furthermore, the 3-point correlation function or bispectrum does not show any evidence of non-Gaussian features of either adiabatic or isocurvature components. To improve the constraints on the isocurvature modes, we perform a joint analysis of the power spectrum and the bispectrum. In order to link the bispectrum and the power spectrum amplitudes, we assume a generic two field model generating arbitrarily correlated adiabatic and isocurvature modes. We have shown that, if we leave the parameters in the model completely free, without a detection of either isocurvature modes (in the power spectrum) or non-Gaussianities, it is impossible to improve the constraints on the isocurvature modes with a joint analysis. This is the case for the Planck 2018 data. Next we studied the impact of fixing the amplitude of the non-Gaussianities or the correlation between the fields. We show that it is possible to improve the constraints if the non-Gaussianity is large enough or equivalently if the correlation between adiabatic and isocurvature mode is low enough.
We show forecasts for LiteBIRD, LiteBIRD+CMB-S4 and a CORE-like experiment separately for the power spectrum and the bispectrum. We study the possibility of detecting isocurvature modes and their non-Gaussian features in a Planck-compatible fiducial sky. Thus, we can find parameter ranges for which we know from the theory we developed that the joint analysis will improve the constraints. We then explicitly show this improvement of the isocurvature constraints in a favorable case.

Modified gravity theories and future observations in astrophysics and cosmology

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General relativity is the most successful theory of gravity yet proposed. It has been tested at several scales in many systems, from the corrections to planet movements in the solar system to the emission and propagation of gravitational waves by a binary black hole. Yet in order to propose an explanation to the accelerated expansion of the universe, one can simply add a "cosmological constant" Λ to the theory. This parameter corresponds to a mysterious "dark energy" that would drive the expansion. However, the measured value for Λ has never been explained by a theoretical model: all predicted values for this constant are many orders of magnitude higher than what is found in the experiments. Therefore, new theories of gravity have emerged, in order to have the same predictions as general relativity while explaining the expansion by another mechanism. We study a subset of these theories, called "DHOST theories", in which gravity is coupled to a scalar field that represents a new degree of freedom. This scalar field appears in the action with higher derivatives, which allow mechanisms mimicking the accelerated expansion of the universe. More precisely, we study black hole solutions in these theories and how the gravitational waves emitted by binary black holes would differ from the profile predicted by general relativity. Such differences could be detected by the next generation of gravitational waves detectors, for example LISA.

Separation of overlapped galaxies with Variational AutoEncoder for weak gravitational lensing

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The next generation of cosmological surveys, such as the Vera Rubin Observatory Legacy Survey of Space-Time (LSST) and Euclid will record great volumes of data. Efficient usage of this data will permit strong constraints on cosmological parameters and particularly on the nature of dark energy. One crucial probe which will constrain these parameters is weak gravitational lensing: the coherent deformation of galaxy shapes due to the mass residing between the observer and the observed galaxies. To use this cosmological probe a large sample of galaxies over a range of distances with accurate measurements of their shapes is needed. The further you look in the universe the older you see, however the further the distance the higher the risk of superposition of galaxies with other astrophysical objects along the line of sight (blending). Blending will be a major challenge for upcoming ground- base, deep, photometric surveys such as LSST, it will contribute to the systematic error budget of weak lensing studies by perturbing object detection and affecting photometric and shape measurements. To accurately measure the shapes of blended galaxies methods are needed to separate (deblend) the galaxies. Here we present a method using a machine learning tool: the variational autoencoder (VAE). We show that our method benefits from the combination of ground and space based surveys data for galaxy shape reconstruction and is robust to decentering due to pixelisation.

Direct Dark Matter Search with XENON Project

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Understanding the properties of dark matter particles is a fundamental problem in particle physics and cosmology. Its Direct Detection (the search of dark matter particle scattering off nuclei target using ultra-low background detector) is one of the most promising technologies to decipher the nature of dark matter. Dual-phase Liquid Xenon TPCs, in particular with the XENON1T detector, have done much to push the sensitivity bounds for detection of a broad range of WIMP masses, from O(100) MeV up to the TeV scale, by combining different analysis techniques. Its upgrade, XENONnT, that will start commissioning in Spring 2020, will increase this sensitivity by an order of magnitude.

One of those techniques is the search for a possible annual modulation of the background, which requires high stability over time of the detector. I'm currently working on the study of all parameters that can be relevant to reach the maximum stability possible.

The poster provides an introduction to the dark matter problem, it presents the XENONnT experiment and its rich physics case, finally, it shows the topics I'm contributing so far, in particular, the development of a data quality monitoring system and the study of some physical quantities that are crucial to determining the performances of the detector and its ability to detect dark matter.

Searching for Dark Matter with Dark Side experiment

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The precise nature of approximately 85 % of the matter in our Universe, or 27 % of its mass-energy content, still remains a mystery, only witnessed by plenty of indirect evidences such as galaxy's rotation velocities or gravitational lensing. Several theories, from the famous MOND theory to the existence of a new kind of particles passing through primordial black holes theory, have candidates explaining this hidden mass, the so-called Dark Matter.

Part of the The Global Argon Dark Matter Collaboration, the Dark Side experiment, based on an Argon double phase time projection chamber, is looking for dark matter particle candidates, and more particularly to WIMPs (Weakly Interacting Massive Particles) and axion-like particles, two of the particle main candidates.

After few years of data taking with a 50 kilos detector who achieved some of the best world limits on WIMPs-neutron cross-section, especially at low mass, the detector is upgrading to a 50 tons detector to gain sensitivity and be able to reach even lower cross-sections. In the meantime, two prototypes are in progress, they have taken data and would be taken more data this year. Both their rigorous calibration and data reconstruction is of primordial importance for further WIMP searches with the next generation detector.

Signal and trajectory reconstruction in a Dual-Phase Liquid Argon Time Projection Chamber

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A neutrino is a fundamental particle that has the particularity of interacting very rarely and therefore it is very difficult to study. The Deep Underground Neutrino Experiment (DUNE) is a project that will allow us to answer questions about the nature of the neutrino. DUNE consists of two detectors placed in the path of an intense neutrino beam, one near the beam source and one 1300 km further away. The far detector technology is expected to give us, with an excellent resolution, the 3D picture of a neutrino interaction happening inside a liquid argon volume. In addition, the interaction energy will also be measured with high precision.

The DUNE collaboration is currently studying two prototype designs of this far detector before launching the full-scale version, expected to have an active volume of $60 \times 12 \times 12\ m^3$. We will focus in this poster on the so-called "Dual-Phase" design, which uses liquid argon but also contains a small amount of gaseous argon. One aspect of this prototype phase is to develop the most efficient tools to analyze the data. Pandora is a multi-algorithm software that tries, via pattern recognition, to reconstruct the 3D trajectory of particles created from a neutrino interaction inside the detector. My work is to adapt and optimize Pandora's current algorithms to specific features of the Dual-Phase technology. The final goal is to achieve the expected reconstruction efficiencies matching DUNE's ambitious physics program.

Earth tomography with KM3NeT/ORCA

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The deep-sea neutrino detector KM3NeT/ORCA, currently being built in the Mediterranean Sea near Toulon (France), is optimized for the study of oscillations of atmospheric neutrinos in the few-GeV energy range, with the main goal to determine the neutrino mass hierarchy. This is possible due to matter effects that modify the probability of neutrino oscillations along their path through the Earth. Measuring the energy and angular distributions of neutrinos with ORCA can therefore also provide tomographic information on the Earth's interior and more specifically on the electron density along the trajectory of the detected neutrino, complementary to standard geophysics methods.

In this contribution the latest results of a study of the potential of ORCA for Earth tomography are presented. They are based on a full Monte Carlo simulation of the detector response and including systematic effects. It is shown that after ten years of operation ORCA can measure the electron density in both the lower mantle and the outer core with a precision of a few percent in the case of normal neutrino mass hierarchy. Additionally, possible future detectors are probed for their sensitivity towards different chemical models of the outer core, based on parameterized detector models.

TPCs test beam analysis for T2K experiment

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The T2K (Tokai to Kamioka) experiment is a long-baseline neutrino oscillation experiment located in Japan. Its Near Detector (ND280), is used to characterize the neutrino beam before oscillations and is being upgraded for the second phase of T2K. One of the new sub-detectors of ND280 will be the High Angle Time Projection Chambers (HA-TPC) that will be read by 16 resistive Micromegas modules. The first prototype of resistive Micromegas was exposed to a beam of charged particles at CERN in 2018 while the second one was exposed to an electron beam in DESY in Summer 2019. These data allowed to test the performance of the resistive Micromegas. Most of the results in this poster are concentrated on the characterizaton of the MicroMegas in terms of deposited energy resolution. We investigated the dependencies of deposited energy resolution on the drift distance, on the angle of the charged particles with respect to the MicroMegas plane, on the number of the cluster. We measured a deposited energy resolution of $\approx$ 9.5% for tracks crossing the entire MicroMegas module. Such performances satisfy our requirements for the new TPCs of T2K

Development and characterization of novel CCD readout electronics for the search of dark matter with DAMIC-M

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Despite plenty of evidence for the existence of Dark Matter (DM), no experiment has ever managed to capture it directly. In the last decades, the Weakly Interacting Massive Particle (WIMP) paradigm, the most popular among the DM models, has proven unsuccessful experimentally in a variety of detection methods in the GeV-TeV mass range. DAMIC-M (DArk Matter In CCDs at Modane) will aim to directly search for light WIMPs (<10 GeV/c2) and hidden-sector DM, using a tower of scientific-grade Charge-Coupled Devices (CCDs) of a kg-size total target mass. In addition, by implementing the Skipper readout technique, a sub-electron energy resolution can be achieved. A fundamental feature of this undertaking will be the development of an acquisition system for the overall control and readout of the CCDs. I will present preliminary results from the evaluation of novel readout electronics including the front- end CCD ReadOut Chip (CROC), which will provide a pre-amplification on the output signal and improve the Signal-to-Noise Ratio, and a new Analog-to-Digital Converter board, allowing for a fast and high-resolution data acquisition.

Experimental validation of LISA interferometric performances

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The Laser Interferometer Space Antenna (LISA) is a space-based mission to detect low frequency gravitational waves. These signals are produced by various events like inspiralling supermassives black holes binaries. Gravitational waves are very small variations of space-time metric which can be detected with high precision laser interferometry. The LISA method consist of measuring distance fluctuations between free-falling test masses.

As with any detector, signal to noise ratio has to be optimised. In actual ground- based interferometers like LIGO/VIRGO experiment, sensitivity is limited by sismic and quantum noises. In the LISA case, the raw measurements are bur- ried within the laser frequency noise Acutally, due to the LISA constellation geometry, the phase fluctuations due to the laser instabilities dominate by 8 orders of magnitude the gravitational wave signal.

A noise reduction method named Time Delay Interferometry (TDI) was devel- opped in the 90's to remove in post-processing the laser frequency noise of future LISA data. This algorithm is crucial for the success of the LISA mission and needs to be tested with simulated data before launch.

For several years and with the support of CNES, an electro-optical bench for metrological demonstration named LOT (for "LISA On Table") has been set up at APC. The objective of this bench is to demonstrate experimentally several aspects of TDI, characterize its frequency response and assess the noise residuals. The main goal of my thesis is to validate experimentally key aspects of LISA noise reduction techniques by improving the LOT test bench to be compliant with the latest developments of TDI.

Modelling cosmic ray acceleration in stellar clusters

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Cosmic rays are charged particles coming from space, whose flux is detected thanks to multiple instruments in space or on the ground. While they have been well studied since their discovery more than one century ago, the origin of their high energy components remains uncertain. In particular, although the standard explanation involving diffusive shock acceleration inside supernova remnants succeeds in describing the flux up to PeV energies, it is much less satisfactory beyond and fails to describe peculiarities of the spectrum such as the so-called knee and ankle. It seems therefore that acceleration mechanisms beyond the standard model should be considered. Among several existing hypothesis, stellar clusters and superbubbles are a promising possibility, being a natural extension to the isolated supernova model. I describe how, in such clusters, stellar winds and supernovae efficiently convert their energy into cosmic ray production. Collective effects such as colliding shock flows are studied, as well as stochastic acceleration in enhanced turbulence. I finally account for systematic reacceleration and escape through the cluster shell to build a model considering the stellar cluster as one single accelerator, aiming at deriving some expectations on the observables such as the shape of the photon spectra or their variability.

Detecting low frequency gravitational waves (PTA)

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Pulsars are very dense and rapidly rotating neutron stars. They emit light on concentrated beams making them appear as series of pulses. They are extremely stable objects and monitoring these series of pulses allows us to use them as clocks. A gravitational wave passing through would disturb the time of arrivals of pulses and provide us information on the local space-time curvature. The Pulsar Timing Array (PTA) collaboration is currently monitoring many pulsars in the galaxy using radio telescopes with the aim to detect gravitational wave signals. It is now composed of a total of 65 pulsars that are constantly observed by many different branches of the collaboration throughout the world. The targeted signals can be separated in two categories : the stochastic Gravitational Wave Background (GWB) which is a low frequency noise resulting from the sum of all supermassive black hole binaries gravitational emissions in the universe and the Continuous Wave (CW) signals which come from stable individual binaries well resolved at one specific frequency. These signals are expected at frequencies around 10nHz which lies in the range of sensitivity of PTA. My PhD concentrates on the CW and individual sources. I will have to develop a statistical analysis pipeline using bayesian inference for gravitational wave detection based on already existing tools to ultimately improve them.

Hierarchical fragmentation in high redshift galaxies revealed by hydrodynamical simulations

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High-redshift galaxies have very different morphologies compared to nearby ones. Indeed, the high gas fractions lead to the formation of giant star forming structures of masses up to 10^8 and 10^9 $M_\odot$ often dubbed «giant clumps». Recent observations at high resolution questioned the physical existence of giant clumps by showing only low-mass structures or no structures at all. We use Adaptative Mesh Refinement hydrodynamical simulations of galaxies with parsec-scale resolution to study the formation of structures inside high-redshift galaxies. We show that star formation occurs in small gas clusters with masses between 10^6 and 10^7 $M_\odot$ that are themselves located inside giant complexes with masses up to 10^8 and 10^9 $M_\odot$. Those massive structures correspond to the giant clumps observed with the Hubble Space Telescope. They are found to be gravitationally bound and present a relation between their Jeans' masses and their substructures masses coherent with a scenario of hierarchical fragmentation. We also compare the top-down fragmentation of an initially warm disk and the bottom-up fragmentation of an initially cold disk. Through mock observations of the simulated galaxies, we show that at very high resolution with instruments like the Atacama Large Millimeter Array or through gravitational lensing, only low-mass structures are detected. This leads to non detection of the giant clumps and therefore introduces a bias in the detection of the structures.

Reducing quantum noise in gravitational-wave detectors using squeezed states of light

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Gravitational waves (GW) are ripples in the fabric of spacetime, emitted by compact accelerating objects. On September 2015, the first direct detection of GW from a binary black hole merger initiates the field of GW astronomy and opened a new window on the Universe. On August 17, 2017, Advanced LIGO and Advanced Virgo detectors jointly detected gravitational waves resulting of the merger of two neutron stars, with the best localization precision ever obtained.
In order to increase the science reach of LIGO and Virgo, it is essential to reduce quantum noise (QN), one of the fundamental sensitivity limits of the detector. QN is originated by the quantum nature of light, and is attributed to the Heisenberg Uncertainty Principle, stating that it is not possible to know simultaneously and with an infinite precision the phase and the amplitude of the light. Since the quantum noise is generated by vacuum fluctuations entering from the dark port of the detector, the injection of non-classical vacuum states of light (or squeezed states) enables the reduction of quantum noise. This technique is now routinely used in LIGO and Virgo to increase the sensitivity in a fraction of their frequency spectrum.
Achieving a broadband reduction of quantum noise requires the use of "frequency-dependent squeezing (FDS)" techniques, where the squeezing ellipse rotates as a function of the frequency before entering the detector. After a general introduction about squeezing, I will present my work on the experimental demonstration of a FDS technique using entangled photons, and known as Einstein-Podolsky-Rosen (EPR) squeezing technique.

Gravitational wave confusion problem across frequency bands

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With radii in the order of 10 km, masses roughly between 1 and 2 solar masses and magnetic fields that could be over 1014 G, neutron stars are fascinating astrophysical laboratories. After the gravitational collapse that gives their birth, they could rotate with periods from some milliseconds to some seconds. The fastest ones, millisecond pulsars (MSPs), can be used as precise clocks because of their extreme stability, with period derivatives around 10^{-20} s^{-1}. This is what does Pulsar Timing Array (PTA) project in order to detect gravitational waves (GWs). Indeed, such waves modulate the pulse period that we detect modifying temporarily space-time curvature between the pulsar and the Earth. In PTA, we are probing low-frequency GWs (nHz-µHz), that would most likely be emitted by supermassive black hole binaries. Among others, we expect to detect stochastic background (isotropic or anisotropic) produced by the whole population of such black holes. This background generates angular correlations within pulsar timing observations with a peculiar signature. My project mainly concerns data reduction and noise characterizations in pulsar timing to permit their separation from the gravitational wave signal. Since the pulse is emitted from the pulsar, many astrophysical phenomemae and other mechanisms affect the period stability of the observed rotation. Internal physics of the pulsar and its magnetosphere or dispersion and turbulence in the interstellar medium be- tween the pulsar and the observatory are good examples. Instrumental noise, clock noise and Solar System planetary ephemerides (SSEs) uncertainties also alter the regularity of the signal. A large part of my work consist in studying the impact on SSEs error signal on PTA results. Pulsar Timing Array experiment is now led in 3 continental consortia (Europe/EPTA, North America/NanoGRAV and Australia/PPTA) that are grouped together in an international collaboration logically named International Pulsar Timing Array. In this context, PTA- France group, formed by researchers working at AstroParticules et Cosmologie (APC) and Unité Scientifique de Nançay (USN), produces competitive pulsar timing data from Nan �cay Radio Telescope (94 m equivalent dish diameter) and develops statistical analysis methods.

Mimicking black hole mimickers

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Black holes mimickers, e.g. boson stars, are compact objects with similar properties to black holes. The gravitational wave signal emitted by a binary of such putative objects during the inspiral phase is difficult to distinguish from the one emitted by a black hole binary. Nevertheless, significant differences might appear in the post merger signal. Inspired by the known behavior of black holes, neutron stars and boson stars we propose a toy model that captures potential characteristics of such systems composed by such mimickers. This model can be exploited to assess how well such signal could be recovered with gravitational waves observations from earth based detectors using standard templates. We find that if any of the black hole binary candidates in the O1/O2 catalogue released by the LIGO/VIRGO collaboration corresponded to such objects we could have detected it, enforcing our belief that those are indeed black hole binaries.

Simulation for realistic LISA configuration

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Gravitational Waves (GWs) has opened a new window for understanding the Universe. Laser interferometer space antenna (LISA) is a large mission to enhance the ability to observe GWs, in the low-frequency band (10^{-4} – 10^{-1} Hz), from various astrophysical sources such as galactic binaries, black holes binaries, supermassive black holes binaries, extreme mass ratio inspirals, ... LISA will give a massive contribution to investigate the entire Universe with GWs: formation and evolution of binary systems, the history of the Universe in high redshifts, gravity effects in the dynamical strong-field regime and the early Universe. In the preparation of the LISA mission, simulation is necessary to support the instrumental development of the mission and its data analysis. We have to take care of all the effects during the long-life mission such as instrumental noises, foreground, and misleading sources, as well as the data processing algorithms to improve the quality of the data. Our work is partly a contribution to this effort. In particular, we have been developed a simulator, LISANode, for implementing the current configuration of LISA mission with various noise sources and applying an up-to-date data processing algorithm, Time Delay Interferometry (TDI), for mitigating some dominant noises. In this poster, we focus on the noise generation in LISANode and the results of noise propagation through TDI. The results indicate a good simulation of LISANode with the current instrumental model, but need to be upgraded at very soon.

Suspended load transport in a small tropical catchment: data analysis and modeling

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Fine particles represent an important fraction of the mass of sediment transported by rivers [1]. Suspended load is therefore a significant contributor to the erosion of landscapes. Fine particles are often considered to travel through streams and rivers with minimal interaction. Yet, recent field campaigns demonstrate that fine particles interact with the bed through erosion and deposition [2]. Based on this observation, we develop a simplified model of suspended transport that accounts explicitly for the exchange of small particles between the river bed and the water column. This model involves three parameters: (1) a threshold water level above which the flow starts eroding fine particles from the bed, (2) an erosion rate that characterizes the intensity of sediment entrainment, and (3) a characteristic settling time accounting for sediment deposition. We then test the validity of the model against data collected in the Capesterre catchment, a small catchment (16.6 km^2) monitored by the Observatory of Water and Erosion in the Antilles (ObsErA). Located in Basse-Terre Island (Guadeloupe archipelago, lesser Antilles arc), this catchment is regularly exposed to floods induced by hurricanes and tropical storms [3][4]. The discharge and the turbidity of the river are measured with a time step of 5 minutes. Using insitu calibrations, we convert the turbidity signal into a suspended load concentration. The resulting data reveal that the transport of fine sediment is highly intermittent: the concentration of suspended particles CSL rises abruptly when the river height exceeds a threshold of the order of 25 cm, corresponding to a discharge of 5 m^3/s. The concentration decrease following the flood peak is more gentle. The resulting concentration-discharge curve takes the form of a counter-clockwise hysteretic loop, as commonly observed in many streams [5]. Using inversion methods, we calibrate the parameters of the model on a few isolated floods. The resulting model consistently reproduces field data and successfully captures the hysteretic behavior of the concentration-discharge loop. This approach might help to better constrain the temporal variability of sediment transport in small catchment.

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Submarine granular flows and generated tsunami waves: from laboratories experiments to simulation of Montagne Pelée flank collapses

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We simulate here granular flow experiments and the generated water waves as well as scenarios of different volumes for possible event of flank collapse of Montagne Peléee volcano, Martinique, Lesser Antilles. Our objectives are to assess the error made using numerical modeling when trying to reproduce granular flow dynamics and its deposits as well as the amplitude of the associated wave. For the laboratory experiments we try to assess the error without calibrating the models for each experiment and using the parameters suggested in the literature for the used material. Numerical simulations are performed using two complementary depth-averaged thin-layer continuum models because no complete models were available in the literature. The first model, SHALTOP, accurately describes dry granular flows over a 3D topography and may be easily extended to describe submarine avalanches. The second model, HYSEA, describes the subaerial and submarine parts of the avalanche as well as its interaction with the water column. However, HYSEA less accurately describes the thin-layer approximation on the 3D topography. Simulations were undertaken testing a single friction law, fixed friction angles, different debris avalanche volume flows and scenarios. Our study suggests that using the two models we are able to assess the shape and runout distance of the laboratory granular flows with error ranging from 1% to 44% depending of the scenario, and the amplitude of the generated waves with error ranging from 25% to 100%. We study also show that using a non-dispersive shallow water models for those type of events may lead to important overestimation of the generated waves amplitude. Comparison of simulations with submarine field data support the hypothesis that large flank collapse events in Montagne Pelée are likely to have occurred in several successive sub-events. This result has a strong impact on the amplitude of the generated waves, and thus on the associated risk, in a region known for its seismic and volcanic risks.

Effect of mass wasting on the topographic evolution of a mid-ocean ridge detachment fault footwall

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We present the preliminary results of the first author's Ph.D. project, entitled "Fluid-rock interactions in the context of mantle exhumation at slow-spreading ridges". At slow-spreading ridges, the new seafloor is commonly made of tectonically exhumed mantle, where hydrothermal reactions lead to the serpentinization of peridotites, the release of hydrogen and methane, formation of high pH fluids and carbonate-crystallization in the serpentinized basement. The objectives of the Ph.D. are to acquire new constraints on the hydrothermal fluid pathways, and on the fluid-rock reaction and exchanges in this tectonically-dominated MOR context, primarily based on data and samples collected in 2017 during ROVsmooth cruise to the SWIR near 64°E. The first few months of work have been focused on the study of High-Resolution bathymetry and ROV videos to constrain geological and tectonic setting of hydrothermal venting and carbonation in the footwall of an active axial detachment. This detachment exhumes serpentinized peridotites in its footwall and hosts the Old City hydrothermal field and carbonate deposits [1]. This work reveals the complex mass wasting structures and its role in channeling hydrothermal fluids to the seafloor. The top portion of the footwall includes $1-3$ distinct breaks in slope, corresponding to coherent mass-wasted blocks 200-1300 m wide and $2880-3500$ m long in along-slope direction. Steeper slopes between these blocks bear decametre scale erosional features which are lined by conical debris deposits. Both these eroded scarps, and intervening mass-wasted blocks are cut by smaller scarps, up to 120 m in downslope-offset and 600 m in along-slope direction, which are interpreted as most recent mass-wasting structures. Some of the scar surfaces do develop erosional and depositional features and others lack them suggesting that they are relatively younger. The Old City hydrothermal field is hosted in one of this relatively recent scarp, that cuts into a relatively high slope region (29°-33°), which may correspond to the eroded scarp of a large (several kilometers) landslide, or an eroded portion of the detachment fault surface. HR bathymetry is lacking to discriminate between the two interpretations. Overall, our observations indicate that the top of this detachment fault footwall is heavily modified by landslides and mass wasting structures play a role in channeling hydrothermal circulations associated with carbonation of the exhumed ultramafic rocks.

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Experimental modeling of the cooling of partially crystallized magma ocean: Application to the thermal history of terrestrial bodies.

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By the end of accretion, the temperature of terrestrial bodies is high enough so that their mantle is largely molten, forming an homogeneous magma ocean (MO). Because of efficient convective and radiative heat transfers, the MO is likely to crystallize quickly, producing a mixture of liquid silicate bearing crystals in suspension. In the case of the Moon, the late stage of the MO solidification is characterized by the crystallization of plagioclase lighter than the surrounding melt, and leading to the formation of a flotation layer. The large amount of anorthosite in the current lunar crust is an evidence justifying this scenario.

The present work develops an experimental approach to characterize and model the behavior of this kind of a floating lid of particles at the top of a convective body. We use a 30x30x5 cm^3 tank filled with a viscous fluid bearing PMMA beads. Both secular cooling and bulk radiogenic heating drive convection in a MO. Experimentally, homogeneous internal heating throughout the fluid is produced thanks to a modified microwave oven. Laser Induced Fluorescence method is used for temperature imaging, whereas the fluid velocity is measured by Particles Imaging Velocimetry.

We first consider the stability of a layer of light crystals at the top of a convective magma ocean. We identify four different regimes: (1) a partial erosion regime, (2) a total erosion regime, where the lid is totally unstable, (3) a deposition regime, where the bulk fluid is hot enough to let particles settle at the bottom of the tank, and (4) a coexistence regime, where particles settle at the top and at the bottom of the tank. We show that the inversion of the buoyancy of the beads relative to the fluid is not appropriate to explain their settling behavior. This result underlines that a special emphasis has to be put on the competition between the buoyancy of beads and the vigor of convection. Thus, a criteria derived from the balance between buoyancy energy of beads and energy carried out by the convective fluid yields a satisfying description of the influence of fluid motion on the stability of the flotation layer.

Unraveling the contribution of the western margin of the Altiplano plateau in North Chile (20°S) to Andean mountainbuilding

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The Andes are the case example of an active Cordilleran-type orogen. It is generally admitted that, in the Central Andes ($\sim$20°S), mountain-building started $\sim$50-60 Myr ago, close to the subduction margin, and then propagated eastward. Though suggested by some early geological cross-sections, the structures sustaining the uplift of the western flank of the Altiplano have been largely dismissed, and the most common view theorizes that the Andes grow only by east-vergent deformation along its eastern margin. However, recent studies emphasize the significant contribution of the West Andean front to mountain-building and crustal thickening, in particular at the latitude of Santiago de Chile ($\sim$33.5°S). The contribution of similar structures elsewhere along the Andes to the kinematics of the orogen is still poorly solved, because not yet well synthesized nor quantified. Here, we focus on the western margin of the Altiplano at 20°S, in the Atacama desert of northern Chile. We focus our work on two sites where structures are well exposed. Our results confirm two main structures: (1) a major west-vergent thrust placing Andean Paleozoic basement over Mesozoic strata, and (2) a west-vergent fold-and-thrust-belt involving Mesozoic units. Once restored, we calculate a minimum of $\sim$4 km of shortening across the sole $\sim$10 km-wide outcropping fold-and-thrust-belt. Further west, structures of this fold-and-thrust-belt are unconformably buried under slightly deformed Cenozoic units, as revealed from seismic profiles. By comparing the scale of these buried structures to those investigated previously, we propose that the whole fold-and-thrust-belt has most probably absorbed $\sim$15-20 km of shortening, sometime between $\sim$68 Ma (youngest folded Mesozoic layers) and $\sim$29 Ma (oldest unconformable Cenozoic layer). Preliminary (U-Th)/He thermochronological data suggest that basement exhumation by thrusting happened at the beginning of this $\sim$30 Ma time span. Minor shortening affecting the mid-late Cenozoic deposits indicates that deformation continued after 29 Ma along the western Andean fold-and-thrust-belt, but remained limited compared to the more intense deformation during the Paleogene. Altogether, the data presented here will provide a quantitative evaluation of the contribution of the western margin of the Altiplano plateau to mountain-building at this latitude.

Imaging the past and present Owen transform fault: preliminary results from the VARUNA seismic cruise

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The Owen transform fault in the northwest Indian Ocean is a $>$300 km-long active structure that constitutes the active plate boundary between Somalia and India. The first-order fault geometry was reached in the Early Miocene when the Carlsberg Ridge propagated westward into the African plate to open the Gulf of Aden. Presently, it accommodates $\sim$23 mm/yr of left-lateral strike-slip motion between the Sheba and Carlsberg spreading centers. The fault was recently surveyed in the Spring of 2019 during the VARUNA and CARLMAG cruises on BHO Beautemps-Beaupré, an oceanographic ship operated by the French Navy. Along with geophysical measurements (multibeam bathymetry, gravity and magnetic fields) a set of high-resolution seismic lines ($>$5000 km) was acquired across both the active and fossil traces of the fault between 9°N and 15°N. The area is largely buried under the distal Indus turbiditic sediments and therefore offers a fairly unique continuous high-resolution stratigraphic record of past regional tectonic events. Here we present the first multibeam map of the Owen Transform system. A remarkable transpressive ridge borders the active trace of the fault along most of its length. At the intersection with the Carlsberg Ridge, the Owen Transform marks an 11° bend characterized by $\sim$1200 m of seafloor uplift. Our preliminary interpretation of the seismic lines brings to light the key unconformities related to Global Plate Reorganization Events. Off the main fault, new data reveal the magmatic nature of the Varuna Bank and similar partially buried highs. These have likely grown in the very early stage of formation of the oceanic crust carrying them, although tectonic emplacement cannot be completely ruled out. Some of the highs show internal structure, which can be interpreted either as carbonate caps or layered volcanic formations. This dataset, combined with previous cruises, offers unprecedented coverage of a 1500 km-long transform corridor along the Arabia-India and India-Somalia plate boundaries.

$\delta_{11}B$ and B/Ca ontogenetic variability within *Globigerina bulloides*

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Understanding the atmosphere-continent-ocean carbon cycle and its associated oceanic carbon system is one of the keystones to face the Anthropocene's climate change. Since the 1990s the isotopic ratio of boron ($\delta_{11}B$) in calcitic shells of planktic foraminifera has proven to be a powerful geochemical proxy to determine the oceanic paleo-pH and its link to atmospheric CO_2 level over geological times [1], whereas the ratio B/Ca as proxy of the seawater carbonate chemistry is still questionable [2,3]. However, the use of planktonic foraminifera in paleoclimatic reconstructions requires calibrations of the pH-$\delta_{11}B$ relationships to correct what is known as "vital effect" [4]: each species controls differently its calcification process and consequently slightly modifies the seawater chemistry during biomineralization [5,6]. Moreover, shell size effect on $\delta_{11}B$ has been reported for some symbiont-bearing species due to photosynthetic increase of pH [7,8]. Calibrations for the symbiont-barren *Globigerina bulloides* have been already determined [9,10] but sparse data have been reported so far for the test size effect on $\delta_{11}B$ [11]. Here we measured the $\delta_{11}B$ of three different fractions (250-315, 315-400 and >400 μm) of *G. bulloides* sampled along the coretop PS97-122 from the Chilean margin (54.10°S, 74.91°W), by using a new protocol developed at IPGP and dedicated to small samples which couple a microsublimation technique and a micro-direct injection device (μ-dDIHEN [12]). Our preliminary results show significantly higher $\delta_{11}B$ values for the large fractions compared to the small ones, as found for symbiont-bearing planktonic species such as *Globigerinoides sacculifer* [7] and *Globigerinoides ruber* [8].

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Machine Learning applied to Greenland seismic signals

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Since the 2000s, global warming has been highlighted by many scientific proofs and the consequences start to be clearly identified. The acceleration of the Arctic's icecap melting is one of its major consequences and it generates more and more icebergs every year. This previously unseen situation leads us to understand quickly what are the mechanisms linked to the melting induced by polar glaciers dynamics. To answer that, seismology is an excellent tool as it allows to describe sources from long distance and to create an exhaustive catalogue of events. In polar region, seismic activity was first detected in the $90s$. Glaciers dynamics can be generated by different seismic sources type like basal slip, iceberg collision in the terminus, surface crevasse collapses and opening for instance. We focus on some of these events, mentioned as Glacial Earthquakes or Icequakes, which can generate seismic signal that can be recorded at distances of hundreds of km and are generally due to major iceberg calving (km scale). However, we must deal with more and more data to understand all these dynamics. Here we show how Machine Learning can help to classify seismic signals sources and build instrumental catalogues of ice-calving event in Greenland. We use these signals characteristics (amplitude, time, energy of the auto-correlation function, etc.) to create features for a machine learning algorithm. We choose to work with the Random Forest algorithm that we trained with the $1993 - 2013$ catalogue of the GLISN network: it gathers a lot of important events that occurred in Greenland which were recorded by the regional stations. For the validation part of the algorithm, we confront Icequakes signals with Earthquakes signals and we assess the precision and the robustness of the algorithm for different training configuration. The new exhaustive catalogue will allow a better understanding of the chronology of ice-calving events over a long time period. Mechanical modelling will be performed to try to retrieve the physical properties of the sources of most of the event in the catalogue. The combined detection and characterization of those events might help to under- stand better the mechanism favouring Arctic icecap melting.

Classification of seismo-volcanic signals of La Soufrière of Guadeloupe by supervised learning

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Seismic activity at La Soufrière volcano of Guadeloupe is composed of various transient signals, which are classified manually by the Observatoire Volcanologique et Sismologique de Guadeloupe (OVSG-IPGP) considering waveforms recorded at several stations. Although five main types of signals are recognized in the data analysis by the observatory (Moretti et al., 2020), only three main classes readily distinguishable on seismic traces during the daily analytical protocol have been catalogued: Volcano-Tectonic events, Long-Period events and Nested events, each related to a distinct physical process.
Automatic classification of seismo-volcanic signals of La Soufrière was performed by using an architecture based on supervised learning, available at github.com/malfante/AAA.
At first, we trained the model with the dataset given by the OVSG consisting of 845 available labeled events (542 VT, 217 nested and 86 LP) recorded in the period $2013-2018$. We obtained an average classification rate of 72%. We determined that the VT class includes a variety of signals covering the LP, Nested and VT classes. Reviewing in details the waveforms and the spectral characteristics of the signals belonging to the 3 classes we then introduced Hybrid events and also defined a monochromatic class of LP signals, thus matching the full description of signals provided in Moretti et al. (2020).
Then, a new model was trained with 5 classes and tested. We obtained a much better classification average rate of 84%. The classification is excellent for Nested events (93% of accuracy and precision) and Tornillo events (93% of accuracy and precision). The classification of VT events (90% accuracy, 89% precision) and LP events (86% accuracy, 82% precision) were also very good. The most difficult class to recognize is the Hybrid class (64% accuracy, 69% precision). Hybrid events are often mixed with VT and LP events. This may be explained by the nature of this class and the physical process that includes both a fracturing and a resonating component with different modal frequencies.
Machine learning is a powerful tool to handle large datasets. From a dataset built manually, the processing we applied allowed to obtain a reliable automatic classification by refining class definitions. This has important implications for observatory data processing during unrest and eruptive activity.

Neural Network Interpretation as a Denoising Tool for Automatic Tremor Location

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We present a new methodology for tremor location, aiming at improving the identification of events close to or below the noise level. This methodology relies on neural networks to denoise tremor waveforms, resulting in cleaner signals with more structure and impulsivity. We find that these denoised waveforms can be used for event location with standard array-based techniques. Our approach consists in two main, consecutive steps. First, we feed waveform spectrograms to a neural network that has been trained to identify tremor, and we rely on neural network interpretation to denoise the raw waveforms. Second, these cleaned waveforms are used as input in an array-based location phase, that relies on the cross-correlation of seismic envelopes to locate tremor events. As proof of concept, we apply this approach in the Cascadia subduction zone. We attempt to locate tremor events during the 2018 slow slip underneath Vancouver Island, Canada. Analyzing a well- studied area allows us to validate our methodology by comparing our results with existing catalogs. We identify tremor patches coherent with existing literature, which validates the assumption that our denoising procedure preserves the events' move-out patterns. Our approach allows us to extract events below the noise level and to identify more events than in existing catalogs.

Towards a high resolution paleosecular variation records of the last interglacialglacial cycle in Central Europe : the loess-paleosol sequence of Dolni Vestonice.

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Loess sequences cover around 10 percent of the Earth's surface and are often studied to recover records of climatic variations. The ability of loess sequences to record a reversing magnetic field is known since the early 1980's from Chinese loess and paleosol deposits. The use of loess sequences as archives of paleosecular variation would improve the geochronology of these Quaternary continental deposits beyond the limits of radiocarbon and luminescence age determinations and at higher resolution than the geomagnetic polarity timescale. Lastly, the correlation between loess deposits and with other records of paleosecular variation, paleoclimate and paleoenvironments would be improved. We present here a full paleomagnetic study of the Dolni Vestonice (DV) loess sequence located in the Moravian region of the Czech Republic. The study's objective is to show whether European loess have the ability to record the Earth's magnetic field at the resolution of secular variations both in term of direction and intensity. Paleomagnetic alternating field (AF) demagnetization experiments were conducted on 212 oriented specimens from the DV sequence. Characteristic remanent magnetizations (ChRM) were isolated through a principal component analysis (PCA) and the Fisher mean of the population of ChRMs yields a declinations and and inclinations of 15.2° and 64.1°, respectively, with a 95$\%$ confidence interval of 1.7 (ranging from -101.3° to 58.3° for the declinations and 31.3° to 87.6° for the inclinations). Relative paleointensity (RPI) proxies were established using all NRM normalizers available including magnetic susceptibility and demagnetizations of anhysteretic remanent magnetization (ARM) and isothermal remanent magnetization (IRM). The reliability of the RPI proxies is being investigated with respect to the sequence's stratigraphy and magnetic mineral assemblage and through comparison with regional and global temporally coeval RPI records.

Geodynamo modelling of double diffusive convection

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The secular cooling of the core and its cristallization induce thermal and chemical inhomogeinities in its external liquid part. The chemical and thermal transport equations are of the same form but they are characterized by diffusivities, which differ from one another to several order of magnitude. This specific kind of convection is called double-diffusive convection and was deeply studied in the case of ocean, where salinity and heat provide two different sources of density anomalies. Unfortunately, only a limited number of studies consider these two sources of buoyancy in the case of planet interiors. The most common approach, called codensity, considers that only one transport equation has to be solved. Recent improvements in numerical methods enable the study of the double-diffusive convection. In the present work, we perform a series of 70 numerical dynamo models varying both the total buoyancy power and the fraction between thermal and chemical convection. We show that simulations with a more powerful chemical convection become multipolar with a weaker total convection than the thermal one. To better understand the breakdown of the dipolarity, previous studies propose that the dipole collapse might be due to an increasing role played by inertia in the dominant force balance characterised by a parameter named the local Rossby number Ro_L. The relevance of this parameter applied to the geodynamo has been however questionned. Here we find that Ro_L indeed poorly captures the transition between dipolar and multidipolar dynamos. Instead the symetry properties of the convective flow characterised by the fraction of the kinetic energy density contained in the equatorialy symetric part of the flow and the total kinetic energy density proves to be a significant parameter to quantify this transition.

Modelling and interpretation of the fast variations of the Earth's magnetic field

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Geomagnetic field models derived from satellite data, obtained through the processing and analyses of a massive amount of vector magnetic data, now cover more than twenty years. The field measured at the surface of the Earth results from the contributions of multiple external and internal sources. The description and understanding of the fast dynamics of the geomagnetic field, in particular the core field, requires for field models to describe more and more sources with deep mathematical and physical accuracy. To address this increasing complexity as well as ever larger amounts of available data, we use a sequential modelling approach (a Kalman filter), combined with a correlation based modelling step. In order to reach high temporal resolution for the core field (close to the year), a sequence of snapshot models, 3-months apart, has been built. The main characteristics of the derived series of Gauss coefficients are the same as those of recently released field models based on classic modelling techniques. The results we obtained show the importance of a careful calibration of the Kalman prediction step as well as the application of the Kalman smoother at the end of the modelling. We identified induced fields in the core as the main limitation for an increased resolution of the core field. We will present how these currents have been handled in a recent version of the model. We also discuss the future steps that should allow us to progress further in the representation and understanding of the Earth's core magnetic field.

New insights into changing palaeoenvironmental conditions in a sub-profile of the Nussloch loess-palaeosol sequence (P9), detected by in-depth environmental magnetic and diffuse reflectance spectrometry methods

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Loess and palaeosol sequences (LPSs) are widespread terrestrial climatic archives in the northern hemisphere covering almost 10% of its terrestrial surface [1]. LPS can archive several glacial (cold and dry) and interglacial (warm and humid) cycles. In Western Europe, the Nussloch LPS, located south of Heidelberg in the Rhine River Valley has been extensively studied by multi-disciplinary approaches (*e.g.* [2,3,4,5,6,7,8]), providing a record of millennial-scale stadial and interstadial cycles of the last Glacial Period [9,10]. The present study targets an in-filled depression flanking the Nussloch loess ridge where previously studied P4 and P8 profiles where sampled. The depression is in-filled with loess, and palaeosol horizons, cross-cutting the depression's surface. Our objective is to understand the timing and mechanism by which the depression was filled, providing insight of local environmental change induced by climate change and time required for soil formation. Two in-filling mechanism hypotheses can be tested: (i) infilling by slope debris or (ii) infilling by accumulation of aeolian dust. A vertical profile (P9) was sampled where the depression displays a maximum thickness. The P9 profile is 5 meters in depth, and bulk material was continuously sampled at a 5 cm interval rendering 95 bulk samples. Here we provide first results of our ongoing study, and more specifically observations stemming from the integration of magnetic mineral analyses and diffuse reflectance spectrometry (DRS). DRS derived proxies $a*$ (redness) and the Q7/4 ratio ([11] the quotient of 700 nm and 400 nm backscattered reflectance) increase across two stratigraphic horizons identified as palaeosols in the field. The combined colorimetric and mineral magnetic data sets complemented by anisotropy of magnetic susceptibility analyses and planned geochronological determinations (OSL, charcoal) will shed light on the timing and mechanism of infilling of the depression, and consequently how climate change impacted the local environment.

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Characterization of black schist occurences and sulfur emissions in the upper Trishuli Valley, Central Nepal

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Several magneto-telluric surveys have revealed mid-crustal conductive regions in the Main Central Thrust (MCT) zone, partially associated with seismic activity. The high polarizability and frequency-dependent electrical conductivity of black schist in this zone has suggested the role of this rock-type bearing graphite to the crustal conductivity structure of the MCT zone. Electrical anomalies have also been detected in the vicinity of the numerous hydrothermal systems located in the MCT zone, sometimes associated with sulfur deposits. Besides, these systems exhibit large carbon dioxide (CO_2) emissions, sometimes carrying hydrogen sulfide (H_2S) to the surface. This CO_2, likely produced in the upper crust by metamorphic reactions at more than 5 km depth, has been strongly affected by the 2015 7.8 Mw Gorkha earthquake in Central Nepal. Based on a multidisciplinary approach, we characterized the occurrences of graphite-rich black schist and H_2S emissions in the Upper Trishuli Valley, Central Nepal. At two black schist outcrops we studied: (1) geology and petrology with a combination of X-ray diffraction analysis, scanning electron microscopy and Raman spectroscopy; (2) geochemistry with sulfur isotopes determination ($\delta_{34}S$); and (3) sub-surface geophysical soundings using Electrical Resistivity Tomography (ERT), Induced Polarization (IP), and, for the first time, Spectral Induced-Polarization (SIP). Gaseous and dissolved sulfur emissions are characterized, by the measurement of H_2S flux at the Syabru-Bensi hydrothermal system based on the accumulation chamber method and by the measurement of dissolved sulfate content and $\delta_{34}S$ values at various hot spring locations of the valley, respectively. Our result shows that the black schist outcrops are characterized by spatial variations of graphite content and conductive signals imaged by ERT, IP and SIP. Associated with spatial variations of metamorphic CO_2 flux over 5 to 6 orders of magnitude, H_2S fluxes on the ground range over more than 3 orders of magnitude (from 0.1 to $>$10 g.m^{-2}.d^{-1}), revealing interesting relationships with CO_2 fluxes. The obtained $\delta_{34}S$ values also help us to constrain the origin of sulfur in this area. All unprecedented combined observations suggest that carbon and sulfur, under various forms, are present in the MCT zone and might play an essential role during the Himalayan seismic cycle.

Uncovering the sulfur isotopic composition of fluids from HP-metamorphic slab

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In order to better understand the fate and behavior of sulfur in subduction zones and the sulfur isotopic signature in arcs, we analyzed the ^{33}S/^{32}S, ^{34}S/^{32}S and ^{36}S/^{32}S ratios (expressed as $\delta^{34}S$ = ($^{34}R_{sample}$/$^{34}R_{std}$–1)*1000; $\Delta^{33}S$ = $\delta^{33}S$ – ((1 + $\delta^{34}S$/1000)$^{0.515}$–1)*1000 and $\Delta^{36}S$ = $\delta^{36}S$–((1 + δ^{34}/1000)$^{1.89}$–1)*1000) in eclogite breccias, serpentinites, metasediments from the Lower Shear Zone (LSZ) of Monviso (Alps, Italy) recording evidence of a channelized fluid flow at the metamorphic peak $\sim$550°C and 2.6 GPa, as well as metabasalt and metagabbros unaffected by these fluids. The $\delta^{34}S$ ranges from -12.4 to 20.8 $\pm$ 0.2‰, $\Delta^{33}S$ from 0 to 0.07 $\pm$ 0.01 and $\Delta^{36}S$ from -0.3 to 0.4 $\pm$ 0.2‰. Metabasalt and metagabbros non-affected by fluids have a $\delta^{34}S$ between 0 and 2‰that suggests a magmatic origin and/or hydrothermal alteration on the seafloor whereas other samples in the LSZ are ^{33}S-^{34}S-enriched compared to the former, except a metasediment being ^{34}S-depleted. Furthermore, the absence of sulfate and the magnetite precipitation in the LSZ suggest that the fluid was reduced, with sulfur as HS or H_2S. We can interpret our data using at least two sources of S that were mixed in the fluid. A first one is ^{33}S-^{34}S-enriched and could derive from sulfates from either evaporite of the Dora Maira unit or from antigorite breakdown ($\delta^{34}S \sim$ 21‰). The second source is ^{34}S-depleted and ^{33}S-enriched and could be typified by sulfate reduced by microorganisms on the seafloor in sediments and altered oceanic crust. This study clearly illustrates that arc lavas could have variable $\delta^{34}S$ from negative values (biogenic sulfides in altered oceanic crust and sediments) to positive values (evaporite and/or antigorite breakdown).

From carbonates to possible organic compounds at high pressure: the carbon journey at the Monviso meta-ophiolite

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The Monviso meta-ophiolite (Western Alps, Italy) is an oceanic lithosphere relict that experienced high pressure and temperature metamorphism (eclogitic facies, P-T conditions of 550-620°C and 1.9-2.6 GPa) during the alpine subduction. Despite its complex metamorphic history, the massif preserves a complete section of the Tethysian oceanic lithosphere. Here we investigate the mechanisms of carbonate solubilisation at high-pressure/high-temperature by studying a suite of meta-serpentinites and meta-ophicarbonates outcropping near a paleo-oceanic detachment fault in the massif. We show that serpentinites preserve typical features related to high pressure metamorphism, such as secondary olivine and titanoclinohumite formed at the expense of antigorite (high pressure serpentine variety), brucite and magnetite. The meta-ophicarbonates contain three types of primary abyssal carbonates – namely calcite, magnesite and dolomite – showing different degrees of decarbonation. In contact with antigorite and secondary olivine assemblages, magnesite displays coronitic textures made of magnetite-calcite and tremolite-talc-chlorite assemblages, while dolomite is partly replaced by calcite, magnetite and chlorite assemblages. The calcite can present complex coronas made of andradite, magnetite and talc. These coronas are associated with poorly organized carbonaceous matter, characterized by microspectroscopy (FTIR and Raman) and microscopy (SEM). This observation suggests changes in carbon redox state (*i.e.* reduction of carbonates) as well as a partial retention of carbon in the form of graphitic material during meta-ophicarbonates devolatilization at high pressure. The reactions leading to carbonate reduction and the amount of carbon devolatilized during these processes will be further investigated via an innovative combination of isotope tracers (C, Fe, Cu, Zn) sensitive to the mobility and redox state of carbon in metamorphic fluids.

Thermal analyses of biocarbonates as part of the search for traces of life on Mars

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The search for organic compounds on Mars is currently the main strategy to highlight a potential extinct or extant life on this planet. However, the Martian environmental conditions (*e.g.* radiations, high level of oxidants) can lead to their degradation. An alternative method to detect clues of life is to search for the presence of biominerals, probably more resistant in this environment. The objective is therefore to be able to distinguish bio- and organo-minerals from their abiotic counterparts by using instruments that can carry out in situ measurements on Mars. Differential thermal analysis (DTA) coupled with gas chromatography and mass spectrometry (GC-MS) share similarities with space instruments dedicated to in situ analyses on Mars, such as SAM (Sample Analysis at Mars) aboard the rover Curiosity or MOMA (Mars Organics Molecule Analyser) from the ExoMars 2020 mission; The both instruments are gas chromatographs coupled to mass spectrometers. Several space missions revealed the presence of carbonates at the surface of Mars. Carbonates are abundant minerals in the Earth's rock record that were mostly formed by biological activity, both by biologically controlled mineralization and biologically induced mineralization. DTA analyses show differences of more than 20°C in phase transition temperatures between natural or laboratory biocarbonates and abiotic carbonates. Additional analyses by pyrolysis-GC-MS reveal in biocarbonates a wide variety of organic fragments characteristic of organic matter with a biological origin. Thus, DTA-GC-MS would have the potential to discriminate biocarbonates from abiotic carbonates and would lead to a better understanding of the physico-chemical properties of these minerals. This approach may eventually be used for the search for possible records of life on Mars.

Marine tephrostratigraphy: a powerful geological tool to better understand the eruptive history of Montagne Pelée in Martinique, Lesser Antilles

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Understanding the past eruptions of volcanic systems in term of frequency, chronology, geochemistry and eruptive dynamics is a fundamental and crucial point for the assessment of future volcanic risk on society and climate. But, quite often scientists have a narrow and fragmented view about volcanic and magmatic history in the past, due to the sedimentary gaps in the land records especially in regions affected by high erosion rate and lack of outcrops (tropical zones). However, tephrostratigraphy of marine deposits can represent a most useful tool to much better constrain the chronology and the features of lacking eruptions. In this perspective, we are studying pristine fragments of volcanic glasses (*e.g.* tephra) recorded in two sedimentary marine cores, which have been collected offshore Martinique, on the western and eastern side of the island during the IODP Expedition 340 (April 2012, Joides Resolution) and the CASEIS cruise (2016, N/O Pourquoi Pas?), respectively. With these two locations, we hope to access to the complete history of Montagne Pelée during the last 120 ka and to identify the most significant volcanic events in the central Lesser Antilles Arc. For this purpose, we firstly distinguished tephra layers s.s. (primary deposits) from the reworked volcanoclastic layers (secondary deposits) and then developed and implemented an assay protocol for the best analysis of tephra using the morphological (*i.e.* SEM) and in-situ geochemical characterization (*i.e.* EPMA and LA-ICP-MS-MS). We show here that this multidisciplinary investigation method that combine the use of tephrochronostratigraphic ($\delta 18O$), observations and the fine geochemical analysis is a great potential tool to more correctly reconstruct the magmatic history of active volcanoes and to more precisely pinpoint the time synchronous marker horizons (isochrons) for each volcanic event or phase (*e.g.* the new Grand Rivière phase of Montagne Pelée during the period $22 - 29$ ka). Consequently, these new insights could help to establish a potential causal chain of events, namely to correlate the eruptive events with the paleoenvironmental and paleoclimatic archive. In this regard, future work concerns the estimate of the impact of volcanic (ash) eruptions on the marine ecosystem by studying the biocalcification of planktonic foraminifera in these same marine sedimentary sequences.

Dynamics of the magmatic reservoir leading to the $2010-2013$ eruption of Kizimen volcano in Kamchatka (Russia)

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My PhD is focused on the dynamics of magmas of two volcanoes in Kamchtaka (Russia): Bezymianny and Kizimen and on correlating disrupting events prior to eruptions with monitoring signals. These volcanoes have been chosen because their eruptions have been well monitored by the Institute of seismology and volcanology of Petropavlovsk, as the 2019 eruption of Bezymianny or the $2010-2013$ eruption of Kizimen, on which this study is focused on. We begin our work with the eruption of Kizimen. This eruption is the first historical magmatic eruption of Kizimen; it produced $0.4\,\mathrm{km}^3$ DRE of magma with the extrusion of a lava dome and its evolution to a lava dome flow. Numerous block- and ash-pyroclastic density currents were produced. A model proposed by Auer et al. (2018) [1] for this eruption suggests that an injection of basaltic magma in a dacitic reservoir occurred at depth in 1963 associated to a seismic crisis. Then, after a long period of dormancy, a phase of unrest begun in April 2009 characterized by 1.5 years of seismicity before the eruption. A rapid mingling of the magma components in the reservoir is at the origin of the eruption that began on November 2010 ejecting a not well mixed magma attested by the abundance of banded andesites and dacites. Dominant phenocryst phases include plagioclase, amphibole, orthopyroxene, Fe–Ti oxides (and trace amounts of olivine, quartz and apatite). A 3-week fieldtrip has been done during the summer 2019 on Kizimen and Bezymianny volcanoes to collect the samples: dacites, silica-rich andesites and mingled samples emitted during this eruption. A petrological and mineralogical study of the samples is presented. Then, the methods used to decipher the architecture and mobility of the magmas in the plumbing system will be presented; orthopyroxenes and plagioclase crystals will be studied by combining a crystal system analysis with timescales estimation of disrupting events prior to eruptions, using $Fe-Mg$ interdiffusion modeling. These results will be correlated with the monitoring data. For this, I will benefit of the experience that I have acquired during my master thesis on four Plinian eruptions ($18-9$ ky BP) of a central volcano in Dominica.

References

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Understanding the link between timescales of magmatic processes and unrest at La Soufrière de Guadeloupe

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Using petrology to constrain the pre-eruptive crystal storage timescales gives an insight into the magmatic mush system. Observing how timescales vary with eruption style is important for understanding volcanic unrest. We focus our work on La Soufrière de Guadeloupe, which in the last 9150 years has exhibited a variety of magmatic explosive eruption styles from Vulcanian to Plinian style eruptions. Unrest at La Soufrière has increased gradually over the last 25 years, with the strongest seismic event since the $1976-77$ volcanic crisis recorded in 2018. Relating unrest to magmatic recharge timescales and eruptible melt production may help us understand what eruption style the unrest could be building to. Using $Fe-Mg$ diffusion in pyroxenes from juvenile eruptive products, we modelled pre-eruptive crystal storage timescales for the last magmatic eruption in $1657CE$ (Vulcanian), $1010CE$ (Plinian), $720BCE$ (Strombolian) and the first explosive eruption $5680BCE$ (Plinian). By using greyscale backscattered electron images (BSE) as a proxy for $Fe-Mg$ composition, which varies due to crystal-melt diffusion, we demonstrate timescales between recharge and eruption range from days to years at La Soufrière. Preliminary results indicate the $1657CE$ began with recharge six months before the eruption; beginning the mush unlocking process. In comparison, the $5680BCE$ Plinian eruption shows rapid timescales ranging from days to weeks. We are developing a probability density function to better constrain the timescales and statistically estimate the timescale error. These results show that the La Soufrière mush system produces eruptible magma quickly and that large explosive eruptions can have a rapid onset. Linking magmatic timescales to observable unrest monitoring, such as seismic swarms, deformation and magmatic gas emissions, will indicate for each eruption style, timescales for recharge magma arrival and eruptible magma production. This has important implications for detecting precursory activity, early warning systems and crisis response and management.

Magnetic signature of a tectonic dominated hydrothermal area (49.25°E) at the ultra slow spreading ocean ridge, SWIR

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Particular reaction and alteration processes in hydrothermal areas located in the ocean ridges usually change rocks' magnetic properties, which in turn makes magnetism a useful method to study hydrothermal areas. Autonomous Underwater Vehicle (AUV) has b een used to collect near bottom magnetic data at a detachment fault controlled hydrothermal area of Southwest Indian Ridge (SWIR). Original magnetic anomaly revealed that there are both negative anomaly and positive anomaly in this area. We used three dime nsion inversion method to inverse its magnetization distribution and obtained tapered stockwork zone and cannular stockwork zone in negative anomaly site and positive anomaly site, respectively. Contacting with the evidences of rock properties and magnetic properties of rock samples, we concluded that this hydrothermal area is composed of both basalt hosted site and ultramafic hosted site and also summarized two situations that both kinds of hydrothermal areas can be seen in the tectonic dominated segments.

Development of chlorine stable isotopes as a new tool to unravel the variations of hydrothermal activity on volcanoes: application to la Soufrière de Guadeloupe

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Closed conduits volcanoes (*i.e.*, most andesitic arc volcanoes) emit gases with different chemical compositions compared to open conduits volcanoes (*i.e.*, most basaltic volcanoes). Noticeably, when compared to pure magmatic gas compositions emitted by open eruptive vents, fumarolic gases from closed conduits volcanoes have water contents that are significantly higher (>95$\%$ versus 60-80$\%$), as well as SO_2 and HCl contents that are significantly decreased due to their entrapment by waters (resulting from their high solubility in H_2O). These differences result from the interaction with waters and rocks of the magmatic gases through their pathways to the surface in volcanic closed conduits, the so-called scrubbing effect. However, despite its crucial role on interpreting the chemical composition of volcanic gas emissions worldwide, it is still difficult to quantify the effect of scrubbing on the respective volatile species involved. Chlorine is moderately soluble in magmas, highly soluble in waters and, unlike most other volatiles, is considered chemically non-reactive. Such combination of geochemical features can be used to characterize the origin of magmas, their differentiation and degassing (like usually done using major volatile compositions), but also, most uniquely, Cl can be used to inimitably trace interactions between gases and aqueous fluids. Importantly, considering current knowledge on chlorine isotopes systematics, large Cl isotope fractionations should only occur during evaporation, boiling and/or vapour condensation in volcanic systems. This thesis aims to use for the first time chlorine isotope compositions ($\delta^{37}Cl$) to quantify the amount of primary emitted HCl that have been scrubbed by subsurface waters, and to possibly extrapolate to other volatiles that are more routinely measured in volcanology. By applying this new methodology to current and historical fumarolic samples of La Soufrière de Guadeloupe volcano ($NaOH$ Giggenbach bottles, condensates from 1998 to present), we anticipate that the spatiotemporal $\delta^{37}Cl$ variations will help to precise the hydrothermal and magmatic activity of this volcano through time. Preliminary data show that the two sampled fumaroles, Napoléon Nord and Cratère Sud Centre, seem to have systematically different $\delta^{37}Cl$ values of about $+1$ and $+8$‰ (n=10), suggesting that condensation-revolatilization processes occur with variable intensities on these two fumaroles. We will present experimental data to help quantifying the effects of these processes.

Towards micromechanics-based numerical models of brittle deformation

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A detailed understanding of the processes involved in strain localization within the brittle crust is critical in the study of the structure formed at the plates boundaries. Mountain ranges and sedimentary basins are indeed usually shaped by cumulative strain across fault systems. At the scale of the brittle crust as well as at the scale of the laboratory experiment, faults are known to be the result of distributed damage growth and coalescence. Damage build-up is however missing from the brittle deformation models used in long term tectonics evolution models (LTTEMs) that instead prescribe a modified Mohr-Coulomb plasticity criterion to model the upper crust as an elasto-plastic material. This approach was shown to to show a great sensitivity to unconstrained empirical parameters and does not account for the strain rate dependence of damage models. After showing how damage can be linked to the rheology of the upper crust in the Sandia mountain range (New Mexico, USA), we present a way to design a new generation of models indexing the nucleation of a fault to the growth and coalescence of an initial population of flaws. The continuum damage model of Ashby and Sammis (1990) was used to formulate contitutive relationships between stress and strain, as well as a damage growth rate in order to implement a damaged brittle rheology into the LTTEM SiStER code. The model setup was modified to perform numerical analogs of triaxial press laboratory experiments, as benchmarks for further validation of the micro-mechanical model. Preliminary results give very promising behaviors with the emergence of (1) a weakening of material elastic properties associed with damage growth, (2) a strain rate dependence of the deformation related to the activation of a brittle viscosity as damage increases.

Effect of pore collapse and grain crushing on the frequency dependence of elastic wave velocities in a porous sandstone

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A saturated Bleurswiller sandstone, of 25% porosity, was compacted by increasing the confining pressure over the critical pressure P* which characterizes the onset of pore collapse and grain crushing. The frequency-dependence of the Young's moduli were measured before and after the compaction using forced-oscillation method in a triaxial cell. For the intact and compacted samples, we observed one dispersive transition within the seismic band (0.01-100 Hz). The dispersion is consistent with crack-topore squirt flow, making the transition from the relaxed to the unrelaxed fluid-flow regime. The induced compaction shifted the critical frequency of the squirt-flow dispersion towards higher frequencies, thus moving it out of the seismic band and allowing Biot-Gassmann to fully apply. This result is a consequence of an increase in the crack aspect ratio after compaction. In addition, the dispersion of elastic modulus after compaction increases from about 25% to 30%, related to the increase of crack fraction.

Nature of oceanic lithosphere across the Equatorial Fracture Zones in the Atlantic Ocean using seismic tomography

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The Equatorial Fracture Zones in the Atlantic Ocean have played fundamental role in the breakup of Africa and Brazil. It has been suggested that the lithosphere beneath these fracture zones is cold. However, the nature of these fracture zones remains unknown. The ILAB SPARC profile1 extends 850 km with 50 OBSs and 2867 airgun sources, crossing the St. Paul and Chain Fracture Zones and Romanche Transform Fault. From north to south, the age contrast cross St. Paul is 70 Ma and 40 Ma, that cross Romanche is 40 Ma and 7 Ma and that cross Chain is 7 Ma and 24 Ma. The seismic data shows that the mantle refractions can be recorded at offsets more than 700 km, which can sample the lithosphere deep to $\sim$80 km below seafloor. The mantle refractions and first order multiples are picked and inverted using seismic tomography. The tomographic result reveals a strong correlation between P wave velocity and the age of lithosphere. Below Moho, the inverted model shows normal velocity for lithosphere north of St. Paul and low velocity (< 7.8 km/s) beneath Romanche and south of Chain. The low velocity anomaly up to 20 km depth beneath Romanche may indicate the penetration depth of the Romanche Transform fault.

From secondary microseism to body-wave tomography

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Secondary microseisms are ground vibrations generated by ocean gravity wave interaction. The purpose of this study is to perform P wave seismic tomography using secondary microseism body waves. We use seismic vertical component recorded by the Alaska array to assess P wave velocity models for the eastern Aleutian arc. In order to extract body waves, we first calculate daily beams and we select beam maxima corresponding to epicentral distances ranging from $30\circ$ to $90\circ$ from the center of the array. These epicentral distances correspond to teleseismic P waves. Then we keep only beam maxima showing a signal-to-noise ratio larger than 2. As several sources can act simultaneously, we apply Blind Source Separation technique (BSS) to isolate signals generated by different sources. We apply this method on a coarse grid and then refine the source location by applying the same method on a fine grid. We then extract relative travel times between stations of the array for each source. Finally, we invert the relative travel times to estimate body wave velocities in the region covered by the seismic array. Using this approach, we demonstrate that relative travel times obtained from secondary microseisms can be used for body-wave tomography studies.

Modeling spectral and directional soil reflectance in the solar domain (400-2500 nm) as a function of soil moisture content

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This PhD, which results from a collaboration between IPGP and ONERA in Toulouse, follows the exploratory work by Aurélien Bablet in the frame of his PhD thesis (IPGP-ONERA). On this occasion, he developed a radiative transfer model called MARMIT (MultilAyer Radiative transfer Model of soIl reflectance), which was one of the first physically-based model to predict soil reflectance as a function of soil moisture content (SMC). The inversion of MARMIT enables to assess soil surface humidity, an important variable of the critical zone for many domains such as agriculture, hydrology or planetology, remotely. The main objective of this PhD is the improvement of the MARMIT model and its multi-scale validation using hyperspectral data: field measurements, airborne images (metric spatial resolution), and satellite images (decametric spatial resolution). The MARMIT model depicts a wet soil as a layer of dry soil covered with a thin slab of pure liquid water. A multi-reflection process takes place in the water film. The reflectance of the wet soil explicitly depends on two parameters: L, the thickness of the water layer, and ϵ, the fraction of ground covered by water. Assuming that the reflectance spectrum of the dry soil is known, the parameters L and ϵ can be retrieved by minimization of the least-square difference between the measured and predicted reflectances. Then, these parameters are linked with SMC by an empirical calibration relation that differs from one soil to another. The dependency of this calibration on the soil type is a current limitation of the MARMIT model for an application to remote sensing.

A main slip partitioning system in the sedimentary wedge of the Lesser Antilles Subduction Zone

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At the Lesser Antilles Subduction Zone (LASZ), the American plates subduct under the Caribbean plate at a slow rate of $\sim 2\,\mathrm{cm.yr}^{-1}$. At the front of the LASZ, the Barbados accretionary wedge (BAW) is one of the largest accretionary wedges in the world. The width of the BAW decreases northward, owing to the increasing distance to the sediment source (Orinoco river) and the presence of several aseismic oceanic ridges, in particular the Tiburon ridge, that stops sediment progression. The curved shape of the plate boundary leads to a strong spatial variation in convergence obliquity, ranging from 75° at the Puerto Rico trench to $\sim 0^\circ$ in the Guadeloupe-Martinique sector. In the northern part of the LASZ, the strong obliquity is accommodated in the sedimentary wedge by a left-lateral strike-slip fault, the Bunce fault. In the Guadeloupe-Martinique sector, a left-lateral strike-slip fault, the Seraphine fault, has also been observed in the BAW despite the low obliquity. Our study aims to understand how slip partitioning is accommodated in the northern LASZ, in the area (approximately from 17°N to 18.5° N) located in between the mapped Bunce fault and Seraphine fault traces. New high-resolution bathymetric data (gridded at 50 meters), CHIRP data and 48 channels seismic reflection profiles were acquired over the BAW in the Guadeloupe-Martinique sector during the CASEIS cruise ($10.17600/16001800$) conducted in 2016 with the IFREMER vessel N/O Pourquoi Pas? We present results from the analysis of these new data set, complemented by existing bathymetry and seismic reflection data acquired by several previous cruises. CHIRP data show evidence of folding of recent sedimentary units, which are linked to the Seraphine fault, supporting the idea of recent activity. The data also reveal a relay zone in the 17°- 18.5°N area. The two large left-lateral forearc faults - Bunce fault and Seraphine fault - could thus be connected through a transpressive domain coinciding with the transition between strong and weak convergence obliquity. Overall, slip partitioning within the forearc domain of the LASZ would extend over about 700 km from the western tip of the Bunce fault to the southern termination of the Seraphine fault offshore Martinique.

From Corinth gulf extension to Ionian subduction/collision (W. Greece): micro-seismicity survey to constrain local tectonics and regional geodynamics

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The North-Eastern zone of the Gulf of Corinth in Greece is characterized by the rotation of a micro- plate in formation. The Island Akarnanian Block (IAB) have been progressively individualized since the Pleistocene (less than ~ 1.5 My ago). This micro-plate is the result of a larger-scale tectonic context, with on one side the N-S extension of the Gulf of Corinth to the East and on the other side the Hellenic subduction to the South and the Apulian collision to the West. To the Northeast, the IAB micro-plate is bounded by a large North-South sinistral strike-slip faults system, the Katouna-Stamna Fault (KSF) and by several normal faults. To the North, normal faults reach the limit between Apulian and Eurasian plates and to the East they form the East-West graben of Trichonis lake. Although the structures and dynamics behind the Gulf of Corinth extension are today relatively known, nevertheless, the set of faults linking the Gulf of Corinth to the Western subduction structures remain poorly studied. The seismicity recorded by the Greek national network shows discrepancies regarding to the faults mapped on the surface. At the end of 2015, a new micro-seismicity campaign started with the deployment of a temporary seismological network in an area ranging from the Gulf of Patras to the Amvrakikos Gulf toward the North. This network includes 17 seismic stations, recording continuously, added to the permanent stations of the Corinth Rift Laboratory (CRL) and of the Hellenic Unified Seismic Network (HUSN). The analysis of the seismological records is still in process for the 2016 and 2017 years. Our study consists first in picking the P- and S- waves, and then to precisely localize the seismic events recorded by our temporary seismological network combined with the permanent ones. We will present here the event location map obtained for the $2016-2017$ period, a new seismic velocity model, and focal mechanisms. The seismic activity including thousands of events, is characterized by the presence of numerous clusters of few days to few weeks duration. The clusters are analysed in detail by relative relocations in order to appraise their physical processes and their implications in the fault activity. We will discuss the deformation mode of the region and build a seismotectonic model consistent with the regional geodynamics and observations.

Mass transfers associated with the 2010 Mw 8.7 Maule earthquake by the GRACE mission

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Time-varying satellite gravimetry (GRACE, GRACE Follow-On) provides a unique way to study the Earth dynamics from the monitoring of its mass redistributions at intermediate spatial and temporal scales (of the order of a few hundred kilometres, every 10 to 30 days). In subduction zones, the oceanic plate initiate its movement towards the mantle depths, forming downwellings within the internal convective system. Our work aims at better understanding and documenting deep deformation processes leading to great earthquakes. Satellite gravimetry data complement surface geodetic and seismological observations by providing a better sensitivity to deeper motions and by recording slow mass transporting deformations throughout the volume around plate boundaries. For instance, the visco-elastic response of the mantle has been observed during, and after, the very large earthquakes that occurred, thanks to GRACE records, since 2003. Recently, the GRACE sensitivity at depth has done it possible to replace the giant rupture of Tohoku-Oki earthquake (Mw 9.1, March 2011), within a regional sequence of mass transfers propagating over a few months from the subduction zone depths to its surface. Significantly larger than predicted from geodetic and seismological observations, this movement includes a pre-seismic phase at about 250 km depth, attributed to a large-scale stretching of the Pacific Plate progressing through the mantle in the months prior to the rupture. Here, we investigate whether similar variations in the gravity field can be detected prior to the Maule earthquake(Mw 8.7, February 2010), and if they are again compatible with a propagation of motion from depth to surface and interior of the oceanic plate during the co- and post-seismic phases. The sources separation is based on their specific time-space characteristics, and makes use of gravitational gradients to depict the geometry of the anomalies. To interpret the evidenced anomalies, we will analyze the variability related to the water cycle over the areas under consideration, as well as an analysis of the striping errors in the geoid models, and confront the gravity signals with surface deformations from GNSS data.

Study of a Biodeterioration process of Cementitious Matrices: Application to Asbestos-Cement Wastes

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Large quantities of asbestos materials were produced and used throughout the 20^{th} century until its utilization was banned in France in 1997, then throughout the European Union in 2005. The amount of material containing asbestos-cement, in-place in 1997, on the French territory has been estimated to be 24 million tons (ADEME 2017). The French regulation considers this asbestos waste as hazardous waste, which is mostly disposed in hazardous waste storage facilities. However, these facilities do not have infinite storage capacities, and are gradually reaching saturation. The objective of this research project is to develop a process for the deterioration of asbestos-cement with the aim of reducing the volume of this type of asbestos waste, which is composed of 5 to $20wt\%$ asbestos fibers. Since the cementitious matrix (*i.e.* the cement containing asbestos fibers) are highly alkaline materials (pH values over 12.5) akin to carbonate rocks, they are vulnerable to acids. Agro-food effluents, waste from agricultural or food industrial activities, are known to be aggressive towards the concrete-based materials of agricultural structures due to the presence of high concentrations of organic acids. Therefore, it is aimed to take advantage of the acidic properties of such effluents to reduce the volume of cementitious asbestos waste, and therefore their management costs.

Siderophores assisted Biorecovery of Technology Critical Elements: Gallium (Ga), Germanium (Ge) and Indium (In) from end-of-life products

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The development of novel high-tech applications such as communications, renewable energies, displays are heavily dependent on technology critical elements (TCEs) also known as critical raw materials (CRMs) such as Germanium, Indium and Gallium. However, the sustainable supply of CRMs is a major concern and the European Commission has listed the supply of these TCEs as critical among other CRMs. Recovery of these TCEs from their end-of-life (EoL) products such as electronic waste and low concentrated wastewater produced during device manufacturing is a way to overcome the shortage of these TCEs. However, there are no technologies available for recycling of these metals due to their low recover these metals. Siderophores has been shown to bind selectively to Ga, In and Ge even when these TCEs are present in very low concentrations. Thus, exploiting siderophores for TCEs recovery can be very interesting. However, no work has been carried out to recovery these TCEs from their EoL products using siderophores. There are many main challenges in the recovery of metals from their EoL products using siderophores. 1) Investigating how the materials may be pre-treated (dismantling, crushing, tinkering with melting temperature) to ensure access of the siderophores; 2) Optimizing the leaching conditions (*e.g.* S/L ratio, pH, quantity of siderophores); 3) Investigating how TCEs speciation in the targeted EoL materials as well as material structure affect TCEs leaching in presence of siderophores. This project aims to develop ambitious and highly innovative technology for the recovery of these TCEs. This project will fill the technology gap where no technology exists. This project will help in improving EU competitiveness in resource recovery and recycling. Further, this project supports the circular economy by converting waste to value.

High pressure serpentinization and abiotic methanogenesis in metaperidotite from the Appalachian and Alpine subduction

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Serpentinization is the process of hydroxylation of olivine-rich ultramafic rocks to produce minerals such as serpentine, brucite, magnetite. This process is commonly accompanied by Fe oxidation and release of H_2, which can be involved in abiotic reaction pathways leading to the genesis of abiotic light hydrocarbons such as methane (CH_4). Examples of this phenomenon exist at the seafloor, such as at the serpentinite-hosted Lost City hydrothermal field, and on land in ophiolites at relatively shallow depths. However, the possibility for serpentinization to occur at greater depths, especially in subduction zones, raises new questions on the genesis of abiotic hydrocarbons at convergent margin and its impact on the deep carbon cycle. This work aims to provide insights on the genesis of H_2 and abiotic CH_4 at depth, as well as their fluid sources and migration pathways. High-pressure ultramafic bodies exhumed in metamorphic belts can provide insights on the mechanisms of high-pressure serpentinization in subduction zones and on the chemistry of the resulting fluids. This study focuses on the ultramafic Belvidere Mountain complex belonging to the Appalachian belt of northern Vermont, USA, and on the Lanzo massif, western Italian Alps. These ultramafic complexes recorded serpentinization in the antigorite stability field, and include graphite veins and CH_4-rich fluid inclusions. This project combines field work, petrological investigation, fluid inclusion study with Raman spectroscopy, and isotopic analysis on $\delta^{13}C$ of solid and fluid phases. Decreasing oxygen fugacity during serpentinization and related abiotic reduction of carbon at high-pressure conditions is proposed at the origin of methane in the fluid inclusions. Complementary, numerical modelling of carbon isotopic evolution is being developed to predict the systems isotopic evolution.

Tracking the origin of the depletion volatile element of the Earth with indium isotopes

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The chemical composition of terrestrial planets is the results of various processes including evaporation during accretion and differentiation and metal/silicate fractionation during core formation. In particular different planets exhibit a depletion in moderately volatile elements that is more or less correlated with their 50$\%$ condensation temperature. One exception is indium that plots over this volatile depletion trend and therefore is apparently over-abundant in the Earth mantle. Since Indium is both siderophile and volatile, it is difficult to decipher whether its abundance is controlled by core formation or volatilization. A possibility would be that the temperature of evaporation of Indium is not well represented by the 50$\%$ condensation temperature which has been evaluated in very reduced conditions relevant to the solar nebula but not to more oxidizing conditions relevant to planet formation. Another scenario would be that the indium content of the Earth mantle has been set by late accretion of material later in the Earth history. Furthermore, the metal/silicate partitioning of indium is not well constrained, especially at high pressure relevant to the Earth's core formation. A series of evaporation and metal/silicate experiments involved indium have been performed to respond these issues which were known very limited. An indium isotope measurement method has been established by MCICPMS and some preliminary results of concentration and isotopic composition of indium of these experiments have been carried out, which could help to constrain the evaporation conditions which caused indium loss during the Earth formation and differentiation, and provide a understanding of In metal/silicate partitioning and isotopic fractionation as a function of variable temperature, pressure and oxygen fugacity.

Isotopic fractionation of chromium during transfer in mining impacted paddy soils

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Mining activities release considerable amount of chromium into the environment. During the extraction of chromium ores called chromites, tailings are stored in the air. When these non viable economically wastes are weathered, chromium is leached with runoff waters. In this study, we focus on the mining area of Sukinda Valley (Orissa, India) which comprises of ~98% of India's chromium ore reserve. There are 85% of deaths due to chromite mine related diseases in the region. This valley was studied in order to determine to what extent Cr speciation and Cr isotopic signature, $\delta^{53}Cr$, can help to identify Cr sources and the biogeochemical processes enhancing or limiting Cr mobility towards the surrounding paddy soils. The chemical characterization of artificial pounds and natural surface and underground waters revealed an increasing gradient of Cr concentration in the valley. The Cr concentration in waters sampled from the geochemical background was below IPC-OES detection limit while the waters concentrations near the mines were up to 1.6ppm. The exchangeable Cr(VI) in tailings was 0.4wt% and up to 0.025wt% in paddy soils. The isotopic signature of underground water was -0.05 ± 0.02‰. However, the surface waters and artifical ponds $\delta^{53}Cr$ were 1.04 ± 0.04 ‰and 1.75 ± 0.02‰respectively, suggesting that Cr is under its toxic form Cr(VI). These results are consistent with runoff waters draining the mine, however Cr undergo further chemical reaction before reaching the aquifer.

Performance comparison of different types of constructed wetlands for the removal of pharmaceuticals and their transformation products

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This work presents a comprehensive and critical comparison of four types of constructed wetlands (CWs): free water surface CW (FWSCW), vertical flow CW (VFCW), horizontal flow CW (HFCW) and hybrid CW (HCW) for the removal of 29 pharmaceuticals (PhCs) and 19 transformation products (TPs) using a global data compiled for 247 CWs reported in 63 peer reviewed journal papers. Biodegradation (aerobic being more efficient than anaerobic) is the major removal mechanism for 16 out of 29 PhCs besides the influence of other processes (e.g., adsorption/sorption, plant uptake and photodegradation). The HCW performed better followed by VFCW, HFCW and FWSCW. The comparatively better removal in HCW might be due to the co-existence of aerobic and anaerobic conditions and longer hydraulic retention time considering more than one compartment enhances the removal of PhCs (e.g., diclofenac, acetaminophen, sulfamethoxazole, sulfapyridine, trimethoprim and atenolol), which are removed under both conditions and adsorption/sorption processes. The augmentation in dissolved oxygen by the application of artificial aeration improved the removal of PhCs, which are degraded under aerobic conditions. Furthermore, the high performance of aerated CWs could be due to the establishment of various micro-environments with different physicochemical conditions (aerobic and anaerobic), which facilitated the contribution of both aerobic and anaerobic metabolic pathways in the removal of PhCs. The removal of some of the PhCs takes place by the formation of their transformation products (TPs) and the nature of these TPs (persistent or non-biodegradable/biodegradable) plays a major role in their removal.

Detection, location and characterization of induced seismicity in the High Agri Valley, southern Italy

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It is worldwide recognized that industrial operations (*e.g.*, oil and gas exploitation, wastewater disposal) may cause induced earthquakes. Mainly, these are classified as microearthquakes ($M_w \leq 2$), but in many cases larger earthquakes occurred, increasing the public concern about such kind of activities. Therefore, understanding the role of industrial-related subsurface perturbations (fluid circulation, stress changes) and the driving processes of induced events, has become a key topic for both the scientific community and the public. One of the current research challenges is the implementation of advanced seismic analysis for detecting and locating microseismic events and improve methodologies to discriminate natural and induced earthquakes, particularly in tectonic active areas. This is one of the aims of my PhD project, which focuses on the implications of fluid-injection operations on induced seismicity and environmental pollution. For this purpose, we selected the High Agri Valley (HAV), a tectonic active region in southern Italy characterized by high seismic hazard, related to fault systems capable of generating large earthquakes (*i.e.*, M_w7, 1857 Basilicata earthquake). Here, two clusters of induced seismicity were recognized as related to: (i) wastewater disposal at the "Costa Molina 2" injection well, associated with the exploitation of the Val d'Agri oil field; (ii) seasonal water level fluctuations in the Pertusillo artificial reservoir. In order to characterize the HAV seismicity, earthquakes recorded from September 2016 to March 2019 by local (CNR "INSIEME") and national (INGV "RSN") seismic networks have been investigated. So far, the 1D preliminary location of 852 detected (WebObs, Beauducel et al., 2010) and manually picked earthquakes has been performed. Based on their locations, 692 events were preliminary classified as tectonic local and 160 as induced earthquakes (117 from reservoir-loading and 43 from injection operations). Aims of my 6 months at IPGP will be: (i) the application of coherency-based detection and location techniques (BackTrackBB, Poiata et al., 2016) to increase the dataset completeness and perform its absolute and relative locations using 3D velocity models of the HAV (Serlenga and Stabile, 2019); (ii) the application and development of methodologies for estimating source parameters, obtain a reference catalogue for better understand source processes of induced earthquakes and develop physics-based discrimination criteria between induced and natural earthquakes.

Sounds of the deep subduction zone plumbing system: modeling non-volcanic tremor activity in a fault-valve, pore-pressure diffusive system

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The activity of slow-earthquakes in subduction zones have been closely linked to fluid circulation processes — like hydro fracturation and pore-pressure pulses — on the one hand by geological observations and on the other hand by slow-earthquake triggering and interaction models. In deep fault zone environments, where slow slip events and various regimes of tremor are observed, fluids coming from metamorphic dehydration of slab sediments are channeled towards the surface. Geological observations indicate that fluid transport conditions vary significantly on short time scales, and along dip, strike and width of the fault zone. In homogeneously permeable systems where fluids transit under stable conditions, pore-pressure can be described by a diffusion equation. We use a time and space bimodal description of the transport properties to model a tremor generating, permeable fault zone. Thin zones of low permeability acting as valves are distributed along the 1D channel with a higher background permeability. When a threshold pore-pressure differential is reached, the valve permeability is brought to background levels, until the barrier is healed and closes again. In this model, the opening of a valve occurs at the same time as the source of a low-frequency earthquake (LFE) is triggered. In such a set up, sources interact uniquely due to the channeling of stress through pore-pressure diffusion, and the interaction characteristics in time/ space are described in the framework of a diffusive system. When the number of sources is high, the model can reproduce clustering behaviours observed for LFE activity in subduction zones. The transition from a Poisson process description of seismicity to highly clustered, cascading events is governed by the source interaction distances, directly relating to the transport properties of the medium. In time, such a model is meant to diagnose the transport conditions in a subduction zone or a magmatic system, provided that it can be characterized by clustering statistics on the low- frequency seismicity it generates.

Simulation of the 2004 tsunami of Les Saintes in Guadeloupe (Lesser Antilles)

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We present a new methodology for tremor location, aiming at improving the identification of events close to or below the noise level. This methodology relies on neural networks to denoise tremor waveforms, resulting in cleaner signals with more structure and impulsivity. We find that these denoised waveforms can be used for event location with standard array-based techniques.
Our approach consists in two main, consecutive steps.
First, we feed waveform spectrograms to a neural network that has been trained to identify tremor, and we rely on neural network interpretation to denoise the raw waveforms. Second, these cleaned waveforms are used as input in an array-based location phase, that relies on the cross-correlation of seismic envelopes to locate tremor events. As proof of concept, we apply this approach in the Cascadia subduction zone. We attempt to locate tremor events during the 2018 slow slip underneath Vancouver Island, Canada. Analyzing a well- studied area allows us to validate our methodology by comparing our results with existing catalogs. We identify tremor patches coherent with existing literature, which validates the assumption that our denoising procedure preserves the events' move-out patterns. Our approach allows us to extract events below the noise level and to identify more events than in existing catalogs.

Detection, location and characterization of VLF events during the $2018 - 2019$ seismovolcanic crisis in Mayotte

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The seismovolcanic crisis of Mayotte started in May 2018 with a sudden activation of seismicity to the east of the island. Along with thousands of volcano-tectonic earthquakes, an energetic very low frequency signal (VLF, 15 seconds of period) was recorded on November $11, 2018$ at seismic stations worldwide. This exceptional monochromatic signal was not an isolated event: in this study we detected and analyze several hundredths of such signals, all along the duration of the Mayotte crisis.
We used a time-frequency detector based on the filtered signal spectrogram. The data comes from local and regional stations in Mayotte, Comores and Madagascar, and from OBH (Ocean Bottom Hydrophones) installed during marine campaigns aboard the R/V Marion Dufresne II, between May and July 2019 (Feuillet et al, 2019), and shorter campaigns since July 2019.
For good agreement we had to correct the hydrophones signal with respect to physical unites and convert the OBH signal in pressure, witch is important for the following. Event location is performed though spatial 3D back-projection of station-pair cross- correlation functions (Poiata et al., 2016), assuming surface-wave speed. Further works are made to confirm the location of the VLFs compared to the seismic swarm and Mayotte island. To study the possible physical origin of such signals, we compare different types of source such as the resonant cavity and the fluid-filled crack model.The addition of some preliminary results on the direct modelling calculated with Axitra would make it possible to understand the source, the path or site effects of these signals.

Detection, classification, and location of seismovolcanic tremors with multi-component seismic data, example from the Piton de la Fournaise volcano (La Réunion, France) and Klyuchevskoy Volcanic Group (Kamchatka, Russia)

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Seismovolcanic tremors are the seismic signature of magmatic and hydrothermal fluids passing through volcanic conduits. They are characterized by a sustained amplitude lasting from minutes to months and by a frequency content ranging from 0.5 to 5 Hz.
Their detection in real-time is a key aspect for volcano monitoring and the 3D location of their sources can bring some interesting insights into the magmatic system behavior. However they represent a challenge because they do not present any clear onset that could be used for picking arrival times.
In this work we apply three different methods based on the analysis of the multi-component seismic data to detect and to classify the tremors and to locate their sources. We use continuous seismograms recorded in two different volcanic context: at the Piton de la Fournaise volcano (La Réunion Island, France) and at the Klyuchevskoy volcanic group (Kamchatka, Russia). The first method allows to detect tremors based on stability in time of the inter-components cross-correlations function. Two other methods based on the simultaneous analysis of the whole network can be used to detect tremors and to locate their sources. The second method consists in performing the back-projection of the inter-stations cross-correlations in order to calculate the network response function. In a third approach, the seismic wavefield is analyzed by calculating the width of the network covariance matrix eigenvalue distribution. Simultaneous analysis of the parameters measured by the three different methods can be used to classify different types of tremors. Furthermore, these results of the multi-component analysis can be used as input for algorithms of machine learning, to build advanced approaches for detection and classification of different seismo-volcanic signals.
For the continuous data recorded during 2010 at Piton de la Fournaise, we efficiently detect three co-eruptive tremors which are located in a distinct region of the volcano for each eruptions and a large number of volcano-tectonic earthquakes located under the summit cone at the sea level. I will also present ongoing studies based on data recorded after 2010 at Piton de la Fournaise and during $2015-2016$ at Kamchatka volcanoes.

Comparison of attenuation and scattering of Lunar and Martian structures

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A limited number of seismic investigations have been performed on other planets and satellites. The only extraterrestrial seismic data available were those collected by the Apollo missions on the Moon and the InSight mission (Interior exploration using Seismic Investigations, Geodesy and Heat Transport) on Mars. Lunar and Martian seismograms appear to be extremely different from terrestrial ones. The seismic signals are characterized by a gradual beginning, a broad maximum and a very long decay lasting up to 20 minutes and 1 hour for Mars and the Moon respectively, compared to a few minutes on Earth. This unexpected long coda results from the low attenuation and intense scattering of highly porous and fractured regolith and megaregolith layers. This intense multiple scattering generates long ringing coda waves and makes difficult to identify direct arrivals of seismic waves such as P and S-waves. However, radiative transfer is well suited to model this process, and it can be approximated by the diffusion equation. Based on the envelope records of Mars and Moon events, the coda has been quantified by two parameters: the time arrival of the maximum of energy ($t_{\max}$) and the decay rate of the energy, named the coda quality factor (Q_c). $t_{\max}$ quantifies the diffusion and Q_c is sensitive to attenuation. The data analysis of event 128a revealed that $t_{\max}$ and Q_c of Mars differ from those of Moon or Earth. In fact, Q c of Mars is significantly smaller than that of the Moon and closer to the value of the Earth. This first result may imply that Mars contains more volatiles than the Moon and less than the Earth. To confirm this hypothesis, we need to separate the attenuation from the scattering by using more data which is in process.

Towards a dynamic vision of the slip along faults

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Faults experience different slip behaviours through time: rapidly during an earthquake, slowly and constantly at the tectonic plate velocity or as transitional pulses called slow slip events. These different behaviours were observed with GNSS temporal series of position, which record the temporal variations of the surface displacements. The seismic cycle was described on the basis of these observations *i.e.* interseismic, coseismic and postseismic phases. As of today, each period is assumed to experience different slip modes. Therefore, assuming that each slip mode has its spatial and temporal distributions, each period is modelled separately from the others. However, thanks to improvements in spatial geodesy accuracy, transitional pulses are suspected to occur on a different time scale. Indeed, it seems that slow slip events might occur very frequently over a wide range of periods during the interseismic and postseismic phases.

This work offers a new modeling strategy: freeing oneself from slip temporal and spatial distributions, we model the full time evolution of slip along fault. This method allows to free oneself from assumptions of slip modes temporal distributions, thus enabling oneself to observe transitional slip on a different time scale. If so, the results of this new method might allow us to revise the common conception of the interseismic phase and therefore better understand large earthquakes’ process. On this basis, we may better anticipate eventual rupture zones and their precursory signals.

Searching for seismic sources around the InSight landing site: focus on sol 173 and 235 marsquakes

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The NASA InSight mission has detected more than 300 seismic events since February 2019. It is dedicated to study the seismic activity and to propose the first internal models of Mars. On sols 173 (S0173a, May 23 rd 2019) and 235 (S0235b, July 27 th 2019) the two largest seismic events have been recorded with Mw $>$ 3 and showing clear P and S waves. The InSight MarsQuake Service has estimated their locations: S0173a probability density function (PDF) is at 28$\pm$3° distance and 91$\pm$10°N azimuth and S0235b, at 26$\pm$3° distance and 74$\pm$10°N azimuth. Both PDF are centered on the Cerberus Fossae fault system (CF), which is one of the largest tectonic structure on Mars of about 1200 km long.

From orbital imagery of MRO CTX and HiRISE cameras, we study the morphology and the lateral segmentation of the CF. We expect that marsquakes are more likely to initiate in intersegment zones, as they usually correspond to structural discontinuities where stress concentrates along faults on Earth . Besides, assuming the scaling law existing between the rupture length and the seismic moment, fault segments of 1 to 10 km long should be involved during such events.

In addition, we represent the moment tensor of the two events as it is a robust visualization of the source geometry. First, we compute Green functions from synthetic seismograms with the Direct Solution Method using Martian velocity models and the estimated locations. Then, the synthetics are inverted with the InSight data, by matching their arrivals of P and S waves on a narrow time window. We select the best fit models to retrieve the focal mechanisms of the marsquakes. We also provide updated constraints on the depth of the events through the lack of detection of surface waves.

Our tectonic analysis show that small inter-segments at several eastern graben tips of CF are good candidates for marsquakes locations. Despite the uncertainties on the internal model and event depths, our moment tensors inversion is consistent with the fault azimuths and dips, showing an extensional slip motion for S0173a.

Investigation of seismic excitation of Martian dust devil vortices using 3D seismic wave propagation simulation

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Since NASA's InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) landed on Mars in November, 2018, it has been conducting observations of seismic waves, pressure, temperature, wind speed and so on (Banerdt et al., 2020).

On Mars, dust devil vortices (i.e. whirlwind) occur on a daily basis due to the diurnal variation of atmospheric temperature. As observed on the Earth, when a vortex moves around, the nearby ground is deformed, generating seismic waves accordingly (Lorenz et al., 2015). From the seismic and atmospheric data of the InSight, a number of seismic signals correlated with transient pressure drops have been detected, and many data among these can be connected with dust devil events (e.g. Lognonné et al., 2020). While the deformation of the ground gives us information about elastic properties around the landing site, seismic signals by the vortices enable us to constrain the subsurface structure of Mars.

Looking at the seismic signals by dust devil vortices, those can be categorized in 3 different families. One family is "spike" type, another is characterized by "High Frequency Oscillations (HFO)" and the other is a complex type (i.e. both spike and HFO type are mixed). However, it is still an open issue that what makes these differences and what kind of parameter plays an important role to characterize them. In this study, we started with an assumption that these differences are due to different seismic excitation, and performed 3D numerical simulations of seismic waves based on the constraints from the observations. As a first step, we focused on a reference dust devil event whose track information, pressure data, wind data and seismic data were tied with each other by Banerdt et al. (2020), and confirmed the overall features of the seismic data were well reproduced by our simulations (Onodera et al., 2020). Then, we conducted parameter studies on input pressure model, internal structure model, track geometry of the vortex in order to discuss which factor plays an important role to characterize the seismic signals of dust devils.

In the presentation, we discuss how seismic signals by dust devils can be modeled and which parameter mainly characterizes them.

Comparison of the elastic properties of reservoir rocks in the field and the laboratory: link between seismic, sonic and ultrasonic measurements

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Elastic waves are commonly studied in geophysics. They are used for example for prospecting, to follow the exploitation of hydrocarbon reservoirs, to study the effect of fluid injection (CO_2 storage)... However, the wave frequencies used in the field (sonic – seismic measurements) are not the same as the ones commonly used in the laboratory (ultrasonic measurements), and fluid-saturated rocks are known to be dispersive, *i.e* the P- and S- wave velocity in fluid-saturated rock change with frequency. The comparison between field and laboratory measurements is therefore not straightforward. In the ENS facilities, it is possible to subject samples, under pressure (1 to 30 MPa) to forced - oscillations varying from 0.01 Hz to 1 kHz (field frequencies) and 1 MHz (ultrasonic frequencies) using a triaxial cell. Axial and radial strain gauges are installed to record the resulting strains on the sample. Forced-oscillation can be done on 1) confining pressure to get the bulk modulus as function of frequency or on 2) axial stress to get the Young modulus and Poisson ratio as function of frequency. With this information, it is thus possible to deduce the P- and S-wave velocities with frequency. The elastic properties were measured on different samples from the Libra oil field, for which logging measurements are available. Thus, the measurements obtained in the laboratory can be compared to the measurements in the field at the same frequency. In addition, the evolution of the velocity with frequency measured in the laboratory allows us to discuss the mechanisms at the origin of the dispersion.

Improvement of focal depth estimations from combination of local and teleseismic data: Application to Far-Western Nepal

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Hypocentral locations of shallow moderate-sized earthquakes are often used to characterize the seismic behaviour of tectonic structures. However, a great accuracy in depth estimation is required while confronting hypocenters and regional or local seismogenic structures. Deployment of dense seismological networks above seismic clusters provides an adequate solution to resolve focal depths and thus has become a classical technique in seismotectonic studies. Unfortunately, most regions are covered by sparse seismological stations which are in most cases distant from the source. For those cases, hypocentral depth estimations are challenging and can sometimes even be better determined using depth phases (sP and pP) picked in the signal recorded at teleseismic distance (30°-90°). Here I thus combine two approaches for depth estimations: 1. an automatized technique based on a cepstral analysis devoted to the retrieval of these teleseismic depth phases and 2. relying on a dense catalogue of earthquakes constrained by a dedicated regional network (HiKNet, Nepal). It allows me to evaluate the depth estimations and their uncertainties associated to 37 events of Far-Western Nepal recorded at both regional and teleseismic distances. Systematic combination of the high quality global network of the IMS (International Monitoring System) allowing teleseismic detections of moderate magnitudes events with the high resolution regional seismic catalogues acquired in Nepal should allow a better characterization of biases and uncertainties associated to the determination of focal depths at teleseismic distances (depth-phases identification, topographic corrections, complexities related to the radiation diagram).

Orientation of short period OBS from P-wave polarisation

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Here we modify and apply a technique to determine the orientation of the horizontal components of the Ocean Bottom Seismometers (OBSs) to OBSs surrounding the Mayotte earthquake swarms. We applied principal component analysis to determine the particle motion directions of P waves, which is used to calculate the orientation angle by constraining the difference between the network-determined and instrument-determined back-azimuths. As short period OBSs are insensitive to teleseismic events, we must use local events and therefore uncertainties in back-azimuth must be taken into account. We tested different cases to check the dependency of the error in orientation angle on the back-azimuth range of the events, no. of events used, magnitude limit and back-azimuth error limit of the individual events. The correct orientation of the horizontal components is crucial to determine the correct amplitude ratios of the P wave and S wave which can further be used to improve the resolution of focal mechanisms of the local events to understand the state of stress in this region. Our goal is to apply this technique to both the Mayotte data and to data from a long-term network on Lucky Strike volcano on the Mid-Atlantic Ridge, in order to better understand the tectonic and magmatic forces driving seismicity.

Elastic Full-waveform inversion using Hamiltonian Monte Carlo approach for imaging the Moho transition zone

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Full-waveform inversion (FWI) is a high-resolution seismic imaging technique which uses waveform from the entire seismic data including phase, amplitude and travel-time for determining the physical parameters of the subsurface. The inversion remains local owning to the fact that it requires a reasonably accurate initial model so that it can converge to the correct model using either gradient or Newton-based optimization methods. The inversions use adjoint-state theory for computation of gradients to update the model. However, while inverting for the Moho-transition zone, things start becoming complex as the amplitude, and phase variation for the critically reflected arrivals no longer remains linear. This results in poor inversion of the Moho-transition zone as the gradients computed for model update and the adjoint-state theory are based on linear approximations. We surmise that the Hamiltonian Monte Carlo (HMC), similar to Bayesian Markov Chain Monte Carlo (MCMC) approaches and takes the gradients into account for updating the model might be the key to resolve this problem. Bayesian approaches can remove our dependence on the initial models. Our goal is to use MCMC approach with Metropolis-Hasting acceptance criterion to prove the feasibility of the Bayesian approaches in inverting active seismic data and quantify the uncertainty. Our further goal is to show that HMC can provide good results for inversion of active seismic data with a dense acquisition geometry. We present a theoretical proof of FWI with HMC algorithm for imaging the Moho-transition zones.

Numerical simulation on small-scaled granite during compression deformation

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We present an application of the full waveform numerical modeling to experimen tal seismic records on a centimetre-scale rock sample using spectral-element method (SEM). This method can detail the procedure of the changes in the velocity structure of rocks during the deformation that allows us to understand the history of the earthquake nucleation. We first recall the experimental records in the laboratory by Zaima and Katayama (2018). The triaxial compression experiment with one-source and one-receiver is applied on a granite rock sample. The P- and S-wave propagating perpendicularly to the compression direction are recorded by the receiver directly opposite the source. Therefore, the changes in velocity structure during the earthquake nucleation can be measured. We briefly outline the spectral-element method and present the system built for full wave form data processing. The numerical examples that illustrate the capabilities of the method and its interest in the time-lapse three-dimensional synthetic waveform modeling of the rock sample during deformation. The regular relationship among velocity, quality factor and stress suggests that understanding the temporal variation of seismic wave characteristics through numerical modeling can provide insights into the mechanisms of rupture and earthquakes.

Surface Rupture from dynamic earthquake modeling

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During an earthquake, the seismic rupture propagates from the depth up to the earth surface generating surface ruptures and deformations. The surface rupture observations of earthquake reveals some complexities. These complexities may be related to several physical parameters of the rupture, such as the fault geometry, the deeper fault characteristics, the underground nature, etc. We use dynamic rupture modeling to investigate surface rupture associated to the earthquake. The simulations are performed using a 3D Fortran code based on Boundary Integral Equations to calculate the spontaneous rupture propagation along a fault embedded in a homogeneous medium in a half space. In a first step of our work, we verified the calculation code using the Southern California Earthquake Center (SCEC) spontaneous earthquake rupture code verification exercice. According to the simulation results of the SCEC application, the code works correctly and can be used to study earthquake dynamic rupture propagation on complicated cases. Then, we studied the $M_w 4.9$ November 2019 Le Teil earthquake rupture in order to numerically quantify the surface rupture associated to this earthquake. We perform two kind of rupture propagation models: kinematic models and dynamic models to understand the physical mechanisms underlying the observed surface rupture complexities. Le Teil earthquake kinematic modeling results allows us to set physical parameters that control spontaneous rupture propagation which are difficult to measure. The information retrieved from kinematic modeling are used to perform 'physic- based' earthquake models. To validate our models, we used the surface ruptures and deformation data derived from correlation of optical satellite images. These surface rupture data are used to generate surface deformation profiles and compare them with numerical results. Our result will be displayed and discussed.

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